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Biology and Management of CUSCUTA

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PREFACE

Parasitic plants are an integral part of the ecosystem. Of all the more than 2, 30, 000 species of flowering plants, approximately 3,900 species of parasitic plants have been recorded. The parasitic mode of existence can be found throughout the kingdoms of life, from bacteria and fungi to insects, arachnids and worms. The transfer of host solutes in to parasitic plants relies on the formation of a bridge (haustorium) between the two organisms. True plant parasites can be hemiparasitic, or holoparasitic. All the species of the genus *Cuscuta* are obligate parasites. In India, *Cuscuta* poses a serious problem in oilseeds (niger, linseed), pulses (blackgram, greengram, lentil, chickpea especially in rice-fallows) and fodder crops (lucerne, berseem) in the states of Andhra Pradesh, Chhattisgarh, Gujarat, Orissa, West Bengal and parts of Madhya Pradesh in rainfed as well as irrigated conditions. Out of the 12 species reported from India, *C. campestris* is dominant. 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*. The infestation of *Cuscuta* results in heavy loss in terms of quantity and quality of produce and many a times it may cause complete failure of the crops. 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 this publication, an effort has been made to compile the salient findings of the research work done at NRCWS Jabalpur and elsewhere on biology and management of *Cuscuta*. The bulletin is arranged in 9 main sections explicating various aspects such as keys to identify most important *Cuscuta* species, germination, growth and reproduction, host range and losses and methods of control using cultural, mechanical, chemical and biological methods. We hope that the bulletin would be of great benefit to students, researchers, extension specialists and policy makers and will serve the purpose of ready reference for managing *Cuscuta* in field crops.

We wish to express our sincere thanks to Dr. M.S. Raghuvanshi, Mr. M.K. Bhat and Mr. Sandeep Dhagat for their painstaking efforts in designing and setting the manuscript.

April, 2006

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1. Introduction

Parasitic plants are an integral part of the ecosystem. They behave as "prudent predators" and are adapted to the life cycle of their principal hosts (Jayasinghe *et al*., 2004). Of all the more than 2, 30, 000 species of flowering plants, approximately 3,900 species of parasitic plants have been recorded (Nickrent, 2002). These plants include some of the most bizarre and beautiful species; including the world's largest flower (*Rafflesia arnoldii*) that is three feet (one meter) in diameter. When one organism steals all of its food from another organism's body it is called a **parasite**. The organism that is being robbed of its food supply is called the **host**. The parasitic mode of existence can be found throughout the kingdoms of life, from bacteria and fungi to insects, arachnids and worms. Parasitism has also evolved in many families of flowering plants. The transfer of host solutes in to parasitic plants relies on the formation of a bridge between the two organisms. This organ, the **haustorium** (from the Latin, *haurire*, to drink) is thus the defining feature of all parasitic plants. True plant parasites can be hemiparasitic (semiparasitic) with photosynthetic leaves (such as mistletoe), or holoparasitic and completely dependent on their host (such as dodder). Some stem parasites are endoparasitic and live completely within the stems of their host. The only part of Pilostyles that emerges from the host is a tiny bud that opens into a minute red flower. This is similar to a pimple appearing on your face that bursts into a tiny blossom.

Cuscuta spp. (dodder) also known as *Akashbel* or *Amarbal*, is a parasitic angiosperm belonging to the family Convolvulaceae in older references, and Cuscutaceae in the more recent publications. Weber (1986) devided the family Cuscutaceae into two genera *i.e. Cuscuta* and *Grammica*, based on the shape of the stigma. The genus *Cuscuta* is comprised of about 175 species world-wide. Out of 12 species are reported from India (Gaur, 1999), *Cuscuta campestris* and *C*. *reflexa* are more common. In some Indian literatures *C. chinensis* (Tosh *et al.*, 1977) and *C. trifolii* 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 (Dawson *et al*., 1994; Holm *et al*., 1997, King, 1966; Parker and Riches, 1993). The invasive characterstics 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* poses a serious problem in oilseeds (niger, linseed) and pulses (blackgram, greengram, lentil, chickpea, especially in rice-fallows) and fodder crops (lucerne, berseem) 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. compestris* 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* impose a severe limitations 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 (Zimmermann, 1962), they are obligate parasites and can not complete their life cycle without attachment to host plants.

1.1 *Cassytha*

Cassytha also known as "laurel dodder" or "love vine" is a high-climbing parasitic vine belongs 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 (Table1). 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 favors 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).

Characters	*Cuscuta*	*Cassytha*
Habit	Parasitic vine	Parasitic vine
Flower	4-5 merous	3 merous
Anther dehiscence	By slits	By pores
Fruit type	Capsule	Drupe
Seed treatment	Needs scarification	Needs scarification
Chlorophyll	Scant	Present and abundant but masked by other pigments
Pubescence	None	Rugae, some hairy
Extrafloral nectaries	Present	Present
Roots and root hairs	Absent	Present
Distribution	Worldwide	Tropical
Habitat	Distributed areas	Distributed areas
Host range	Favours herbaceous plants	Favours woody plant
Number of described species	Ca. 150	Ca. 17

Table - 1: Comparison of the genera *Cuscuta* and *Cassytha* (Dawson *et al*. 1994)

2. 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 m 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 membraneous

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, syles 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 exserted, fimbriate, not bifid**. Seeds 1-1.5 mm. Very widespread. ....***C. campestris***

3. 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* is the most widespread of the Cuscutas and the most aggressive and troublesome in our 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 *C. chinensis* (Rath, 1975; Rath and Mohanty, 1986). To identify the species correctly, *Cuscuta* seeds were collected from niger (Orissa), lucerne (Gujarat), blackgram/greengram (Andhra Pradesh) and linseed (Madhya Pradesh) 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.

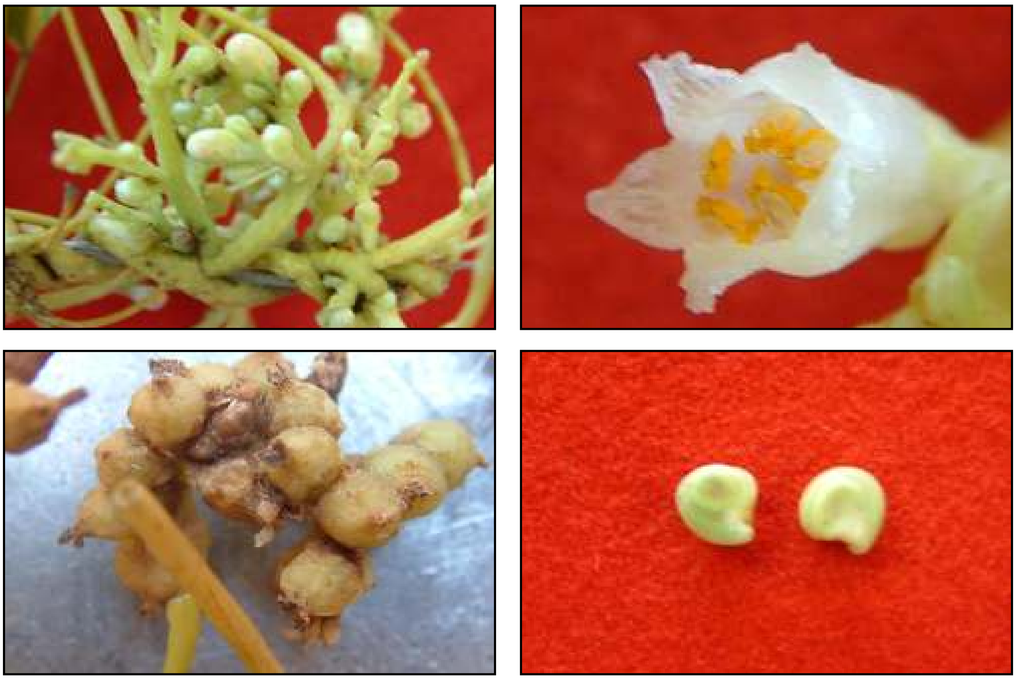
"Capsules not circumscissile, corolla lobes are not keeled; the withered corolla is at the base of most of the capsules, lobes of calyx and corolla not thickened at their

Flowers of ***C. campestris***

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* is 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, up to 10 mm long, white, with a very short calyx, and an elongated conical capsule. The style is so short as to appear



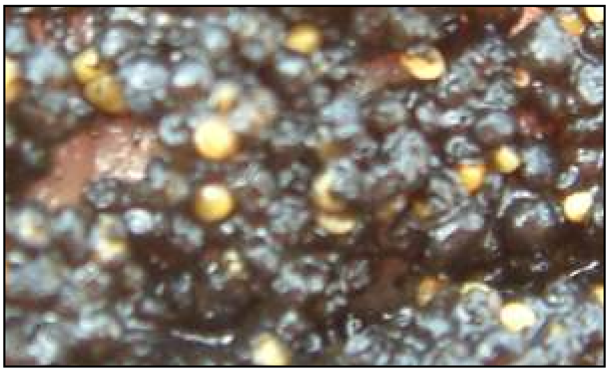
Flowers, fruits and seeds of *C.reflexa*

chickpea (Table 6).

Table 6. Effect of varying densities of *C. campestris* on seed yield of different field crops.

4. 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 up to 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* seed 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 minutes (Zaki *et al*., 1998; Nojavan and



Sulfuric acid treated *Cuscuta* seeds

9.1 Prevention

Seeds of *Cuscuta* are transported as a contaminant of seed of crops such as

Treatment time	Days after treatment							
	1	2	3	4	5	6	7	8
Control	0	4.054 (0)	8.848 (3.34)	8.848 (3.34)	11.56 (6.68)	11.56 (6.68)	11.55 (6.68)	11.55 (6.68)
5 minutes	0	4.054 (0)	4.054 (0)	4.054 (0)	4.054 (0)	8.848 (3.34)	8.848 (3.34)	13.64 (7.50)
10 minutes	0	8.848 (3.34)	30.78 (26.6)	36.85 (36.6)	45.29 (50)	49.22 (63.3)	49.22 (56.6)	51.14 (60)
15 minutes	0	23.855 (16.6)	46.92 (53.3)	50.85 (66)	50.85 (60)	50.85 (60)	52.77 (63.3)	52.77 (63.3)
20 minutes	0	28.78 (23.3)	55.77 (66.6)	64.5 (76.6)	64.5 (76.6)	64.5 (76.6)	64.5 (76.6)	64.5 (76.6)
30 minutes	0	35.22 (33.3)	81.15 (96.6)	81.15 (96.6)	81.15 (96.6)	81.15 (96.6)	81.15 (96.6)	81.15 (96.6)
45 minutes	0	45 (50)	85.38 (100)	85.38 (100)	85.38 (100)	85.38 (100)	85.38 (100)	85.38 (100)
60 minutes	0	55.78 (66.6)	81.15 (96.6)	85.38 (100)	85.38 (100)	85.38 (100)	85.38 (100)	85.38 (100)
90 minutes	0	49.14 (56.6)	63.93 (80)	63.93 (80)	63.93 (80)	66.14 (83.3)	78.44 (86.6)	78.44 (93.3)
LSD (P=0.05)		13.73	13.06	15.55	17.5	16.95	18.11	17.68

* Data subjected to arc sin transformation, Original values in percentage are given in parenthesis

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.

"*Prevention is better than cure*". The best method of controlling *Cuscuta* in cropland is to prevent its introduction onto a field. Planting crop seed contaminated by *Cuscuta* seed has been the major means of *Cuscuta* spread. Therefore, the crop seeds should completely be free from *Cuscuta* seeds. Strict seed laws and programs 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

Germination of *Cuscuta* without host

Greengram

Paddy

Cowpea

Niger (early stage)

Niger (late stage)

Germination and attachment of *Cuscuta* seedlings with host plants

animals is not moved to clean fields.

Destruction of individual plants

Depth of seeding (cm)	Seedling emergence (%) at different days after seeding							
	Linseed				Summer blackgram			
	4	8	12	16	4	8	12	16
Surface	46.4	62.6	53.0	39.9	45	65.9	55.8	46.0
2	37.6	59.8	52.0	45.5	4.05	47.9	39.2	34.2
4	32.3	55.4	45.5	41.1	4.05	12.7	33.2	31.1
6	4.05	19.7	27.8	27.7	4.05	4.05	27.7	25.3
8	4.05	7.01	7.01	7.01	4.05	4.05	16.6	19.9
10	4.05	4.05	4.05	4.05	4.05	4.05	4.05	4.05
LSD (P=0.05)	26.3	24.2	18.2	22.2	3.8	3.2	3.5	3.1

Values transformed to ($Sin^{-1}\sqrt{X}$) transformation

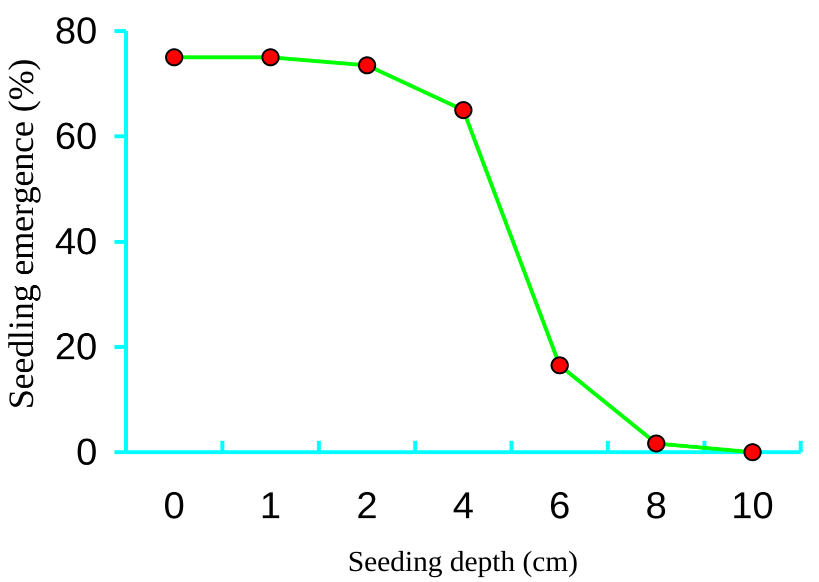


Fig 1. Effect of seeding depth on the emergence of *Cuscuta*

Awareness and vigilance are important companions to prevention in managing *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.

9.2 Cultural and mechanical methods

Various cultural practices will 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

Treat-ments	*Cuscuta* attachments at different days after sowing*					
	10 DAS	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS
0 DAS	28.8 (23.3)	57.64 (71.3)	85.38 (100.0)	85.38 (100.0)	85.38 (100.0)	85.38 (100.0)
2 DAS	24.8 (17.7)	54.57 (66.3)	85.38 (100.0)	85.38 (100.0)	85.38 (100.0)	85.38 (100.0)
4 DAS	8.74 (2.3)	16.06 (7.7)	25.59 (18.7)	31.73 (27.7)	35.26 (33.3)	35.25 (33.3)
6 DAS	6.02 (1.0)	15.7 (7.3)	24.09 (16.6)	30.21 (25.3)	35.26 (33.3)	35.25 (33.3)
8 DAS	4.61 (0.3)	11.01 (3.7)	21.96 (14)	26.56 (20)	30.65 (26.0)	35.25 (33.3)
10 DAS	4.05 (0.0)	4.05 (0.0)	4.05 (0.0)	4.05 (0.0)	4.05 (0.0)	4.05 (0.0)
12 DAS	4.05 (0.0)	4.05 (0.0)	4.05 (0.0)	4.05 (0.0)	4.05 (0.0)	4.05 (0.0)
14 DAS	4.05 (0.0)	4.05 (0.0)	4.05 (0.0)	4.05 (0.0)	4.05 (0.0)	4.05 (0.0)
LSD (P=0.05)	2.54	2.23	1.23	0.96	1.3	1.74

*Arc sign transformed; Figures in parenthesis are original values in %

Under favourable conditions, *Cuscuta* seeds germinate without host plant and seedlings die after 8 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 control and when combined with hand plucking, complete control was achieved (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 has already occurred, the pulled material must be removed from the field and eventually burnt. Sher and shad (1989) however, reported that manual control (hand plucking) alone does not give effective control of *Cuscuta*.

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 remain viable and present a

Development and penetration of haustoria potential problem to susceptible crops for many years.

Irrigation

Time of irrigating can some times 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

Fruits

Seeds

almost non-existent. The seeds are large, 3-3.5 mm long.

7. Hosts of *Cuscuta* and losses

Cuscuta spp. is a serious problem in forage legumes, principally alfalfa (*Medicago sativa*), clovers (*Trifolium* spp).), and niger (*Guizotia abyssinica*). Other crops plagued by *Cuscuta* include linseed (*Linum usitatissimum*), chickpea (*Cicer arietinum*), lentil (*Lens culinaris*), pea (*Pisum sativum*), blackgram (*Vigna mungo*), greengram (*Vigna radiata*), 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. *Cuscuta* also transmits the viral diseases in host plants (Zhang *et al*., 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 and 85.7 % in chickpea (Moorthy *et al*., 2003), 72 % in tomatao (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 NRCWS, Jabalpur revealed that crops *viz.*, frenchbean, mustard, wheat, rice and cowpea were not affected by the *C. campestris* infestation as evidenced by no yield reduction (Table 5). The other crops *viz*., chickpea, lentil, greengram, niger and sesame were highly affected while pea, linseed, soybean, blackgram, groundnut and pigeonpea were moderately affected.

Crop (winter season)	Yield (kg/ha)		Yield loss (%)	Crop (rainy season)	Yield (kg/ha)		Yield loss (%)
	with *Cuscuta*	without *Cuscuta*			with *Cuscuta*	without *Cuscuta*	
Chickpea	239	1656	85.7	Rice	2147	1987	0
Lentil	45	345	87.0	Blackgram	793	1050	24.5
Pea	694	1288	46.1	Cowpea	1421	1371	0
Frenchbean	171	173	0	Soybean	1050	2389	56.0
Linseed	539	1072	49.7	Sesame	147	527	72.1
Mustard	1617	1616	0	Niger	237	1178	79.9
Wheat	4010	4016	0	Pigeonpea	1080	1301	17.0
				Greengram	32	345	90.7
				Groundnut	569	694	18.0

Pigeonpea

Niger

Chickpea

Onion

Brinjal

Lucerne

Lentil

Field bind weed

8. Damage potential of *C. campestris* in different field crops

Table 5. Yield (kg/ha) and the extent of yield loss due to *C. campestris* infestation in different crops

Field experiments were conducted to find out the damage potential of *C. campestris* in summer greengram, niger, lentil and chickpea. Treatments consisting of 11 *Cuscuta* densities (0 to 10/m^2) were replicated three times in a randomized block design in micro plots of 1 m^2. Results revealed that increasing densities of *Cuscuta* decreased the seed yields of all the crops. The loss in seed yield of the crop due to *Cuscuta* from 1 to 10/m^2 ranged from 27.7-

Showing the effect of *C. campestris* densities in niger

88.3%, 39.3-98.4%, 49.1-84.0% and 54.7-98.7%, respectively in summer greengram, niger, lentil and

(No. of *Cuscuta* plants/ m^2)	Seed yield (g/m^2)				Loss in yield due to *Cuscuta* (per cent)			
	summer greengram	niger	lentil	chickpea	summer greengram	niger	lentil	chickpea
0	83.0	277.1	177.7	368.3	-	-	-	-
1	60.0	168.2	90.0	166.7	27.7	39.3	49.1	54.7
2	45.9	160.0	80.6	101.7	44.7	42.3	54.7	72.4
3	35.8	103.5	77.5	88.3	56.8	62.6	56.4	76.0
4	21.2	118.9	77.0	70.0	74.5	57.1	56.6	81.0
5	20.0	70.0	70.9	50.0	75.9	74.7	60.4	86.4
6	16.8	68.0	68.1	27.0	79.7	75.5	61.5	92.7
7	16.0	63.6	58.5	20.0	80.7	77.0	67.2	94.6
8	12.9	8.6	50.3	14.5	84.5	96.9	71.7	96.1
9	12.0	6.6	48.3	6.13	85.5	97.6	72.7	98.3
10	9.7	4.3	28.3	4.63	88.3	98.4	84.0	98.7
LSD(P= 0.05)	8.7	38.4	24.1	23.5	-	-	-	-

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 the *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*) along with 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 where as 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 (1987) exposed five varieties of tomato, three of sweet pepper and two of eggplant to attack by *C. campestris* and found all tomato varieties resistant and eggplant and pepper susceptible. Goldwasser *et al*. (2001) also found three tomato varieties tolerant to *C. campestris*. However, Ashton and Santana (1976) and Hutchinson (1977) reported that all commercial tomato varieties were seriously attacked by *Cuscuta* in Israel and California.

In linseed 14 varieties *viz*., 'Garima', 'Parvati', 'JLS-27', 'NL-97', 'R-17', 'Padmini', 'J-23, Meera', 'Shekhar', 'T-397', 'Sweta', 'Shubhra', 'Sheela' and 'JLS-9' were evaluated for their relative tolerance against *C. campestris* at Jabalpur. Results revealed that different varieties varied significantly in their response to *Cuscuta* infestation in terms of plant height, branches/plant, capsules/plant, seeds/capsule, 1000-seed weight and seed yield (Table 7). Irrespective of the varieties, *Cuscuta* infestation reduced the growth and yield attributes and seed yield of linseed as compared to *Cuscuta* free conditions. 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*.

Table 7. *Cuscuta* infestation and seed yield of linseed as influenced by different varieties.

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, 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 *Cascuta* seeds back to the surface.

9.3 **Chemical control**

When a *Cuscuta* infestation has not been prevented, and when 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 have 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 the strong *C. campestris* sink and inhibit parasite growth (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).

9.3.1 Nonselective foliage-applied herbicides

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 nonselective destruction is useful for treating scattered patches of *Cuscuta* and thereby preventing seed production and expansion of an infestation.

9.3.2 Selective 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 shoveling 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 (Mishra *et al*., 2004, Rao and Gupta, 1981) 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, 1991; 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

Varieties	Linseed plants attached with *Cuscuta* (%) at different days after sowing* (Mean of three years)			Seed yield (kg/ha)						Mean seed yield (kg/ha)		Mean reduction in yield due to *Cuscuta* (%)
				2002-03		2003-04		2004-05		*Cuscuta* infested	*Cuscuta* free	
	25	50	75	*Cuscuta* infested	*Cuscuta* free	*Cuscuta* infested	*Cuscuta* free	*Cuscuta* infested	*Cuscuta* free			
Garima	21.6	33.3	31.9	2459	3087	2188	2115	1883	1817	2177	2340	7.26
Parvati	22.0	31.7	30.7	1933	3008	1788	1789	1750	1833	1824	2210	17.47
JLS-27	18.8	31.4	27.6	2487	2556	1520	1917	1850	2117	1952	2197	11.15
NL-97	16.9	26.1	31.5	1884	3341	1315	1900	1750	2033	1650	2425	31.96
R-17	19.9	29.3	32.9	2444	3488	1379	2159	1800	2000	1874	2549	26.48
Padmini	19.5	37.8	46.8	2186	3421	1787	1880	1750	1967	1908	2423	21.25
J-23	22.9	48.5	48.8	1103	2705	1475	1947	1083	1917	1220	2190	44.29
Meera	23.8	47.5	68.5	973	2998	1663	2573	1733	2200	1456	2524	42.31
Shekhar	18.9	28.9	22.0	1760	3606	1705	2279	1783	2483	1749	2789	37.29
T-397	20.0	33.5	35.5	1122	3320	1660	2069	1433	1983	1405	2457	42.82
Sweta	16.9	25.2	18.0	1601	2587	1977	2007	2083	2167	1887	2254	16.28
Shubhra	26.6	36.5	25.1	2056	3602	1844	2296	1833	1867	1911	2588	26.16
Sheela	22.7	41.0	44.0	1102	3086	1907	2371	2033	2467	1681	2641	36.35
JLS-9	23.7	36.8	47.1	1717	3872	1253	2093	1617	2017	1529	2661	42.54
LSD (P=0.05)	3.8	6.1	6.5	165	294	258	400	364	455	262	383	

division and formation of spindle microtubulus in the cells of germinated *Cuscuta* seedlings.

In general, trifluralin is less effective for controlling *Cuscuta* than is 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) but this herbicide is not available in India. Pre-emergence application of pronamide at 1.5 kg /ha although controlled the parasite but found phytotoxic to balackgram (Kumar, 2000).

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

9.3.3 Selective foliage-applied herbicides

A herbicide that would move to the *Cuscuta* after application to the foliage of the host plant could be very effective and useful. Glyphosate at 75-150 g/ha applied to the foliage of *Cuscuta*-infested alfalfa controlled *Cuscuta* selectively (Dawson and Saghir, 1983). They confirmed that the translocated herbicide glyphosate would preferentially accumulate in *Cuscuta* tissue

and cause severe damage to the attached parasite.

Cuscuta can regenerate freely from isolated haustoria within the host stem. When glyphosate at 50 g/ha was applied as post-emergence to control *Cuscuta* in niger, chickpea and lentil, it killed the extended vines of *Cuscuta* and checked its growth for a period of 25-30 days. There after the parasite grew in bunches from imbedded haustoria and infested the crop plants at later stage of growth. In contrast, glyphosate applied to alfalfa foliage controlled *Cuscuta* better because it contacted the imbedded haustoria during translocation from host to parasite. Nevertheless, glyphosate seldom killed all of the attached *Cuscuta*. Some imbedded haustoria usually survived and new shoots regenerated from this surviving tissue.

Pendimethalin at 0.50 kg/ha applied at 2 weeks after sowing effectively controlled the *C. campestris* in lucerne and berseem without damaging the crop. Its pre-emergence application was, however, phytotoxic to both the crops. Graph *et al*.

(1985) reported that post-emergence application of pronamide at 0.50 kg/ha provided early control of *C. campestris* in chickpea, where as glyphosate too at 0.13 kg/ha controlled the parasite effectively but severely damaged the crop.

9.3.4 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 program 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 die, simply because they cannot reach a host plant.

9.3.5 Efficacy of herbicides against *C.campestris* in different field crops

Blackgram

Application of herbicides significantly reduced the germination of *Cuscuta* in blackgram. Pre-emergence application of pendimethalin at 1.0 kg ha^{-1} being at par with fluchloralin 1.0 kg ha^{-1} significantly reduced the emergence of *Cuscuta*. Trifluralin and oxyfluorfen were not effective. Among the post emergence herbicides, imazethapyr at 50-100 g ha^{-1} and glyphosate at 12-50 g ha^{-1} significantly checked the *Cuscuta* infestation as compared to control. Maximum leaf area (848 cm^2) and dry matter (4.03 g $plant^{-1}$) was obtained from weed-free plot. Pendimethalin, fluchloralin, squadron (PE) and imazethapyr (50 g) significantly increased the leaf area and plant dry weight as compared to *Cuscuta*-infested plots. Post-emergence application of pendimethalin (500 g), squadron (1500g) and imazethapyr (100g) was however, phytotoxic to blackgram. Yield attributes *viz*., pods $plant^{-1}$, seeds pod^{-1} and 100-seed weight under pendimethalin and fluchloralin were comparable to weed free plot but these were significantly higher than *Cuscuta*-infested plots. Application of fluchloralin provided the highest seed yield, which was at par with weed free and pendimethalin at 1.0 kg ha^{-1} as pre-emergence (Table 8).

Lentil, chickpea and linseed

Pre-emergence application of pendimethalin at 1000 g ha^{-1} and squadron (ready mixture of pendimethalin (240 g a.i. l^{-1}) + imazaquin (40 g a.e. l^{-1}) 3000 g ha^{-1}

significantly reduced the emergence of *C. campestris* as compared to *Cuscuta* infested plot in both lentil and chickpea. Pre-plant incorporation of fluchloralin at 1000 g ha^{-1} was not effective on *Cuscuta*. Post-emergence application of imazethapyr (50 and 100 g ha^{-1}) and glyphosate (50 g ha^{-1}) killed the extended vines of *Cuscuta* and checked its growth up to 25-30 days only. Maximum seed yield of lentil (4175 and 3407 kg ha^{-1}), chickpea (3615 and 2949 kg ha^{-1}) and linseed (1994 kg ha^{-1}) was recorded in *Cuscuta* free plots (Table 9,10,11). Pedimethalin at 1000 g ha^{-1} in all three crops, squadron at 3000 g ha^{-1} in chickpea and glyphosate at 50 g ha^{-1} in linseed significantly increased the seed yield. Squadron was phyto-toxic to lentil and linseed. Imazethapyr and glyphosate (except at 50 g ha^{-1} in linseed) were phyto-toxic to the crops.

Regeneration of *Cuscuta* from isolated haustoria

Niger

Pre-emergence application of pendimethalin 1000 g/ha yielded (2262 and 1297 kg/ha) significantly higher as compared to other herbicides. Post-emergence application of imazethapyr and lower doses of glyphosate though checked the *Cuscuta* spread for a certain period but thereafter *Cuscuta* was regenerated from the isolated haustoria within the host stem and soon infested the crop causing severe damage. Pendimethalin 500 g/ha at 10 DAS and SQUADRON 3000 g/ha as pre-emergence or 1500 g/ha at 20 DAS were highly phyto-toxic to niger. Post-emergence application of glyphosate and imazethapyr did not give satisfactory control of *C. campestris* in niger (Table 12,13).

9.4 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*.

Table 8. Effect of herbicides on germination of *C.campestris* and growth, yield attributes and yield of blackgram

Table 9. Effect of herbicides on *C. campestris* and lentil.

Treatment	Dose ($g\ ha^{-1}$)	Time of application	No. of *Cuscuta* plants m^{-2} 10 DAS	Blackgram plants infested with *Cuscuta* (%) at 25 DAS*	Leaf area (cm^2 $plant^{-1}$) 35 DAS	Dry weight (g $plant^{-1}$) 35 DAS	Pods $plant^{-1}$	Seeds pod^{-1}	100 seed weight (g)	Seed yield (kg ha^{-1})
Fluchloralin	1000	PPI	4.0	18.8 (10.8)	636	2.8	20	6.6	4.08	1453
Pendimethalin	1000	PE	2.7	4.05 (0.0)	600	2.5	20	6.6	3.92	1430
Pendimethalin	500	10 DAS	12.0	25.3 (18.3)	206	1.1	22	6.3	3.51	646
Squadron**	3000	PE	6.3	19.6 (11.3)	550	1.8	20	6.0	3.32	1013
Squadron	1500	20 DAS	10.0	43.7 (47.6)	205	1.3	16	5.3	3.16	400
Imazethapyr	100	20 DAS	11.0	33.0 (29.6)	305	1.1	23	6.3	3.44	790
Imazethapyr	50	20 DAS	15.0	42.9 (46.3)	609	1.9	21	5.6	3.45	886
Imazethapyr + 0.1% S +250 g A	100	20 DAS	15.3	39.8 (41.0)	372	1.6	22	5.6	3.24	540
Glyphosate	50	20 DAS	11.7	35.2 (33.3)	426	1.7	17	6.0	3.57	1123
Glyphosate	25	20 DAS	20.7	47.5 (54.3)	209	1.2	19	5.6	3.54	753
Glyphosate	12	20 DAS	20.7	51.3 (61.0)	365	1.6	17	6.0	3.52	860
Oxyfluorfen	200	20 DAS	23.3	40.0 (41.3)	541	1.3	19	5.6	3.82	740
Trifluralin	1000	PPI	23.3	84.6 (99.3)	327	1.9	23	6.0	3.27	946
Cuscuta infested			21.7	84.0 (99.0)	472	2.0	17	6.0	3.83	793
Cuscuta free			-	4.05 (0.0)	846	4.0	23	6.6	3.88	1450
LSD (P= 0.05)			3.4	3.3	57	0.3	5	1.3	0.62	130

*$Sin^{-1}\sqrt{x}$ transformed; Values in parentheses are original, **Ready mixture of pendimethalin (240 g a.i. l^{-1}) + imazaquin (40 g a.e. l^{-1})

Treatments	Dose (g ha^{-1})	*Cuscuta* density (No. m^{-2})		Lentil plants attached with *Cuscuta* (%)* (Days after sowing)						Plant height (cm)		Seed yield (kg ha^{-1})		Seed production of *Cuscuta* (No.' 000 m^{-2})	
				30		60		90							
		2002-03	2003-04	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04
Fluchloralin	1000	6	7	16.6	19.7	67.4	71.5	81.5	78.5	32.6	30.7	1557	1280	155	147
Pendimethalin	1000	2	3	5.3	5.8	20.9	21.5	42.3	42.4	45.3	41.6	2753	2216	54	42
Squadron**	3000	4	1	4.4	6.8	16.2	17.7	32.6	34.6	31.0	29.2	2275	1281	50	14
Imazethapyr	50	6	7	52.3	57.0	25.3	36.1	32.6	42.4	30.2	36.2	1153	889	60	104
Imazethapyr	100	10	6	37.0	41.0	22.0	35.0	30.9	53.9	30.0	38.1	1959	1271	50	66
Glyphosate	50	6	8	40.0	39.0	25.0	29.4	35.0	42.1	35.0	37.4	1061	797	16	111
Cuscuta infested	-	8	8	36.7	21.0	46.8	50.1	61.0	77.2	18.6	16.3	1654	0	176	33
Cuscuta free	-	0	0	4.05	4.05	4.05	4.05	4.05	4.05	51.8	45.9	4175	3407	0	0
LSD (P=0.05)	-	2	2	12.1	10.8	15.3	17.3	16.0	19.5	8.3	9.4	141	289	16	22

*Data transformed to arcsine transformation; **Ready mixture of pendimethalin (240 g a.i. l^{-1}) + imazaquin (40 g a.e. l^{-1})

Table 10. Effect of herbicides on *C. campestris* and chickpea.

Treatments	Dose (g ha^{-1})	*Cuscuta* density (No. m^{-2})		Chickpea plants attached with *Cuscuta* (%)* (Days after sowing)						Plant height (cm)		Seed yield (kg ha^{-1})		Seed production of *Cuscuta* (No.' 000 m^{-2})	
				30		60		90				2002-03	2003-04	2002-03	2003-04
		2002-03	2003-04	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04				
Fluchloralin	1000	7	6	11.3	9	24.0	18.6	37.5	31.4	42.2	47.6	1930	1981	107	27
Pendimethalin	1000	3	2	9.0	7.2	16.3	13.6	31.5	22.3	50.6	52.0	3077	2564	31	9
Squadron**	3000	3	0	7.6	4.05	18.2	4.05	28.6	4.05	49.3	42.8	3252	2415	31	0
Imazethapyr	50	6	8	31.2	28.2	25.1	43.4	71.4	83.5	25.6	20.6	1272	51	33	92
Imazethapyr	100	10	9	35.4	23.1	30.5	26.0	89.6	85.9	31.2	39.3	1290	7	11	77
Glyphosate	50	8	8	31.0	28.6	18.0	21.0	72.0	85.9	26.0	42.8	1031	20	15	115
Cuscuta infested	-	6	9	45.5	59.2	72.3	85.9	76.5	86.9	26.5	24.9	776	0	221	35
Cuscuta free	-	0	0	0	4.05	4.05	4.05	4.05	4.05	50.6	55.6	3615	2949	0	0
LSD (P=0.05)	-	2	2	5.3	6.6	10.2	11.4	13.2	14.4	2.1	1.99	190	103	10	9

*Data transformed to arcsine transformation; **Ready mixture of pendimethalin (240 g a.i. l^{-1}) + imazaquin (40 g a.e. l^{-1})

Table 11. Effect of herbicides on *C. campestris* in linseed

Treatments	Dose (g ha^{-1})	Time of application	Linseed population m^{-2} at		Linseed plants attached with *Cuscuta* (%)* (Days after sowing)			Plant height (cm)	Branches $plant^{-1}$	Seed yield (kg ha^{-1})
			30 DAS	At harvest	30	60	90			
Fluchloralin	1000	PPI	88	47	14.8	24.9	21.8	48.1	5.0	908
Fluchloralin+ Pendimethalin	400+600	PPI+PE	105	45	11.5	18.9	16.0	45.7	4.0	1060
Pendimethalin	1000	PE	94	67	6.9	9.5	12.1	55.3	4.8	1276
Squadron**	3000	PE	0	0	4.05	4.05	4.05	0	0	0
Glyphosate	100	30 DAS	132	101	37.4	31.4	31.3	50.7	4.1	980
Glyphosate	50	30 DAS	144	128	30.4	20.4	24.8	59.1	3.3	1264
Imazathapyr	100	30 DAS	125	53	32.2	18.2	25.2	53.9	4.0	963
Imazathapyr	50	30 DAS	116	77	32.3	24.6	26.3	52.7	4.4	980
Pendimethalin *fb* water spray	2500	30 DAS	110	65	36.8	25.5	19.2	37.4	3.5	983
Pendimethalin *fb* water spray	1500	30 DAS	129	115	28.3	24.4	23.0	44.1	3.3	1183
Pendimethalin *fb* water spray	2000	30 DAS	139	51	37.3	23.2	22.0	39.4	2.3	424
Pendimethalin sand mix	2000	PE	73	19	4.05	4.05	4.05	43.0	2.0	133
Isoproturon	1000	30 DAS	138	92	35.4	85.9	85.9	31.2	4.4	256
Cuscuta infested			128	45	40.9	85.9	85.9	28.6	4.8	404
Cuscuta free			126	99	4.05	4.05	4.05	63.1	5.4	1994
LSD (P=0.05)			39	31	10.1	8.5	7.9	14.3	1.2	150

*Data transformed to arcsine transformation; **Ready mixture of pendimethalin (240 g a.i. l^{-1}) + imazaquin (40 g a.e. l^{-1})
PPI-Pre-plant soil incorporation; PE-Pre-emergence; DAS-Days after sowing; fb-followed by

Table 12. Effect of herbicides on *C. campestris* in niger.

Treatments (g/ha)	Number of *Cuscuta* emerged/m^2		No. of niger plants attached with *Cuscuta**				Seed yield of niger (kg/ha)	
			25 DAS		50 DAS			
	2003	2005	2003	2005	2003	2005	2003	2005
Fluchloralin 1000 g/ha (PPI)	15.7	10.3	9.4 (86.9)	8.2 (67.4)	8.2 (66.7)	8.6	733	664
Pendimethalin 1000 g/ha (PE)	8.7	5.6	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	0.7	2262	1297
Pendimethalin 500 g/ha (10 DAS)	11.0	11.3	9.7 (94.4)	7.6 (57.4)	7.3 (53.4)	6.3	82	430
Squadron** 3000 g/ha (PE)	10.7	9.0	2.7 (6.8)	2.6 (6.0)	1.7 (3.3)	1.3	469	338
Squadron 1500 g/ha (20 DAS)	13.3	23.7	7.6 (57.6)	7.8 (60.5)	8.0 (63.4)	6.9	284	213
Imazethapyr 100 g/ha (20 DAS)	13.0	22.3	8.5 (71.3)	7.1 (50.5)	5.7 (31.4)	5.1	645	575
Imazethapyr 50 g/ha (20 DAS)	13.0	20.0	9.0 (81.1)	7.0 (48.6)	8.7 (75.1)	6.2	561	418
Glyphosate 50 g/ha (20 DAS)	13.3	22.7	9.1 (81.3)	7.6 (57.0)	9.5 (93.1)	6.3	836	492
Glyphosate 25 g/ha(20 DAS)	13.7	21.3	9.7 (93.2)	7.6 (57.4)	9.3 (86.1)	7.4	637	416
Glyphosate 12.5 g/ha (20 DAS)	12.0	237	9.2 (83.5)	7.3 (52.5)	9.7 (94.2)	7.5	622	340
Oxyfluorfen 200 g/ha (PE)	15.7	20.3	7.8 (60.2)	7.5 (55.8)	7.3 (53.5)	7.8	564	314
Trifluralin 1000 g/ha (PPI)	15.0	16.3	9.8 (95.9)	9.4 (88.2)	9.3 (86.0)	9.7	616	542
Cuscuta infested	15.3	22.0	10.0 (100.0)	9.9 (96.5)	10.0 (100.0)	10.0	337	129
Cuscuta free	-	-	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	0.7	2357	1347
LSD (P=0.05)	3.2	3.8	0.3	0.3	0.3	0.3	50	43

*Square root ($\sqrt{X}$+0.5) transformed; figures in parenthesis are original values
** SQUADRON (mix of pendimethalin 240 g ai/l + imazaquin 40 g ae/l)
PE-Pre emergence; PPI-Pre-plant incorporation; DAS-Days after sowing

Table 13. Effect of pendimethalin on C. *Campestris* as influenced by dose and time of application.

Treat-ment	Number of Cuscuta emerged/m2*		Niger plants attached with Cuscuta (%)**				Niger seed yield (kg/ha)		Cuscuta seed yield (kg/ha)	
	2004	2005	35 DAS		45 DAS		2004	2005	2004	2005
			2004	2005	2004	2005				
Dose (kg/ha)										
0.50	3.2 (9.4)	2.7 (6.9)	52.6 (63.1)	43.6 (47.6)	66.9 (84.6)	55.5 (66.9)	338	794	380	803
0.75	3.0 (8.5)	2.5 (5.6)	44.1 (48.4)	40.3 (41.8)	59.1 (73.6)	51.2 (60.7)	364	814	341	638
1.00	2.7 (6.5)	2.2 (4.3)	42.7 (46.0)	36.9 (36.1)	54.9 (66.9)	45.0 (50.0)	687	1156	207	108
LSD (P=0.05)	0.2	0.1	NS	NS	11.9	9.6	41	153	38	172
Time of application (days after sowing)										
1	0.8 (0.2)	0.7 (0.0)	13.8 (5.7)	9.4 (2.7)	20.1 (11.8)	15.3 (7.0)	970	1116	466	205
3	2.0 (3.3)	1.5 (1.8)	22.8 (15.0)	13.6 (5.5)	45.3 (50.5)	25.9 (19.1)	639	1106	482	323
5	2.2 (4.1)	1.6 (2.2)	37.8 (37.6)	22.5 (14.6)	57.0 (70.3)	41.7 (44.2)	492	1088	567	572
7	2.8 (7.3)	2.0 (3.4)	40.3 (41.8)	26.8 (20.3)	61.0 (76.5)	47.5 (54.3)	381	1049	320	112
9	3.1 (8.9)	2.2 (4.2)	55.8 (68.4)	35.4 (33.6)	73.8 (92.2)	52.6 (63.1)	323	894	163	112
11	4.5 (19.9)	2.7 (6.7)	69.2 (87.4)	48.3 (55.7)	78.8 (96.2)	69.3 (87.5)	279	698	137	103
13	5.2 (26.54	3.2 (9.9)	90.0 (100)	61.5 (77.2)	90.0 (100)	78.8 (96.2)	157	499	34	97
LSD (P=0.05)	0.3	0.2	18.8	14.7	18.3	15.7	63	233	59	246

* Data subjected to square root ($\sqrt{X+0.5}$) transformation.
**Data subjected to arc sin ($\sin^{-1}\sqrt{x}$).
Values in parentheses are original.

Niger

Chickpea

Lucerne

Berseem

Effect of Pendimethalin against *C.campestris* in different crops

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