Puncturevine (*Tribulus terrestris* L.): noxious weed or powerful medical herb

Kotvičník zemný (*Tribulus terrestris* L.): nebezpečná burina alebo silná liečivá rastlina

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Abstract

Tribulus terrestris L., an annual dicot species of the family *Zygophyllaceae*, is a common herb that is often found in disturbed habitats and agricultural areas in many parts of the temperate, tropical and desert regions of the world. *T. terrestris* is an aggressive species that has the potential to injure livestock, reduce hay and wool values, detour recreationists and reduces plant biodivesity. The species may become troublesome because of its weedy potential. It has been declared a weed in at least 37 countries and in at least 21 crops (cotton, maize, vineyards, orchards, etc.). It is adapted to a wide range of climatic conditions and grows on a wide variety of soil types. The management of *T. terrestris* can be achieved by herbicide application, mechanical (hand pulling, hoeing, mulching) and biological control methods. Beside its invasive potential as a noxious and troublesome weed, *T. terrestris* is considered highly useful herb which is used for various purposes in folk and modern medicine and sport, as well.

Keywords: agriculture and medical importance, biology, control, ecology, *Tribulus terrestris*

Abstrakt

Kotvičník zemný (*Tribulus terrestris* L.), jednoročný dvojklíčnolistový druh z čeľade jarmovcovité (*Zygophyllaceae*), je bežnou liečivou bylinou, ktorá sa často vyskytuje na narušených stanovištiach a na poľnohospodárskej pôde v mnohých častiach teplých, tropických a púštnych oblastí sveta. *T. terrestris* je agresívny druh, ktorý potenciálne môže poraniť hospodárske zvieratá, redukovať hodnotu sena či vlny a redukuje diverzitu rastlinného krytu. Tento rastlinný druh môže spôsobovať problem pre jeho potenciál stať sa burinným druhom. Bol deklarovaný ako burina v najmenej

37 krajinách a v najmenej 21 plodinách (bavlna, kukurica, vinohrady, sady, ai.). Je adaptibilný na široký rozsah klimatických podmienok a rastie na rozmanitých pôdnych typoch. Manažment regulácie *T. terrestris* zahŕňa aplikáciu herbicídov, mechanickú (ručné vytrhávanie, bránenie, nastielanie) a biologickú reguláciu. Napriek jeho inváznemu potenciálu ako nebezpečná a problémová burina, *T. terrestris* je považovaný za vysoko užitočnú liečivú rastlinu, ktorá je používaná na rôzne účely v ľudovej aj modernej medicíne a v športe.

Kľúčové slová: poľnohospodársky a medicínsky význam, biológia, regulácia, ekológia, kotvičník zemný, *Tribulus terrestris*

Detailný abstrakt

Kotvičník zemný (*Tribulus terrestris* L.) je jednoročná dvojklíčnolistová bylina z čeľade jarmovcovité (*Zygophyllaceae*) pochádzajúca zo Saharskej oblasti. Je bežnou liečivou bylinou, ktorá sa často vyskytuje na narušených stanovištiach a na poľnohospodárskej pôde v mnohých častiach teplých, tropických a púštnych oblastí sveta. Na druhej strane *T. terrestris* je agresívny druh, ktorý potenciálne môže poraniť hospodárske zvieratá, redukovať hodnotu sena či vlny a taktiež redukuje diverzitu rastlinného krytu. Tento rastlinný druh môže spôsobovať problém pre jeho potenciál stať sa burinným druhom. Bol deklarovaný ako burina v najmenej 37 krajinách a v najmenej 21 plodinách (bavlna, kukurica, vinohrady, sady). *Tribulus terrestris* sa stáva burinným druhom aj kvôli svojmu hlboko rozkonárenému drevnatému koreňu. Rastlina vytvára veľké množstvo bočných vetiev dlhých až 3 m a tým pokrýva pôdu a vytvára hustý porast. Je adaptibilný na široký rozsah klimatických podmienok a rastie na rozmanitých pôdnych typoch. Manažment regulácie *T. terrestris* zahŕňa aplikáciu herbicídov, mechanickú (ručné vytrhávanie, bránenie, nastielanie) a biologickú reguláciu. Najdôležitejším opatrením pri regulácií kotvičníku zemného je regulácia jeho generatívnych orgánov rozmnožovania v pôdnej zásobe a zabránenie v tvorbe semien a plodov všetkými dostupnými prostriedkami. Napriek jeho inváznemu potenciálu ako nebezpečná a problémová burina, *T. terrestris* je považovaný za vysoko užitočnú liečivú rastlinu, ktorá je používaná na rôzne účely v ľudovej aj modernej medicíne a v športe.

Introduction

Tribulus terrestris L. (puncturevine, punctureweed, goatshead), is an herbaceous, monocarpic, a C_4 summer annual, broadleaf weed a member of the *Zygophyllaceae* or caltrop family (Donaldson and Rafferty, 2003; Šalamoun et al., 2006). It is occurs widely throughout the world from latitudes 35°S to 47°N (Holm et al., 1991). *T. terrestris* is native to southern Europe (Grin, 2000, Parker 1972), Africa, temperate and tropical Asia, and north Australia (Grin, 2000). According Squires, (1979) *T. terrestris* probably originated in the Saharan region, and spread into the Mediterranean region. It is one of the most widely distributed species and well adapted to temperate, mediterranean, sub tropical, tropical and warm temperate climate (Lamp and Collet, 1990; Scott and Morrison, 1996). *T. terrestris* requires relatively high temperatures for growth and is prevalent in areas having hot summers (WSNWCB, 2001; CDFA, 2002), but it is intolerant of freezing temperatures (Squires,

1979). Boydston (1990) notes that *T. terrestris* can be found in a wide range of conditions: it thrives on dry, loose, sandy soils and prospers near sand dunes and in wind-blown loose soil by field margins; however, it also grows in heavier soils, especially if they are fertile and moist, and on compacted soils such as those found along the sides of unsurfaced roads or in playgrounds (El-Ghareeb, 1991). *T. terrestris* is an aggressive species that has the potential to injure livestock (Glasonbury et al., 1984; Kellerman et al., 1994; McDonough, 1994), reduce hay and wool values (Gould & Deloach, 2002; Knight and Walter, 2003; SIR and EPD, 2004) and detour recreationists (Donaldson and Rafferty, 2003). *T. terrestris* reduces plant biodivesity by quickly invading and crowding out desirable species (Van Vleet, 2005). The species may become troublesome because of its weedy potential (Boydston, 1990; Scott and Morrison, 1996; Geier and Stahlman, 1999). Due to its ability to extract soil moisture from great depth in the soil, *T. terrestris* competes well in many crops (Holm et al., 1991). It has been declared a weed in at least 37 countries and in at least 21 crops (cotton, maize, vineyards, orchards, etc.) (Asher et al., 2002; Kostov & Pacanoski, 2007; Verd'u and Mas, 2007; Cheema et al., 2008; Geier et al., 2006; Tahir et al., 2009; Kir & Dogan, 2009). Out of cultivated fields, *T. terrestris* exist on disturbed places, along streets, roadsides, railways, waste places, walk ways, pastures, lawns and yards, etc. (Hickman, 1993; Guertin and Halvorson, 2003; CDFA, 2002). Beside its invasive potential as a noxious and troublesome weed, *T. terrestris* is considered highly useful herb. It is an herbal remedy which is used for various purposes in folk medicine. Ancient Greeks used *T. terrestris* as a diuretic and a mood-enhancer. In ancient Chinese medicine, it was used for a variety of liver, kidney, and cardiovascular diseases (Sahelian, 2003). Traditional herbs have emerged in the past few years as an 'instant' treatment for sexual and erectile dysfunctions (Adimoelja, 2000).

Taking into consideration previous mentioned facts, *Tribulus terrestris* is common in many parts of the world and it has remarkable features as a cosmopolitan weed and highly invasive and aggressive species. Thus, the aim of this report was to summarize the available information and bring together new information and recent trends particularly from an agronomic point of view i.e. agricultural importance and management of puncturevine *Tribulus terrestris*.

Biology and ecology of *Tribulus terrestris*

Tribulus terrestris has a deep woody taproot. The plant produces numerous prostrate stems, up to 3 m long that are much branched and arise from the crown to produce a dense mat. The leaves are cotyledons oblong, opposite, short-petioled, 2-5 cm long, pubescent, and divided into pinnate elliptic or oblong leaflets (3-7 leaflet pairs per leaf); each leaflet 3-15 mm long. The small, yellow, 5-petaled perfect flowers are borne on short stalks at leaf nodes. The fruit is a schizocarp; woody burr with sharp, rigid spines to approximately 1-1.8 cm in diameter. Seeds are usually 2-5 per burr, and remain enclosed within the burrs (Yingxin, 1998; Donaldson and Rafferty, 2003; Kostov, 2006; WSNWCB, 2008). A plant may produce 200 to 5,600 seeds during one growing season (Boydston, 1990), and a large plant may produce up to 10,000 seeds (CDFA, 2002). Various studies showed seeds can remain viable for several years (CDFA, 2002), staying dormant in the soil for 4-5 years (Whitson, 1992). Humans and their activities as well as animals are the most important means of seed dispersal (Ernst and Tolsma, 1988; Squires, 1979; Whitson 1992).

Seeds germinate from spring to autumn under suitable moist and warm conditions (from 24 °C to 27 °C) and it grows rapidly producing deep root system in a few weeks. (Scott and Morrison, 1996; CDFA, 2002). Ernast and Tolsma (1988) observed that germination of *T*. *terrestris* in the field can start after a rain shower of more than 10 mm. *T. terrestris* can flower within 3–4 weeks after emergence when temperatures are above 20 °C (Boydston, 1990) primarily from July to August (Parker, 1972). Once the plant begins to flower, it is continuous throughout the plant's life (Reddi et al., 1981). Fruits mature in approximately 2 weeks, and subsequently split apart into segments soon afterward (Holm et al., 1991). Plants continue to reproduce and produce fruit until the cool season begins. Boydston (1990) reports during trials in Washington, fruit/burr production stopped in October when average temperatures were under 20°C. Seeds can be produced as soon as 5-6 weeks after germination (Scott and Morrison, 1996; CDFA, 2002; WSNWCB, 2001). Because of its large seed production and the long-term viability of seeds, this species can increase in numbers rapidly under suitable conditions (Boydston, 1990). The plants usually die in autumn or sinter after the first frosts (Squires, 1979). Generally, *T. terrestris* has a considerable seed dormancy lasting over fall and winter months (WSNWCB, 2001) with some seeds staying dormant for longer periods of time, but in tropical areas it was observed that seeds may still germinate in the fall (Pathak, 1970). In these areas under suitable conditions *T. terrestris* develops woody roots and becomes perennial (Holm et al., 1991; CDFA, 2002).

Tribulus terrestris is adapted to a wide range of climatic conditions. It is prevalent in areas having hot summers (Boydston, 1990) in warm, temperate and desert regions (WSNWCB, 2001). *T. terrestris* requires relatively high temperatures for growth, and is intolerant of freezing temperatures (CDFA, 2002; Squires, 1979). It occurs in areas with a mean annual minimum precipitation of 280 mm and a mean annual maximum precipitation of 380 mm (Rice, 2002). Seedling establishment was observed to be poor on sites that were shaded (Pathak, 1970). *T. terrestris* grows on a wide variety of soil types, but it is found most commonly on dry, loose, sandy soils and prospers near sand dunes and in wind-blown loose soil by field margins (WSNWCB, 2001; CDFA, 2002); however, it also grows in heavier soils, especially if they are fertile and moist (Holm et al., 1991), and on compacted soils such as those found along the sides of unsurfaced roads or in playgrounds (El-Ghareeb, 1991).

Agricultural importance of *Tribulus terrestris*

Tribulus terrestris is considered to be an aggressive, highly invasive species, problematic and “cosmopolitan” weed with a worldwide distribution, that is mainly attributed to human activity (Van Vleet, 2005). *T. terrestris* requires disturbance to establish and is most often associated with an anthropogenic disturbance. Because the ecological amplitude of *T. terrestris* is so broad, it can invade most ecological types in Arizona when they are anthropogenically disturbed to a significant degree (Guertin, 2001). Puncturevine is classified as a class B designate noxious weed in Washington and among invasive plant species with the greatest and most immediate threats to the biological resources (Evans et al., 2003).

In cropping systems, *Tribulus terrestris* decreases crop yield through competition for sunlight, soil water, and nutrients. In Pakistan a list of important weed species of cotton crop includes *T. terrestris* (Hakoomat et al., 2005) with frequency of 53.75 % (Memon et al., 2007). *T. terrestris* with *Cyperus rotundus* are the most dominant

weeds in maize fields in Pakistan (Tahir et al., 2009). According to Marwat, (1984) and Ahmad et al. (2000) *T. terrestris* is one of the most serious weeds that cause damage to the maize and soybean crop in this country. A phytosociological study of weeds carried out at Ajmer in the agriculture semi-arid zone of India, revealed the dominant presence of *Cynodon-Tribulus-Tephrosia* community of weeds in many crops during the summer season, growing on coarse and sandy soils (Sharma, 1981). In accordance with these results, *T. terrestris* is recorded as a problematic weed in soybean (Singh and Jolly, 2004), sugarcane (Singh and Kaur, 2003), chickpea (Aujla and Cheema, 1983), onion (Randhawa and Bhalla, 1976) and young peach orchards (Chatha and Chanana, 2007). *T. terrestris* (37.5 %) was detected as a major weed species together with *Amaranthus* spp. (41.5 %), *Sorghum halepense* (29%), *Echinochloa crus-galli* (25 %) and *Convolvulus arvense* (24%) in dry bean (Ahmadi *et al.,* 2007), and, also in maize fields in Iran (Mahmoodi and Rahimi, 2009). Results of Kir and Dogan, (2009) and Uremis et al. (2004) showed that *T. terrestris* is a weed with high frequencies in maize fields and one of the most common weeds in strawberry growing areas (Boz, 2003) in Turkey. *T. terrestris* is one of the most common weeds of cotton (Chenault et al., 1986; Asher et al., 2002) and green bean (Black *et al*., 2003) in Texas, as well, but weed with less density in sorghum (Wiese et al., 1964; Hennigh et al., 2010) and maize in Kansas (Geier and Stahlman, 1999; Geier *et al.,* 2006). In Republic of Macedonia, *T. terrestris* is important weed with negative economical impact on melon crops (Kostov, 2006; Kostov and Pacanoski, 2007). Also, *T. terrestris* was recorded as a troublesome weed in the peanuts in Cyprus (Vouzounis, 2006), tomato in Southern Italy (Tei *et al.,* 2003), capsicums and chillies in Australia (Frost and Hingston, 2006) potato in Sudan (Mohamed and Nour, 1986), safflower in Colorado (Anderson, 1985) and mandarin orchards in Spain (Verd´u and Mas, 2007). Johnson and Talbert (1993) reported that *T. terrestris* is a problematic weed in peas used by commercial vegetable processors, because its burrs and seeds can be difficult to remove from peas and lima bean seed (Parker and Boydston, 2007). *T. terrestris* is a nuisance weed in alfalfa beacause contaminated hay can contain high levels of nitrates and burs can injure mouths of livestock, lowering the value and quality of the hay (Boydston, 2010). The stiff, sharp spines are a nuisance in many settings and grazing of the foliage can poison livestock (Squires, 1979; Kostov, 2006). Sheep eating *T. terrestris* develop photosensitivity secondarily to biliary obstruction that is result of steroidal saponins in the plant (Glasonbury *et al.,* 1984; Knight and Walter, 2003). Severe effects include blindness, necrosis of skin, loss of lips and ears, and death in young animals.

Integrated Management of *Tribulus terrestris*

Taking into consideration fact that *Tribulus teresterris* is aggressive, highly invasive and toxic species, problematic and “cosmopolitan” weed, control methods should be combined into an integrated management system for the best long-term control of this weed. Management techniques selected are dependent upon a specific site and will be determined by land use objectives, extent of *T. terrestris* infestations and effectiveness and limitations of available control measures (Schultz, 2005). Long-term control of *T. terrestris* can be achieved by reducing the amount of seeds in the soil. This is best accomplished by removing plants before they produce seeds (i.e. before or at flowering) and continuing to do so over several years (Donaldson and Rafferty, 2003).

A number of herbicides are effective in various crops and situations against *T. terrestris*, but its control is difficult because seeds can germinate throughout summer and then rapidly flower and produce viable seed (Affeldt and Campbell, 2007) which may enable *T. terrestris* to persist in spite of weed control programs (Boydston, 1990). Guethle et al., (1990) found imazethapyr at 0.07 kg a.i.*ha^{-1} applied PPI controlled 92 % of *T. terrestris* and reduced its seed 94%Imazethapyr applied to southern peas at 0.07 kg a.i.*ha^{-1} PPI, PRE, and 3 and 6 d after *T. terrestris* emergence controlled *T. terrestris* at least 95% at the 2-week rating. At the 4-week rating, imazethapyr at 0.07 kg a.i.*ha^{-1} applied PRE provided this level of control. Imazaquin at 0.07 and 0.14 kg a.i.*ha^{-1} controlled *T. terrestris* greater than 93% when applied up to 12 d after emergence (Johnson and Talbert, 1993). Successful control of *T. terrestris* and other weeds in peanuts was achieved through the pre-and post-emergence application of imazethapyr at 0.1 to 0.12 kg a.i.*ha^{-1} (Vouzounis, 2006). The results of Tahir et al., (2009) showed that pendimethalin applied at 1,050 g a.i.*ha^{-1} and pendimethalin + prometryn applied at 1,400 g a.i.*ha^{-1} significantly controlled (78.25%, and 69.57%, respectively) *T. terrestris* in maize over the weedy check. Based on the ED_{90} values *D. stramonium*, *T. terrestris, E. crus-galli*, *S. halepense*, *A. retroflexus, A. blitoides*, and *S. nigrum* were highly sensitive to foramsulfuron and were controlled with less than 50% of the recommended herbicide rate in maize (Kir and Dogan, 2009). Control of *T. terrestris* in corn with EXP 31130A alone or in tank mixtures with acetochlor, atrazine and metolachlor was 75 % or greater (Geier and Stahlman, 1999). In investigation of Geir et al., (2006) *T. terrestris* control in corn exceeded 94 % with KIH-485 and *S*-metolachlor applied at different rates, but mixtures of atrazine with KIH-485 or *S*-metolachlor generally provided the most effective control of *T. terrestris* and other broadleaf weeds studied. Oxadiargyl at 400 g a.i.*ha^{-1} was generally more effective than clomazone at 480 g a.i.*ha^{-1} and pendimethalin at 660 g a.i.*ha^{-1} for controlling *T. terrestris* in capsicum and chillies (Frost and Hingston, 2006). Pendimethalin (1.48 kg a.i.*ha^{-1}) and oxidiazon (0.45 kg a.i.*ha^{-1}) showed excellent performance in controlling of *T. terrestris* and other weeds in autumn sown soybean (Ahmad et al., 2000). In alfalfa, preemergence applied flumioxazin and norflurazon control early season *T. terrestris* germination. Imazamox, 2,4-DB, and bromoxynil applied postemergence control *T. terrestris* seedlings less than 4 cm tall (Boydston, 2010). Glyphosate plus metsulfuron and glyphosate plus 2,4-D ester gave an average of 90 and 88% control, respectively of the *T. terrestris* and other summer-growing weeds on fallows in southern Australia (Leys et al., 1990).

Tribulus teresterris can be managed using mechanical (hand pulling, hoeing, and mulching) and biological control methods, as well. As with all annuals, mechanical controls are partially effective in control of *T. terrestris*. On small infestations, hand-pulling prior to flower and seed production is effective in controlling new infestations (CNAP, 2000), but mowing is not effective because of the low growth habit of the plant. Hoeing and shallow cultivation (about 2-3 cm deep) are, also effective at killing existing plants, and should be initiated prior to flowering and seed production (Fenner, 1985; Holm et al., 1991; Donaldson and Rafferty, 2003). If plants have produced fruits before a cultivation effort is made, subsequent to the effort the plants and fruits should be collected and burned (Muenscher, 1980; WSNWCB, 2001). Several years' cultivation may be required to exhaust the seedbank in established infestations (WSNWCB, 2003). Mulches can be used to control *T. terrestris* in ornamental plantings, orchards, vineyards, vegetable crops, and gardens, if they screen out all light. Results of Verd´u and Mas, (2007) indicated that black geotextile

and almond husk, used as mulches, controlled the presence of 74 weeds species in mandarin orchards, including *T. terrestris*, as well as or better than the applications of glyphosate at least during the first year after their introduction. Grazing as a control method is not allowed, because plant is toxic and can cause physical injury to animals (Holm et al., 1991).

Biological control agents have been relatively successful for *Tribulus terrestris* control. It is controlled by two weevils native to India, France, and Italy (WSNWCB, 2003). They are the stem weevil (*Microlarinus lypriformis*) and the seed weevil (*Microlarinus lareynii*) (Hickman, 1993). The larvae attack the stems and seed and have reportedly provided reasonably good results (WSNWCB, 2003). Both insects provide good control of the plant, but it may take several years to deplete the seed bank in the soil. Good biological control has been achieved in Hawaii (Julien and Griffiths, 1998) where *T. terrestris* being completely eradicated within 4 years (Markin et al., 1992). Wilson et al., (1997) and Gould and Deloach (2002) reported for partial success in biological control of *T. terrestris* in some areas of Nevada, California, Arizona, Texas and New Mexico. These insects have not overwintered in many northern latitudes.

Medical uses and values of *Tribulus terrestris*

Tribulus terrestris is a strong herbal remedy which is used for various purposes in folk and modern medicine and sport, as well. It has been used as tonic, aphrodisiac, astringent, analgesic, stomachic, anti-hypertensive, antibacterial, antifungal and urinary anti-septic (Kianbakht and Jahaniani, 2003; Al-Bayati and Al-Mola, 2008). According to Arcasoy et al. (1998), *T. terrestris* has been commonly used as a diuretic as well as treatment for hypertension, hypercholesterolemia and colic pains. Wang et al. (1990) found that *T. terrestris* supplementation may reduce the remission rate of angina pectoris and decrease myocardial ischemia without any unwanted effects on hepatic or renal function. Dimitrov et al., (1987) found increased plasma testosterone levels and reversed sexual impotence in rams following supplementation with *T. terrestris*. It has a complex stimulating effect on germinative and endocrine functions of the testes producing its precocious development (Bashir et al., 2009). Arsyad (1996) showed that *T. terrestris* (protodioscin) treatment led to an invariable increase in concentration of spermatozoa in humans to approximately 160%. The author attributed this to an increase in the LH (luteinizing hormone) level which acted on Leydig cells and enhanced testosterone secretion, and stimulated Sertoli and germinal cells. *T. terrestris* is considered an aphrodisiac, a putative testosterone elevator. It increase sexual function in animal studies and also reportedly improves libido in humans (Adaikan et al. 2000, Dimitrov et al. 1987). *T. terrestris* has been used for centuries in Europe as treatment for impotence (Sharifi et al. 2003). It enhances plasma testosterone levels and promotes skeletal muscle hypertrophy. Supplement manufacturers claim that *T. terrestris* enhances testosterone production via the stimulation of luteinizing hormone from the pituitary glands; thus, gain in skeletal muscle mass may occur secondary to an augmentation of plasma testosterone. Because of that, *T. terrestris* was and still is a source of the success and top secret of many sport stars in the past and nowadays.

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