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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.

References

Adaidan, P.G., Gauthaman, K., Prasad, P.N. (2000) Proerectile pharmacological effects of *Tribulus terrestris* extract on the rabbit corpus cavernosum. Ann. Acad. Med. Singapore, 29(1), 22–26.

Adimoelja, A. (2000) Phytochemicals and the breakthrough of traditional herbs in the management of sexual dysfunctions. Int. J. Androl., 23(Suppl. 2), 82–84.

Ahmad, M., Shah, S.M., Mirza, M.Y., Ali, N. (2000) Evaluation of pre-emergence herbicides in autumn soybean. Pak.J. Bio.Sci., 3(1), 144–146.

Ahmadi, A., Talarposhti**,** R.M., Mousavi**,** S.K., Mohammadi, H. (2007) Determination of the critical period of weed control in dry bean using a thermal basis. Iranian Journal of Weed Science, 3(1–2), 21–38.

Affeldt, R., Campbell, C. (2007) Puncturevine control in right-of-way areas. Central Oregon Agricultural Research Center 2006 Annual Report, Special Report 1072, 16–17.

Al-Bayati, F.A, Al-Mola, H.F. (2008) Antibacterial and antifungal activities of different parts of *Tribulus terrestris* L. growing in Iraq. J. Zhej.Univ Sci., 9(2), 154–159.

Arcasoy, H.B., Erenmemisoglu, A., Tekol, Y., Kurucu, S., Kartal, M. (1998) Effect of *Tribulus terrestris* saponin mixture on some smooth muscle preparations: a preliminary study. Boll. Chim. Farm., 137(11), 473–475.

Anderson, R.L. (1985) Chlorsulfuron for weed control in safflower (*Carthamus tinctorius*). Weed Science, 33(6), 840–842.

Arsyad, K.M. (1996) Effect of protodioscin on the quantity and quality of sperms from males with moderate idiopathic oligozoospermia. Medika, 22(8), 614–618.

Asher, B.S., Keeling, J.K., Dotray, P.A. (2002) Weed management in transgenic and non-transgenic cotton (*Gossypium hirsutum*) in the Texas high plains. Texas Journal of Agriculture and Natural Resources, 15(1), 27–36.

Aujla, T.S., Cheema, S.S. (1983) Modifying profile water storage through tillage, herbicide, chemical evaporation retardent and straw mulch and its effect on rainfed chickpea (*Cicer arientinum* L.). Soil and Tillage Research, 3(2), 159–170.

Bashir, A., Tahir, M., Samee, W., Munir, B. (2009) Effects of *Tribulus terrestris* on testicular development of immature albino rats. Biomedica, 25(1), 63–68.

Black, M., Dainello, F., Anciso, J., Troxclaire, N., Holloway, R.L. (2003) Crop Profile for Green Beans in Texas [Online]. National Site for the USDA Regional IPM Centers Information System. Available at: http://www.ipmcenters.org/cropprofiles/docs/TXbeans-green.pdf [Accessed 5 June 2013].

Boz, O. (2003) Efficacy of different treatments on some weed species in strawberry. Asian Journal of Plant Sciences, 2(17), 1215–1219.

Boydston, R.A. (1990) Time of emergence and seed production of longspine sandbur (*Cenchrus longispinus*) and puncturevine (*Tribulus terrestris*). Weed Sci., 38(1), 16–21.

Boydston, R.A. (2010) Managing puncturevine in alfalfa hay and along field edges. Washington State Hay Growers Association 2010 Conference. Jan. 13-14. Prosser: The Vegetable and Forage Crop Research Unit, 45–47.

CDFA (California Department of Food and Agriculture) (2002) *Tribulus* [Online]. Healy, E.A., S. Enloe, J.M. DiTomaso, B. Roberson, N. Dechoretz, S. Schoenig, P. Akers, L. Butler, and J. Garvin, eds. Non-Cropland Weed group, UC Extension Service, Weed Science Program, Department of Vegetable Crops, The University of California. Davis, CA. 95616. Available at: http://pi.cdfa.ca.gov/weedinfo/TRIBULUS2.htm [Accessed 5 June 2013].

Chatha, P.S.R., Chanana, Y.R . (2007) Studies on weed management in young peach orchards. Indian Journal of Horticulture, 64, 234–239.

Cheema, M.S., Nasrullah, M., Akhtar, M., Ali, L.(2008) Comparative efficacy of different planting methods and weed management practices on seed cotton yield. Pak. J. Weed Sci. Res., 14(3–4), 153–159.

Chenault, E.W., Wiese, A.F., Harman, W.L. (1986) An economic analysis of incorporation methods for preplant herbicides on clay loam soil. Weed Science, 34(3), 419-422.

CNAP (Colorado Natural Areas Program) (2000) Creating an integrated weed management plan: a handbook for owners and managers of lands with natural values. Denver: Colorado State Parks.

Dimitrov, M., Georgiev, P., Vitanov, S. (1987) Use tribestan on rams with sexual disorders.Vet. Med. Nauki, 24(5), 102-110 (in Russian).

Donaldson, S., Rafferty, D. (2003) Identification and management of puncturevine (*Tribulus terrestris* L.) : Fact Sheet-03-34 [Online]. Available at: http://www.unce.unr.edu/publications/files/nr/2003/FS0334.pdf [Accessed 10 July 2013].

El-Ghareeb, R.M. (1991) Suppression of annuals by *Tribulus terrestris* in an abandoned field in the sandy desert of Kuwait. Journal of Vegetation Science, 2(2), 147–154.

Ernst, W.H., Tolsma, D.J. (1988) Dormancy and germination of semi-arid annual plan species, *Tragus berteronianus* and *Tribulus terrestris*. Flora, 181(3–4), 243–251.

Evans, J.R., Nugent, J.J., Meisel, J.K. (2003) Invasive plant species inventory and management plan for the Hanford Reach national monument. Seattle: The Nature Conservancy of Washington.

Fenner, M. (1985) Seed ecology. London: Chapman & Hall.

Frost, P.R., Hingston, T.L. (2006) Evaluation of new herbicides for capsicums and chillies.In Weed management: balancing people, planet, profit. 14th Australian Weeds Conference, Wagga Wagga, New South Wales, Australia, 6-9 September 2004: papers and proceedings, 261-263.

Geier, P.W., Stahlman, P.W. (1999) EXP 31130 A efficacy and corn (*Zea mays*) response in Western Kansas. Weed Technol., 13(2), 401–410.

Geier, P.W., Stahlman, P.W., Frihauf, J.C. (2006) KIH-485 and *S*-metolachlor efficacy comparisons in conventional and no-tillage corn. Weed Technol., 20(3), 622–626.

Glasonbury, J.R.W., Doughty, F.R., Whitaker, S.J., Sergeant, E. (1984) A syndrome of hepatogenous photosensitization resembling geeldikkop in sheep grazing *Tribulus terrestris*. Aust. Vet. J., 61(10), 314–316.

Gould, J.R., Deloach, C.J. (2002) Biological control of invasive exotic plant species; protocol, history, and safeguards. In Tellman, B., ed. Invasive exotic species in the Sonoran Desert region. Tuscon: University of Arizona Press and The Arizona-Sonora Desert Museum.

GRIN (Germplasm Resources Information Network) (2000) United States Department of Agriculture, Agricultural Research Service, National Genetic Resources Program, National Germplasm Resources Laboratory, Beltsville, Maryland [Online]. Available at: http://www.ars-grin.gov/cgibin/npgs/html/index.pl [Accessed 15 July 2013].

Guertin, P. (2001) Observations made during the duration of weed distribution mapping for the USGS Weeds in the West project occurring in the southern Arizona National Park Service management areas. May 1999-June 2001. USGS/BRD, Sonoran Desert Field Station. Tuscon: University of Arizona.

Guertin, P., Halvorson, W.L. (2003) Status of fifty introduced plants in southern Arizona Parks [Online]. U.S. Geological Survey, Sonoran Desert Research Station, School of Natural Resources, University of Arizona, Tucson. Available at: http://sdrsnet.srnr.arizona.edu/index.php?page=datamenu&lib=2&sublib=13 [Accessed 15 July 2013].

Guethle, D.R., Sims, B.D., Baysinger, J.A., Avery, D.A. (1990) Puncturevine control in southern peas with Pursuit. Abstr. Proc. South. Weed Sci. Soc., 43, 161.

Hakoomat, A., Dilbaugh, M., Shoukat, A.A. (2005) Weed control practices in cotton (*Gossypium* h*irsutum* L.) planted on bed and furrow. Pak. J. Weed Sci. Res., 11(1–2), 43–48.

Hennigh, D. S., Al-Khatib, K., Currie, R.S., Tuinstra, M.R., Geier, P.W., Stahlman, P.W., Claassen, M.M. (2010) Weed control with selected herbicides in acetolactate synthase-resistant sorghum. Crop Protection, 29(8), 879–883.

Hickman, J.C. (1993) The Jepson Manual: Higher plants of California. Berkeley: University of California. Press.

Holm, L.G., Plunknett, D.L., Pancho, J.V., Herberger, J.P. (1991) The world's worst weeds: distribution and biology. Malabar: Krieger Publishing Company.

Johnson, D.H., Talbert, R.E. (1993) Imazethapyr and Imazaquin control puncturevine (*Tribulus terrestris*) but carry over to spinach (*Spinacia oleracea*). Weed Technology, 7(1), 79–83.

Julien, M.H., Griffiths, M.W. (1998) Biological control of weeds: A world catalogue of agents and their target weeds. 4. ed. Wallingford: CAB International.

Kellerman, T.S., Miles, C.O., Erasmus, G.L., Wilkins, A.L., Coetzer, J.A.W. (1994) The possible role of steroidal saponins in the pathogenisis of geeldikkop, a major hepatogenous photosensitization of small stock in South Africa. In

Colegate SM, Dorling PR, eds. Plant-Associated Toxins. Wallingford: Cab International, 287–292.

Kianbakht, S., Jahaniani, F. (2003) Evaluation of antibacterial activity of *Tribulus terrestris* L. growing in Iran. Iranian Jour. Pharmac. Therap., 2**,** 22–24.

Kir, K., Dogan, M.N. (2009) Weed control in maize (*Zea mays* L.) with effective minimum rates of foramsulfuron. Turk. J. for Agric., 33(6), 601–610.

Knight, A.P., Walter, R.G. (2003): Plants affecting the skin and liver. In Knight, A.P. and Walter, R. G., eds. A Guide to Plant Poisoning of Animals in North America. Jackson: Teton NewMedia.

Kostov, T. (2006) Herbology. Skopje.

Kostov, T., Pacanoski, Z. (2007) Weeds with Major Economic Impact on Agriculture in Republic of Macedonia. Pak. J. Weed Sci. Res., 13, 227–239.

Lamp, C., Collet, F. (1990) A field guide to weeds in Australia. Melbourne: Inkata Press.

Leys, A.R., Amor, R.L., Barnett, A.G., Plater, B. (1990) Evaluation of herbicides for control of summer-growing weeds on fallows in south-eastern Australia. Australian Journal of Experimental Agriculture, 30(2), 271–279.

Mahmoodi, S., Rahimi, A. (2009) Estimation of critical period for weed control in corn in Iran. Proceedings of World Academy of Science: Engineering & Technology, 49, 67–72.

Markin, G.P., Lai, P., Funasaki, G.Y. (1992) Status of biological control of weeds in Hawai'i and implications for managing native ecosystems. In Stone, C.P, C.W. Smith, and J.T. Tunison, eds. Alien plant invasions in native ecosystems of Hawaii: management and research. Manoa: University of Hawai, Cooperative National Park Resources Studies Unit.

Marwat, K.B. (1984) Studies on weeds of important cereal crops of NWFP. PhD. thesis. Peshawar: Peshawar University.

McDonough, S.P., Woodbury, A.M., Galey, F.D., Wilson, D.W., East, N., Bracken, E. (1994) Hepatogenous photosensitization of sheep in California associated with ingestion of *Tribulus terrestris* (puncture vine). J. Vet. Diagn. Invest., 6(3), 392–395.

Memon, R.A., Bhatti, G.R., Khalid, S., Soomro, R., Ahmed S. (2007) A survey of weeds found in cotton fields of the Khairpur district, Sindh, Pakistan. Pak. J. Bot., 39(7), 2265–2274.

Mohamed, A.I., Nour, M.O.M. (1986) Weed competition, yield and tuber size of potato as affected by herbicides under sudanese conditions. Experimental Agriculture, 22(1), 59–65.

Muenscher, W.C. (1980) Weeds. 2. ed. Ithaca: Cornell University Press.

Parker, K.F. (1972) An illustrated guide to Arizona weeds. Tuscon: University of Arizona Press.

Parker, R., Boydston, R.A. (2007) Puncturevine, *Tribulus terrestris* PNW0133. Prosser: Washington State University Extension.

Pathak, P.S. (1970) Contributions to the ecology of *Tribulus terrestris* Linn. II. Habitat studies. Agra University Journal of Research Science, 19(2),149–166.

Randhawa, K.S., Bhalla, P.L. (1976) The effect of herbicides on weeds of onion in the Punjab. International Journal of Pest Management, 22(3), 405–407.

Reddi, C.S., Reddi, E.U., Reddi, N.S. (1981) Breeding structure and pollination ecology of *Tribulus terrestris*. Proceedings of the Indian National Science Academy, Part B, 47(2),185–193.

Rice, P.M. (2002) INVADERS Database System [Online]. Missoula: University of Montana, Division of Biological Sciences (Published 07-Jan-1998). Available at: http://invader.dbs.umt.edu [Accessed 20 July 2013].

Sahelian, R. (2003) Experimental *Tribulus terrestris* poisoning in sheep: clinical laboratory and pathological findings. Vet. Res. Commun., 27(1), 53–62.

Schultz, B. (2005) Identification, biology, habitat, and control of noxious weeds in Humboldt County and adjacent areas of northern Nevada: An Introductory Handbook. Special Publication 05-18. Reno: University of Nevada.

Scott, J.K., Morrison, S.M. (1996) Variation in populations of *Tribulus terrestris* (*Zygophyllaceae*). 1. Burr Morphology. Australian Journal of Botany, 44(2), 175–190.

Sharma, B.M. (1981) A phytosociological study of a weed community in fallow land in the semi-arid zone of India. Weed Science, 29(3), 287–291.

Sharifi, A.M., Darabi, R., Akbarloo, N. (2003) Study of antihipertensive mechanism, of *Tribulus terrestris* in 2K1C hypertensive rats: role of tissue ACE activity. Life Sci., 73(3), 2963–2971.

Singh, A., Kaur, C. (2003) Evaluation of herbicides for the control of weeds in spring planted sugarcane. Sugar Tech, 5(4), 317–318.

Singh, G., Jolly, R. S. (2004) Effect of herbicides on the weed infestation and grain yield of soybean (*Glycine max*). Acta Agronomica Hungarica, 52(2), 199–203.

SIR (Susanville Indian Rancheria) and EPD (Environmental Protection Department)(2004) Evaluating management methods for five non-native invasive plant species: perennial pepperweed (*Lepidium latifolium* L.), yellow starthistle (*Centaurea solstitialis* L.), spotted knapweed (*Centaurea maculosa* L.), puncturevine (*Tribulus terrestris* L.), and dalmation toadflax (*Linaria genistifolia ssp. dalmatica*).

Squires, V.R. (1979) The biology of Australian weeds. 1. *Tribulus terrestris* L. Journal of the Australian Institute of Agricultural Science, 45(2), 75–82.

Šalamoun, I., Habán, M., Baranec, T., Habánová, M., Knoll, M. (2006) The occurrence of puncture vine (*Tribulus terrestris*) and its metabolic characteristics in Slovakia. Biologia, 6(1), 25–30.

Tahir, M., Javed, M.R., Tanveer, A., Nadeem, M.A., Wasaya, A., Bukhari, S.A.H., Rehman, J.U. (2009) Effect of different herbicides on weeds, growth and yield of spring planted maize (*Zea mays L.*). Pak. J. Life Soc. Sci., 7(2), 168–174.

Tei, F., Montemurro, P., Baumann, D.T., Dobrzanski, A., Giovinazzo, R., Kleifeld, Y., Rocha, F., Rzozi, S.B., Sanseovic, T., Simončič, A., Zaragoza, C. (2003) Weeds and weed management in processing tomato. Acta Hort. (ISHS), 613, 111–121.

Uremis, I., Bayat, A., Uludag, A., Bozdogan, N., Aksoy, E., Soysal, A., Gonen, O. (2004) Studies on different herbicide application methods in second-crop maize fields. Crop Protection, 23(11), 1137–1144.

Van Vleet, S.M. (2005) Invasive Weeds of Eastern Washington. Pullman: Washington State University Extension.

Verd´u, A.M, Mas, M.T. (2007) Mulching as an alternative technique for weed management in mandarin orchard tree rows. Agron. Sustain. Dev., 27(4), 367–375.

Vouzounis, N.A. (2006) Chemical control of *Commelina benghalensis* and other weeds in peanuts. Miscellaneous reports 91. Nicosia: Agricultural Research Institute (Cyprus) ARI.

Wang, B., Ma, L., Liu, T. (1990) 406 cases of angina pectoris in coronary heart disease treated with saponin of *Tribulus terrestris*. Chung Hsi. J. Chieh Ho Tsa Chih., 10(2), 85–87 (in Chinese).

Whitson, T.D., Burrill, L.C., Dewey, S.A., Cudney, D.W., Nelson, B.E., Lee, R.D., Parker, R. (1992) Weeds of the West. Laramie: University of Wyoming.

Wiese, A.F., Collier, J.W., Clark, L.E., Havelka, U.D. (1964) Effect of weeds and cultural practices on sorghum yields. Weeds, 12(3), 209–211.

Wilson, R.C., Stevenson, T., Knight, J.B. (1997) Biological control of invasive range weeds in Nevada. Reno: University of Nevada Cooperative.

Yingxin, L. (1998): *Tribulus* L. Flora Reipublicae Popularis Sinicae: Oxalidaceae, Geraniaceae, Tropaeolaceae, Linaceae, Erythroxylaceae, Zygophyllaceae, 43(1), 142–144.