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RESEARCH ARTICLE

Identification of host range, germination ecology and management of field dodder

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ABSTRACT

This study aimed to assess the distribution, host range, habitat, germination ecology, and management of *C. campestris* in the central zone of Kerala, India. A field survey across five districts identified 40 host species of *Cuscuta*, predominantly dicotyledons, with severe infestations in converted rice fields, agricultural fields, rice-fallows and wastelands. Experiments were conducted to study the germination response of *C. campestris* seeds to various dormancy breaking treatments, pH, burial depth and moisture levels. Scarification by sandpaper and concentrated H_2SO_4 improved the germination rate, while neutral pH (pH 7) gave higher germination (85%). Seeds failed to emerge beyond 5 cm burial depth and alternate-day irrigation promoted the highest germination (47%). Post-emergence management of *Cuscuta* in cassava using foliar spray of ammonium phosphate sulphate (3% and 5%) and urea (3% and 5%) exhibited effective control with complete drying of the parasite by 10-15 days after treatment. However, regrowth necessitated repeated applications.

Keywords: Ammonium phosphate sulphate, Field dodder management, Germination ecology, Host range, Urea toxicity

INTRODUCTION

Field dodder is an obligate stem parasite belonging to the family Convolvulaceae. It is native to North America and that has been spread to different parts of Asia. Its broad geographical distribution, wide host range, and the difficulties associated with management place it among one of the most damaging parasites world-wide. The genus *Cuscuta* consists of about 180 species worldwide of which 12 species are reported in India (Gaur 1999). Of these *C. campestris* and *C. reflexa* are more common. *Cuscuta* seeds usually germinate on or near the soil surface. Seedlings are rootless, leafless having thin stems about 0.8 mm in diameter. After emergence, the seedlings twine around the leaf or stem of a suitable host plant and penetrate the host through haustoria formation, absorbing water and nutrients from the host plant. Once *Cuscuta* attaches to a host plant, it remains parasitic until the host was harvested. *Cuscuta* causes severe damage in forage legumes, pulses, citrus and numerous ornamental plants and crop losses ranging from 24 to 90 % have been reported previously (Mishra *et al.* 2006).

Recently, *Cuscuta* infestations have emerged as a significant challenge for farmers in Kerala. As reported by the AICRP on Weed Management (AICRP 2022), the weed has infested crops such as cowpea, amaranthus, cassava, bitter gourd and ornamental plants in the state. The severity of these infestations has also intensified following the floods in 2018.

If *Cuscuta* infestation is not managed timely, it is too strenuous for mechanical removal; hence, post-emergence herbicide application is a viable option. Post-emergence applications of herbicides such as pendimethalin and imazaquin suppress the parasite, but *Cuscuta* generally recovers. Contact herbicides like paraquat and diquat and non-selective systemic herbicides like glyphosate kill *Cuscuta* and also damage the host plant (Mishra *et al.* 2006).

The present study was a non-herbicidal approach to manage *Cuscuta* without damaging the host using nutrient formulations such as urea and ammonium phosphate sulphate. A survey was conducted to investigate the habitat and host range, and laboratory experiments were conducted to study the influence of environmental factors on germination, which could help formulate better weed management practices.

MATERIALS AND METHODS

Identification of host range

A survey was conducted throughout Kerala to identify the distribution and host range of *C. campestris*, with focus on the districts of Thrissur,

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Ernakulam, Palakkad, Kozhikode, and Malappuram. The survey was conducted from June 2023 to May 2024, using a selective sampling method focused on crop fields, rice fallows and wastelands of roadsides and railway tracks. The infested plants were initially recorded based on visual observation of the attachment of vegetative parts of *Cuscuta* to the host plant. The species was confirmed as *C. campestris* based on the standard characteristics outlined by Costea and Tardif (2005). The girth of the *Cuscuta* stem was measured as 0.6-0.8 mm.

Germination ecology

C. campestris seeds were collected from *Cuscuta* infested rice-fallows around Kerala Agriculture University, Thrissur, India (10°32' N and 76°17' E). Cleaned seeds were stored at room temperature in air tight plastic containers. Laboratory experiments were conducted during 2023 and 2024 in the Department of Agronomy lab, College of Agriculture, Vellanikkara, Kerala Agricultural University. Germination of *C. campestris* collected from infested areas was evaluated by placing 25 scarified seeds evenly in Petri dishes containing Whatman No. 1 filter paper and 5 ml distilled water. The number of germinated seeds was counted daily after the start of the experiment, with visible protrusion of radicle being the criterion for germination and time to take 50% germination also calculated. As seeds of *C. campestris* were reported to show dormancy, various dormancy breaking treatments were tried. The methodology followed is given below.

Effect of scarification treatments on germination

Fully matured seeds, collected two weeks prior, were subjected to various scarification treatments in batches of twenty-five seeds per type, with five replicates. These included mechanical scarification by rubbing the seed with sandpaper and chemical scarification using concentrated sulfuric acid for two minutes, followed by washing in running water. The scarified seeds were then allowed to germinate in petri dishes at room temperature. The non-scarified seeds were used as a control.

Effect of pH on germination

The effect of pH on seed germination was investigated using solutions of pH 4, 7, and 9, prepared with 4, 7, and 9.2 buffer capsules. These solutions were used to moisten 10 scarified seeds in petri dishes and the number of germinated seeds was counted daily from the start of the experiment, with visible protrusion of the radicle being the criterion for germination. Scarified seeds were used for this experiment, and unbuffered distilled water (pH 6.6) was used as a control.

Effect of burial depth on germination

The experiment was conducted in pots of depth 20 cm and radius 10 cm filled with sandy clay loam soil. The soil was collected from uninfected area to avoid any interference in germination count. Mechanically scarified seeds were sown in each pot at depths of 0, 2, 5 and 10 cm. The soil was kept moist throughout the study period. Emergence of *C. campestris* was recorded daily for two weeks.

Effect of soil moisture on germination

Germination of seeds of *C. campestris* was studied at different irrigation intervals. A pot culture experiment was done in CRD with four replications. Treatments were saturated condition (maximum water holding capacity), daily irrigation, irrigation on alternate days and irrigation at two days intervals. Pots (depth 20 cm and radius 10 cm) for experimenting were filled with an equal quantity of soil (5 kg) and water was added according to treatments. Twenty-five seeds of *C. campestris* were sown in each pot on the soil surface and covered with a thin layer of soil. The number of germinated seeds was counted daily after the start of the experiment, with visible protrusion of radicle being the criterion for germination.

Management of *C. campestris* in cassava (*Manihot esculenta*)

The experiment was conducted at two locations in the farmer's field in 2023-2024, where severe infestation of *Cuscuta* was observed in cassava. Treatments were 3% and 5% solution of urea (46-0-0), ammonium phosphate sulphate (20-20-0-13) and unsprayed check (no. of treatments=5). Three infested plants were selected in each replication (3 numbers). The treatments and doses of chemicals were fixed based on the preliminary investigation conducted in *Cuscuta* infested weed singapore daisy (*Sphagneticola trilobata*) in a rice fallow. Chemicals were applied by spraying, along with adjuvant, at the rate of 2 ml/L using a knapsack sprayer calibrated to a rate of 200 litres per acre with a flood jet nozzle. Phytotoxicity symptoms of browning, drying, and necrosis were systematically recorded at intervals of 1, 3, 5, 7, 10 and 15 DAT (days after treatment). These symptoms were evaluated using a rating scale ranging from 0 to 5 (0- no control, 1- slight control, 2- moderate control, 3- good control, 4- very good

control, 5- complete control for *Cuscuta*) (rating scale: 0- no injury, 1- slight injury, 2- moderate injury, 3- severe injury, 4- very severe injury, 5- complete destruction for host) by Thomas and Abraham (2007).

Statistical analysis

The data generated were processed through the statistical package "GRAPES" (General R- based Analysis Platform Empowered by Statistics) developed by Gopinath *et al.* (2021). Wherever large variation in data was observed, angular transformation was performed (Gomez and Gomez, 1984). Multiple comparisons among treatment means, where the F test was significant (at 5% level), were made with Tukey's HSD test (Honestly Significant Difference).

RESULTS AND DISCUSSION

Distribution and host range of *C. campestris*

The survey revealed that distribution of C. *campestris* was primarily found in converted rice fields, agriculture fields, rice-fallows, potting media of ornamental plants and roadside wastelands (**Figure 1**). The incidence of *C. campestris* was identified among 42 host species belonging to 22 families. Of these, 88% were dicots, and the rest (12%) were the monocots (**Table 1**). These results indicated predominance of *C. campestris* mostly on dicotyledonous annual and perennial host plants and rarely parasitised monocotyledonous plants. Mishra *et al.* (2006) reported that *Cuscuta* has a wide host range, mainly dicotyledonous, including legumes, pulses, ornamental plants and numerous weeds. *Cuscuta* also parasitise asparagus and onion, which are monocotyledonous crops, but grasses and grains

Table 1. Host range of *C. campestris* in central zone of Kerala

Hosts plant species	Family	Habit	Dicot/ Monocot/ Another group
Weed hosts			
Ageratum conyzoides L.	Asteraceae	Herb	Dicot
Alternanthera bettzickiana (Regel) G.Nicholson	Amaranthaceae	Herb	Dicot
Alternanthera sessilis (L.) R.Br. ex DC.	Amaranthaceae	Herb	Dicot
Brachiaria mutica (Forssk.) Stapf	Poaceae	Herb	Monocot
Centrosema pubescens Benth.	Fabaceae	Herb	Dicot
Calopogonium mucunoides Desv.	Fabaceae	Herb	Dicot
Calotropis gigantea (L.) W.T.Aiton	Apocynaceae	Shrub	Dicot
Christella dentata (Forssk.) Brownsey& Jermy	Thelypteridaceae	Herb	Fern
Chromolaena odorata (L.) King et H. E. Robins.	Asteraceae	Herb	Dicot
Cleome rutidosperma (Wight & Arn.)	Cleomaceae	Herb	Dicot
Cyanthillium cinereum (L.) H.Rob.	Asteraceae	Herb	Dicot
Cyclea peltata (Burm.f.) Hook.f. & Thomson	Menispermaceae	Climber	Dicot
Digitaria sanguinalis (L.) Scop.	Poaceae	Herb	Monocot
Ficus hispida L.f.	Moraceae	Tree*	Dicot
Leucas aspera (Willd.) Link	Lamiaceae	Herb	Dicot
Ludwigia perennis L.	Onagraceae	Herb	Dicot
Macaranga peltata (Roxb.) Mull.Arg.	Euphorbaceae	Tree*	Dicot
Megathyrsus maximus (Jacq.) B.K.Simon & S.W.L.Jacobs	Poaceae	Herb	Monocot
Melochia corchorifolia L.	Sterculiaceae	Herb	Dicot
Merremia vitifolia (Burm.f.) Hallier f.	Convolvulaceae	Climber	Dicot
Mikania micrantha Kunth	Asteraceae	Climber	Dicot
Mimosa invisa Mart.	Fabaceae	Herb	Dicot
Mimosa pudica L.	Fabaceae	Herb	Dicot
Pennisetum pedicellatum Trin.	Poaceae	Herb	Monocot
Phyllanthus niruri L.	Phyllanthaceae	Herb	Dicot
Ricinus communis L.	Euphorbaceae	Shrub	Dicot
Sida acuta Burm. F.	Malvaceae	Shrub	Dicot
Sphagneticola trilobata (L.) Pruski	Asteraceae	Herb	Dicot
Synedrella nodiflora (L.) Gaertn	Asteraceae	Herb	Dicot
Urena lobata L.	Malvaceae	Herb	Dicot
Xanthium strumarium L.	Asteraceae	Herb	Dicot
Crop hosts			
Amaranthus L.	Amaranthaceae	Herb	Dicot
Capsicum annuum L.	Solanaceae	Herb	Dicot
Manihot esculenta Crantz	Euphorbaceae	Shrub	Dicot
Momordica charantia L.	Cucurbitaceae	Climber	Dicot
Musa spp.	Musaceae	Herb	Monocot
Solanum melongena L.	Solanaceae	Herb	Dicot
Solanum lycopersicum L.	Solanaceae	Herb	Dicot
Vigna unguiculata (L.) Walp	Fabaceae	Herb	Dicot
Ornamentals			
Duranta erecta L.	Verbenaceae	Shrub	Dicot
Polyscias fruticosa (L.) Harms	Araliaceae	Shrub	Dicot
Pseuderanthemum carruthersii var. Atropurpureum	Acanthaceae	Shrub	Dicot

*****Infestation observed on seedlings

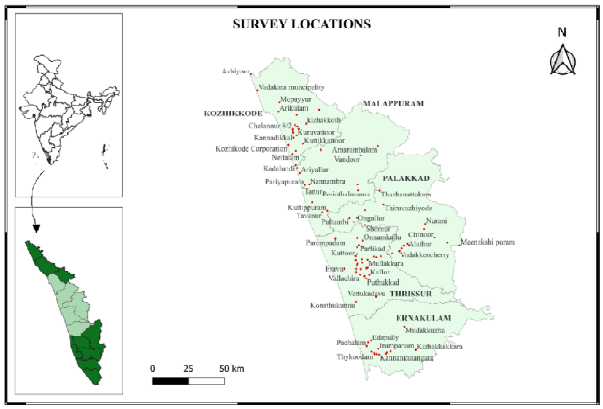

Figure 1. Distribution of *C. campestris* in central zone of Kerala

(Poaceae) are usually not parasitised. The prevention of haustoria penetration to monocot stem could be because of lignified tissues and the absence of epidermal hairs or sclerenchymatous hypodermis in monocots (Dawson *et al*., 1994). However, in our study, we observed that monocotyledons (*Brachiaria mutica, Digitaria sanguinalis, Megathyrsus maximus, Pennisetum pedicellatum* and *Musa* spp.) were also affected by the parasite, but the severity and intensity were very low, and haustorial connections were inconspicuous and needs further studies to confirm parasitisation.

Infestation of *C. campestris* was observed mostly on 31 weed hosts, 8 cultivated crops and 3 ornamental plants. The host species includes 29 herbs, 7 shrubs, 4 climbers and 2 trees. Mostly, herbs were found to be affected by the parasite, while the trees were resistant. Trees are affected only in the juvenile or seedling stages. Some of the crops infested with *Cuscuta* are cassava, banana, bitter gourd, cowpea, chilli, brinjal, tomato, amaranthus and few ornamental plants. The most preferred hosts are *Mikania micrantha* and *Sphagneticola trilobata* both of which belong to the family Asteraceae. Sarma *et al*. (2008) also reported that the prominent plant families infested with *Cuscuta* are Rosaceae, Asteraceae and Solanaceae due to their suitable morphology for haustoria attachment.

Germination ecology of *C. campestris*

Effect of scarification: Scarification treatments improved the germination of *C. campestris*, with the higher germination percentage observed in sandpaper scarification (89%) and scarification by concentrated H_2SO_4 (86%) (**Figure 2**). Similarly, Benvenuti *et al*. (2005) reported that germination rate of non-scarified seeds of *C. campestris* did not exceed 20% whereas, scarification by concentrated H_2SO_4 for 10 minutes increased germination to over 80%. According to

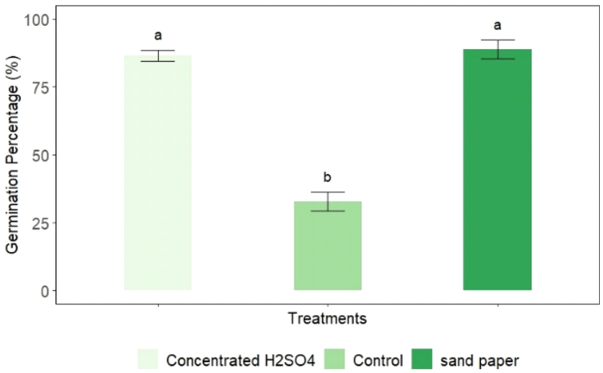

Figure 2. Effect of scarification treatments on germination

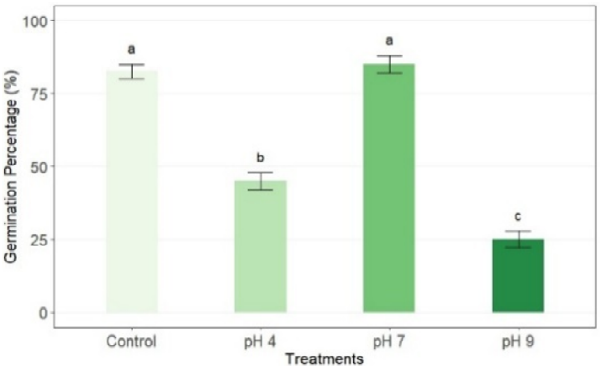

Figure 3. Effect of pH on germination

Ashton and Santana (1976) rubbing seeds between fine sandpaper gave almost 100% germination of *C. campestris*. The higher time to take 50% germination (2 days) was observed in non-scarified seeds which was significantly higher than scarification treatments (1.71 days).

Effect of pH: The seeds of *C. campestris* were germinated at pH 4, 7 and 9 (**Figure 3**). Germination of *C. campestris* was higher (85%) at neutral pH (pH 7) and was on par with the control treatment (distilled water having pH 6.6). Zaki *et al*. (1998) also recorded the highest germination of C*uscuta* at a pH of 7. There was a decrease in germination with either increase or decrease in pH. Alkaline pH was found to be unfavourable for germination compared to acidic pH. The ability of *C. campestris* to germinate under pH 4 and 9 indicated that this weed can also become problematic in all soils. However, in alkaline pH, the chances of infestation are less. The highest time to take 50% germination was observed in pH 9 (2.3 days) which is significantly different from other treatments (1.6 days).

Effect of burial depth: Emergence of *C. campestris* decreased with increase in depth of placement of seeds in the soil (**Figure 4**). *C. campestris* seeds exhibited highest emergence at surface (92%) which significantly differed from deeper layers. At 2 cm depth, emergence was reduced by about 50%. No

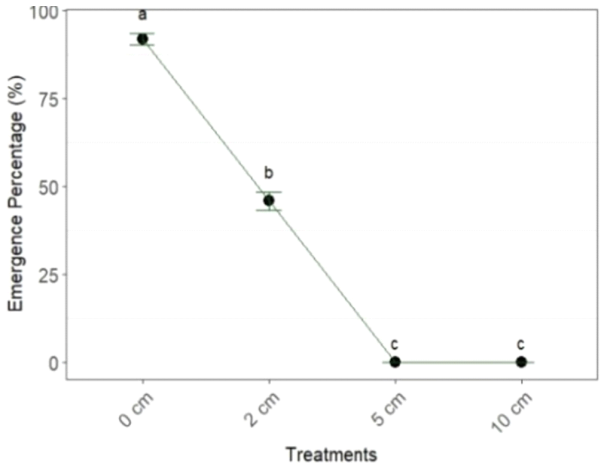

Figure 4. Effect of burial depth on emergence

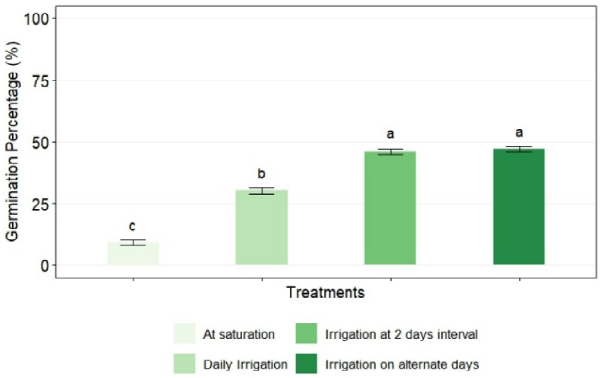

Figure 5. Effect of moisture content on germination

emergence was recorded at depth of 5 cm and beyond. According to Benvenuti *et al*. (2005) no emergence was observed at a sowing depth greater than 4 cm, and the lack of emergence was not because of fatal germination. Lack of oxygen presence and poor diffusion with increasing soil depth decrease the emergence rate (Benvenuti 2003).

Effect of moisture content: The germination percentage recorded under irrigation on alternate days and irrigation at two days intervals were on par (46%), which was significantly higher than that under daily irrigation and saturated condition (**Figure 5**). The lowest germination was observed at saturated condition (9%). Jang and Kuk (2020) observed poor germination of *C. pentagona* under saturated conditions. The higher time take to 50% germination observed at saturation (2.06 days) which was significantly higher than other treatments (1.88 days).

Effect of weed management treatments on phytotoxicity

The phytotoxic effects on *Cuscuta* and cassava due to various treatments are presented in **Table 2** and **3**. Ammonium phosphate sulphate and urea application resulted in complete drying of *Cuscuta* at 15 days after spraying (score of 5). Phytotoxicity score of 4 was observed in all treatments at 5 days after treatment (DAT). The oxidative damage caused by these chemicals led to tissue scorching in *Cuscuta*. Maleva *et al*. (2015) also observed urea-induced oxidative damage in *Elodea densa* leaves. Lim *et al*. (2009) noted that, at higher concentrations, urea functions as a chaotropic agent, causing protein denaturation in *Cuscuta* cells.

Regrowth of *Cuscuta* was observed in all treated plants at 7 DAT, indicating the need for repeated applications for sustained control. The second dose of all treatments was sprayed in 7 DAT. Although some phytotoxicity on young cassava leaves was observed, the crop regained the vigour by two weeks post spraying. No phytotoxicity was observed on cassava stem. The anatomical difference between

Table 2. Phytotoxicity on *Cuscuta* due to various treatments

Treatment	Days after treatment application					
	Day 1	Day 3	Day 5	Day 7	Day 10	Day 15
Urea (3%)	1	2	4	4	4	5
Urea (5%)	1	2	4	4	5	5
Ammonium phosphate sulphate (3%)	2	3	4	4	5	5
Ammonium phosphate sulphate (5%)	2	3	4	4	5	5
Unsprayed check	0	0	0	0	0	0

(Rating scale: 0- none, 1- slight toxicity, 2- moderate, 3- good, 4- very good, 5- complete drying)

Table 3. Phytotoxicity on cassava due to various treatments

Treatment	Days after treatment application					
	Day 1	Day 3	Day 5	Day 7	Day 10	Day 15
Urea (3%)	1	1	1	1	0	0
Urea (5%)	1	2	2	2	2	0
Ammonium phosphate sulphate (3%)	1	2	2	2	2	0
Ammonium phosphate sulphate (5%)	2	2	2	2	2	0
Unsprayed check	0	0	0	0	0	0

(Rating scale: 0- no injury, 1- slight injury, 2- moderate injury, 3- severe injury, 4- very severe injury, 5- complete destruction)

Table 4. Effect of treatments on plant height and yield of cassava

Treatment	Location 1			Location 2			Pooled yield/plant (kg)
	Plant height (cm)		Yield/ plant (kg)	Plant height (cm)		Yield/plant (kg)	
	Before treatment	Harvesting stage		Before treatment	Harvesting stage		
Urea (3%)	80.00^{c}	127.50^{b}	4.25^{b}	95.00^{b}	184.00^{b}	4.60^{b}	4.40^{b}
Urea (5%)	80.50^{c}	128.05^{b}	4.15^{b}	93.75^{b}	186.00^{b}	4.70^{b}	4.40^{b}
Ammonium phosphate sulphate (3%)	85.00^{b}	129.00^{b}	4.30^{b}	96.00^{b}	186.25^{b}	4.65^{b}	4.47^{b}
Ammonium phosphate sulphate (5%)	83.00^{bc}	128.00^{b}	4.20^{b}	96.00^{b}	185.00^{b}	4.82^{b}	4.51^{b}
Unsprayed check	82.00^{bc}	93.50^{c}	1.00^{c}	94.50^{b}	120.00^{c}	1.33^{c}	1.17^{c}
Uninfested plant	93.00^{a}	134.50^{a}	5.00^{a}	112.50^{a}	196.00^{a}	5.43^{a}	5.22^{a}
LSD (p=0.05)	3.50	2.44	0.31	6.42	6.11	0.60	0.18

cells of *Cuscuta* and hardy nature of cassava plant resulted in less phytotoxicity of cassava compared to *Cuscuta*.

Effect of treatments on plant height and yield of cassava

In general, infestation caused an average 40% decrease in plant height and an 80% reduction in yield (**Table 4**). Yield loss was only 15% with foliar spray of urea and ammonium phosphate. Average tuber yield differed statistically among the treatments. The highest average tuber yield was observed in uninfected plants (5.22 kg/plant). The tuber yield in urea and ammonium phosphate sprayed plots were at par. The lowest yield of 1.17 kg/plant registered from *Cuscuta* infested plants, when no management measures were adopted.

Conclusion

The survey revealed extensive distribution of *C. campestris* in converted rice fields and wastelands, infesting 40 host species, mainly dicots, and affecting crops such as cassava, banana, bitter gourd, cowpea as well as various weeds and ornamental plants. Seed dormancy enables *Cuscuta* to emerge annually from the soil. Scarification significantly enhances its germination and the species has the adaptability to germinate even in extreme pH conditions. However, saturated soil and deep seed burial inhibit its emergence. The management study indicates the possibility of using a foliar spray of urea or ammonium phosphate solution at 3 and 5% concentrations, along with an adjuvant for managing *Cuscuta* in a hardy crop like cassava. However, regrowth was observed within a week post-spray, indicating repeated treatments for sustained management.

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