

Tithonia Diversifolia

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Tithonia diversifolia (Hemsl.) A. Gray (Asteraceae) is native to Mexico and Central America. The species is spreading quickly and has naturalized in more than 70 countries. It has often been recorded as a harmful invasive plant which disturbs native plant communities. Phytotoxic chemical interactions such as allelopathy between invasive plants and native plants have been reported to play an important role in the invasion. Evidence for allelopathy of *T. diversifolia* has accumulated in the literature over 30 years. Thus, the objective of this review was to discuss the possible involvement of allelopathy in the invasive potential of *T. diversifolia*. The extracts, root exudates and plant residues of *T. diversifolia* inhibited the germination and growth of other plant species. The soil-water and soil collected from *T. diversifolia* fields also shown growth inhibitory effects. The decomposition rate of *T. diversifolia* residues in soil was reported to be high. Phytotoxic substances such as sesquiterpene lactones were isolated and identified in the extracts of *T. diversifolia*. Some of phytotoxic substances in *T. diversifolia* may be released into the soil through the decomposition of the plant residues and the exudation from living tissues of *T. diversifolia* including its root exudates, and act as allelopathic substances. Those allelopathic substances can inhibit the germination and growth of neighboring plants, and may enhance the competitive ability of the plants and make the plants invasive.

allelopathy

invasive plant

phytotoxicity

sesquiterpene lactone

Tithonia diversifolia

1. Introduction

Tithonia diversifolia (Hemsl.) A. Gray (phylum: Spermatophyta, class: Dicotyledonae, order: Asterales, family: Asteraceae, genus: *Tithonia*) is known as Mexican sunflower, tree marigold, or Nitobe chrysanthemum. It grows rapidly, reaching 2–3 m in height with large alternate lobe leaves (up to 45 cm long). The monocarpic capitulum are 10–30 cm long and bear bright yellow flowers (5–15 cm in diameter). The plant often forms pure stands with high density (8–20 plants/m²) [1][2][3].

T. diversifolia can be harvested year-round and all parts of the plants have been used by indigenous people as folk medicine for a wide range of diseases and ailments, through topical administration to treat abdominal pain, wounding, dermatosis, and muscular disorder; and through oral administration to treat infection, malaria, fever, hepatitis, and diabetes [3][4]. Thus, the plants have a broad spectrum of medicinal values.

More than a hundred secondary metabolites in many classes have been isolated from various parts of *T. diversifolia* extracts, including sesquiterpenoids, diterpenoids, and flavonoids. Tagitinins A, C, and F were first isolated from *T. diversifolia* [5][6]. The effects of the extracts of *T. diversifolia* and those compounds isolated from *T. diversifolia* have been widely studied in human cell lines, microorganisms, and some animal models. These studies showed an extended spectrum of biological activities for the extracts and compounds, such as anti-inflammatory and analgesic activities; antiprotozoal activity, including antimalarial effects; and antiviral and anticancer activities. The compounds of *T. diversifolia* and their pharmacological activities have been discussed in the review articles [3][4][7]. Therefore, *T. diversifolia* is one of the important sources of pharmacologically active substances, and the study of these compounds may contribute to developing potential medicines for various treatments.

T. diversifolia also works as green manure, increasing crop productivity, and acts as fodder for domestic animals because of its high mineral and nutrient values [8][9][10][11]. On the other hand, *T. diversifolia* aggressively expands its habitat into agricultural and non-agricultural areas, becoming a serious farmland weed and disturbing native plant communities as an invasive plant species [2][7][12]. The species has shown allelopathic potency on the germination and growth of several other plant species [13][14][15]. Allelopathy may play an important role in the invasion of *T. diversifolia*. The objective of this review was to discuss the possible involvement of allelopathy in the invasive potential of *T. diversifolia*. Thus, this review summarized the allelopathic properties and invasive traits of *T. diversifolia* and discussed the importance of allelopathy for its invasive characteristics.

2. Invasive Traits of *T. diversifolia*

T. diversifolia is native to Mexico and Central America, but it is spreading quickly and has naturalized in more than 70 countries. The species has often been recorded as a harmful invasive plant in tropical and subtropical regions, threatening to disrupt agricultural crop production and native plant communities [2][3]. The life history characteristics, such as the high reproduction and high growth rate, as well as phenotypic plasticity of the plants, are important for the naturalization of invasive plants into non-native ranges [16][17][18]. *T. diversifolia* reproduces asexually and sexually, producing a large number (80,000–160,000 seeds/m²/year) of small seeds [1][12]. The phenotypic plasticity and genetic diversity of *T. diversifolia* populations were recorded to be high [19][20].

The interactions of the invasive plants with natural enemies, such as herbivores and pathogens, are also very critical for their naturalization. The high defense capacity from herbivores and pathogens contributes to the ability of invasive plants to naturalize in non-native ranges [21][22][23]. Sesquiterpene lactones and flavonoids of *T. diversifolia* probably act as defensive agents against herbivores and pathogens [3][4][7][24]. Insecticidal properties of the extracts and compounds of *T. diversifolia* have also been reported [10][24][25][26][27].

In addition, the interactions of the invasive plants with native plants are crucial. In fact, some invasive plants contain many phytotoxic or allelopathic substances [28][29][30]. *Centaurea maculosa* Lam. is invasive and releases an allelopathic substance, catechin, which is toxic and helps its invasion into bunchgrass fields [28]. Several other observations also suggest that some invasive plant species are allelopathic, and that their allelopathic substances are more toxic against other plant species in the invasive areas than those in native areas of the invasive plants [21][30][31]. Therefore, allelopathy is probably one of the important factors for invasive plants to naturalize and establish their habitats in non-native ranges [30][31]. As described previously, *T. diversifolia* is allelopathic, and this allelopathic property may help the invasion of this species into non-native ranges.

Many of the phytotoxic substances from the invasive plants have been reported to have multiple effects, such as antiherbivore, antifungal, antimicrobial, and allelopathic activities. The functions of these phytotoxic substances were considered to provide the plants with advantages in terms of increasing their populations in the new environments [18][30][31][32]. More than a hundred secondary metabolites have been isolated from various extracts of *T. diversifolia*, including sesquiterpenoids, diterpenoids, and flavonoids, while these compounds were also reported to possess wide ranges of biological activities [3][4][7][24]. Therefore, these compounds may enhance the competitive ability of *T. diversifolia* and make the plant invasive. The novel weapon hypothesis states that some invasive plant species gain a competitive advantage through the release of some compounds that are unique to the invading plant communities [30][31]. It is also possible that some of the compounds released from *T. diversifolia* were unique to the invaded plant communities.

3. Conclusions

T. diversifolia works as green manure, increasing crop productivity, and acts as fodder for domestic animals because of its high mineral and nutrient values [8][9][10][11]. However, the species has often been recorded as a harmful invasive plant that disturbs native plant communities [2][7][12]. The evidence summarized in this paper indicates that *T. diversifolia* is allelopathic and contains several phytotoxic substances, such as sesquiterpene lactones. The evidence also suggests that some of the phytotoxic substances in *T. diversifolia* are probably released into the soil through the decomposition of the plant residues and the exudation from living plant tissues of *T. diversifolia*, which act as allelopathic substances. The allelopathic substances can inhibit the germination and growth of neighboring plants [33][29][30][31]. Therefore, the allelopathic substances released from *T. diversifolia* may provide the plants with a competitive advantage against native plants, and may contribute to the plants establishing their habitats as invasive plant species. Allelopathy of *T. diversifolia* may be involved in the invasive potential of *T. diversifolia*.

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