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Allelopathic Plants: 33. *Rottboellia cochinchinensis* (Lour.) W.D. Clayton

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ABSTRACT

Itchgrass [*Rottboellia cochinchinensis* (Lour.) W.D. Clayton] is a C_4 annual upland grass, which is self-pollinated and invades disturbed and agricultural areas in more than 40 countries in tropical and subtropical regions of the world. The plant exerts high competition for row crops due to its high tillering capacity. Conversely, itchgrass is an allelopathic plant, which is often used as a mulching material for weed control in vegetable fields in Chae Hom district, Lampang Province, Northern Thailand. Itchgrass plant mulch can conserve soil moisture, minimize soil erosion and suppress other weed species. In this review, the available published literature has been compiled to understand the mechanism of allelopathic action of this important grass and to highlight its significance in the cropping systems. It has been noted from the literature that the allelochemicals released from itchgrass in the soil can adversely influence the germination of some adjacent weeds and test crops, causing a growth reduction of seedlings. Various authors have concluded that *trans-p*-coumaric acid (*trans*-4-hydroxycinnamic acid) is the major allelochemical present in itchgrass. Additionally, two active substances have been reported to be isolated from *n*-hexane crude extracts of the itchgrass aerial part and has been identified as linoleic acid (9,12-octadecadienoic acid) and linolenic acid (9,12,15-octadecatrienoic acid). It can be concluded that both direct and indirect allelopathic effects are involved in facilitating succession of itchgrass plant. Better understanding

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of its allelopathic potential will provide a basis for improving the non-chemical weed management strategies in vegetable fields for sustainable agriculture.

Keywords: Allelochemicals, allelopathic plant, allelopathy, invasive weed, Itch grass, mulch, *Rottboellia cochinchinensis*, weed control.

1. INTRODUCTION

Itchgrass [*Rottboellia cochinchinensis* (Lour.) W. D. Clayton] is an annual upland weed, which is self-pollinated and widely distributed in the tropical and subtropical regions of the world (27). It has been reported as a problematic weed in row crops, especially grass crops and pastures, in several countries (22,28). The plant is a dominant species in some regions including Thailand where it has become a serious weed problem in various crops, such as soybean [*Glycine max* (L.) Merr.], maize (*Zea mays* L.) and sugarcane (*Saccharum* spp.) as well as in orchards (26). Several studies have reported that itchgrass competes with plants for nutrients, water, space and light for photosynthesis. Inter-specific competition of itchgrass with field crops can lead to crop yield losses and a reduction in crop quality (11,16,22,26). This species is a native to Southeast Asia (16) and has been recognized as an aggressive invader in disturbed areas in Brazil, Costa Rica, Cuba, Guatemala, Malaysia, Mexico, South America, Trinidad and Venezuela (3,4,5,31,36). This plant possesses stiff, irritating trichomes on the leaf sheaths and exerts allelopathic and phytotoxic effects on neighboring plants by releasing allelochemicals in the soil (26,31). All these attributes have contributed this species being listed among the world's most problematic weeds (27).

The different biotypes of itchgrass commonly found in Thailand can be divided into two groups (Group A and Group B) by cluster analysis based on specific morphological characteristics and genetic diversity related to allelopathic properties (7).

Group A. Red-pink leaf sheath: It consisted of itchgrass from 7-locations (Chaehom-Lampang, Si Thep-Phetchabun, Phrom Phiram-Phitsanulok, Amphur Muang-Nakhon Sawan, Kamalasai-Kalasin, Amphur Muang-Chachoengsao, and Bang Yai-Nonthaburi), having red-pink leaf sheath colour and purple ligule.

Group B. Green leaf sheath: It consisted of itchgrass from 3-locations (Amphur Muang-Chiang Mai, Pak Chong-Nakhon Ratchasima, and Kamphaeng Saen-Nakhon Pathom), having green leaf sheath colour and slightly green ligule.

Thus, the specific biotype of itchgrass with a minimum interference to crop should be used as a mulching material for weed control in vegetable fields in Chae Hom district of Lampang Province in Northern Thailand. Other biotypes of itchgrass, which can harm the growth and yield of crops, should be controlled to prevent weed problem. Biotype of itchgrass with a low interference ability to the main crop is an allelopathic plant, which is commonly used as a mulching material for weed control in vegetable fields in Chae Hom district of Lampang Province in Northern Thailand (Figure 1A-B), where traditional method of weed control is extensively practiced. It has been reported to be allelopathic to various crops, including maize (3,4) and rice (*Oryza sativa* L.) (11). There have been reports of the inhibitory activity of aqueous extracts from itchgrass on germination and seedling growth in non-soil (filter paper and sea sand mixed with peat) medium (11). Some studies have reported the allelopathic potential of itchgrass powder incorporated into the soil under controlled environments (20). The allelopathic potential of itchgrass on some test plants has been observed in bioassays using filter paper soaked with aqueous extracts (11,26).

Similarly, Kobayashi *et al*. (20) found that soil amended with shoot or root ground powder of itchgrass inhibited the growth of radish (*Raphanus sativus* L. var. *radicula*) seedlings under controlled conditions with decreasing allelopathic activity in the soil over time. Additionally, this specie releases allelochemicals into the soil under natural field conditions. Itchgrass seeds are sown, seedlings emerge and grow and mature plants are used to spread as a mulch before vegetables cultivation. Interestingly, the density of other weed species has been remarkably reduced in fields that are mulched with itchgrass (20,26). This indicates that itchgrass has strong competitive and allelopathic activity to other adjacent competing plant species by adversely impacting their germination and growth.

Figure 1. Itchgrass mulching materials (A) and its utilization for weed control in a vegetable crop (B) in Chae Hom, Lampang Province, Northern Thailand.

Traditional weed control using the allelopathic potential of itchgrass has been practiced, using it as a mulching material for weed control in vegetable fields, such as cabbage (*Brassica oleracea* L. var. *capitata*), Chinese cabbage (*Brassica rapa* subsp. *chinensis*) and kale (*Brassica oleracea* var. *sabellica*). In this review, the allelopathic potential of itchgrass is described as an effective biological solution for weed control to reduce dependence on synthetic herbicides in vegetable fields. Its phytochemicals contain allelopathic properties, which can be utilized as one of the non-chemical strategies in weed management. Therefore, a better understanding of the allelopathic activity of itchgrass will provide a basis for improving weed management in vegetable fields for sustainable agricultural systems.

2. MORPHOLOGY, GEOGRAPHICAL DISTRIBUTION, TAXONOMY

Itchgrass is a warm season annual grass often found in pastures, roadsides and fields of row crops, such as maize, beans, soybean, rice, peanut (*Arachis hypogaea* L.) and sugarcane. The major natural propagating material for this plant is seed. The plant produces large quantities of seeds (between 2,200 and 16,500 per plant depending on the growing season) (16), with a maximum dormancy period up to four years (24). The long dormancy and massive seed production have made it a noxious weed, the antagonistic allelopathic effects of itchgrass on other weeds have great prospects for weed control.

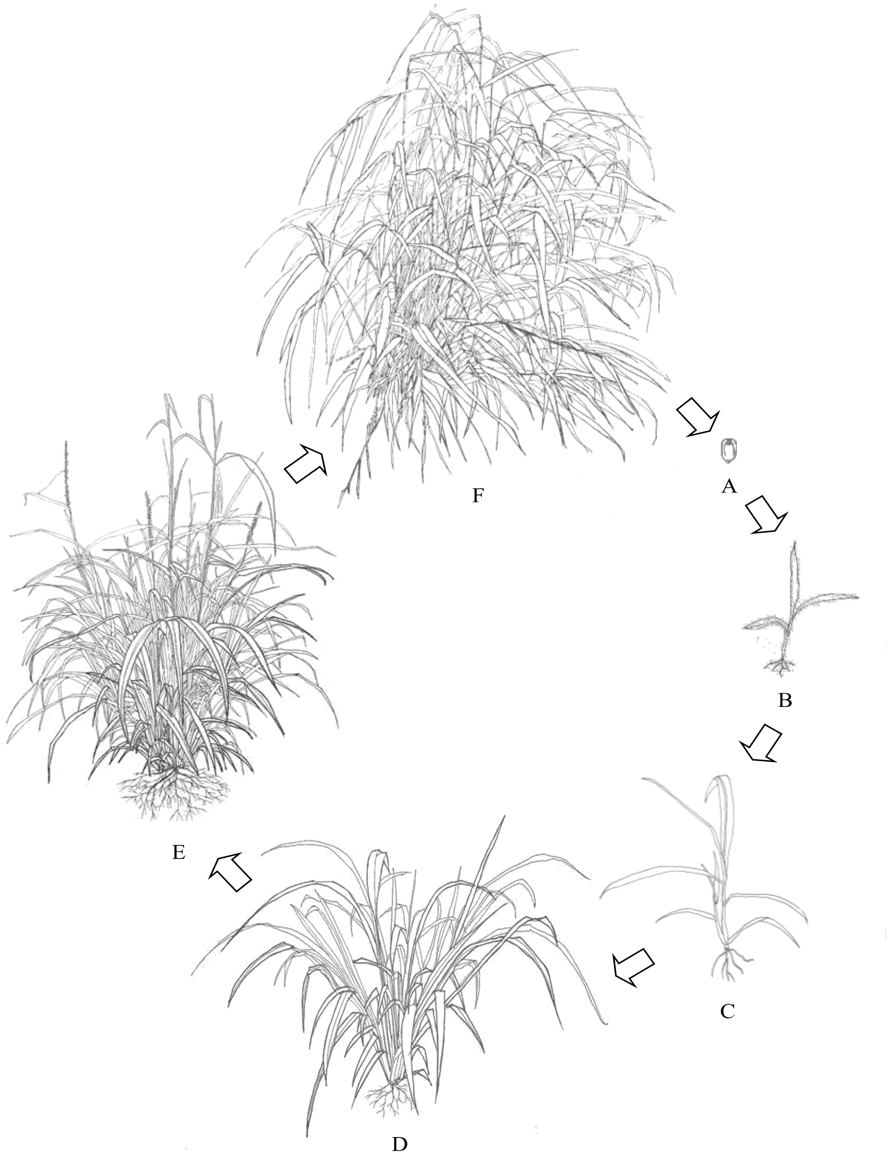

Figure 2. Life cycle of itchgrass from the farmer's fields: A = seed, B = 3-leaf stage, C = first tiller stage, D = maximum tillering, E = flowering and F = maturity (25).

The life cycle of itchgrass from farmer's field is shown in Figure 2. Itchgrass seedlings grow to the three-leaf stage at 5-7 days after planting (DAP), reach first tiller stage at 15-19 DAP until maximum tillering at 30-33 DAP, with the flowering stage at 35-41 DAP and maturity (seed set) at 104-112 DAP. Bundit *et al.* (7) observed that soft trichomes and dark purple colour stems of itchgrass are the specific morphological traits. However, some traits of itchgrass may be dependent on the genotype and environment.

Itchgrass can reach 3 m or more in height and produce many tillers. It has short stiff hairs on the sheaths, especially near the collar, which can puncture. The plant is characterized by having thick roots emerging from the base of the culm; leaf blades and sheaths with siliceous tuberculate hairs; inflorescence is cylindrical terminal and axillary racemes 3-15 cm long, usually subtended by an inflated leaf sheet; rachis is fragile, inflated, releasing in cylindrical diaspores composed of an internode segment fused to the internode, one sterile pedicellate spikelet and one fertile sessile spikelet.

The inflorescence is a raceme approximately 10 cm long with spikelets in pairs and no awns. One of each spikelet is stalked and sterile, the other is stalkless and fertile. Each spikelet is attached to a thickened axis. The fertile, stalkless spikelet is oblong and around 0.5 cm long. Plant growth is fast under favourable conditions with seed production initiating 6-7 weeks after emergence. Seed production continues throughout the growing season. Seeds break off as they mature, but require 5-6 months for ripening prior to germination.

Since itchgrass often dominates in rights-of-way areas, the most possible mechanism of dispersal is via maintenance equipment, such as mowers. It may also occur in other managed habitats, such as pastures and row crops.

3. AGRICULTURAL IMPORTANCE

Itchgrass releases allelochemicals into the soil under natural field conditions. The allelopathic activity of itchgrass in soil is influenced by the soil moisture, soil texture and environmental conditions. Soil moisture regulates the decomposition rate of plant materials in the soil. Dry condition slows decomposition rate of plant materials by influencing microbial ecology. Therefore, the allelochemicals may remain within the plant materials longer under dry conditions, compared with moist soil conditions. In addition, its possible interactions with soil chemical properties reduces the germination and plant growth, either directly or indirectly, by interfering with the soil chemical properties and nutrient availability.

3.1. Invasion of itchgrass

The allelochemicals secreted by itchgrass possess a prospective potential to become an agriculturally-important plant due to the inhibitory effects of those allelochemicals on other weed species. Farmers in Thailand are using itchgrass to control weeds despite being an exotic weed (26). Although the allelochemicals released by itchgrass may interfere with neighbouring weeds and thereby work in our favour if managed properly, the suspicion on its invasion at the first place through allelopathy still remains according to the "novel weapon hypothesis" (37,38). Moreover, many studies are also in favour of allelopathy on the ability of exotic species to stand in an invaded ecosystem (39). However, such phenomenon for itchgrass invasion in Thailand and other countries in the world is not well documented, but its fast-growing nature, large vertical and horizontal canopy coverage; and competition with other plants for nutrients, water, space and light remains superior facts for its invasion (11,16,28). The probable major invasion process of itchgrass since the beginning of the 20th century is through contamination of agricultural implements and propagation materials as seed, (28). In several places, for example, USA, itchgrass was introduced as a pasture grass. Animals and birds are minimally considered as a dispersion agent as only 0.3 % seeds have chances to survive their gut mucus (40). Although the actual means of introduction of itchgrass in Thailand cannot be determined, the possibility of invasion can be assumed from Vietnam, its place of origin.

3.2. Use for weed control in Thailand

To evaluate the varied growth responses and impacts of different itchgrass biotypes on other weeds, itchgrass was cultivated in a farmer's fields in Ban Saa, Chae Hom district, Lampang Province, Northern Thailand (18°41'43.5"N, 99°34'22.8"E). The area has an elevation of 268.8 m above mean sea level, annual rainfall of 955.8-1,219 mm (averaged over five years) and a temperature ranging between 8.2 and 41.5°C. It was found that some biotypes of itchgrass are not very hairy (have less trichome), less itchy and do not germinate in the dry season; however, these biotypes can be grown in the wet season, especially in lowland areas. In the dry season, the plant was almost 2 m high when the seeds reached to maturity. When itchgrass plant material was spread on the soil surface, it was possible to transplant the seedlings of vegetable crops, such as cabbage, Chinese cabbage and kale without any tillage operation (Figure 1A-B). Itchgrass plant mulch can conserve soil moisture and control other weed species, but its seeds can germinate toward the end of the growing season (4 to 5 months after spreading the itchgrass plant material on the soil surface) and the itchgrass itself can interfere with the following crop. However, the key to the feasibility of using itchgrass as a weed control mulch remains in its favour of growing habitat and photoperiodic nature (27). Itchgrass seed is very sensitive to moisture and light for germination. Under dry environments, itchgrass seeds did not germinate well (40), whereas germination drastically increased with an increasing water content of the soil. Insufficient light also had an inhibitory effect on germination of in-husk seeds; however, no effect was observed on de-husked seeds. Therefore, apparently itchgrass remains left after crop harvest may continue to suppress the itchgrass itself during the fallow season, and cultivating crops with low water requirement should not face any threat from itchgrass propagules.

Weed control by itchgrass incorporation into the soil in the vegetable fields in Chae Hom, Lampang, Northern Thailand, might be induced by phytotoxic chemical(s) released from the incorporated materials in the soil. The density of other weed species was markedly reduced in the field with itchgrass incorporation into the soil. The degree of phytotoxic effects of allelochemicals in the soil are largely influenced by soil properties and environmental conditions. Based on the bioassay data, it is highly possible that allelochemicals are present in itchgrass root and shoot powder and can persist in the soil. Kobayashi *et al*. (20) and Bundit *et al*. (6) reported that the allelochemicals released from itchgrass persisted only for 14 days after incorporation in the soil, but farmers in Chae Hom, Lampang Province use itchgrass as a mulching material for 1-2 months for controlling weeds. Thus, the allelopathic activity of itchgrass might remain in the soil for more than 14 days after incorporation. According to Xuan *et al*. (32), toxic compounds were detectable upto 2 months after incorporation. The results suggest that the maximum period for activities of residues in the soil might be 15-30 days after incorporation. The residual effects of allelochemicals under field conditions decreases over time and may be affected by the concentration, type of compound and soil properties (2,12).

Several studies have reported that allelopathic activity is affected by the level of soil moisture (30,33), which directly influences the decomposition rate of plant materials in the soil (29). Dry soil conditions might cause as low decomposition rate of plant materials by influencing microbial ecological factors (17). Therefore, the allelochemicals may remain within the plant materials longer under dry conditions than in moist soil. This is in agreement with Dalton *et al*. (13) who found that organic matter was the main source of irreversible sorption of ferulic acid, but another study found inconsistent trends between the organic matter contents and sorption in some soils (14). Thus, allelochemicals may remain within the plant residue depending on the soil moisture status and be slowly released as the plant material is degraded by soil microorganisms or leached by soil water.

3.3. Bio-ecological Agriculture

In case of nuisance situations with itchgrass, pendimethalin, nicosulfuron, cyclohexanediones containing herbicide formulations can be used (36), but adopting biological control remains the safest route. Itchgrass is highly susceptible to head smut fungus, *Sporisorium ophiuri* (41,42), and spike rot fungus, *Exserohilum monoceras* (41), a fungus being considered for *Echinochloa colona* biocontrol. Itchgrass is also susceptible to some native fungal species, such as pathogenic strains of genera *Curvularia*, *Drechslera* and *Fusarium* (43,44), but the use of these as biocontrol should be selected depending on the cropping practice.

In most cases, farmers can grow at least two crops having a short life cycle before the arrival of monsoon. Notably, allelochemicals from itchgrass that can effectively suppress weed emergence can aid in reducing weeds populations and in improving soil quality and crop yields.

Farmers' usually use mature itchgrass as a mulching material, for which they sow the seeds of itchgrass in the rainy season and wait until the plant reaches maturity and seed production stages. Then, the itchgrass plant parts are manually or mechanically spread as a mulch on top of the soil surface before starting the cultivation of vegetable crops. Itchgrass mulch has been reported to remarkably reduce weeds density in vegetable fields (6,7,26). It has been suggested that itchgrass may produce and release allelochemicals into the soil negatively affecting neighbouring weeds. Almost all allelopathic activities due to the release of allelochemicals from itchgrass occur under field conditions. The effect of soil moisture on the allelopathic activity of itchgrass in soil have been observed by Kobayashi *et al*. (20) and Bundit *et al*. (6). Incorporating itchgrass powder into soil had inhibitory allelopathic effects on the growth of *Ageratum conyzoides* L. and *Echinochloa crus-galli* (L.) Beauv. The effectiveness of inhibitory allelopathic effects was intensified with increased concentrations of itchgrass powder. The allelopathic activity of itchgrass in soil persisted for a maximum of 15 days after incorporation, followed by a decrease over time. The allelopathic activity of itchgrass was lower in submerged soil compared with half-saturated soil conditions and was the highest in dry soil. The utilization of itchgrass in practice as a mulching material might be useful for biological weed control and for reducing the amounts of herbicides that are used in vegetable production systems in Thailand.

3.4. Sustainability of Agriculture

Traditional non-chemical weed control using allelopathic potential of itchgrass has been practised through mulching of itchgrass plant materials in vegetable fields. A notable reduction in weed density has been recorded in different crops, where itchgrass has been incorporated through mulching, indicating its strong allelopathic impact on the adjacent plants. The phytotoxic activity of itchgrass could be linked with the direct release of one or more allelochemicals from living plant parts or the indirect release of one or more toxic substances or both after decomposition of the plant residues by microorganisms in the soil. These findings suggest that allelochemicals from itchgrass, which exhibit a strong ability to suppress weed emergence, are helpful in reducing weed populations and in improving soil quality and crop yields.

The allelopathic effects of itchgrass powder incorporated in soil samples confirm that itchgrass releases allelochemicals into the soil that subsequently inhibit plant growth (20). In addition, weed density in itchgrass-infested areas remain significantly different from that in non-infested areas, indicating a better weed control potential of itchgrass in its vicinity (26). The allelopathic effect of itchgrass on germination and seedling growth of other plant species has been investigated using bioassays. Some weeds contain and release phytotoxic compounds (allelochemicals) into the soil that inhibit the germination and growth of other plants (18). Experimental results have shown that itchgrass can suppress the growth of major competitive plants in the field, such as the growth of *Bidens pilosa* L. *radiata* Sch. Biq., *Mimosa pudica* L., *A. conyzoides* L. and *E. crus-galli*. However, the growth of two cultivated crop species, *Oryza sativa* L. var. RD6 and *Lactuca sativa* L. var. OP, which do not often compete with itchgrass in natural ecosystems, has been also inhibited. The results suggest that weed control by itchgrass incorporation into the soil in vegetable fields in Chae Hom, Lampang Province, Northern Thailand might be induced by allelochemicals released from the incorporated materials in soil water. It is possible that allelochemicals are contained in itchgrass parts and can persist in the soil. Therefore, the use of itchgrass as a mulching material holds promise for non-chemical weed control in vegetables crops and for reducing the amounts of herbicides that are commonly used in vegetable fields in Thailand. The use of the allelopathic activity of itchgrass offers great promise for improving weed management strategies in achieving ecologically sustainable weed management.

It has been also observed that itchgrass samples from different accessions have different allelopathic effects. For example, the aqueous extract from a farm field had inhibitory effects on the seedling growth of *B. pilosa*, *E. crus-galli* and *L. sativa*, while the aqueous extract of itchgrass from other sites did not significantly inhibit the growth of test seedlings. This indicates inconsistency in allelopathic potential of itchgrass from diverse origins. Such divergence in allelopathic potential has been attributed to genetic background of the allelopathic plant, nature of the chemical and environmental factors (35). However, molecular analysis is consistent with morphological traits clustering and has been related to bioassay testing for allelopathic effects (7). Therefore, specific traits, such as soft trichomes, dark purple stems and roots, can be used for the preliminary evaluation of genetic diversity related to the allelopathic potential in itchgrass.

Itchgrass extract can be prepared using distilled water and organic solvents, all extracts exerted inhibitory effects on the growth of test plants (6,7,8,26). However, itchgrass extracts isolated using different solvents contain different types of allelochemicals as the properties of solvents vary depending on their polarities.

The greatest phytotoxic activity of itchgrass in soil has been observed 15 days after incorporation, with a gradual reduction of activity afterwards. The inhibition of the growth of test plant in soil incorporated with itchgrass powder is primarily caused by the allelochemicals released from the powder of itchgrass into the soil. Similar results have been observed when the allelopathic performance of itchgrass has been evaluated on radish [*Raphanus raphanistrum* subsp. *sativus* (L.) Domin] (20) and sweet vernal grass (*Anthoxanthum odoratum* L.) (33).

4. ALLELOPATHIC RESEARCH

4.1. Allelochemicals

The structural elucidation of allelochemicals provides important information to understand the biological plant interactions in an ecosystem or under field conditions. Therefore, the isolation and identification of allelochemicals and their biological activity provides basic information in deciding the optimum weed management programme in cropping systems. The structure of allelochemicals in itchgrass can be classified into the following types:

(i). *Trans-p*-coumaric acid: Its powdered aqueous methanol extracts exert inhibitory effects on the seedling growth of tested plant species. The inhibitory potential depends on the solvents used. Thus, the top priority was to isolate and identify the allelochemicals. *Trans-p*-coumaric acid had been isolated and purified from aqueous methanol extracts (Figure 3A) (9). Its chemical structure was identified using electrospray ionization mass spectrometry (ESI-MS) data, ^{1}H and ^{13}C nuclear magnetic resonance (NMR) spectroscopy. However, *cis*- form of *p*-coumaric acid has been detected in the ^{1}H NMR spectral analysis, while the *trans*- form of *p*-coumaric acid has been observed more abundant in the fraction based on the ^{1}H NMR spectral signal. The *cis*- form might be evident during the extraction process (23) by isomerization through photo-induction (15,21). Under field conditions, farmers use dried itchgrass material as a mulch for 1-2 months for weed control in vegetable cropping, where the daytime temperature can exceed 40 °C. Thus, *cis-p*-coumaric acid may be produced by temperature induction under field conditions and subsequently may influence weeds suppression (Figure 3B).

(ii). Linoleic acid and linolenic acid: Two fatty acids [linoleic acid (Figure 3C) and linolenic acid (Figure 3D)] have been isolated and identified from the itchgrass *n*-hexane extracts, based on ^{1}H and ^{13}C NMR (8). Both these fatty acids are classified as allelochemicals; linoleic acid has also been isolated from *Sesbania punicea* seed and identified as dominant plant growth inhibitor (10) and linolenic acid induces jasmonate biosynthesis in plant cell, leading to the suppression of mitosis (34). Thus, linolenic acid may exhibit inhibitory activity on plant growth *via* an indirect inhibition mechanism.

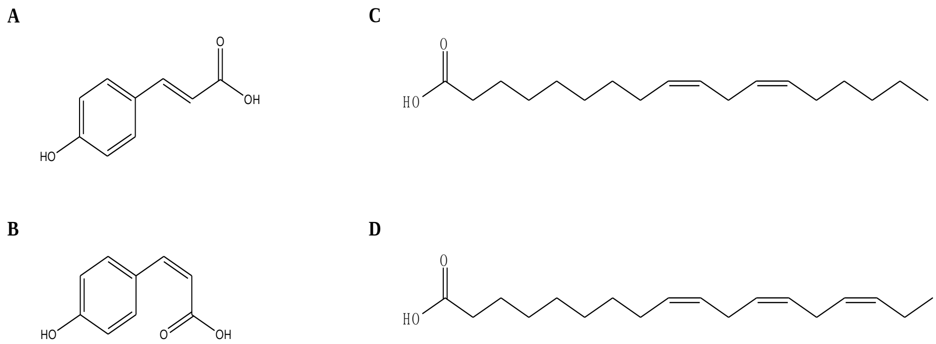

Figure 3. Isolated compounds from itchgrass. A: *trans*-*p*-coumaric acid, B: *cis*-*p*-coumaric acid, C: linoleic acid and D: linolenic acid.

4.2. Bioassays

The bioassay are done to study the bioactivity and potential allelopathic effects of identified biologically active substances. While exploring other phytotoxic compounds from the aerial part of itchgrass, the *trans*-*p*-coumaric acid has been identified as the major allelochemical in itchgrass. Additionally, two active substances have been identified as linoleic acid and linolenic acid. The allelochemicals identified from itchgrass are classified as (i) cinnamic acid and its derivatives, and (ii) long-chain fatty acids and polyacetylenes. Many of these compounds have strong allelopathic effects on several weed species. Its herbicidal allelopathic compounds may be developed as ecofriendly herbicides to reduce reliance on synthetic herbicides.

4.3. Field studies

One of the major challenges in agrochemical research is managing weeds with less dependence on synthetic herbicides use. Phytotoxic substances from plants have drawn increased attention as they provide an alternative biological approach in controlling weeds. Thus, it is expected that allelopathic plants can be exploited as a new strategy for weed management in agricultural systems. Although mulching material has physical effects on suppressing weeds under field conditions, the allelopathic activity of donor plants also involves weed suppression. It has been speculated that both direct and indirect allelopathic effects are involved in facilitating the invasion success of itchgrass plant. Three allelochemicals have been isolated from itchgrass using different organic solvents; *trans*-*p*-coumaric acid has been isolated from the methanolic extracts, whereas linoleic acid and linolenic acid have been isolated from *n*-hexane extracts from the aerial part of itchgrass. However, the phytotoxic effects of these 3-allelochemicals significantly inhibits the growth of test plants in a dose-dependent manner (8,9). The inhibition caused by allelochemicals on the growth of test plants increases with an increase in concentration. Thus, to understand allelopathic activity, further investigation is necessary on endogenous levels of linoleic acid, linolenic acid and *trans*-*p*-coumaric acid in different parts of itchgrass plant and in soil, previously incorporated with itchgrass in vegetable fields. This information will provide greater understanding of the allelopathic potential of itchgrass for weed control in vegetable crops. Its herbicidal allelopathic compounds may be developed as ecofriendly herbicides to reduce reliance on synthetic herbicides.

5. ECOLOGICAL WEED CONTROL

Plants are dependent to the nature and there is competition for growth resources (sunlight, water and soil nutrients) in every ecosystem. To ensure efficient resource capture, plants employ various strategies for their own succession. For example, itchgrass uses its allelochemicals to suppress other plants so that it can thrive. Exploiting such naturally existing weed control measures and using those in favour of crop production is the main principle of ecological weed control (Figure 4).

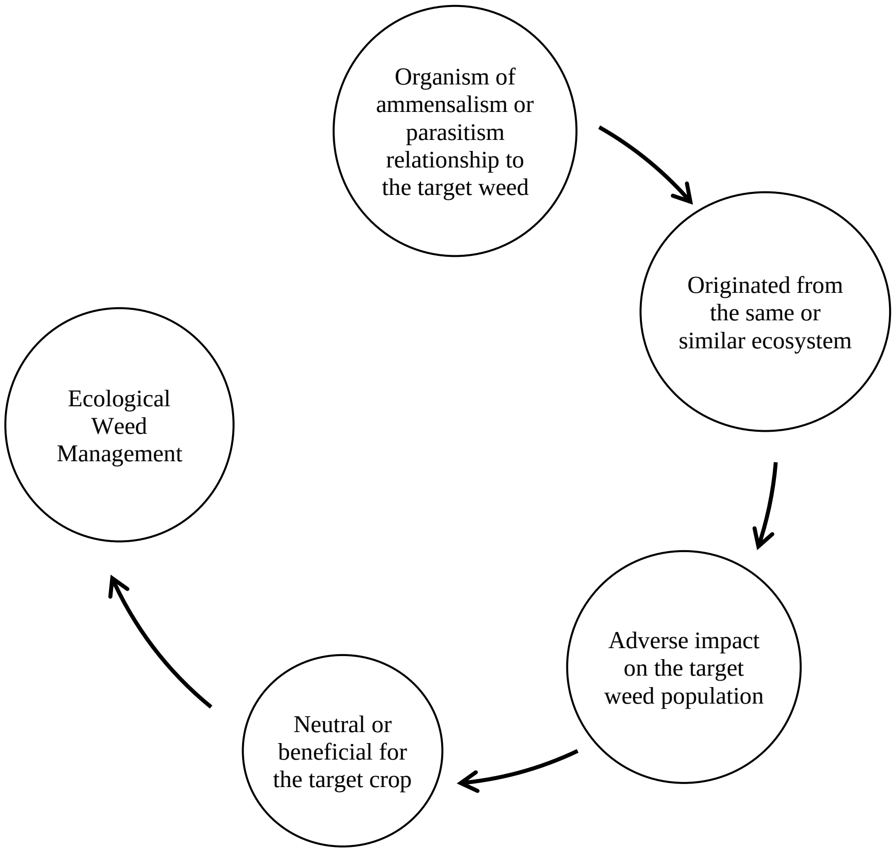

Figure 4. Concept and principle of ecological weed control. Adapted from Bahadur *et al*. (1).

Ecological weed control directly comes under biological control approaches of sustainable weed management that involves the use of living organisms from the same ecosystem or broadly from the same country of origin as the target weed species that affect its health or reduce its population (1).

6. FUTURE AREAS OF RESEARCH

The allelochemicals from itchgrass strongly suppresses the weeds emergence, thereby reduces weeds populations and improves soil quality and crop yields. The allelopathic potential of itchgrass can be exploited for the development of natural herbicides. Future research on the allelopathic potential of itchgrass in controlling weeds should focus on the following aspects:

a) Structural elucidation of the constituents of the allelochemicals from different plant parts.
b) Clarification of the action mechanism of each allelochemical and characterization of their sorption-desorption behaviors in soil.
c) Investigation of the exact interactions between itchgrass and plant species and of concentrations sufficient to suppress the growth of weeds present under field conditions, by examining effective doses and the total activity of allelochemicals on the principal invasive and harmful weeds.
d) Investigation of the influence of climatic factors on the allelopathic activity of itchgrass.
e) Improvement of the weed management program by using other allelopathic plants in the same manner as itchgrass.
f) Evaluation of the comparative response of different weeds under the allelochemical action of itchgrass to identify the weed species most effectively controlled by the allelopathic action of itchgrass.

7. CONCLUSIONS

Itchgrass is an allelopathic plant and releases herbicidal allelochemicals into the soil under natural field conditions. It has been used as mulch for weed control in vegetable production in farmer's fields in Chaehom-Lampang area, Northern Thailand, where traditional weed control is practiced. The allelopathic potential of itchgrass can be used for the development of natural herbicides. Furthermore, the introduction of allelopathic traits from accessions with a strong allelopathic potential to the target crops will enhance the efficacy of the allelochemicals from itchgrass in the future sustainable agricultural production.

DECLARATION

We declare that all authors of this Ms. have made substantial contributions. We did not exclude any author who substantially contributed to this Ms. We have followed our ethical norms established by our respective institutions.

CONFLICT OF INTEREST

The authors announce that they have no conflict of interest.

ETHICAL APPROVAL

The authors declare that the study was carried out following scientific ethics and conduct. However, this study did not involve any use of animals, hence no ethical approval has been obtained from the concerned committee.

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