J. Crop Prot. **2025, 14 (3): 229-244**

Review Article

Weeds of tea plantations of Assam and West Bengal of India and their management: A review

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Abstract: The most renowned tea-producing areas in India are located near the foothills of the Himalayan Mountains. The locations above encompass Assam and West Bengal. These areas are characterized by tropical to subtropical climates, with annual precipitation ranging from 1150 to 2800 mm and temperatures ranging from 10 to 35 °C. Furthermore, these conditions facilitate the proliferation of a diverse range of weed species. Weeds interfere with the growth of tea plants at almost all stages, but most interfere during the initial period of plantation. Weeds are the most common pest, reducing tea productivity by 10-50% depending on growth intensity, level of competition, weed type, and the competing ability of clones. Utmost care is required, as if left unattended, the weeds can outgrow the tea plantlets, eventually leading to their death due to tough competition for nutrients and moisture. This review focuses on the weeds in tea plantations in Assam and West Bengal. The study also reveals their harmful and beneficial effects, their invasiveness, and their management.

Keywords: Weeds, Weed management, Tea plantation, Assam, West Bengal

Introduction

The cultivation of tea in India has consistently played a crucial role in fostering socio-economic progress in the nation's tea-producing areas. The most renowned tea-producing areas in India are located in the northeastern region, close to the foothills of the Himalayas. The locations above encompass Darjeeling and Assam (Magar and Kar, 2016). India emerged as the world's second-largest producer and consumer of tea, producing over 1,000 million kilograms from a total area of 619,773.70 hectares (Tea Board of India, 2022). The history of tea in India began with the British planting tea in the lowlands of Assam in the late 1830s, following the discovery of tea in the highlands of Assam by Robert Bruce and Maniram Dewan (Magar and Kar, 2016). And in West Bengal, it was in 1835 that tea seeds were first planted in a trial nursery at Lebong. In the early months of 1839, Dr. Campbell established the pioneering tea garden in the hills behind his bungalow, which is today known as Beechwood and is located 2134 metres above mean sea level. With a few seeds cultivated in the Kumaon plantations from Chinese stock, the first experimental attempt at Darjeeling was

Handling Editor: Majid Aghaalikhani

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Received: 07 June 2024, Accepted: 05 October 2025
Published online: 20 October 2025

conducted in 1841 and proved to be quite successful. The origins of tea growing in Terai can be traced back to Dr. Campbell's 1839 tea plantation in the Darjeeling District. In 1862, tea cultivation moved from the Darjeeling highlands to the Terai region. The initial tea plantation in Dooars was established in 1874 (Ghosh, 2006). Today, as a result of the recent inclusion of small tea growers, Assam's tea plantations have grown and mushroomed to such an extent that it has become one of the world's largest tea-growing regions, producing 52.04 percent of India's tea and constituting 53.97 % of the country's tea area (Magar and Kar, 2016). Following Assam, with an annual production of 329.7 million kilograms, West Bengal ranks second among states in tea production, accounting for 26% of the country's total production (Tea Board of India, 2017). Tea plantations are grown on practically every continent and in 58 countries worldwide (Wolski *et al*., 2021).

Assam, in northeast India, is located in one of the world's most biodiversity-rich regions and holds enormous potential for the conservation and efficient use of its abundant biological resources (Bhagabati *et al*., 2006). Assam is part of the Indo-Burma biodiversity hotspot, which hosts a diverse range of angiospermic plants. Because of its floristic diversity, many experts refer to Assam as the "Biological Gateway" of the North East (Baruah, 2019). The picturesque tea gardens here harbour a large variety of valuable tree species, shrubs, and climbers with considerable ecological, medicinal, and economic values. The weed flora comprises numerous herbaceous plants with medicinal, aromatic, and other economic attributes. The vertical structure of the historic tea garden communities, which includes herbs, trees, shrubs, vines, and epiphytes and is comparable to that of secondary forest, was revealed by life forms analysis of plant species, but in typical tea gardens, herbs predominate and there are no trees (Sheng, 2013).

On the Other hand, the main tea-producing area of West Bengal lies in its northern part, including the Darjeeling hills, the Terai, and the Dooars region. And the abundant biodiversity of this northernmost region of the state is another reason why scientists find it so significant. Nearly in the centre of the Eastern Himalaya, Darjeeling's western and eastern borders are equally rich in wildlife (Das and Chanda, 1987; Bhujel and Das, 2002). The Darjeeling Hills are part of the Singalila Range in the Eastern Himalaya, which is well known to botanists, horticulturists, floriculturists, and others for its extraordinarily high biodiversity. One of the top eight most significant hotspots, the Darjeeling Hills region is currently a part of the Himalayan Hotspot, which was formerly a part of the Indo-Burma hotspot (Ghosh, 2006). This type of lush vegetation is not limited to the hills alone. The vegetation diversity in Terai and Dooars is likewise abundant (Ghosh *et al*., 2004).

The per humid and warm environments required by tea, which are also favourable for the growth of weeds, are one of the reasons for the severe infestation of weeds in tea plantations. Another aspect that makes tea prone to weeds is the farming system (Ohsawa, 1982). Like other plantation crops, tea also requires adequate agronomic care for high, sustained yields. Uncontrolled weed growth can cause a loss of production ranging between 10-50% (Rajkhowa et. al., 2005; Deka and Barua, 2015). The weeds primarily compete with the tea plants for nutrients, but also act as alternate hosts for various pathogens and pests. It also hinders the branching system and frame formation in the tea bush. For effective control measures of this unwanted plant, knowledge of its floristic composition and seasonal behavior is essential. Due to ground exposure, there are two crucial periods for weed growth in tea: new clearance (the first 2 years after planting) and pruning periods. Other variables that contribute to a higher prevalence of weeds include the use of a single weed-checking method and the growth of weed seeds, cuttings, etc., through media such as compost and mulches (Prematilake, 2003). Exotic weeds are very fast-growing and harder to control than indigenous ones. According to Saxena (1991), 40% of the species in the Indian weed flora are introduced. In Assam, there is an abundance of therapeutic plants that have wide uses. Various plant species have been utilised for multiple types of infection (Sailo *et al*., 2017). The inhabitants of the tea tribes are fundamentally rural in nature and are estimated to constitute around 18% of the state's population. They have an immense and in-depth understanding of plants, both common and uncommon, for food and medicine (Saikia *et al*., 2010; Biswas *et al*., 2020). In view of the emerging challenges in agriculture due to declining soil health, water shortage, energy crisis, climate change, and global warming, etc. Long-term impact of chemical abuse on weed flora shift, weed seed bank, and insect-pest dynamics, and their management strategies need to be worked out.

The word "weed" is fairly common and widely used in English. It is typically used to refer to undesirable plants in a crop field, but it can also mean "unwanted," "weak," "an unrelated disturbing element," etc. However, in botany and Agriculture, the term refers to a wide variety of undesired plants growing in cultivation fields (Ghosh, 2006). Plants known as weeds grow in managed or regulated areas without being seeded or otherwise cultivated (Srithi *et al*., 2017). According to Bidira *et al*. (2021), Weeds are a persistent part of the agricultural ecosystem. They are undesirable plants that compete with crop plants for nutrients, water, space, and light (Concenço *et al*., 2014).

Objectives of weed assessment:

Information on weed density, location, and species composition can help anticipate crop losses and determine whether it is cost-effective to control a certain weed problem (Kropff *et al*., 1992). One of the main components of integrated weed control is paying attention to the ecology of weed populations in tea gardens and their structural characteristics throughout growth (Mirghasemi and Sharifi, 2004). Phytosociological studies of the weed flora in tea plantations provide crucial information for identifying significant and recalcitrant weeds across seasons and for formulating effective control measures. Weed flora and its composition in a crop are influenced by the type of cultivar, time or season of cultivation, spacing, soil type, soil pH, climatic conditions such as rainfall, temperature, cultivation practices like irrigation, tillage systems, application of fertilizers, and weed management practices (Savedra *et al*., 1990; Kolar and Mehra, 1992). A thorough understanding of the weed flora for various crops in a region is essential for weed management (Ghosh, 2006).

Weeds of young tea

Young tea had a critical window of weed competition between 8 and 16 weeks after planting, and tea growth was negatively impacted by weed infestations lasting longer than 12 weeks (Prematilake, 1999). According to Soedarsan *et al*. (1975), some weeds such as *Eupatrium* spp., *Paspalum conjugatum* P.J. Bergius, and *Eleusine indica* (L.) Gaertn. are very noxious to young tea (two years old) due to their high nutrient uptake. Such weeds showed higher biomass accumulation, resulting in adverse effects on the tea bush, including fewer primary branches, chlorosis, and reduced leaf size. However, it is interesting that some weeds, such as *Spermacoce alata* Aubl. The plant, which grows profusely in the tea fields, did not affect the overall growth of the tea plants. In a new plantation, the first three to four years after planting in the field are the most vulnerable period for a tea plant, as it is subjected to various biotic and abiotic stresses and weed infestation. The planting density of young tea is 15,500/ha. The gap between young tea plants is relatively wide, making them vulnerable to weeds. In newly established tea fields, the bare soil surface is susceptible not only to weed invasion but also to soil erosion (Eden, 1976). When the tea is young, there is strong competition between weeds and the tea plant for water and nutrient uptake, rather than for light. Sanusi and Suhargyanto (1978) reported that the growth retardation of tea grown with particular weed species may be due to competition for magnesium (Mg) by the weeds, as these weeds contained relatively high Mg levels. The establishment of underground parts of some lianas or perennial weeds that persist and regenerate vegetatively in mature tea fields often occurs during this young stage of tea plants. Deka and Barua (2015) identified some dominant weeds in young tea fields of Assam, as shown in Table 1.

Table 1 Some dominating weed species present in the young tea field of Assam.

Name of the weed	Family
Scoparia dulcis L.	Plantaginaceae
Spermacoce hispida L.	Rubiaceae
Mimosa pudica L.	Fabaceae
Mesosphaerum suaveolens (L.) Kuntze	Lamiaceae
Axonopus compressus (Sw.) P. Beauv.	Poaceae
Cynodon dactylon (L.) Pers.	Poaceae
Paspalum conjugatum P. J. Bergius	Poaceae
Paspalum lindenianum A. Rich.	Poaceae
Ageratum houstonianum Mill.	Asteraceae
Sida acuta Burm.f.	Malvaceae

Weeds of mature tea

The mature tea plants establish a closed canopy and cast deep shade, so that the heliophilous weeds, such as Ageratum conyzoides L., cannot grow vigorously. Instead, some weeds originating from the undergrowth or epiphytes that invade mature tea fields and coexist with tea might have adverse effects on the tea bush. In mature tea sections, the main competition between tea and weeds is for space and light. At certain stages, the weeds overgrow and compete with mature tea plants for light above the closed canopy of the tea by growing tall, such as Crassocephalum crepidioides (Benth.). S. Moore, *Clerodendrum infortunatum* L., etc. Climber weeds like *Mikania micrantha* Kunth, *Paederia foetida* L., *Ipomoea cairica* (L.) Sweet is an invasive species that can completely smother the tea bushes. These weeds, which damage mature tea by covering the crown, might be designated 'crown weeds'. It is difficult for weeds to invade the tea root system once established, except for those with very shallow root systems. Weeds with stout roots can invade as epiphytes on the collar of a mature tea bush, where some soil and litter have accumulated. This effective method of invasion into densely rooted, mature tea fields is only possible under moist, humid conditions. Some ferns with short rhizomes can also invade the stem of the tea bush. An old tea stem serves as the host tree for epiphytic weeds such as ferns, mosses, and lichens (Ronoprawiro, 1975). Various unrelated elements, such as weed growth type, density, and the timing of emergence relative to crops, affect weeds' capacity to compete (Romaneckienė *et al.*, 2008). According to Deka and Barua (2015), some dominant weeds in the mature tea fields of Assam are listed in Table 2. According to Ghosh *et al.* (2004), some weeds are most prevalent in mature tea fields in West Bengal. Those are shown in Table 3. Chowdhury *et al.* (2016) identified several dominant ferns from mature tea fields in West Bengal, listed in Table 4.

Table 2 Some dominant weed species present in the mature tea field of Assam.

Name of the weed	Family
Mikania micrantha Kunth	Asteraceae
Paspalum sp.	Poaceae
Spermacoce hispida L.	Rubiaceae
Gynura bicolor (Roxb. ex Willd.) DC.	Asteraceae
Axonopus compressus (Sw.) P.Beauv.	Poaceae
Cynodon dactylon (L.) Pers.	Poaceae
Mesosphaerum suaveolens (L.) Kuntze	Lamiaceae
Melastoma malabathricum L.	Melastomataceae
Osbeckia sp.	Melastomataceae
Sida acuta Burm.f.	Malvaceae
Chromolaena odorata (L.) R. M. King and H. Rob.	Asteraceae
Lantana camara L.	Verbenaceae
Mimosa diplotricha var. *diplotricha*	Fabaceae
Dichanthelium sp.	Poaceae

Table 3 Some dominant weed species present in the mature tea field of West Bengal.

Name of the weed	Family
Spermacoce alata Aubl.	Rubiaceae
Ageratum conyzoides L.	Asteraceae
Oxalis corniculata L.	Oxalidaceae
Grona triflora (L.) H.Ohashi and K.Ohashi	Fabaceae
Digitaria ciliaris (Retz.) Koeler	Poaceae
Gamochaeta pensylvanica (Willd.) Cabrera	Asteraceae
Ageratum houstonianum Mill.	Asteraceae
Mitracarpus hirtus (L.) DC.	Rubiaceae

Table 4 Some dominating ferns from the mature tea fields of West Bengal.

Name of the fern	Family
Diplazium esculentum (Retz.) Sw.	Aspleniaceae
Hemionitis albomarginata (C. B. Clarke) Christenh.	Pteridaceae
Thelypteris dentata (Frossk.) E. P. St. John	Aspleniaceae
Dryopteris filix-mas (L.) Schott	Polypodiaceae
Lygodium microphyllum (Cav.) R. Br.	Schizaeaceae
Nephrolepis cordifolia var. cordifolia	Polypodiaceae
Pteris vittata L.	Pteridaceae

Harmful effects of weeds

Unlike the emergence of other pests, which might be random and irregular, weeds can significantly reduce crop yields without visible indicators of damage in crop production (Varanasi *et al*., 2016). Weeds can remove up to 270 kg of nitrogen per hectare from young tea. Along with competing with crops for nutrients, weeds also battle with them for moisture and light. Some weeds growing on tea bushes absorb nutrients and mix with the tea plant tissue. Due to their luxuriant growth, epiphytic ferns and orchids also affect tea plants. Some weeds, particularly climbers, cover the tea bushes, slowing picking. The quality of tea can also be affected by the foetid smell of various plants (Ghosh, 2006). Weeds are the most common pest, reducing tea productivity by 10-50% depending on growth intensity, level of competition, weed type, and the competitive ability of clones (Rana, 2017). Grassy weeds diminish tea productivity by 21%, whereas broad-leaved weeds reduce productivity by 9-12%. The tea sector in Northeast India spends approximately INR 200 million per year on weed management (Rana, 2017). Weeds are the primary cause of low production and economic losses for growers (Concenço *et al*., 2014). According to Eden (1961), crop losses of 9% to 12% occur due to soft weed competition in tea in Sri Lanka and South India, respectively. Cramer (1967) reported that 14-15% crop loss occurs in tea worldwide due to weeds. In tea farming, unchecked weed development can result in production losses of 10-50% (Sen *et al*., 2016). Besides these, some weeds can be highly poisonous. Ghosh and Das (2011) reported some poisonous weeds from tea plantations and their toxic effects, as shown in Table 5.

Beneficial effects of weeds

Weeds may also be beneficial, and some are crucial to humankind. Weeds reduce the force of raindrops when they fall. Decrease soil erosion on sloping land, particularly in hilly terrains. Many weeds have therapeutic properties. Some weeds are utilised as food and fodder. Weeds add a lot of humus to the soil. Weeds either maintain or improve the real soil structure. Some weeds fix nitrogen from the atmosphere in the soil. Weeds help maintain an ecosystem's balanced structure. Many local animals rely on weeds for food and refuge (Ghosh, 2006). According to Saikia *et al*. (2010), some weeds from Assam's tea plantations are used as medicinal plants. Those are shown in Table 6. Ghosh and Das (2011) identified medicinal weeds from the tea fields of West Bengal, listed in Table 7. According to Ghosh *et al*. (2020), some tea garden weeds can be used as vegetables. Those are listed in Table 8.

Weeds as alternate hosts for animal pests

Some prominent weeds may act as alternate hosts for certain animal pests, such as the tea mosquito bug. Weeds like *Mikania cordata*

(Burm.f.) B. L. Rob. , *Chromolaena odorata* (L.) R. M. King and H. Rob. , *Emillia* sp., *Persicaria chinensis* (L.) H. gross and Lantana camara L. offer excellent hiding places and serve as alternate hosts for the tea mosquito bug, *Helopeltis theivora*. The extensive survey of tea plantations conducted by Srikumar *et al*. (2016) recorded a few plants belonging to eight different families as new host plants for the important pest of tea, *Helopeltis theivora* Waterhouse. The new host plants recorded were *Acalypha wilkesiana* Müll. Arg., *Cyclea peltata* (Burm.f.) Hook.f. and Thomson, *Dioscorea* sp., *Ludwigia peruviana* (L.) H.Hara, *Malvavicus penduliflorus* Moc. and Sesse ex DC. *Helopeltis theivora* is a polyphagous pest with a rapid, devastating capacity; hence, there is a need for continuous monitoring of its occurrence on alternate host plants (weeds) within the tea plantations to track its population. Many alternate non-economic host plants for red spider mite in and around the tea fields are *Ageratum conyzoides* L., *Bidens* sp., *Spermacoce hispida* L., *Crassocephalum* sp., etc. Roy et. al. (2014). Das (1965) found *Spermacoce hispida* L., *Ageratum conyzoides* L., *Litsea lancifolia* (Roxb. ex Nees) Fern. -Vill., *Melastoma malabrathicum* L., etc, act as alternate host plants for the dominant tea pest *Oligonychus coffeae*.

Invasive alien weeds of the tea ecosystem

Species that establish themselves in natural or semi-natural environments or ecosystems, cause change, and endanger the biological variety of the country in which they are introduced are referred to as "Invasive Alien Species" (IAS) (IUCN, 2016). Alien species are defined as non-native or exotic organisms that occur outside their native ranges and can spread. Our agroforestry systems benefit greatly from the assistance of numerous alien species. However, some alien species become invasive when intentionally or unintentionally transported outside their original habitats to new locations where they can establish, invade, and outcompete native species (Singh, 2005; Yan *et al*., 2001). Invasive species can alter ecological processes and environmental conditions, thereby transforming ecosystems (Denóbile *et al*., 2023). For example, certain C3 plants can adopt the C4 photosynthetic pathway when they invade arid, hot environments. This will help the plants survive, grow, and invade successfully (Wang *et al*., 2011). Tea plantations can sustain biodiversity when managed in an agroecological context with good agricultural practices, making tea gardens highly suitable for invasive species. Some Invasive alien weeds from the tea gardens and their source are shown in Table 9.

Table 5 Some poisonous weeds present in the tea plantations.

Plant Name	Family	Poisonous Effect
Calotropis gigantea (L.) W. T. Aiton	Apocynaceae	Harmful for eyes
Cannabis sativa L.	Cannabaceae	Euphoria, elation, heightened senses, hallucinations, depression and comatose sleep; die in overdose
Cuscuta reflexa Roxb.	Convolvulaceae	Unbearable pain in the upper abdomen if consumed
Datura stramonium L.	Solanaceae	Unquenchable thirst, vomiting, enlarged pupils, jumbled speech, nervous twitches, convulsions; death in overdose
Equisetum diffusum D. Don	Equisetaceae	Dangerous to horses and cattle; causes loss of condition, fast and weak heartbeat and unsteady.
Jatropha curcas L.	Euphorbiaceae	Severe collapse if consumed
Mikania micrantha Kunth	Asteraceae	Fish-poison
Parthenium hysterophorus L.	Asteraceae	Severe allergy, dermatitis, internal bleeding
Persicaria hydropiper (L.) Delarbre	Polygonaceae	Food and fish poisoning
Pteridium aquilinum (L.) Kuhn	Dennstaedtiaceae	Particularly horses and cattle are vulnerable; well-known fish poison

Weed management

Overgrown weeds in tea fields also affect different important field operations. Some weeds act as shelters for harmful insect pests and help spread deadly diseases. A thick covering of weeds provides a suitable habitat for fungal growth by increasing relative humidity. Unchecked weed growth can reduce crop yield by 50-70%. From April to September, the period is very unfavorable for yield, as it is highly conducive to weed growth due to high rainfall and temperatures. Eighteen weeks without watering in a young tea plantation can lead to plant death. Hence, weed control is a very crucial part of tea field operation (Deka and Barua, 2015).

Table 6 Some important medicinal weeds of tea plantations of Assam.

Name of the species	Family	Part used	Uses/ailments treated
Leucas aspera L.	Lamiaceae	Leaves, young shoot	Sinusitis, Loss of appetite
Centella asiatica (Linn.) Urban	Apiaceae	Whole plant	Dysentery, stomach disorders, memory booster
Colocasia esculenta Linn.	Araceae	Leaves and Roots	Pharyngitis.
Spilanthes paniculata	Asteraceae	Flowers	Gum pain.
Commelina benghalensis	Commelina ceae	Young shoots	Eye problem

Table 7 Some important medicinal weeds of tea plantations of West Bengal.

Name of the species	Family	Part used	Uses/ailments treated
Achyranthes aspera L.	Amaranthaceae	Roots, leaves, seeds	Insect bites, hydrophobia, dysentery, pneumonia, gonorrhea; contraceptive, abortifecient
Artemisia indica Willd.	Asteraceae	Leaf, shoot	Headache, asthma, ringworm, pimples, ulcer, menorrhagia, flatulence, breathing problem, insect repellent, important in folk medicine
Biophytum sensitivum (L.) DC.	Oxalidacdeae	Whole Plant	Used to treat urinary calculi, bilious fever, wounds, absses, gonorrhoea, asthma, snake bite, etc
Blumea lacera (Burm. f.) DC.	Asteraceae	Leaf	Diuretic, anthelmintic, stimulant
Cassia tora (L.) Roxb.	Fabaceae	Leaf	Dried leaf powder used in soup to reduce body pain
Catharanthus roseus (L.) G. Don.	Apocynaceae	Leaf, Flower	Improves memory; used in leucorrhoea, leukaemia, diabetes, intestinal worms, septic wound, asthma, blood pressure, cancer, etc
Clerodendrum indicum (L.) Kuntze	Lamiaceae	Grown plant	Ornamental; used in asthma, worm, leprosy, snake bite, septic wounds, herpes, antidote, remittent fever
Drymaria diandra Blume	Caryophyllaceae	Shoot	Sinus congestion, nasal bleeding, headache, internal haemorrhage, pneumonia, asthma, snakebite, diphtheria
Euphorbia hirta L.	Euphorbiaceae	Shoot	Used against warts, diarrhoea, gonorrhoea, ringworms, eye troubles, bronchial asthma, expectorant; improves lactation
Heliotropium indicum L.	Boraginaceae	Inflorescence	Used in ringworms, gouts, pregnancy related anaemia, rheumatism, typhoid, skin diseases, insect bites, snake bite, bronchitis
Marsilea quadrifolia L.	Marsileaceae	Leaf	Insomnia, memory loss, BP, epilepsy, fever, leprosy, hemorrhoids, bronchitis, psychopathic, ophthalmia
Mimosa pudica L.	Fabaceae	Root	Used against boils, bleeding, inflammation, fistula, piles, leucoderma, leprosy, asthma, vaginal and uterine complains, iron deficiency
Persicaria capitata (Buch. -Ham. ex D. Don) H. Gross	Polygonaceae	Whole plant	Used in diarrhoea, dysentery
Piper peepuloides Roxb.	Piperaceae	Ripe fruits	used in common cold and cough

Long-term tea cultivation in the same place degrades soil quality by depleting nutrients. The output of tea can be enhanced through skillful, integrated agricultural practices that employ effective weed-control techniques. If weed control practices are not implemented during the critical weed infestation period, weeds will compete with plants for nutrients, sunlight, moisture, and other resources, reducing tea leaf output by 12-21%. The tea garden's everyday activities are disrupted by weeds, which also serve as breeding grounds for several insect and disease pests. Preventative actions are beneficial because they reduce the soil's weed seed bank, thereby reducing current and future weed populations (Kundu *et al*., 2020). There are several recommended weed control strategies for tea plantations. Adopting preventive measures is beneficial because it reduces weed seed banks in the soil, lowering weed numbers now and in the future (Banerjee *et al*., 2019). In the conventional method, chemical herbicides are used because they are relatively cheaper and more effective (Deka and Barua, 2015). Agroclimatic conditions strongly influence the effectiveness of applied herbicides. Glyphosate is highly effective during the pre-monsoon season. In contrast, paraquat is more effective during the post-monsoon season for managing plant pests in the tea gardens of the Terai region of Darjeeling district, West Bengal (Ghosh *et al*., 2020). 2,4-D (post-emergence), diuron, and simazine (pre-emergence) control all dicotyledonous weeds. Except for *Ipomoea* sp., *Borreria hispida* (L.) K. Schum., *Mikania micrantha* Kunth, *Eupatorium* sp., and *Polygonum* sp. Paraquat can also eliminate broadleaf weeds. Dalapon (which should only be applied in mature tea), paraquat, and glyphosate are used to manage the majority of monocotyledonous weeds. It is advisable to uproot resistant species before they blossom and produce seeds, and to do so manually. Leaf burn or discoloured leaves, followed by wilting, are signs of accidental damage caused by herbicide residues in sprayers or drifts (The Planters′ Handbook, 2005). Herbicides are intended for plants, but since many fundamental and universal biochemical processes that are necessary for all forms of life are the same, they may also have a direct impact on other organisms. Direct effects on sensitive organisms can occur when chemicals reach the soil through targeted deposition of pre-emergent herbicides, inadvertent deposition via spray and spray drift, or dripping from contaminated plant material onto the soil. Due to fewer competitors, a decrease in the number of sensitive species may result in an increased population of resistant soil microorganisms. As a result, their use may affect species that benefit the broader agroecosystem. Herbicides may either boost or suppress the population of soil microflora, depending on the chemical, preparation, dose, sample time, and soil type (Barman and Varshney, 2008).

Table 8 Some important weeds from tea plantations as food source.

Name	Family	Edible part
Alternanthera sessilis (L.) R. Br. ex DC.	Amaranthaceae	Young shoot
Amaranthus spinosus L.	Amaranthaceae	Young shoot
Amaranthus viridis L.	Amaranthaceae	Young shoot
Cardamine hirsuta L.	Brassicaceae	Shoot
Diplazium esculentum (Retz.) Sw.	Aspleniaceae	Young fronds
Dryopteris filix-mas (L.) Schott	Polypodiaceae	Young fronds
Stellaria media (L.) Vill.	Caryophyllaceae	Shoot
Lantana camara L.	Verbenaceae	Ripe fruit
Leucas zeylanica (L.) W. T.Aiton	Lamiaceae	Flower, Shoot
Marsilea minuta L.	Marsileaceae	Leaves
Oldenlandia corymbosa L.	Rubiaceae	Whole plant
Oxalis debilis Kunth	Oxalidaceae	Whole plant
Oxalis corniculata L.	Oxalidaceae	Whole plant
Paederia foetida L.	Rubiaceae	Leaf
Persicaria hydropiper (L.) Delarbre	Polygonaceae	Leaves, stem
Pteridium aquilinum (L.) Kuhn	Dennstaedtiaceae	Young fronds
Scoparia dulcis L.	Plantaginaceae	Leafy twig
Solanum nigrum L.	Solanaceae	Ripe fruit
Solanum torvum Sw.	Solanaceae	Young fruit

Table 9 Some Invasive alien weeds of tea plantations.

Plant Name	Family	Native	Reference
Ageratum conyzoides L.	Asteraceae	Tropical America	(Thinley and Sonam, 2022).
Argemone mexicana L.	Papaveraceae	Tropical Central and South America	(Namkeleja *et al*., 2014).
Axonopus compressus (Sw.) P. Beauv.	Poaceae	Tropical and Subtropical America	(US Forest Service, 2011).
Blumea lacera (Burm. f.) DC.	Asteraceae	Tropical America	(Oudhia *et al*., 1998).
Calotropis gigantea (L.) W. T. Aiton	Apocynaceae	Tropical Africa	(Hassan *et al*., 2015).
Cannabis sativa L.	Cannabaceae	Central Asia and Pakistan	(Zheng *et al*., 2021).
Chromolaena odorata (L.) R. M. King and H. Rob.	Asteraceae	Tropical and Subtropical America	(Wei *et al*., 2017).
Senna alata (L.) Roxb.	Fabaceae	West Indies	(Jana, 2016).
Celosia argentea L.	Amaranthaceae	Tropical Africa	(Grant, 1954).
Crotalaria pallida Aiton	Fabaceae	Tropical America	(Fonseca *et al*., 2006).
Datura innoxia Mill.	Solanaceae	Tropical America	(Mardare *et al*., 2022).
Datura metel L.	Solanaceae	Tropical America	(Holm *et al*., 1979).
Grangea maderaspatana (L.) Poir.	Asteraceae	Tropical South America	(Jana, 2016)
Ipomoea pes-tigridis L.	Convolvulaceae	Tropical East Africa	(Shrikhandia *et al*., 2017).
Ipomoea quamoclit L.	Convolvulaceae	Tropical America	(Sekar *et al*., 2012).
Lantana camara L.	Verbenaceae	Tropical America	(Joshi *et al*., 2015).
Leonotis nepetifolia (L.) R. Br.	Lamiaceae	Tropical Africa	(Mendes, 1986).
Melilotus albus Medik.	Fabaceae	Europe	(Jeffery *et al*., 2018).
Mimosa pudica L.	Fabaceae	Brazil	(Parsons and Cuthbertson, 2001).
Opuntia stricta (Haw.) Haw.	Cactaceae	Tropical America	(Jana, 2016).
Oxalis corniculata L.	Oxalidaceae	Europe	(Ghosh, 2006).
Parthenium hysterophorus L.	Asteraceae	Tropical and Subtropical America	(Thinley and Sonam, 2022).
Pedalium murex L.	Pedaliaceae	Tropical America	(Jana, 2016)
Pontederia crassipes Mart.	Pontederiaceae	Tropical South America	(Datta *et al*., 2021).
Scoparia dulcis L.	Scrophulariaceae	Tropical America	(Jain and Singh, 1989).
Sida acuta Burm.f.	Malvaceae	Tropical America	(Kumar *et al*., 1996).
Solanum torvum Sw.	Solanaceae	West Indies	(Cuda *et al*., 2002).
Sonchus oleraceus L.	Asteraceae	Mediterranean	(CABI, 2020).
Synedrella nodiflora (L.) Gaertn.	Asteraceae	West Indies	(Ghayal *et al*., 2013).
Tribulus terrestris L.	Zygophyllaceae	Tropical America	(Jana, 2016).
Tridax procumbens L.	Asteraceae	Tropical Central America	(Reed, 1977).
Triumfetta rhomboidei Jacq.	Malvaceae	Tropical America	(Motooka, 2003).
Xanthium strumarium L.	Asteracea	Tropical America	(Venodha, 2016).
Erigeron canadensis L.	Asteraceae	Tropical South America	(Wiese *et al*., 1995).
Nicotiana tabacum L.	Solanaceae	Bolivia	(Baek *et al*., 2017).
Leucaena leucocephala (Lam.) de Wit	Fabaceae	Mexico	(Shrikhandia *et al*., 2017).
Amaranthus spinosus L.	Amaranthaceae	Mexico to Tropical America	(Chinmayee *et al*., 2012).
Amaranthus viridis L.	Amaranthaceae	Tropical South America	(Ghosh, 2006).
Ageratina adenophora (Spreng.) R. M. King and H. Rob.	Asteraceae	Mexico	(Ghosh, 2006).
Paspalum notatum Flüggé	Poaceae	Brazil	(Austin, 1998).
Alternanthera philoxeroides (Mart.) *Griseb.*	Amaranthaceae	Trinidad to North Argentina	(IUCN, 2016).
Mikania micrantha Kunth	Asteraceae	Tropical and Subtropical America	(Vijay, 2015).

Nowadays, cases of chemical-resistant weeds have also been noticed. A cheap and effective organic weed management method remains lacking for organic tea cultivation (Deka and Barua, 2015). Following the Green Revolution, agriculture was largely chemicalized due to poor nutrient management practices. The tea industry is also affected by this chemical threat, driven by profit-seeking strategies and negligent nutrition management practices. Due to certain growers' greed for profit, the tea business is also threatened by the use of chemicals. Tea garden soil is also affected by various chemical pesticides, such as synthetic weedicides, insecticides, and fungicides. As a result, the tea market has started decreasing globally. Only when environmentally friendly practices are used in its production does tea qualify as organic. For the best possible use of resources on the plantation itself, it is vital that an organic unit fundamentally be self-sustaining and created for the farm at the time of formation of the organic tea plantation. To construct organic tea plantations, it is vital to increase the soil's natural nutritional content and remove any synthetic pesticide residues from previous production. This advancement can be attributed to a number of factors, including increased public knowledge of the hazardous pesticide and heavy metal residues found in conventional teas as well as other potential health risks associated with an intense tea production system (Mandal, 2018). The garden management now prefers bio-organic weed/pest control after becoming aware of the detrimental consequences of chemical herbicides/pesticides (Ghosh and Das, 2011). Currently, mechanical weed treatment is unsatisfactory and has mostly been replaced by chemical-based weed management using weedicides due to increased costs and a staff shortage during the peak season. Weedicides work by interfering with key physiological processes in plants, such as photosynthesis, mitosis, and the biosynthesis of pigments and vital amino acids (Kundu *et al*., 2020). To reduce damage, weeds can be controlled by manual methods such as hand uprooting, sickling, etc. But these processes are too costly and time-consuming. Weeds can also be controlled by mechanical methods such as chisel hoeing and collar weeding. In the cheel hoeing method, surface roots can be damaged, so it is inappropriate to use it just before fertilizer application. The tools used for the collar weeding method can damage tea plant roots, forming depressions (The Planters′ Handbook, 2005). Manual weed removal/uprooting is commonly used in nurseries of tea and young tea plantations to control weeds such as *Mikania, Imperata, Setaria, Melastoma*, and others. Mechanical control, such as cheeling, sickling, hoeing, or forking, is widely used in young plantations. In comparison to herbicidal weed management, mechanical and manual weed control can be harmful to young tea roots. An integrated strategy to weed management practices includes growth. A suitable combination of diverse strategies for weeds control are now available. Weed growth is reduced through closer spacing of tea plants, inter-cropping, and the use of fast-growing varieties. Planting materials will aid in uniform ground coverage, reducing weed growth. The push-pull technology is a pest management strategy that employs repelling "push" plants and trapping "pull" plants (Rana, 2017). Because of the time, season, and cost involved, manual and mechanical methods are not a superior alternative (Kumar *et al*., 2014). New processes like the use of robotics and allelopathy may provide potent results for managing weeds in organic tea (Deka and Barua, 2015). The term "biological weed control" refers to the process by which living organisms suppress weeds. Because certain plant species can inhibit the growth of other weed species by competing for resources such as light, water, and nutrients, the biological way of growing tea can also be regarded as an ecological method. For instance, if planted together, *Urochloa brizantha* and *Panicum repens* might inhibit each other's growth through allelopathy (Prematilake, 2003). According to a study by Pathinayake *et al*. (2019), the mature foliage of several shade trees, including *Gliricidia sepium* (Jacq.) Kunth, *Calliandra calothrysus* Meisn., *Acacia pruinose* A. Cunn. ex Benth., *Erythrina lithosperma* Blume ex Miq., and *Grevillea robusta* A. Cunn. ex R. Br., has been found to contain certain allelochemicals. Among these, an 80% W/V concentration of G. *sepium*'s oven-dried leaf extract may be used to control succulent broad-leaf leaf weeds in tea estates. G. *sepium* at 80% recorded the significantly highest dead weed count 14 days after treatments (*Cleome aspera* J. Koenig ex DC., 100%; *Bidens Pilosa* L., 66.6%; *Ageratum conyzoides* L., 66.6%). *Striga* *hermonthica* (Delile) Benth. and *Striga asiatica* (L.) Kuntze were successfully controlled by a few fungus, including *Fusarium oxysporum*, *Fusarium solani*, and *Fusarium nygamai*. *Striga hermonthica* (Delile) Benth. seed germination is also effectively suppressed by rhizobacteria (Ambrose *et al*., 2018). The weed population can be suppressed by acetic acid, organic herbicidal soaps such as ammonium nonanoate and pelargonic acid, as well as several essential oils like clove, citrus, cinnamon, and lemongrass oil (Tiwari and Kanissery, 2021). Weeds like *Parthenium hysterophorus* L. and *Lantana camara* L. can be controlled by some bio-control agents, such as *Zygrogramma bicolarata* and *Crocidosema lantana*, respectively (Behera and Nanda, 2019). Despite the ecological, environmental, and health benefits of non-chemical weed control techniques, small-scale growers are less likely to employ them for a number of reasons, including a high labor rate and a labor scarcity (Owombo *et al*., 2014).

Conclusion

Understanding weed ecology and the physiological, biochemical, and molecular mechanisms of crop-weed interactions and herbicide resistance under a changing climate is essential. The development of weed risk-assessment protocols for major alien-invasive weeds (AIWs) and their practical implementation is urgently required. Digitization of presence AIWs and biocontrol agents nationwide is strongly needed. Efforts should be made to introduce more biocontrol agents. In view of the emerging challenges in agriculture due to declining soil health, water shortages, energy crises, climate change, and global warming, etc., the long-term impacts of chemical abuse on weed flora shifts, weed seedbanks, and insect-pest dynamics, and the management strategies to address them, need to be worked out.

Disclosure of conflicting interests

The authors did not report any potential conflicts of interest.

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مروری بر علف‌های هرز مزارع چای آسام و بنگال غربی هند و مدیریت آن‌ها

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دریافت: ۱۸ خرداد ۱۴۰۳؛ پذیرش: ۱۳ مهر ۱۴۰۴

چکیده: مشهورترین مناطق تولید چای در هند در نزدیکی دامنه کوه‌های هیمالیا واقع شده‌اند. مکان‌های فوق شامل آسام و بنگال غربی است. این مناطق دارای آب و هوای گرمسیری تا نیمه‌گرمسیری با بارندگی سالانه از ۱۱۵۰ تا ۲۸۰۰ میلی‌متر و دمای ۱۰ تا ۳۵ درجه سلسیوس مشخص می‌شوند. به‌علاوه، این شرایط تکثیر طیف متنوعی از گونه‌های علف هرز را تسهیل می‌کند. علف‌های هرز تقریباً در تمام مراحل رشد گیاهان چای حضور دارند، اما بیشتر آن‌ها در دوره اولیه کاشت اهمیت اقتصادی دارند. علف‌های هرز بسته به‌شدت رشد، سطح رقابت، نوع علف هرز و توانایی رقابت کلون‌ها، ۱۰ تا ۵۰ درصد از بهره‌وری چای را کاهش می‌دهند. لذا درصورت عدم‌مراقبت، علف‌های هرز می‌توانند از بوته‌های چای پیشی بگیرند و درنهایت به‌دلیل رقابت شدید برای مواد مغذی و رطوبت، منجر به مرگ آن‌ها شوند. این بررسی بر علف‌های هرز در مزارع چای در آسام و بنگال غربی تمرکز دارد. این مطالعه همچنین اثرات مضر و مفید آن‌ها، تهاجمی بودن و مدیریت آن‌ها را آشکار می‌کند.

واژگان کلیدی: علف‌های هرز، مدیریت علف‌های هرز، مزارع چای، آسام، بنگال غربی