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The Influence on Livestock Industry and Development Prospect of *Eupatorium adenophorum* Spreng

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Abstract

Eupatorium adenophorum Spreng has seriously threatened the sustainable development and the grassland ecosystem of the world livestock industry. This review has elaborated the geographic distribution, chemical constituent, damage to the grassland and livestock industry and ecological influence of *Eupatorium adenophorum* Spreng. The prevention and control, development and application prospect as feed and medical resources has also been stated.

Keywords: *Eupatorium adenophorum* Spreng; Livestock industry and ecological influence; Prevention and control, Development and application

Eupatorium adenophorum (*E. adenophorum*) Spreng is a species of flowering plant in the daisy family known by many common names, including eupatory, sticky snakeroot, crofton weed, and Mexican devil. After the introduction as a ornamental plant to USA in 1960s, it has spread worldwide. *E. adenophorum* Spreng can reproduce both sexually and asexually. It spreads fast, dies fast and has a great adaptation to environment. It is threatening the native biodiversity by its allelopathic competition with other plant species. It contains chemicals such as hemiterpenes, sterides, triterpenes, flavonoid and phenylpropanoids phenol, etc. This essay mainly illustrates and concludes the current research progress about *E. adenophorum* Spreng.

Distribution

It is native to Mexico and Costa Rica, but it is known in many other parts of the world as an introduced species such as Europe, Oceania and Asia [1]. Due to the reason that its seed can spread along with the wind, it is an invasive species in many tropical and subtropical countries, including USA, Australia, New Zealand, South Africa, Spain, India, Philippine, Malaysia, Singapore, Indonesia, Papua, New Guinea, Thailand, Burma, Vietnam, Nepal, Pakistan, Pacific Islands and China. It was first inadvertently introduced to Yunnan around 1940 from the China-Burma border. Now it distributes in the Province of Sichuan, Guizhou, Guangxi and Tibet. It still spreads at a speed of 60 km per year towards East and North. If the spreading trend continues, *E. adenophorum* Spreng may cover the entire southern Yangzi River area after a century [2].

Main Chemical Constituents and Harm to Livestock Industry

As reported, several compounds has separated and characterized from *E. adenophorum* Spreng stem, flowers and leaves, including hemiterpenes, sterides, triterpenes, flavonoid and phenylpropanoids phenol etc (Table 1). Elaborations for harm to animals are as follows: Flowers and leaves of *E. adenophorum* Spreng contain substances which are with strong local stimulation(especially at skin, mucosa and eyes) and even contact dermatitis, such as butanedioic anhydride and 9-Oxo-10, 11-dehydroageraphorone (generally known as Euptox A) [3]. It is proved that Euptox A is also a liver toxin [4,5], which may lead to icterus, bile duct hyperplasia and expansion, liver cell necrosis, a obvious increase of total bilirubin, alkaline phosphatase, aspartate aminotransferase and alanine aminotransferase. *E. adenophorum* Spreng's seeds have a huge mass of cilium, which may cause blind if it floats into eyes, especially for horses [6]. *E. adenophorum* Spreng also contains volatile chemicals such as camphor, bornyl acetate, geranial, citronellal, dimethylsulfide [7]. The stimulus smell would poison horse for the tall-stem and high-density of *E. adenophorum* Spreng. The pollen and seed contain ageraphorone, which would cause allergic bronchial pneumonia of horses with the symptoms of acute pulmonary edema early of the illness and cerebral hemorrhage later on which caused the final death [8]. The tannin, clavulanic alcohol and lactone can stimulate the mucosa of animal stomach, affecting the digestion system [9].

The invasion of *E. adenophorum* Spreng may decrease the grass production and livestock number, even lose the grazing value. As reported, under the background of the severe drought, invasive plant *E. adenophorum* Spreng has spread across the entire Guizhou province caused serious damage to the grassland and livestock. 1.2 billion kilogram grass has been cut down per year, which leads to a 400 million RMB direct lost, Only 3 years after, the coverage of *E. adenophorum* Spreng in Liangshan Prefecture of Sichuan Province reached to 85%~95% of the entire grassland, and forage grass has reduced to 2400 kg~2940 kg/hm^2 which has fallen 70.1%~79.36% [10].

Harm to Eco-system

After China was invaded by *E. adenophorum* Spreng, the local eco-system has been seriously damaged which caused enormous loss to Chinese livestock industry, agriculture, forests, natural landscape

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Toxins	Toxicity	Distribution
2-deoxo-2-(acetyloxy)-9-oxoageraphorone	Hepatotoxicity	Flowers, leaves, Stem
9-oxo-agerophorone	Hepatotoxicity	Flowers, leaves, Stem
9-oxo-10,11-dehydro-agerophorone	Hepatotoxicity	Flowers, leaves, Stem
Butanedioic anhydride	skin, Mucosa, Eyes	Flowers, leaves, Stem
Camphor Bornyl acetate Geranial Citronellal Dimethylsulfide	Horse	Whole plant
2-hydroxycoumaric acid	Plant	Whole plant

Table 1: Main toxins and their distribution of *E. adenophorum* Spreng.

and species diversity. Inhibiting local plants growth and altering the nutrition construction in soil have been declared to be the most harmful factors about *E. adenophorum* Spreng invasion.

Inhibiting the Growth of Plants

E. adenophorum Spreng can spread madly in China because there are no natural enemies. It also performs an allelopathy effect, such as ground leaching allelopathy substances, 4,7-dimethyl-1-(PorPna-2-ylidene)-l,4,4a,8a-tetrahydronaphthalene-2,6(1H,7H)-dione (DTD) and 6-hydorxy-5-isoporpyl-3,8-dimehtyl-4a,5,6,7,8,8a-hexahydronaphthalen-2(1H)-one (HHO) [11]. The other two primary allelochemicals (9-Oxo-10,11-dehydroa-geraphorone and 9b-Hydroxyageraphorone) had been identified in *E. adenophorum* leachates [12]. These chemicals can cause prominent crowding-out effect to local plants, threatening the native vegetation eco-balance [13]. However, there is a distinction between different species and communities. And the leaves' leach liquor of *E. adenophorum* Spreng has different effect on the germination rate and seed growth degree of different plants under different environment condition [14]. According to the results, non-gramineous plants are more sensitive to the allelopathy effect than gramineous plants, leguminosae and trees. Single community is more sensitive than multifarious communities [15]. But the allelopathy effect keeps adding up as the concentration of the leach liquor increases. This result may imply the relationship between the allelopathy of *E. adenophorum* Spreng and its invasion.

Another experiment indicates that o-Coumaric acid is a potent toxin that might play an important role in the competition of *E. adenophorum* with its neighboring plants during its invasion and establishment [16].

Absorbing Soil Nutrition

E. adenophorum Spreng is able to utilize the abundant available nitrogen, potassium and phosphorus in the soil to compete with the local plants. However, beneficial changes have been made to the soil. That is, invasion can promote the NH^{4+}-N and NO^{3-}-N level in the soil, reduce the total phosphorus and available phosphorus content, effect microorganism community distribution, improve the soil nutrition level and the enzymatic activity, and increase the number of microorganism [17]. These changes can help *E. adenophorum* Spreng surviving on an infertile land and providing a convenient way for its invasion while may cause the grassland degeneration and the outcome of crops or trees reduction [18].

Prevention and Control

Chemical and physical control

Chemical prevention is to utilize selective chemicals which are sensitive to *E. adenophorum* Spreng to spray plants in order to make them withered. 2,4-D, 2,4-D butyl ester, 2,4,5-T, tebuthiuron, sulfometuron, sodium chlorate, glyphosate isopropylamine, picloram, sulfonylurea and glyphosate were reported as effective chemicals [19]. The sulfometuron-methyl and saflufenacil were strongly inhibited flowering and fructification of *E. adenophorum* [20]. Some study showed that using sensitivity to control *E. adenophorum* growth was feasible and effective [21]. But these chemicals have some limitations such as harm to other plants, large dosage, influence in weather factors and not thorough effect.

Physical prevention is to utilize human labors and machines to prevent invasive plants. But manual weeding takes a lot of labor work and not as much efficiency. Mechanical weeding is much faster, but the success rate is quite low. And another drawback for using machine is some plants grow on the mountain and hillside, where machines can hardly work.

Biological Control

Biological prevention is to use the competitive relation of other plants, *E. adenophorum* Spreng natural enemies or microbial to conduct prevention. Two primary methods are vegetation coverage and natural enemy prevention.

Vegetation cover

Present grasses that have been proven effective for vegetation cover are *Pennisetum hydridum*, *Herba Setariae Viridis*, Ryegrass, *Paspalum natatum*, *Imperata cylindrica*, *Alfalfa*, *Imperatoria* etc., and trees are Masson pine, *Semen Castaneae Mollissimae*, *Eucalyptus* etc., among which the best plant is Masson pine [22]. Although these plants do have made progress in the plant displacement, whether or not they have allelopathy effect to *E. adenophorum* Spreng needs further study. *Herba Artemisiae Annuae* and *Herba Junci Setchuensis* have allelopathy effect which helps it growing in the *E. adenophorum* Spreng invasive areas, meanwhile, affect *E. adenophorum* Spreng seed growing and expansion negatively to some extent [23]. This shows while ecologically controlling *E. adenophorum* Spreng and restoring local vegetation, we should choose plants that have the same resources use mode but different resources with *E. adenophorum* Spreng. Multi-species combination can build multi-function community, thus, the ecological superiority of *E. adenophorum* Spreng will be pillaged and eventually remain the sustainable development of the ecosystem.

Natural enemy control

Fungus and insects like *Procecidochares utilis* and *Dihammus Cervinus* can control the growth of *E. adenophorum* Spreng effectively. *Cercospora mikaniacola*, *Alternaria alternata eupatori*, *Mycovellosiella eupatorii-edomti*, leaf spot fungus, *Ageratum conyzoides Mirisporites* can cause leave spot disease, making stem and leaves being infected and eventually inhibiting the growth [24]. In addition, Kunming

Institute of Botany has found that truffle may also inhibit the growth of *E. adenophorum* Spreng, which provide another way of prevention. *Procecidochares utilis* can affect the germination rate of *E. adenophorum* Spreng seeds, but it does no effect on the latter growth. After plant displacement, the new ecological environment affects not only the *E. adenophorum* Spreng stem height, but the parasitism rate of *Procecidochares utilis*. Another finding is 3 different types of parasitic wasp have considerable high parasitism rate to *Procecidochares utilis*. These factors are the reason why utilizing *Procecidochares utilis* to control the growth is not as effective. *Dihammus Cervinus* can also cause mechanical damage or even death to *E. adenophorum* Spreng. However, the root remained in the soil may grow back into an intact plant next year. And a native insect known as *Ortheziidae* in Yunnan, Yingjiang, and this type of insect like gathering at the stem junction sucking the juice, making the plants [25].

Microbial control

Comparative studies showed that mycelium of *Phaeoramularia* sp. was as pathogenic as conidia of crofton weed (*Ageratina adenophora*) and that the former may have potential for further development as a mycoherbicide [26]. However, its low growth rate has cut off the utilization prospect. Another study showed that mycelia of *Alterttaria alternate* (Fr.) Keissler Strain 501 which separated from *E. adenophorum* were produce herbicides to slow down the invasion rate [27]. So far, there is no more effective method to control the growth and breeding about *E. adenophorum*. Biodegradation of the main toxin named Euptox A was performed by us. And 3 strains of bacteria, *Stenotrophomonas* sp. XC-07, *Klebsiella* sp. XC-08 and *Pseudomonas* sp. XC-09, separated from *E. adenophorum* leaves, deposit soil and the rumen of native goat, were proved to have the degrading rates of 91.2%, 94.3% and 93.2% respectively in the 45 mg/L Euptox A in 24 h, determined by TLC and HPLC [28]. The overall results may lay the foundation of preventing *E. adenophorum* invasion and imply potential applications for the optimal approach to the utilization, improvement and feed production.

Applications

Feed resources

E. adenophorum Spreng has a wide distribution area among China. This plant grows fast and spreads fast. The nutrition it contains such as protein, microelement and fat are above average level among grass. If *E. adenophorum* Spreng could be made into feed products, it would bring great significance to remitting the current shortage of feed resources. Numerous researches have proved across the world that detoxified *E. adenophorum* Spreng is an idea feed material. For instance, the degradation rate of the organic substances inside *E. adenophorum* Spreng increase 8% after plants being solarized, after the feed being mixed with both *E. adenophorum* Spreng and *Ficus cunia*, goats' grazing rate is prominently increased [29]. After 4 weeks feeding, no obvious negative effect to the body weight. Feeding goats with 20 g feed which has been mixed with *E. adenophorum* Spreng and *Folium mori* (4:6) after being solarized can promote the rumen digestion of goats, decrease rumen gas production, adjust the structural proportion of formic acid, acetic acid and propionic acid, improving the rumen protein production [30]. And added 20%-40% *E. adenophorum* Spreng which has been detoxified with *Aspergillus flavus* and *Aspergillus* to feed the goats, it turned out with no negative effect. All the research above has testified that the *E. adenophorum* Spreng has the potential as a kind of feed resources.

Medical resources

E. adenophorum Spreng can not only become the feed resource, it also contains considerable chemical substances with pharmacological effects such as anti-Inflammatory potential [31], acaricidal activity [32, 33], antioxidant activity of ethanolic leaf extract [34] and antifungal of activity of cadinene sesquiterpenes [35]. Flowers and leaves extract of *E. adenophorum* Spreng which were extracted by alcohol and acetone could control chicken coccidiosis disease [36]. The inflorescence oil showed higher antibacterial activity against *Klebsiella pneumoniae*, and the root oil was more effective against *Staphylococcus aureus* [37]. The study has found that *E. adenophorum* Spreng toxin has positive effects in the chicken coccidiosis disease treatment. And there were reported that *E. adenophorum* Spreng contains chemicals like volatile oils which can be used in producing essence, antibiotics and pesticides [38]. The cadinene sesquiterpenes of cadinan-3-ene-2,7-dione have highly inhibitory towards *S. rolfsii* (ED50 181.60 ± 0.58 μg/ml) and *R. solani* (ED50 189.74 ± 1.03 μg/ml). Our laboratory has already extracted Euptox A from *E. adenophorum* Spreng and declared a national invention patent. We proved that Euptox A had highly acaricidal activity against *S. scabiei* and *P. cuniculi in vitro* and *in vivo* [39,40] and Euptox A presented significanty antitumor activity against the human lung cancer A549, HeLa and Hep-2 cell lines *in vitro* in a dose-dependent manner [41,42]. Other studies have also found that *E. adenophorum* Spreng contains a great amount of chlorogenic acid known as "Botanic Gold" and the extraction rate is 1%. Chlorogenic acid is an important biological active substance with functions like antibacterial, antivirus, elevating the leucocyte, protecting liver and bile, antineoplastic, antihypertensive, hypolipidemic, eliminating radicals, antioxidative and stimulating the central nerve system [43]. It also can be made into decent health-care product.

Chemical material resources

As a chemical raw material, *E. adenophorum* Spreng is a natural dye, which after being boiled under higher temperature helps turn items into a bright yellow color, without fading. *E. adenophorum* Spreng is seen extensively used in ethnic tie-dye industry and can also be of quality source for fragrance making. The geranyl butyrate and (-)-Caryophyllene Oxide found in *E. adenophorum* Spreng can be fermented with numerous yeasts to create xylitol [44]. The *E. adenophorum* can be as Rotten Fertilizer Application in agricultural production [45], and can be as activated carbon and high calorific value gas [46]. Other benefits of *E. adenophorum* Spreng include expelling mosquito effects.

Prospect

Although the results have manifested *E. adenophorum* Spreng has done massive damage to husbandry industry and eco-system, only the scientific and dialectical methods we take, the invasion of *E. adenophorum* Spreng be eventually conquered and make great economic value for us.

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