A CONSOLIDATED ACCOUNT OF PAST AND PRESENT WORK ON EMEX

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Abstract: The genus *Emex* is represented by two weedy species- *E. australis* and *E. spinosa*. The two have spread to different places around the world widening thereby the range of their distribution. Of the two, *E. australis* is more obnoxious on account of its hard spiny seeds which remain dormant for years leading to the formation of persistent seed banks in the soil. Though the reports of the two species in India date back to mid- 1980's little work has been carried out despite the fact that *E. australis* has spread to different parts of J&K. It is quite likely to assume an aggressive status in near future and may interfere with major crops like wheat as it has already done in Australia. Keeping this impending problem in mind the authors besides initiating research have consolidated the past and present work on this species.

Key words: *Emex australis, E. spinosa,* Australia, weed, wheat.

INTRODUCTION

The genus *Emex* belonging to family Polygonaceae is represented by two species (Pheulong *et al.* 1996); *Emex australis* Steinh. and *E. spinosa* (L.) Campd. The former is commonly known as spiny emex, doublegee or three-cornered jack and the latter as little jack or devil's thorn. *E. australis* has been referred to by synonyms like *E. spinosus* var. *capensis*, *E. centropodium, Podocentrum* and *Rumex spinosus* in taxonomic literature of mid 1800's (Gilbey 1972). However in recent works, it is invariably described as *E. australis* (Gilbey and Weiss 1980).

E. australis is a native of Cape region of South Africa (Steinheil 1838). It was deliberately introduced into Western Australia in 1830 by settlers who thought it had the potential of a vegetable (Turner 1912). Hence the name 'Cape Spinach'. But soon it became an aggressive weed and spread throughout the agricultural areas of Western Australia. Gradually its distribution extended to Southern Australia where it was first described in 1870. Further extension to Victoria and New South Wales was reported in 1883 (Gilbey and Weiss 1980). Although also introduced and naturalized in USA (California and Hawaii), India, Pakistan, Taiwan, Trinidad and Zimbabwe (Shivas and Sivasithamparam 1994), it has assumed a problematic status only in South Africa and Australia (Holm *et al*. 1979).

Lacking in tropical areas the species grows extensively in temperate regions of Australia (Meadly 1963; Rylands 1966; Parson 1973; Gilbey 1974a, 1975; Gilbey and Weiss 1980; Keighery 1996; Moore 1996; Zaicou-Kunesch 1996; Fromm 1996; Lemerie 1996) being most abundant in wheat belt areas of Central and northern Western Australia and some parts of New South Wales (Gilbey and Weiss 1980). *E. australis* is able to grow under a wide range of climatic conditions from high to low rainfall regions. Besides pastures, it is found in highly disturbed sites like roads, tracks, firebreaks, picnic sites, old homesteads, watering points, edges of creeks, riverine flats and granite rocks.

The sister species, *E. spinosa* a native of Mediterranean region (Steinheil 1838) has also naturalized in Australia, Kenya, Mauritius, Californian and Hawaiian regions of US (Holm *et al*. 1979), Eucador (Brandbyge 1989) and Pakistan (Siddiqi 1973). Being precocious in flowering and seed formation, it sets three times more seed than *E. australis* under similar conditions of day length and mean daily temperatures. Optimum day/night temperatures for both the species are between 15/10°C and 20/15°C. In the absence of these optimum conditions, flowering gets delayed which leads to reduced seed production. High temperatures cause premature terminal necrosis of seed/shoots (Weiss and Simmons 1977). This is the possible reason for the absence of *E. australis* in tropical Australia, Tasmania and higher regions of New South Wales (Gilbey and Weiss 1980).

This genus is distributed very scarcely in India. There are only 3 reports of its occurrence, two being of *E. spinosa* (Bhandari 1978; Varma *et al*., 1984) and one of *E. australis* (Sharma and Jamwal 1987). The latter grows luxuriantly on wastelands, along railway tracks and highways in Jammu district (J&K, India).

Emex australis Steinh. is a herbaceous winter annual forming dense populations in the wild. The plant body initially a rosette of leaves, later on differentiates shoots/stems (4-5) at the base which are dichotomously branched and reach upto 51.37 cm (21.4-76.1 cm) in length. The shoots are solid when young and glabrous with green stripes which form ridges and grooves on drying (Bala 2008, unpublished). Leaves (86-491 per plant) are alternate, with long petioles, pinnately veined and triangular with undulating margins (Bala 2008, unpublished).

It is monoecious bearing staminate and pistillate flowers. Flowers are borne at the base very close to soil surface and on the shoots, and accordingly they are referred to as basal and aerial. Female flowers at the base are solitary and subsessile while the male are pedicellate. The aerial flowers are axillary; male in the form of racemes and female solitary in clusters of 4-6 per node placed regularly below the male.

Androecium enclosed by a herbaceous perianth comprises stamens with large, straight, dithecous, basifixed and dull yellow anthers held on small white membranous and persistent filaments. Female flowers show a unique pattern of flowering. At the 3 nodes closest to the base, a single flower differentiates in the axil of a leaf. At the successive nodes, 4 female flowers develop (2 old and 2 young) with the number increasing to 6 at those nodes where male inflorescence develops (Bala 2008, unpublished). Female flowers are subsessile, each consisting of a 6-toothed perianth which becomes urceolate, hard and accrescent in the fruit. All the 6-teeth are straight, the outer being rigid and spiny, and inner connivent. The gynoecium consists of feathery trifid stigma, reduced, inconspicuous style and a white trigonous ovary. The stigma is white, dry and papillate. The ovary is unilocular with a single basal and orthotropous ovule. In addition to the normal unisexual flowers, some plants also differentiate bisexual flowers. Their structure is similar to that of female flowers except for the presence of stamens around the pistil in a single whorl (Bala 2008, unpublished).

E. spinosa is dimorphic in nature and produces subterranean and aerial achenes (Weiss 1980). Plants allocate more to reproduction and less to vegetative structures. Of the resources allocated to reproduction, greater proportion is allocated to subterranean achenes compared to aerial achenes. Aerial achenes weigh uniformly and form the bulk of seed production due to relatively uniform environmental conditions encountered by them. Their production is necessary for maintaining genetic diversity through outcrossing. Subterranean achenes on the otherhand, exhibit a range in individual seed weight which may be due to differences in soil conditions. Development of two types of achenes is an important characteristic in making it a weedy species.

E. australis allocates maximum resources (~93%) towards vegetative structures and least towards reproduction (~7%). Partitioning of majority of resources towards production of leaves is an adaptation to enable plants to live in different habitats and capture as much light as is possible (Bala 2008, unpublished).

It is self-compatible (Gilbey and Weiss 1980) producing seeds both by geitono- and xenogamy (Bala 2008, unpublished). Vegetative reproduction is not on record (Gilbey and Weiss 1980). Fruit set per stem averages ~64% under natural conditions (Bala 2008, unpublished).

Fruits are small (7-9 mm), one-seeded, brown indehiscent achenes with very hard, persistent perianth having 3 equidistant and straight spines. Each fruit is three faced with 4 grooves on each face, 2 each in upper and lower row. Fruits of *E. spinosa* on the other hand are smaller (3-4 mm), with numerous grooves on each face and recurved spines. In both the species, every fruit contains a small, trigonous, brown, glossy seed. Fruit and seed are shed as a single unit and seed hardly comes out of the fruit.

The number of achenes at the base in *E. australis* range from 3-10 while total number of achenes per plant may go upto 930 (Bala 2008, unpublished). In its native place, a solitary plant can produce more than 1100 achenes containing viable seeds (Gilbey and Weiss 1980). The number of seeds produced decreases with increasing plant density. At a density of 32 plants per sq. m. less than 120 achenes per plant were formed (Weiss 1978). Achenes formed at the crown assure re-establishment near the parent plant and those borne on the stem help in dispersal to distant places. The erect spines of achenes are responsible for their dispersal; human beings being the main agents. Hay and other fodders transported from infested areas, rubber tyred vehicles and other equipments probably account for the spread of the doublegee throughout the area.

Freshly harvested seeds of both the species are dormant. Hagon and Simmons (1978) tried germination of seeds at 30/20°C (8hr/16hr) with or without light. The seeds were scarified by removing a section from the radical end of the seed. The intact as well as scarified seeds were unable to germinate in either light or dark under moist conditions at a favourable temperature regime. Application of phytohormones like Gibberllic acid (GA_3) and Kinetin (KT) reduced the level of dormancy only in scarified seed; reduction being greater in presence of light.

As already mentioned, freshly harvested seeds of *E. australis* are dormant and over the summer months, these seeds undergo further ripening. Germination of seeds start during early autumn and a peak in germinability is reached during late autumn (Cheam 1996). Seeds aged less than 1 year exhibit maximum germinability and emergence during the first autumn, which decline thereafter. Decrease is progressive over a period of three years (Cheam 1987). Seedling emergence and seedling survival depend upon the burial depth. Seeds placed at 1-5 cm depth gave maximum emergence but those placed at 15 cm or deeper donot emerge at all. According to Cheam (1987) increase in depth leads to a decrease in emergence and increase in dormancy.

At cooler and wetter sites a high retention of dormant seeds is on record since cooler temperature induces secondary dormancy (Panetta and Randell 1993) upto eight years (Gilbey 1987). The prolonged seed dormancy leads to the formation of persistent seed banks in the soil (Bewley and Black 1982). For wiping out the seedlings by herbicides higher rate of seed germination is required. This can be made possible by adopting measures that can break seed dormancy which will in turn reduce the extent and formation of seed banks. In this direction, storage of seeds at alternating temperatures in the field or laboratory has proved effective. The decrease however is rapid for *E. spinosa* (Hagon and Simmons 1978).

Generally, the two species of *Emex* grow in geographically isolated areas. Wherever they occur in mixed strands, they have been found to hybridize readily (Weiss and Julien 1975). In an attempt to gather information on the extent of interspecific hybridization between the two, Putievsky and his coworkers (1980) collected seeds of each in those regions and raised plants there from. Detailed morphological and cytological analyses of these plants revealed 50% progeny of *E. australis* and 0.5% of *E. spinosa* to be interspecific hybrids. The hybrids were more vigorous having greater length of stems, more nodes, leaves and dry matter than either parent. Following self-pollination these hybrids showed irregular meiosis with approximately 5 bivalents and 10 univalents at metaphase-I, segregation abnormalities and a high degree of sterility. On back crossing with either parent they produced viable seeds.

There are a few reports of interspecific competition between *E. spinosa* and *E. australis.* For this purpose plants of each were raised and grown together (Weiss 1977). *E. australis* was found to show greater seedling mortality and reduced growth as compared to *E. spinosa*. A general increase in the growth of the latter was attributed to its greater competitiveness conferred by its erect stems which are likely to shade the more prostrate *E. australis.* Keeping in view the greater competitive ability, greater chances of seedling survival and high seed set, Weiss and Julien (1975) predicted that *E. spinosa* will possibly become dominant over *E. australis* in areas where the two co-exist (Weiss and Simmons 1977) and is likely to pose a serious threat to *E. australis* in terms of its weedy nature (Weiss and Julien 1975; Weiss 1978). These results, however, differ from those of Williams and his associates (1984). They reported suppression of *E. spinosa* by *E. australis* and attributed the variation in results to different seasonal conditions and disease incidences.

Both the species are known to retard initial growth of regenerating annuals (Pearce 1964) growing in pastures. Reduction in agricultural produce has been alarming. In Western Australia more than $20 million have been lost annually over an estimated 1 million hectare of pasture and 5 lac hectare of cereal crop particularly wheat (Hawkins and Black 1958; Gilbey 1974; Williams *et al*. 1984).

In an attempt to understand the causes and/or factors underlying wheat yield reduction by species of *Emex*, Williams and his co-workers (1984) conducted an experiment by growing the two with wheat at 4 (9 $KgNha^{-1}$, 28$KgNha^{-1}$, 50 $KgNha^{-1}$ and 125$KgNha^{-1}$) different levels of nitrogen. They concluded that competition between wheat and *E. australis* is dependent on the levels of N_2 in soil. At 9-28 $KgNha^{-1}$ wheat is more competitive than *E. australis*. However, as the N_2 levels increased wheat's initial competitive advantage decreased considerably till it got totally suppressed *E. spinosa* exhibited a similar pattern, however, the intensity of competition was less.

Hawkins and Black (1984) and Gilbey (1974b) correlated the reduction in wheat yield with the density of plants growing in an area. Presence of 8-9 plants of *E. australis* per sq. m in wheat fields reduced the grain yield by 40%. The possible reasons responsible are competition for either N_2 or moisture; former in early stages of growth and latter at the end of the season. Gilbey (1974) found 58% reduction in wheat yield where plants of *E. australis* were growing at a density of about 120 plants per sq. m. On the contrary, *E. spinosa* known to be a serious contaminant of wheat does not affect its yield significantly. Since its achenes are similar to wheat grains in size and colour, adulteration deteriorates grain quality leading to its rejection (Weiss and Simmons 1977) from the market and loss in revenue.

The spiny fruits of *E. australis* also contaminate dried Sultanas, an important ingredient of cakes and muesli bar causing a loss of thousands of dollars per year to the respective companies (Pohlner 1996). Apart from its disadvantages, the plants of *E. australis* offer some advantages as well. Unripe fruits are a major source of food for Major Mitchell Cockatoos and Island red tailed Cockatoos and a minor source for galahs; little and long billed corellas (Keighery 1996). There are also a few reports of its being eaten as a vegetable. Its leaves contain oxalates which when taken in large quantities act as laxative. Besides the plants may contribute to the stabilization of sandy soils in association with other annuals (Gilbey and Weiss, 1980).

Plants of *E. australis* have assumed the status of an obnoxious weed on account of their competitive abilities conferred by several features. These include production of hard, dominant three-spined seeds, which contribute towards the formation of seed banks in the soil and toxicity to stock due to high levels of oxalic acid in its leaves. The spiny seeds are a source of serious discomfort and injuries to animals and barefooted humans, and cause lameness in sheep and sheepdogs.

Due to its aggressive nature and the difficulty faced in eradicating it, different workers have tried various chemical and biological methods for controlling its growth and spread. Many herbicides like dicamba, manuron, five triazine derivatives, diquat, 2, 4-dichloroacetic acid (2, 4-D) and D.N.B.P. have been developed (Pearce, 1964). Of these dicamba is most effective and has long been used for its control. Plants absorb this herbicide through the leaves, stem and roots which accumulates in areas of greatest metabolic activity and results in disruption of cell growth and subsequent death (Ralph, 1996). Another potential herbicide is sulphonylurea group, a concoction consisting of Glean (chlorsulfuron methyl), Ally (Metsulfuron methyl), and Muster (ethametsulfuron methyl), all of which are highly efficacious (Addenbrooke, 1996). 2, 4-D is effective only when sprayed at 12-leaf stage. Plants with more than 12 leaves are difficult to control (Gilbey, 1977).

Chemical methods alone are insufficient because of the harmful effects of various herbicides on other broadleaf pasture species. To overcome this bottleneck, biological control programme was started in 1974. The year marked the release of a stem boring weevil Perapion antiquum whose adults make small shot holes by feeding on leaves, petioles and stems. It established where irrigation prolonged the seasonal occurrence of *E. australis*, but it did not control the weed (Julien 1981). Adults of another weevil, *Lixus cribricollis* are known to cause heavy damage to foliage of *E. australis*, *E. spinosa* and *Rumex* spp. (Hoffman, 1954). Its larvae make extensive tunnels in stems and floral stalks leading to the death of plants (Julien, *et al.*, 1982). Similar mode of activity of *Rhodometra sacraria* (Geometriae) and *Apion antiquum* are also on record (Harley and Kassulke 1975; Shepherd, 1989). In addition to the insects, fungal pathogen *Phomopsis emicis* also cause leaf lesions or stem collapse of five closely related species of Polygonaceae members namely *E. australis*, *E. spinosa*, *Rumex alcockii*, *R. dumoscus* and *R. pulcher* (Shivas 1992; Shivas *et al.*, 1994. Under controlled conditions infection by *Phomopsis emicis* and *Perapion antiquum* led to 77% and 68% reduction in new fruit production respectively. Mixed infection by the two slashed fruit production by 83%.

The populations of the weed were forcibly grown out-of-season, established and put to use as nurseries for supporting the populations of biological control agents which otherwise die in the absence of their host (Panetta 1990).

Except for three reports, no information is available on the breeding and meiotic systems, seed-to-seed cycle, spread and control of the genus in India even though the reports date back to 1980's. As mentioned before, *E. australis* grows luxuriantly at many places in and around Jammu district and is likely to spread to larger areas. During our collection trips, we have noticed these plants growing in groups in those localities where previously they were not found. Even in our Campus (University of Jammu) the plants which used to grow in 2 to 3 patches are now forming small, semi-continuous belts. By extending its distribution ranges it can attain obnoxious status in near future. This fear is based upon the plants' ability to grow fast, produce ample fruit and seed. Fruits which are hardy, three spined having highly dormant seeds can persist for as long as 8 years in soil. Dispersal is largely man-driven and to some extent brought about by animals. Wind pollination ensures sufficient gene flow through pollen. In the absence of even small wind currents pollination is assured because flowers are self-compatible.

All these features together confer reproductive efficiency on the plant. Therefore more data are required to be collected and consolidated so that appropriate remedial measures are sought.

As of now, manual deweeding of the plant at seedling stage can help in controlling the plant. Use of numerous chemicals in other countries has not proved satisfactory in eradicating the weed. Additionally their indiscriminate use has proved deleterious to various crop and pasture plants of economic importance.

Timely deweeding, occasional stubble burning and development of better crop rotational strategies can help in controlling the spread of this species.

ACKNOWLEDGEMENTS

The authors are thankful to the Head, Department of Botany, University of Jammu for providing necessary laboratory and library facilities and to the Botanical Survey of India for identification of Emex australis.

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