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Biology and Management of *Cuscuta* species

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ABSTRACT

Field dodder (*Cuscuta campestris*) is an annual obligate stem parasite belonging to family Cuscutaceae. The genus Cuscuta is comprised of about 175 species worldwide. Out of 12 species reported from India, *C. campestris* and *C. reflexa* are more common. It is a major problem in pulses, oilseeds and fodder crops in the states of Andhra Pradesh, Chhattisgarh, Gujarat, Orissa, West Bengal and parts of Madhya Pradesh under rainfed as well as in irrigated conditions. It reproduces mainly by seeds and unlike root parasites, *Cuscuta* seeds do not require a specific stimulant to induce germination. The yield reductions due to *Cuscuta* are reported to the tune of 60-65% in chillies, 31-34% in greengram/blackgram, 60-65% in niger, 87% in lentil, 86% in chickpea, 72% in tomatao and 60-70% in alfalfa depending upon its intensity of infestation. *Cuscuta* can be controlled by using *Cuscuta* free crop seeds, harrowing in crop rows before it parasitizes the host, cultural practices like tillage, planting time, crop rotation and intercropping, selection of *Cuscuta* tolerant varieties and use of selective herbicides like pendimethalin, fluchloralin and pronamide. If the infestation is in patches, it can be easily controlled by spraying non-selective herbicides such as glyphosate and paraquat. In this paper, an attempt has been made to review the research work done on biology and management of *Cuscuta* in India and elsewhere.

Key words : Biology, losses, control measures, host

INTRODUCTION

Cuscuta spp. (dodder) also known as *Akashbel* or *Amarbal*, is a parasitic angiosperm belonging to the family Convolvulaceae in older references and *Cuscuta*ceae in the more recent publications. Weber (1986) divided the family *Cuscuta*ceae into two genera i. e. *Cuscuta* and *Grammica*, based on the shape of the stigma. The genus *Cuscuta* is comprised of about 175 species worldwide. Out of these 12 species are reported from India (Gaur, 1999), *C. campestris* and *C. reflexa* are more common. In some Indian literatures *C. chinensis* (Tosh *et al.*, 1977) and *C. trifolii* are also reported. The wide geographical distribution of dodder species, their wide host range, and the difficulties associated with their control, place them among the most damaging parasites worldwide (King, 1966; Parker and Riches, 1993; Dawson *et al.*, 1994; Holm *et al.*, 1997). The invasive characteristics of *Cuscuta* spp. could be detrimental to the cultivation of many economically important crops. It could also affect the natural ecological balance and floristic composition in natural ecosystems. Some *Cuscuta* spp. have important medicinal, pharmacological and edible values, while others are a threat to the natural ecosystems and agricultural crops (Jayasinghe *et al.*, 2004).

In India, *Cuscuta* spp. poses a serious problem in oilseed [niger (*Guizotia abyssinica*), linseed (*Linum usitatissimum*) and pulses (blackgram (*Vigna mungo*), greengram (*Vigna radiata*), lentil (*Lens culinaris*), chickpea (*Cicer arietinum*), especially in rice-fallows) and fodder crops (lucerne (*Medicago sativa*), berseem (*Trifolium* spp.)] in the states of Andhra Pradesh, Chhattisgarh, Gujarat, Orissa, West Bengal and parts of Madhya Pradesh under rainfed as well as in irrigated conditions. Legislation in 25 countries lists the dodder as "declared noxious weed" with seeds and plant material denied entrance. In the United States, it is the only weed seed whose movement is prohibited in every state. In former Soviet Union, *C. campestris* is one of the worst weeds of field crops and in some areas 80% of sugarbeet monoculture are struck with the weed and 75,000 seeds/m^2 have been accumulated in the soil (Lukovin and Rudenko, 1975). In the production of crop seeds, the *Cuscuta* imposes a severe limitation because of difficulty of removal of their seeds when the crop is graded out, thus, reducing the yield and quality. To this must be added increased cost of harvesting and cleaning.

Cuscuta seeds usually germinate on or near the soil surface. Seedlings are rootless, leafless stem. After emergence, the seedlings twin around the leaf or stem of a suitable host plant. Haustoria from the *Cuscuta* penetrate the host and establish a parasitic union. Once the *Cuscuta* is attached to a host plant, it remains parasitic until harvest. It reproduces mainly by seeds and to a lesser extent by shoot fragments. Although *Cuscuta* seedlings contain a small amount of chlorophyll (Zimmerman, 1962), they are obligate parasites and cannot complete their life cycle without attachment to host plants.

Cassytha

Cassytha also known as "laurel dodder" or "love vine" is a high-climbing parasitic vine beloning to family Lauraceae (sub-family Cassythoideae). The genus *Cassytha* has 20 species of parasitic herbs, of which *Cassytha filiformis* L. also known as *amarbeli*, is very common in India, especially near the sea coast. It is almost similar to *Cuscuta* and is often mistakenly identified as such even by botanists. However, the fruit is a drupe with the single seed enclosed in a white translucent, fleshy pericarp. Like dodder, *Cassytha* seeds will germinate without any host influence although they too must be scarified. The mature *Cassytha* vine is usually a greenish-orange and on the whole favours woody rather than herbaceous hosts. Extracts from the plants are used in curing skin diseases and cleaning ulcers besides being useful in chronic dysentery. The powdered stem, mixed with sesamum oil, is used as hair tonic. However, *Cassytha* contains laurotetanine, an alkaloid which produces severe cramps when used in large doses (Mondal and Mondal, 2001).

Key to the Most Important *Cuscuta* Species (Yuncker, 1932; Parker and Riches, 1993; Jayasinghe *et al.*, 2004)

A. One Style, Supporting Two Stigmas (Section Monogyna)

Style shorter than the elongated stigmas, flowers 6-8 mm long : White with purplish rim. Calyx very short. Capsule conical 5-8 mm long, seeds 3-3.5 mm. Mainly Central to E. Asia.........................*C. reflexa*

Style about as long as stigmas : All extremely short, flowers 3-4 mm, calyx with broad fleshy lobes, almost equalling corolla tube. Capsule elongated, cone-shaped, 6 mm long. Seeds 3-3.5 mm. Mainly in the Middle East ....*C. monogyna*

Style about twice as long as stigmas : Flowers 3-4 mm long, in elongated clusters, sometimes red-spotted, calyx much shorter than corolla tube, the lobes narrower than above. Seeds 2-3 mm long. Mainly in Europe ....*C. lupuliformis*

Style much longer than the short stigmas : Flowers 3-4 mm long in elongated clusters. Seeds about 3 mm long. Mainly in E. Asia.....................*C. japonica*

B. Two Styles, Stigmas Linear, without Knobs (Section *Cuscuta*)

Perianth mostly 4-parted

Flowers 2-3 mm, pedicelled, in loose heads of 3-8 flowers. Stigmas sub-sessile. Capsule round, closely enclosed by corolla. Seeds about 1.25 mm. Mainly W. and Central Asia …...............................*C. pedicellata*

Flowers 1.5-2 mm, sessile in very small, dense heads 4-6 mm across; corolla lobes with erect hooded tips. Capsule round. Seeds about 1 mm. Mainly E. Mediterranean.......................................*C. palaestina*

Perianth mostly 5-parted

Calyx lobes fleshy at least at the tip : Flowers 1.5-2.5 mm, sessile in heads 5-6 mm across. Capsule round, enveloped in corolla. Seeds about 1 mm. Widespread...*C. planiflora*

Calyx lobes membranous : Flowers 3 mm long in heads 10-15 mm across; styles plus stigmas shorter than the ovary. Capsule roughly round. Seeds about 1.2 mm. Only in flax and linseed fields.
Widespread……………………………....*C. epilinum*

Stems slender, reddish : Flowers 3-4 mm in dense heads 7-10 mm across, styles plus stigmas slightly longer than ovary. Seeds about 1 mm. Mainly
Europe..*C. epithymum*

C. Two Styles, Capitate, with Knobs (Section Grammica)

Flowers granulate : Covered with minute protuberances, 2-2.5 mm long on distinct pedicels. Seeds about 1.5 mm. Mainly N. and C. America and Caribbean..*C. indecora*

Flowers not granulate

Capsule enclosed in corolla : Flowers 2-4 mm long, pedicelled, in a loose head, somewhat glandular, corolla lobes deflexed. Corolla persisting as a cap on the capsule. Seeds about 1.5 mm. Mainly N. America..*C. gronovii*

Flowers 2-3.5 mm in dense heads. Corolla lobes fleshy at the tip. Capsule 3-4 mm across, enclosed tightly by corolla, circumscissile. Seeds about 1.2 mm. Mainly in E. Asia..*C. chinensis*

Capsule exposed

Flowers about 2 mm, in compact heads. Corolla lobes obtuse. Seeds about 1.5 mm. Sometimes reddish-glandular on capsule. Distinct crater between styles. Infrastaminal scales bifid. Widespread through Europe and Asia …........……….........................*C. australis*

Flowers 2-3 mm, in compact heads 10-12 mm across. Corolla lobes acute, often flexed upwards. Capsule round, 2-3 mm across, not concealed by corolla. Infrastaminal scales exerted, fimbriate, not bifid. Seeds 1-1.5 mm. Very widespread....................*C. campestris*

The Most Common *Cuscuta* Species in India

***Cuscuta campestris* Yuncker**

Known as field dodder in U. S. A., this is by far the most important single *Cuscuta* species, native to N. America, but now occurring at least sporadically through all the other continents and causing acute local problems. Parker (1978) and Parker and Wilson (1986) expressed that *C. campestris* was the most widespread of the *Cuscuta* spp. and the most aggressive and troublesome in world's economic crops. Out of the 12 species reported from India, *C. campestris* is severely infesting field crops like alfalfa, niger, blackgram, greengram, lentil, chickpea and linseed. However, there is always confusion in the correct identification of the species. In most of the Indian literature, it is mentioned as *Cuscuta* spp. and in few cases, as *Cuscuta chinensis* (Rath, 1975; Rath and Mohanty, 1987). To identify the species correctly, *Cuscuta* seeds were collected from niger (Orissa), lucerne (Gujarat), blackgram/greengram (Andhra Pradesh) and linseed (Madhya Pradesh) crops and grown in pots with host plants. Photographs of *Cuscuta* vines, flowers, fruits and seeds were taken and sent to Mr. Chris Parker, U. K. and Dr. L. J. Musselman, Parasitic Plant Laboratory, Virginia, USA for identification of the species of *Cuscuta*. Both of them unanimously identified the species as *Cuscuta campestris* Yuncker due to following reasons :

"Capsules not circumscissile, corolla lobes are not keeled; the withered corolla is at the base of most of the capsules, lobes of calyx and corolla not thickened at their tips, filaments broadest at base, tapering distally".

***Cuscuta reflexa* Roxb.**

C. reflexa is the most common species found on woody plants and shrubs in Hyderabad region (Rao, 1986). In Holm *et al.* (1979), *C. reflexa* was listed as a 'principal' or 'serious' weed in Afghanistan, Nepal, India and Pakistan. In Sri Lanka, the *C. reflexa* has been reported in the montane zone (Trimen, 1895; Austin, 1980). It is one of the more robust species of *Cuscuta* with a vine 1-2 mm thick when fresh, reddish or yellow, rather than orange and with a tinge of green sometimes, as a result of a significantly higher level of chlorophyll than in many other species (Parker and Riches, 1993). This can cause confusion with *Cassytha* in the vegetative stage but the latter can be distinguished by the presence of hairs, at least on the scales; *Cuscuta* species are all quite glabrous. The length of haustorium can reach about 2-3 mm (Dawson *et al.*, 1994). The flowers are large, upto 10 mm long, white, with a very short calyx, and an elongated conical capsule. The style is so short as to appear almost non-existent. The seeds are large, 3-3.5 mm long.

Hosts of *Cuscuta* and Losses

Cuscuta spp. is a serious problem in forage legumes, principally alfalfa, clovers, and niger. Other crops plagued by *Cuscuta* include linseed (*Linum usitatissimum*), chickpea, lentil and pea (*Pisum sativum*), blackgram, greengram and pigeonpea (*Cajanus cajan*), sesame (*Sesamum indicum*), soybean (*Glycine max*), tomato (*Lycopersicon esculentum*), potato (*Solanum tuberosum*), carrot (*Daucus carota*), sugarbeet (*Beta vulgaris*), cranberry (*Vaccinium macrocarpon*), blueberry (*Vaccinium* spp.), citrus (*Citrus* spp.), and numerous ornamental species. *Cuscuta* also parasitizes numerous species of dicotyledonous weeds and wild plants. *Cuscuta* can parasitize asparagus (*Asparagus* *officinalis*) and onion (*Allium cepa*), which are monocotyledonous crops, but grasses and grains (Poaceae) are usually not parasitized.

The infestation of *Cuscuta* results in heavy loss in terms of quantity and quality of produce. Many times it may cause complete failure of the crops. As an absolute parasite, when attached to a host, *C. campestris* operates as a 'super-sink' overcoming the host's sinks (Wolswinkel, 1984). The highly efficient absorption system allows the parasite to divert resources (water, amino acids and assimilates) from the host to itself (Tsivion, 1979; Dorr, 1987), thus reducing host vigour and crop production. The twining vines not only deprive the host plants of nutrients but also inhibit the growth and seed germination of host plants. *Cuscuta* also transmits the viral diseases in host plants (Zhang, 1991; Marcone *et al.*, 1999). The yield reductions due to *Cuscuta* are reported to the tune of 60-65% in chillies (Awatigeri *et al.*, 1975), 31-34% in greengram and blackgram (Kumar and Kondap, 1992), 60-65% in niger (Tosh *et al.*, 1977), 87% in lentil, 85.7% in chickpea (Moorthy *et al.*, 2003), 72% in tomato (Marambe *et al.*, 2002) and 60-70% in alfalfa (Narayana, 1989) depending upon its intensity of infestation. The intensity of damage caused by *Cuscuta* depends upon its capacity to rapidly parasitize the host crop. Field experiments conducted at the NRCWS, Jabalpur revealed that frenchbean, mustard, wheat, rice and cowpea were not affected by the *C. campestris* infestation as evidenced by no yield reduction. The other crops viz., chickpea, lentil, greengram, niger and sesame were highly affected, while pea, linseed, soybean, blackgram, groundnut and pigeonpea were moderately affected.

Damage Potential of *Cuscuta* in Different Field Crops

Infestation of *Cuscuta* results in heavy loss in host crops. Experiments conducted at Jabalpur revealed that increasing densities of *Cuscuta* decreased the seed yields of all the crops. The loss in seed yield from 1-10 plants/m^2 of *Cuscuta* ranged from 27.7-88.3, 39.3-98.4, 49.1-84.0 and 54.7-98.7%, respectively, in summer greengram, niger, lentil and chickpea.

Germination of *Cuscuta*

Seeds of *Cuscuta* are spheroid, mostly 0.5 to 1.0 mm in diameter, and have a hard, rough seed coat. Seeds of *Cuscuta* can survive upto 50 years or more in dry storage depending on the species (Gaertner, 1950) and at least 10 years in the field (Menke, 1954). Unlike root parasites, *Cuscuta* seeds do not require a specific stimulant to induce germination. A high percentage (often more than 95%) of newly matured *Cuscuta* seeds is impervious to water (Dawson, 1965; Hutchison and Ashton, 1980). Such "hard seed" may remain viable but ungerminated in soil for many years. Breakdown of the seed coat depends on environmental conditions, such as wetting and drying, freezing and thawing, mechanical abrasion in the soil and microbial activity. Mechanical scarification (Hassawy, 1973; Marambe *et al.*, 2002) and seed treatment with concentrated sulfuric acid for 30 min (Zaki *et al.*, 1998; Nojavan and Montakhab, 2001) increased the germination of *Cuscuta* seeds. 'Immature seeds' showed higher germination (47%) than 'mature seeds' (15%) probably due to variation in seed coat thickness (Berrie, 1992), but the independent life duration of seedlings from 'immature seed' was six days shorter than 'mature seeds' (19 days) (Marambe *et al.*, 2002). The seed will germinate in response to favourable conditions of temperature (30-33°C) (Zaki *et al.*, 1998) and moisture. However, it can germinate over a range of temperature from 15-39°C (Stojanovic and Mijatovic, 1993; Hutchison and Ashton, 1980). Zaki *et al.* (1998) obtained better seed germination in sandy soils than in clay soils. Germination of *Cuscuta* seed is completely independent of any influence from a host plant. When the seed germinates, the seedling elongates and emerges from the soil. Under favourable conditions, seed can germinate in the fruits.

Effect of Time and Concentration of Sulfuric Acid Seed Treatment on Germination of *Cuscuta*

Results of a laboratory experiment conducted at Jabalpur indicated that the germination of *Cuscuta* seeds started two days after treatment. Maximum germination was recorded when treated for a period of 60 min. The 100% germination was recorded at three days after sowing when treated for 45 min, however, 30 and 60 min timings were at par with 45 min. This shows that fresh *Cuscuta* seeds must be treated with concentrated sulfuric acid for a minimum of 30 min to obtain maximum germination.

Emergence of *Cuscuta* Seedlings and Contact with Host Plants

Cuscuta seeds are very small. They cannot emerge when placed deep in the soil. The results showed that the *Cuscuta* seedlings started emerging within four days from surface to 4 cm depth. Higher emergence was recorded at eight days after sowing from surface to 4 cm depth and thereafter some *Cuscuta* seedlings showed mortality. Maximum seedling emergence was recorded at the surface sowing closely followed by 2 and 4 cm depths. Further increase in seeding depths significantly reduced its emergence and there was no emergence beyond 8 cm seeding depth. Delayed and decreased seedling emergence at deeper depth seems to be due to mechanical impedance, poor aeration and shorter length of coleoptiles of *Cuscuta* seeds.

Seedlings of *Cuscuta* are thin, rootless, yellow-orange leafless arch-shaped stem when they emerge from the soil. Soon after emergence, the seedling straightens itself and begins to twine indiscriminately about any elongated object it contacts. If the object is not living or is a non-host plant, the twined seedling dies after 8-12 days depending upon environmental conditions. *Cuscuta* seedlings are succulent, resist desiccation and evidently need little additional water from the soil after they reach a length of 3 to 6 cm. *C. campestris* seedling has a relatively short independent life, loses its ability to attach to a host and dies after eight days.

On contact with a stem, the *Cuscuta* shoot twines around tightly making upto three complete coils (Parker and Riches, 1993). Within 2 to 4 days after the seedling has twined about the leaf or stem of a host plant, haustorial protuberances become evident, closely oppressed to the epidermis of the host (MacLeod, 1961). Enzymes from the *Cuscuta* soften the surface tissue of the host plant, and the haustorium penetrates the host tissue (Thoday, 1911). Vascular cells of the parasite contact vascular cells of the host (Tsivion, 1978; Israel *et al.*, 1980), and the materials from the phloem and xylem of the host are diverted into the parasite (Littlefield *et al.*, 1966). The *Cuscuta* then continues to grow, being completely supported by the host. Under favourable growing conditions, many stems may grow from a twined seedling of *Cuscuta* after attachment to the host. Once a coil of *Cuscuta* stem has made a successful haustorial connection, new shoot buds are formed in this zone, and in *C. campestris*, upto 20 shoots can arise from a single point of attachment (Dawson *et al.*, 1984). As *Cuscuta* grows, it maintains its support by continually reattaching to host plants.

Detached fragments of *Cuscuta* stem and/or tendril are capable of establishing themselves on the host. This characteristic has been used in north-eastern India as a means of spreading *C. campestris* deliberately for control of the twining weed *Mikania micrantha* in tea (Parker and Riches, 1993).

Reproductive Potential of *C. campestris*

• Number of fruit bunches/plant	3696
• Number of fruits/bunch	17
• Number of fruits/plant	38475
• Number of seeds/fruit	3
• Number of seeds/bunch	38
• Number of seeds/plant	116973
• 1000 seed weight (g)	0.78
• Seed weight/plant (g)	83.81

Control Measures

It is extremely difficult to achieve effective control of *Cuscuta* because its seeds have a hard seed coat, can remain viable in soil for many years and continue to germinate and emerge throughout the year. In addition, the nature of attachment and association between host and parasite requires a highly selective herbicide to destroy the parasite without crop damage.

Prevention

Seeds of *Cuscuta* are transported as a contaminant of seed of crops such as alfalfa and clover. Consequently, most *Cuscuta* problems have originated from human carelessness in transporting and planting contaminated crop seed. *Cuscuta* persists and spreads within infested fields through further agricultural activities, by periodic onsite seed production, and because the seed may remain viable for several years in the soil.

As the saying goes, "Prevention is better than cure", the best method of controlling *Cuscuta* in crops is to prevent its introduction onto a field. Therefore, the crop seeds should completely be free from *Cuscuta* seeds. Strict seed laws and programmes of seed certification are required to reduce the crop seed contamination by *Cuscuta*. Great care must be exercised in moving machinery or livestock between fields, so that seed within harvesting machines, in mud on wheels of machinery, in mud or manure on animal hooves, or within the digestive systems of animals is not moved to clean fields.

Destruction of Individual Plants

Awareness and vigilance are important companions to prevent *Cuscuta*. Farmers should be aware of the serious threat of *Cuscuta*. They should watch for *Cuscuta* so that any plants discovered can be destroyed. When an individual *Cuscuta* plant is found, it should be dried and burned before it produces any seed.

Cultural and Mechanical Methods

Various cultural practices can kill, suppress or delay *Cuscuta*. Such control methods are inexpensive and can be combined with other methods to develop integrated management systems for *Cuscuta*.

Stale Seedbed Preparation

Under favourable conditions, *Cuscuta* seeds germinate without host plant and seedlings die after eight days in absence of host. Shallow tillage or spraying of non-selective herbicides (glyphosate or paraquat) after seedling emergence but before sowing of crop reduces the *Cuscuta* infestation. Allowing *Cuscuta* to germinate and then destroying it by tillage gave some level of control and it was completely controlled when combined with hand plucking (Sher and Shad, 1989).

Hand Pulling

Hand pulling is the simplest and most effective method of controlling *Cuscuta*. In this practice, it is necessary to pull the infested host plant together with the parasite. If flowering and seed set have already occurred, the pulled material must be removed from the field and eventually burnt.

Crop Rotation

Cuscuta does not parasitize members of the Poaceae. Hence, it can be controlled completely by crop rotation. Without a host plant nearby, *Cuscuta* seedlings emerge and die. Broadleaf weeds must be controlled in such crops to deprive *Cuscuta* of all hosts, so that no new *Cuscuta* seed is produced. During each year without host plants, the reservoir of *Cuscuta* seed in the soil will be reduced. Nevertheless, some hard seed of *Cuscuta* usually remains viable and presents a potential problem to susceptible crops for many years.

Irrigation

Time of irrigation can sometimes be manipulated to help control *Cuscuta*. Because *Cuscuta* seeds cannot germinate without moisture near the soil surface, a period of *Cuscuta* control can be extended by delaying irrigation in certain crops such as alfalfa grown for seed production (Dawson *et al.*, 1984). Such a delay also allows the crop canopy to increase in density, and thus to be better able to shade *Cuscuta* seedlings that emerge following irrigation.

Time of Planting

Unlike root parasites, *Cuscuta* seeds do not require a specific stimulant from hosts to induce germination. However, seedlings die after 8-10 days in the absence of host. Hence, delay in host planting by 8-10 days reduces the *Cuscuta* infestation.

Method of Planting

Cuscuta is very sensitive to shade. Therefore, the crop management practices that favour vigorous crop growth would suppress the growth of *Cuscuta*. However, if the main flush of *Cuscuta* germinates before the crop is well established, this will be ineffective. The shade from dense crop foliage suppresses *Cuscuta* significantly to control it almost completely (Dawson, 1966).

Mixed Cropping

There is some possibility for control of *Cuscuta* by mixed cropping of host crop with non-host crops. The pulse crops can be partially protected from *Cuscuta* parasitism by growing the *Cuscuta* resistant clusterbean (*Cyamopsis tetragonoloba*) alongwith greengram or blackgram in a mixed cropping system (Rao and Reddy, 1987; Reddy and Rao, 1987). A reduction of 60% *Cuscuta* infestation due to inter crop of corn in soybean has been reported by Liyang-Han (1987).

Resistant Species and Varieties of Crops

Crop species and cultivars are known to differ in their competitiveness with weeds (Lemerle *et al.*, 1995). There are genotypic differences with regards to tolerance to *Cuscuta* infestation. The penetration of haustoria to the host plant depends on several factors such as reaction on the external attachment of the haustorium to the host surface, growth behaviour of the haustorial cells within the host tissue, reaction of the protoplasts of the parasitic cells and reaction of the host tissue (Dawson *et al.*, 1994). The vigorous growth of some cultivars, high pubescence and hardness of stems may restrict the entry of parasite into the cultivars. This offers opportunities to select and breed for competitive cultivars that can be adopted by the farmers as a part of integrated weed management programme. There has been only limited interest in developing *Cuscuta*-resistant crop varieties, and presently no resistant varieties of normally susceptible species have been developed. Lucerne variety T9 was found to be highly sensitive, whereas LLC 6 and LLC 7 were moderately tolerant to *Cuscuta* infestation (Narayana, 1989). Greengram variety M2 and blackgram variety T9 were tolerant to *Cuscuta* as compared to other varieties (Kumar and Kondap, 1992). Nemli (1978) tested five varieties of tomato, three of sweet pepper and two of eggplant to be attacked by *C. campestris* and found all tomato varieties resistant and eggplant and pepper susceptible. Goldwasser (2001) also found three tomato varieties tolerant to *C. campestris*. However, Ashton and Santana (1976) reported that all commercial tomato varieties were seriously attacked by *Cuscuta* in Israel and California.

Similarly, Mishra *et al.* (2006) evaluated 14 linseed varieties viz., Garima, Parvati, JLS-27, NL-97, R-17, Padmini, J-23, Meera, Shekhar, T-397, Sweta, Shubhra, Sheela and JLS-9 for their relative tolerance against *C. campestris* at Jabalpur and found that different varieties varied significantly in their response to *Cuscuta* infestation. Reduction in seed yield due to *C. campestris* in different varieties varied from 7.26% in Garima to 44.29% in J 23 indicating Garima as the most tolerant linseed variety against *C. campestris*.

Mechanical Methods

In any crop grown in rows, such as alfalfa grown for seed production, sugarbeets, carrots, or onions, timely cultivation can kill *Cuscuta* seedlings and their potential weed hosts. Once *Cuscuta* is attached to the host plant, only mechanical removal of the part of the host bearing the *Cuscuta* will control the parasite. Such selective pruning may be practical in woody crops such as citrus or in woody or herbaceous ornamentals.

Cuscuta seeds do not germinate if placed deeply (Mishra *et al.,* 2003). Deep ploughing of *Cuscuta*-infested land should greatly reduce the chances of the parasite and establishing from the most recently shed seed but older seed in the soil may be brought to the surface by this practice. Rotation in tillage i. e. deep ploughing in one season followed by shallow or minimum tillage for some years may be done to avoid bringing seeds back to the surface.

Chemical Control

1. Foliage-applied herbicides

When a *Cuscuta* infestation has not been prevented, and the infestation is too general for mechanical removal of individual plants, herbicides can be used to control the pest. However, the nature of attachment and association between host and parasite requires a highly selective herbicide to control the parasite without crop damage. Hassar and Rubin (2003) reported that herbicides such as photosynthesis inhibitors had no effect on *C. campestris*. However, amino acid biosynthesis inhibitors such as glyphosate and acetolactate synthase inhibitors affect the growth of *C. campestris*. When applied on the host, these phloem-mobile herbicides accumulate selectively in *C. campestris* sink and inhibit parasite growth (Dawson and Saghir, 1983; Fer, 1984; Liu and Fer, 1990; Bewick *et al.,* 1991; Nir *et al.,* 1996). Some *Cuscuta* spp. have, however, been reported to show resistance to glyphosate (Hassar and Rubin, 2003). Graph *et al.* (1985) reported that post-emergence application of pronamide at 0.50 kg/ha provided early control of *C. campestris* in chickpea

Because *Cuscuta* is an obligate parasite and cannot live without a host plant, any herbicide that kills the host will also destroy the *Cuscuta*. Contact herbicides such as paraquat and diquat and translocated herbicides such as glyphosate kill *Cuscuta* effectively, but they also kill the host foliage on which it is growing. As the contact herbicides are not translocated, they kill only the parts of plants that they contact directly. Such non-selective destruction is useful for treating scattered patches of *Cuscuta* and thereby preventing seed production and expansion of an infestation.

2. Soil-applied herbicides

Several soil-applied herbicides were found to kill *Cuscuta* seedlings before or soon after they emerge from the soil. Such treatments keep the *Cuscuta* from becoming attached to the host plant. Various crop plants tolerate these herbicides. Consequently, *Cuscuta* can be controlled selectively when these herbicides are applied appropriately.

Trifluralin controlled *Cuscuta*, but only at rates several times higher than those used to control other weeds (Dawson, 1967). In vineyards, trifluralin applied at 3 kg/ha before shovelling or at 1.5 kg/ha after shovelling effectively controlled the *Cuscuta* (Nojavan and Montakhab, 2001).

Fluchloralin 1.5 kg/ha as pre-emergence (Kumar, 2000) and 1.0-1.25 kg/ha as pre-plant soil incorporation (Rao and Gupta, 1981; Mishra *et al.*, 2004) controlled *Cuscuta* effectively in blackgram.

Pendimethalin 0.5-1.5 kg/ha applied as pre-emergence controlled *Cuscuta* in niger (Mishra *et al.*, 2005), blackgram (Rao and Rao, 1993; Mishra *et al.*, 2004), linseed (Mahere *et al.*, 2000), onion (Rao and Rao, 1993), chickpea and lentil (Mishra *et al.*, 2003). Liu *et al.* (1990) reported that pendimethalin inhibited the cell division and formation of spindle microtubulus in the cells of germinated *Cuscuta* seedlings. However, pre-emergence application of pendimethalin in berseem and lucerne has been found phytotoxic to both the crops.

In general, trifluralin is less effective for controlling *Cuscuta* than pendimethalin. In two greenhouse experiments, the rates required to control 98 to 100% of *Cuscuta* were 0.6, 0.6 and 4.5 kg/ha for pendimethalin, prodiamine and trifluralin, respectively (Dawson, 1990).

Promising control of dodder in niger crop by pronamide has been reported (Misra *et al.*, 1981). Pre-emergence application of pronamide at 1.5 kg/ha although controlled the parasite but found phytotoxic to blackgram (Kumar, 2000).

Liu *et al*. (1991) reported imazaquin as a promising herbicide for control of *Cuscuta* in soybean.

Indirect Chemical Control of *Cuscuta*

Cuscuta parasitizes many annual broad-leaved weeds. Control of these weeds in general can assist in control of *Cuscuta*. In a weedy field, much of the *Cuscuta* that infests crop plants first becomes attached to seedlings of broadleaf weeds. Any programme that controls these weeds reduces the possibility of *Cuscuta* seedlings attaching to a host plant. Such indirect control is especially helpful when the crop plants are widely spaced, as is common in plantations of tomatoes and of alfalfa grown for seed. A high percentage of emerging *Cuscuta* seedlings dies, simply because they cannot reach a host plant.

Biological Control

Insects and disease organisms may damage *Cuscuta*. Although damage may be severe, it is often incomplete and may develop too slowly to protect the host plant. In China, the fungus, *Colletotrichum gloeosporioides* attacks *Cuscuta* (Zhang, 1985) and has been used to control *Cuscuta* selectively in soybean (Li, 1987). The fungus can be cultured. The spores are collected and applied uniformly to the *Cuscuta*-infested crop, where they germinate, grow and cause a disease that suppresses *Cuscuta*.

CONCLUSIONS

Cuscuta, a stem parasitic plant poses a serious problem in oilseeds, pulses and fodder crops in rainfed areas of the country. The most common species of *Cuscuta* in India are *C. campestris* and *C. reflexa*. Depending upon the severity of infestation, *Cuscuta* can reduce the crop yields by 27-100%. It is extremely difficult to achieve effective control of *Cuscuta* because its seeds have a hard seed coat, can remain viable in soil for many years and continue to germinate and emerge throughout the year. Integrated management strategies involving preventive, cultural and herbicidal methods can provide an acceptable degree of *Cuscuta* control in field crops. If the infestation is in patches, it can be easily controlled by spraying of non-selective herbicides such as glyphosate and paraquat.

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