Original Article: Evaluation of non-host crops as trap crops to reduce *Orobanche* seed bank in tomato fields

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Citation Bipana Devi Acharya, Anjana Bista, Sanju Jyawali, Nabin Kumar Darai. 2021. Evaluation of non-host crops as trap crops to reduce *Orobanche* seed bank in tomato fields. Journal of Research in Weed Science, 4(3), 210-217.

http://dx.doi.org/10.26655/JRWEEDSCI.2021.2.7

Article info

Received: 24 January 2021
Accepted: 24 April 2021
Available Online: 26 April 2021
Checked for Plagiarism: Yes
Peer reviewers approved by:
Dr. Mohammad Mehdizadeh
Editor who approved publication:
Dr. Amin Baghizadeh
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Keywords:
Broomrape, Holo-parasite, Infested, Parasitic weed, Seed density

ABSTRACT

Orobanche species, commonly known as broomrape, are root holo-parasite of the family Orobanchaceae. In Nepal two species, *Orobanche aegyptiaca* and *O. cernua* are causing threat to wide range of important vegetables and crops of family Brassicaceae and Solanaceae. To evaluate non-host plants as potential trap crops, different crop plants were tested in two *Orobanche* infested tomato fields of Lalbandi, Sarlahi, South-Eastern part of Nepal in 2018 -19. *Orobanche* seed density in soil samples collected from plots before planting and after harvest of each crop species were recorded and compared for the seed bank. On the basis of *Orobanche* seed bank reduction in both the fields, the investigated crop species like *Capsicum frutescens, Cicer arietinum, Lens culinaris* and *Vicia faba* were classified as highly potential trap crops and reduced seed bank from 52 to 70%. Crops like *Cuminum cyminum, Daucus carota, Foeniculum vulgare, Phaseolus vulgaris, Sessamum orientale* and *Trigonella foenum-graecum* were classified as moderately potential trap crops and reduced *Orobanche* seed bank from 41 to 52 %. The other tested crops like *Allium cepa, Allium sativum, Coriandrum sativum, Glycine max, Hordeum vulgare, Pisum sativum, Solanum tuberosum, Raphanus sativus* are classified as non-potential trap crops. Among all the tested crops *Capsicum frutescens, Cicer arietinum, Lens culinaris* and *Vicia faba* were identified as the potential trap crop to reduce *Orobanche* seed bank in infested tomato fields.

Introduction

The genus *Orobanche* is a parasitic weed commonly known as broomrape and has more than 140 species (Das et al. 2020). However, only seven broomrape species, *Orobanche crenata* Loefl., *Orobanche cernua* Loefl , *Orobanche cumana Wallr.*, *Orobanche foetida* Poir, *Orobanche minor* Sm., *Phelipanche aegyptiaca (synonym Orobanche aegyptiaca Pers.)*, and *Phelipanche ramosa* L. (Synonym *Orobanche ramosa* L.) have been reported for attacking crops causing trouble in agriculture along Mediterranean, Central and Eastern Europe, and Asia (Parker, 2009). The crops parasitized belong to different important families like Asteraceae, Brassicaceae, Apiaceae, Fabaceae, or Solanaceae. The members of these families such as sunflower, oilseed rape, carrot, faba bean, or tomato and many others are attacked by these parasitic weeds (Parker and Riches, 1993). It is threat to about 16 million hectares of arable land, which is about 1.2% of the total world arable land (Sauerborn, 1991). In lentil *O.crenata* and *O.aegyptiaca* are causing up to 95% yield loss depending on the severity of the infestation and planting date (Rubiales et al. 2009). The yield loss in Solanaceous plants like potato, brinjal, tomato and tobacco by *O. ramosa* is reported to be more than 75% in Algeria. In severe infestation crop yields of cash crops like tomato and brinjal may reduce up to 100% (Parker, 2009; Fernandez et al. 2016). In the Middle East, annual losses due to these parasitic weeds are estimated to be worth 1.3-2.6 billion dollars (Aly, 2007).

A single *Orobanche* plant can produce more than 500,000 seeds, which are very small 0.25 to 0.4 mm in diameter. These seeds can remain viable for decades in soil in absence of suitable host. This help parasite to have genetic adaptability to environmental changes, including host resistance, agronomical practices and herbicide treatments (Joel et al. 2007). This increases seed bank in soil every year making its eradication difficult.

Several available control methods (like chemical, physical, biological, cultural etc. have been tried around the world for control of this weed but none of the single method is found to be effective in terms of economic return (Perez-de-luque et al. 2010). There are some reports that the crop rotation with certain non-host crop can reduce *Orobanche* seed bank in infested field (Parker, 1991; Sauerborn, 1991; Acharya, 2013). Use of trap crop and catch crop is one of the effective methods currently available to control agricultural root parasites according to many researchers (Aksoy et al. 2016, Acharya et al. 2002). Trap crops also called as false host are plants which stimulate the germination of the parasite seeds but cannot be infected and thus reduce the seed population in the soil. Catch crops are usual host which allow the development of the parasite. They are planted in high densities to stimulate high percentage of the parasite seeds to germinate but are destroyed before the parasite flowers and develop seeds, which stop further addition of seeds in the soil.

Press et al. (2000) reported eight species of *Orobanche* in Nepal, of which two species namely *Orobanche aegyptiaca* and *O. cernua* are causing threat to wide range of important vegetables and cash crops, particularly *Brassica campestries* var. *toria*, *B. campestries* var. *sarson*, *B.juncea*, *Lycoperiscon esculentum*, *Solanum melongena* and *Nicotiana tabaccum* grown in south eastern plane and dun valleys (Khattri et al. 1991*)* of Nepal. *Orobanche* problem in Nepal have received little attention as compared to other weeds and therefore extensive research work is needed to mitigate this problem. Hence this study was conducted in highly Orobanche infested fields of Lalbandi, one of the leading tomatoes growing areas of the country, to evaluate the effect of different non-host crops as trap crops through the study of *Orobanche* seed bank in soil before planting non host crops and after its harvest.

Materials and Methods

The study area was Lalbandi, which is situated at about 170 km south east of Kathmandu. It is located at 27° 3′ 30″ N to 85° 38′ 0″ E. and elevation of 154 meter above sea level. Average maximum and minimum temperature recorded were 35.4 °C and 8.17 °C, respectively. The annual precipitation in the study area was 1330.9 mm, with maximum precipitations during the summer months of June-August and minimum rain during winter months of December-February.

The field experiment was conducted in two infested tomato fields – Field A and Field B, with different cropping pattern. The Field A was an upland rain fed field with maize cultivation in summer season and tomato in winter for last 10 years where as Field B was a low-lying field with paddy cultivation in summer and tomato or mustard in winter for last ten years. Both the fields have homogenous nutrient and moisture regimes. The soil type in field A was loam with 47.8% sand, 43.4% silt and 8.8% clay. Soil nitrogen content was 0.09%, phosphorus 35.02 kg/ha, potassium 455.6 kg/ha, organic content 1.02% and soil pH 7.5. The soil type of field B was also loam with 41.8% sand, 49.40% silt and 8.80 % clay. In field B, nitrogen content was 0.09%, phosphorous 24.72 kg/ ha, potassium 388.60 kg/ha and organic content was 1.06% and soil pH 7.2.

Both the fields were ploughed twice in last week of September 2018 with the help of tractor with disc harrow. Manure in both the fields were done with animal dung along with mustard oil cakes at the rate of 133.33kg/ha) and DAP (Diammonium phosphate (at the rate of 66.60 kg /ha) as the usual practice of local farmers.

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Altogether 23 non host crops in Field A and 20 non host crops in Field B, which are also grown locally, were selected along with fallow as control treatment. Experiments were conducted in randomized complete blocks design with three replications and fallow as control plots. The size of experimental plot was 2m x 1m in both fields.

The seed / seedling (of *Capsicum frutescens* and *Allim cepa*)/bulb-let (of *Allium sativum*) /tuber (of *Solanum tuberosum*) of the non-host test crops were obtained from local market of Kathmandu and Lalbandhi, and were planted in the infested fields of Lalbandhi after the final preparation of the field in the first week of October. Plots were irrigated a day before sowing. Later irrigation was done at regular interval as required. The distance between rows and plants were maintained as in usual practices of farmers.

For *Orobanche* seed estimation, about 1 kg of soil samples were collected from the surface up to 15 cm depth from each plot of Field A and Field B with the help of an auger by composite sampling method from each plot. The sampling spots were located between rows and there were three equally spaced spots between each row in the plots. First soil sample collection was done before sowing and the second soil sample collection was conducted after harvest of test crops. The collected soil samples were labelled and transported to laboratory for seed bank estimation. The seed count in each sample were done in triplicates. The percentage reduction of *Orobanche* seeds was determined from the difference of initial seed count before sowing and final seed count after harvest of non-host crops. *Orobanche* Seed bank estimation was conducted following the method of Ashworth (1976) with some modifications (Acharya et al. 2003).

To analyze the significant differences in percentage reduction of seed bank, the data obtained were analyzed statistically using Analysis of Variance (ANOVA) followed by Duncan's Multiple Range Test (DMRT) at significance level of P= 0.05 using SPSS statistics 17.0 program.

Results and Discussion

Field A: Number of *Orobanche* seeds per meter square recorded before and after harvest of different test crops in Field A is shown in Figure 1. The figure indicates that there was reduction in seed banks in all test crops including fallow. The *Orobanche* seed density.m^2 ranged from 95,425 to 48,495 before sowing the test crops in plots of Field A and this seed density was found to be reduced and ranged from 48,564 to 26,235 after the harvest of test crops.

Field B: Number of *Orobanche* seeds per meter square recorded before and after harvest of different test crops in Field B is shown in Figure 2. The histogram clearly indicates that there was reduction in seed bank in all test crops including control. The *Orobanche* seed density (mean value) ranged from 5,495 to 16,485 seeds.m^2 before sowing the test crops in plots of Field B and it was found to be reduced after the harvest of test crops and ranged from 3,140 to 9,420 seeds/m^2. The *Orobanche* seed density.m^2 in field B is comparatively less than that in Field A, as it was a paddy field. Generally, paddy fields remain in inundated condition during paddy cultivation and this possibly reduces *Orobanche* seed bank (Krishnamurthy et al., 1977; Punia 2014).

Reduction (%) of *Orobanche* seed density in Field A was highest (70.29) in the plots grown with *Vicia faba* (fababean) and lowest in the plots grown with *Hordeum (*barley). But in Field B highest reduction (%) in seed density was recorded in plots grown with *Capsicum* and lowest in Fallow plots (Table 1).

Orobanche seed density in soil reduced significantly (P=0.05) after the harvest in the plots grown with *Capsicum* (Chili*)*, Cicer (chickpea), *Fagopyrum* (buckwheat), *Lens* (lentil) and *Vicia faba* (faba bean) in Field A. Similarly, *Orobanche* seed density reduced significantly (P=0.05) in the plots that were grown with *Capsicum* (chili), *Cicer* (chick pea), *Lens* (lentil), *Sesamum (*sesame) and *Vicia faba* (faba bean) of Field B (Table 1.). *Orobanche* seed bank in the above-mentioned plots reduced from 52 to 70% after their harvest.

Insignificant reduction of *Orobanche* seed density was recorded in the test crops like *Allium cepa* (Onion), *Coriandrum* (coriander), *Cuminum* (cumin), *Foeniculum* (fennel), *Linum* (linseed), *Phaseolus* (French bean), *Solanum* (potato) and *Trigonella* (fenugreek) in Field A. Similarly, moderate range of *Orobanche* seed bank reduction was observed in (Glycine) soybean, *Hordeum* (barley) and *Fagopyrum* (buckwheat) in field B. The *Orobanche* seed bank reduction (mean value) with these crops ranged from 41 to 51%.

Similarly seed bank was found to be insignificantly different than in control among test crops like *Allium sativum*, *H. vulgare*, *R. sativus*, *T. aestivum*, *V. unguiculata* and *Z. mays* in both Fields (Table 1).

Comparing the seed bank reduction in two fields, *C. frutescens*, *C. arietinum*, *L. culinaris* and *V. faba* significantly reduced *Orobanche* seeds in both fields and can be regarded as highly potential trap crops. These non-host plants have also been regarded as trap crops by various researcher for different species of *Orobanche*. The emergence of few *Orobanche* shoots in two plots of Field A with *Capsicum frutescens* L in the present field study indicated that the root exudates of this plant are able to induce seed germination of *Orobanche* and was also suggested by Qasem (2019) in *O. ramose*. Hence *capsicum* can be used as trap crops or in intercropping in infested tomato fields of our study area which are infested with both *O. aegyptiaca and O. cernua.*

Cicer arietinum is a common host of *O. aegyptiaca*, *O. ramosa* and *O. cernua* (Parker, 1986). Although this crop has been reported as host in other countries, but not a single crop plant was found to be parasitized by the *Orobanche* in the present study, indicating that the *Orobanche* species present in Nepal is physiologically different from other species found elsewhere. Data of seed bank clearly indicate that chickpea can be used as a trap crop in crop rotation or as mixed cropping in order to reduce *Orobanche* in infested field. Its cultivation also increases soil nitrogen content which may reduce *Orobanche* emergence as suggested by Abu Irmaileh (1994) in *O. ramosa.*

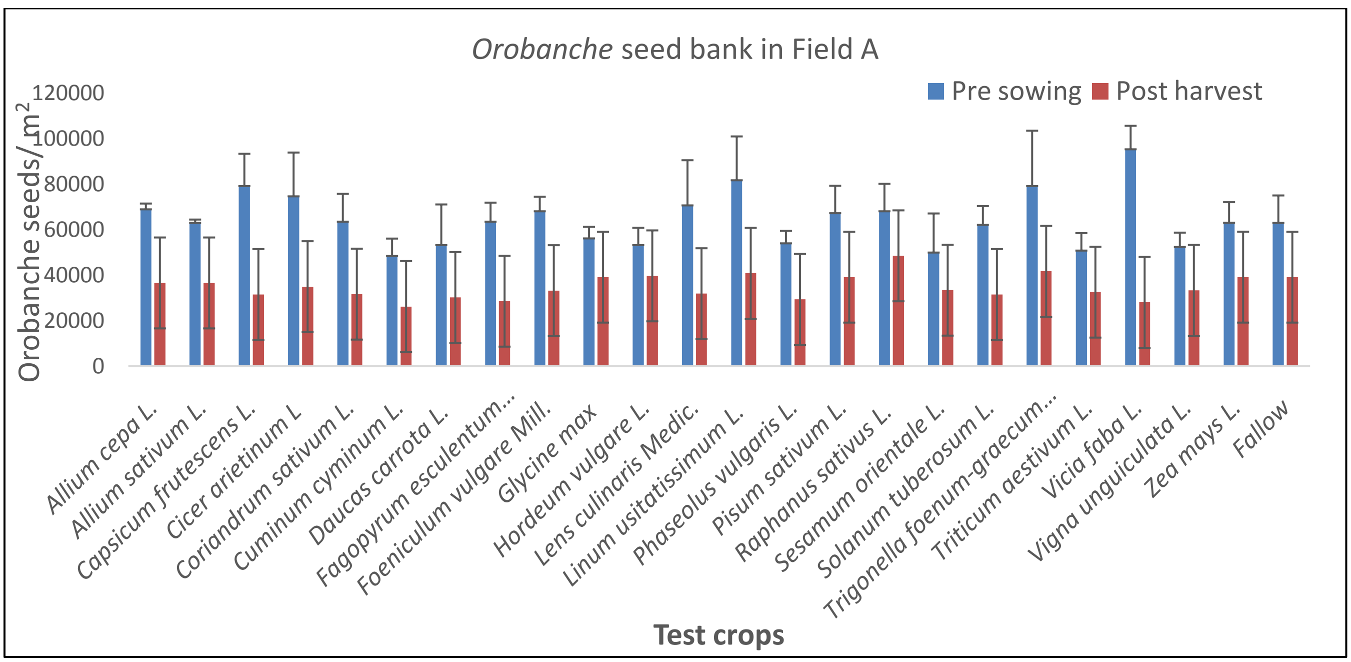

Figure 1- Number of *Orobanche* seeds / sq. m. at the time of pre- sowing and post -harvest of different test crops in Field A (Lalbandhi, 2018/2019).

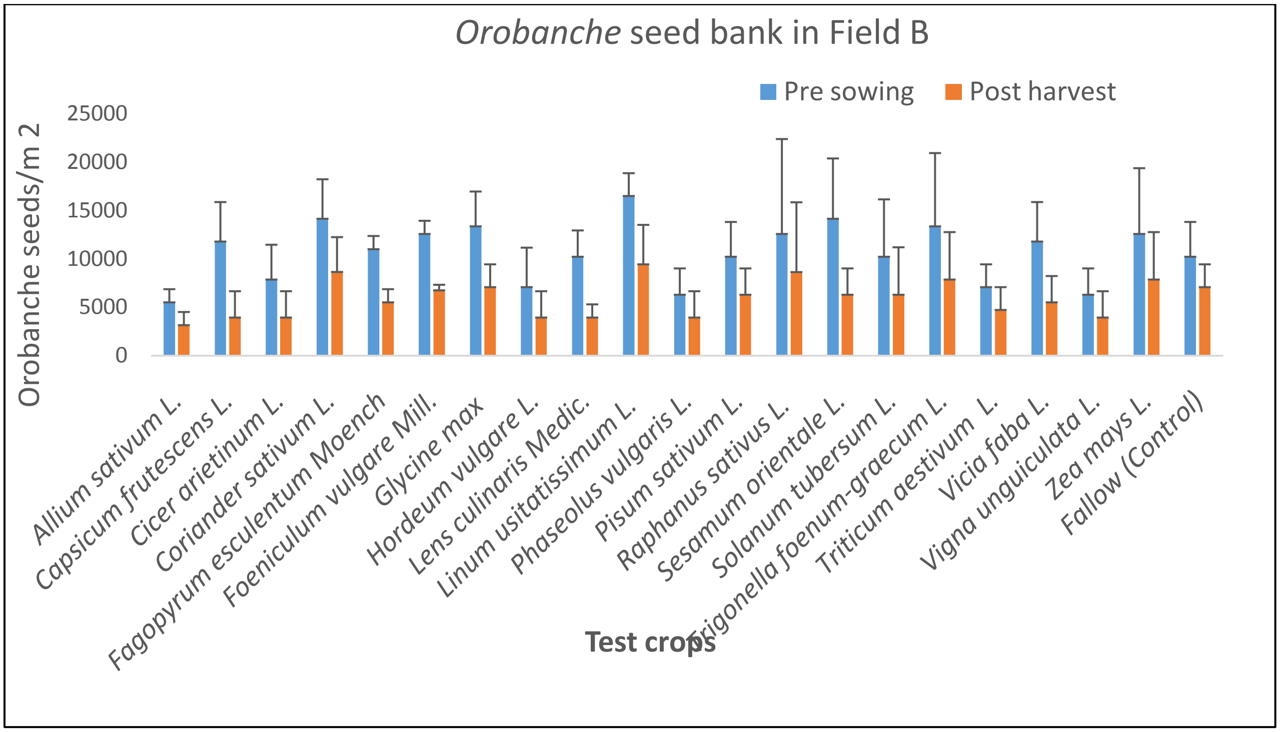

Figure 2- Number of *Orobanche* seeds / sq. m. at the time of pre sowing and post -harvest of different test crops in Field B (Lalbandhi, 2018/19).

Lens culinaris L. (Lentil) is regarded as an usual host of different species of *Orobanche, (O. aegyptiaca,O. muteli* and *O. crenata*) and losses losses up to 95% yield (Rubiales et al. 2009). It is regarded as a rare host of *O. aegyptiaca* in Nepal and the parasitization was limited only to subsoil stage (Khattri, 1997). In present studies not a single plant of lentil was found to be parasitized, but it reduced seed bank of *Orobanche* significantly in both the fields. Hence it can be grown as trap crops in infested tomato fields. Similarly, Schnell et al. (1994) demonstrated that the *Vicia faba* (faba bean) was most effective for reducing the *Orobanche crenata* seed bank by (47.3%). Lopez-Granados and Garcia –Torres (1993) also found a decrease of the number of *Orobanche* shoots on faba bean and the hormone bioassay of its root exudates revealed gibberellin activity, which might have stimulated seed germination in *Orobanche crenata*. *Vicia faba* is not a usual host but was reported as a rare host of *O. aegyptiacai* in Nepal (Khattri, 1997). As in *O. crenata*, the root exudates of *Vicia faba* probably induced suicidal germination and this might have reduced the seed bank in the present study. Hence *Vicia faba* can be used as potential trap crops in infested tomato fields. Many researchers have frequently used *Linum ussitatissmum* as a trap crop for different species *Orobanche*. In Israel, it is reported to heavily attack by *O. aegyptiaca* (Kleifeld et al. 1994). Sauerborn (1991) has found 35% of *O. aegpytiaca* and *O.crenata* seed germination in presence of linseed in laboratory condition. Krishnamurthy et al (1977) suggested that linseed can be used as trap crop for *O. cernua* as its root exudation could germinate 25% of parasitic seeds. In the present study about 44-45% *Orobanche* seed bank reduced with Linseed and have been identified as moderate potential trap crop. Similarly, *Fagopyrum esculentum* also reduced 50-54% seed bank in the present study. Though *Fagopyrum* showed insignificant reduction in seed bank (Acharya 2012) in *Orobanche aegyptica* infested mustard fields. In the present study, significant reduction was observed in field A and insignificant in Field B. This might be due to more infestation of *O. Cernua* in Field A and possibly *Fagopyrum* is capable in inducing suicidal germination of *Orobanche cernua* seeds.

Table 1. Reduction (%) of *Orobanche* seed in different test crops grown in Field A and Field B at Lalbandhi.

Test crops	Common name	Reduction (%) in seed density in Field A (Mean ± Sd)	Reduction (%) in seed density in Field B (Mean ± Sd
Allium cepa L.	Onion	47.18±11.02 BC	-
Allium sativum L.	Garlic	41.67±14.57 AB	44.44±9.62 ABC
Capsicum frutescens L.	Chili	59.57±5.52 CD	66.67±16.67 D
Cicer arietinum L.	Chickpea	52.78± 5.99 CD	52.22±13.47 BCD
Coriander sativum L.	Coriander	44.30± 5.47 BC	40.48±10.91 AB
Cumin cyminum L.	Cumin	45.52± 4.06 BCD	-
Daucus carota L.	Carrot	45.95± 5.94 BCD	-
Fagopyrum esculentum Moench	Buckwheat	54.58±5.99CD	50.00±10.00 ABCD
Foeniculum vulgare Mill.	Fennel	51.59±5.84 BC	43.33±5.77 ABC
Glycine max (L.) Merr.	Soyabean	30.48±4.03 A	47.62±4.12 ABCD
Hordeum vulgare L.	Barley	25.16± 4.55 A	46.67±5.77 ABCD
Lens culinaris Medic.	Lentil	57.59 ± 13.7CD	62.22±3.85 CD
Linum usitatissimum L.	Linseed	45.84±12.05 BC	44.05±16.88 ABC
Phaseolus vulgaris L.	French bean	45.83± 4.17 BCD	41.67±14.43 ABC
Pisum sativum L.	Pea	41.83±2.21 AB	38.89±9.62 AB
Raphanus sativus L.	Radish	28.04±6.32 A	35.21±13.59 AB
Sesamum orientale L.	Sesame	36.40± 3.99 AB	55.19±5.01 BCD
Solanum tuberosum L.	Potato	49.08±8.63 BC	42.86±12.37 ABC
Trigonella foenum-graecum L.	Fenugreek	46.67±5.77 BC	43.45±6.27 ABC
Triticum aestivum L.	Wheat	35.61 ± 5.11 AB	36.11±12.73 AB
Vicia faba L.	Faba bean	70.29±7.85 D	55.56±9.62 BCD
Vigna unguiculata L.	Cow pea	34.61± 5.22 AB	41.67±14.43 ABC
Zea mays L.	Maize	36.08± 7.99 AB	40.48±10.91 AB
Fallow		38.16±8.37 AB	30.56±4.81 A

Same letter followed after the mean ± standard deviation in a column indicates that the values do not differ significantly at P= 0.05 according to Duncan's Multiple range tests followed after ANOVA

Conclusion

From this study it can be concluded that the non-host crops like *Capsicum frutescens* L. (Chili), *Cicer arietinum* (Chickpea), *Lens culinaris* L. (Lentil) and *Vicia faba* (Faba bean) are highly potential trap crops to reduce *Orobanche* seed bank.

The crops like *Cuminum cyminum* (cumin), *Daucas carota* (carrot), *Fagopyrum esculentum* (Buckwheat) *Foeniculum vulgare* Mill. (fennel), *Linum usitatissimum* L. (Linseed), *Phaseolus vulgaris* L. (French-bean), *Sesamum orientale* L. (Sesame) and *Trigonella foenum-graecum* L. (Fenugreek) are less potential trap crops to reduce *Orobanche* seed bank.

The other tested crops like *Allium cepa* L (onion), *A. sativum* L. (Garlic), *Coriandrum sativum* L. (Coriander), *Glycine max* L Merr. (soybean), *Hordeum vulgare* L. (Barley), *Pisum sativum* ***L.*** (Pisum), *Solanum tuberosum* L. (potato), *Raphanus sativus* (Radish), *Triticum aestivum* L. (Wheat) and *Zea mays* (maize) are non-potential trap crops to reduce the Orobanche seed bank.

Acknowledgments

The authors acknowledge thanks to the University Grants Commission (UGC) for providing fund through the Faculty Research Grant (FRG-73/74-S&T-11) to carry out this work. We would also like to acknowledge thanks to Department of Botany, Amrit Campus, Tribhuvan University, for providing laboratory facilities for seed estimation.

Conflicts of Interest

All authors declare that they have no conflict of interest.

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