ECOPRINT **20:** 97-106, 2013 ISSN 1024-8668
Ecological Society (ECOS), Nepal
www.nepjol.info/index.php/eco; www.ecosnepal.com

RELATIONSHIP BETWEEN SEED VIABILITY LOSS AND SEED BANK REDUCTION OF *OROBANCHE AEGYPTIACA* PERS. USING NON-HOST CROPS

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ABSTRACT

Orobanche spp. are serious and difficult weed to control to many economically important plants. The seed bank of this noxious weed in soil can be reduced by using trap crop. But all the seed bank reduction is not due to trap crop only; some reduction is also contributed by edaphic and/or pathogenic factors. So in the present study, the relationship between reduction in *Orobanche* seed bank in soil and loss of seed viability due to trap crop has been investigated in pots and natural infested fields at Vedabari (Field A) and Beldia (Field B). Results of viability loss and seed bank reduction indicated that nearly 11% to 25% of the reduction of seed density of *Orobanche* in soil is contributed by seed viability loss due to trap crops. On combining data of all three experiments, it was found that the loss of seed viability in *Orobanche* due to combined effects of treatments with test crops was nearly 24%. When the value obtained from viability loss and seed bank reduction is compared with the value obtained in control treatment, it is found that the contribution of edaphic factors for seed bank reduction is about 76% and that of tested trap crops is about 24%, respectively.

Key words: *Orobanche*, seed bank, viability loss.

INTRODUCTION

Some seed bearing plants are true parasite or holo-parasite as chlorophyll is entirely lacking in them and are dependent upon other green plants to which they are attached for their food materials. Genus *Orobanche* is one of such holo-parasitic plants with about 150 species (Musselman 1980) . This genus is supposed to be very difficult weed to control as they have tremendous potential of seed production of up to 500,000 seeds/plant in *Orobanche crenata* (Cubero and Moreno 1979). Their seeds are very tiny (0.25-0.3 mm diameter) and can remain viable possibly up to 20 years in soil in absence of suitable host (Kadry and Tewfic 1956, Cubero and Moreno 1979, Puzzilli 1983).

Orobanche spp. are serious weed of many economically important plants because of their complex life cycle they are very difficult to control. There are several discrete steps in the life cycle; production of a large number of seeds that require a post-ripening period as well as warm and moist conditions, induction of germination by host-derived stimulants, haustorial initiation by host-plant, haustorium inducers, attachment to the host root and penetration, establishment of contact with host vascular system, subterranean development, emergence, and flowering. The most serious damage to host crops occurs underground before emergence (Parker and Riches 1993). The seeds of

Orobanche is triggered by root exudates of host and some non-host plants (Brown *et al.* 1951, Abbes *et al.* 2008). Methanolic extracts of many Chinese herbal species effectively stimulated seed germination among the *Orobanche minor*, *O. cumana* and *O. aegyptiaca*, even though they were not the typical hosts (Ma *et al.* 2012) and can serve as potential trap crops.

Trap crops or non-host plants may stimulate the germination of *Orobanche* seed but can not infect and thus reduces density of seeds in soil due to suicidal germination. Hence it can be hypothesized that *Orobanche* seed density in soil is dependent on its viability, or in other words, *Orobanche* seed viability loss will reduce seed bank in the soil. Therefore, an attempt has been made to study the relationship between reduction of *Orobanche* seed bank and viability loss due to different non-host crops in naturally infested soil.

MATERIALS AND METHODS

The experiments were conducted in Nawalparasi District, an inner Tarai region of Nepal, where infection of *Orobanche* sp. was fairly high . Two sites- Site A (at Vedabari) and Site B (at Beldia) were selected, both of which were farmer's fields hired for tori growing season. Pots and field experiments were conducted simultaneously in site A (Vedabari) but in site B (Beldia) it was limited to field experiments only. The experiments to study the effects of different non-host crops on *Orobanche* seed viability was overlapped in the same pots, and plots designed for the seed bank studies.

Pot experiments: Altogether, 22 winter crops were tested for pot experiments. The pot mixture included: a) soil collected from naturally infested field by *Orobanche* seeds, b) Fertilizers (N–0.8 g/kg, P 1.2 g/kg and K 0.6 g/kg of soil) and, c) compost. The earthen pots of size 9 inches diameter were first moistened with water and then filled with soil mixture. About 3/4th portions of pots were buried into the soil to avoid rapid fluctuation of soil temperature and moisture.

Seeds or seedlings of test crops were collected from the local market. Crop seeds were sown 3-4 cm deep in the soil. Tubers of potato, bulb-lets of garlic and, seedlings of onion, egg plants and that of chili were planted in the pots. To avoid dehydration of the germinating seeds, regular watering was done. There were three replications for each treatment, including control pots.Soil samples for quantitative estimation of *Orobanche* seeds were collected from each pot at the time of crop sowing and after harvest.

Field Experiments: Altogether, 21 winter crops were tested for field experiments.The fields at Site A and Site B were both rain fed with maize and tori as summer and winter crops, respectively. The fields were prepared by ploughing twice and were set in randomized complete block design with 22 treatments including control. All the treatments were in triplicates.

The field had homogenous nutrient and moisture regimes. The soil type in field A was sandy-loam with 71% sand, 22% silt, 7% clay and 2.01% total organic matters. Soil nitrogen was 0.151%, phosphorus 189 kg/ha, potassium 516 kg/ha, and the soil pH was 6.2. Manuring was done with animal dung. Unlike the Field-A, the soil type in Field-B was loam with 49% sand, 30% silt, 21% clay and 2.28% total organic matters. And Nitrogen was 0.132%, Potassium 724 kg/ha, and Phosphorous 161 kg/ha. The soil pH was 6.7. The mean soil temperature of experimental area varied from 12°C to 23°C in the morning (at 6 AM) and from 15°C to 25°C in the afternoon (at 1 PM) during the study period.

Soil sample collection and seed bank estimation

Soil was sampled two times from each plot: first immediately after sowing and, the second after harvest. The sampling spots were located between plant rows and there were three equally spaced spots between rows. Soil was sampled using auger reaching up to 15 cm deep. Soil sampled from different spots of a plot are mixed together and divided and re-divided and, finally one kg of soil was collected for laboratory estimation of *Orobanche* seeds (Composite soil sampling). *Orobanche* seed recovery from soil was done following the method of Asworth (1976) with slight modification (Khattri 1997, Acharya *et al.* 2003). The percentage reduction of *Orobanche* seeds were determined from the difference of initial and final *Orobanche* seed count before sowing and after harvest, respectively.

Viability of *Orobanche* seeds buried in pots and plots

To study the effect of trap crops on viability, initially the seed viabiliy of *O. aegyptiaca* seeds collected from tori fields was determined by the method of Aalders and Pieters (1986), with slight modification, using 1% aqueous solution of 2, 3, 5-Triphenyl Tetrazolium Chloride, 2% sodium hypochlorite. The viability of *O. aegyptiaca* seeds was estimated corresponding to the number of stained red seeds and it was considered as initial viability for the present study.

Then, the seed bags were prepared by tying about 10 mg of *O. aegyptiaca* seeds in muslin cloth with nylon thread. Seed bags were buried 10 cm deep in each pots and plots soil after final thinning. The seed bags were taken out after the harvest of crops and final viability of seeds tested. All the treatments were in triplicates. The initial and final viability of Orobanche seeds in different pots and plots including fallow (as control) was compared for viability loss. Viability loss due to non-host crop was calculated by deducting the viability loss obtained due to edaphic factors and test crops together from the viability (mean) of each non-host treatment.

Statistical Analysis: All data obtained from seed bank and viability study were processed for ANOVA followed by Duncan Multiple range Test using statistical program SPSS 15. Regression analysis between viability loss and seed bank reduction were conducted to understand the relationship between them.

RESULTS

Results of seed bank reduction and viability loss due to different investigated trap crops in pot and field experiments are given in Tables 1, 2 and 3. Comparison of seed bank in soil before sowing and after harvest of different test crops showed that the number of *Orobanche* seeds reduced in all cases, even in fallow pots or plots (controls). Mean viability loss of buried *Orobanche* seed due to soil factor and non-host crop together was 30.41%, 30.43% and 23.11% in pot experiments, Field A and Field B, respectively. Viability loss of *Orobanche* seeds buried in the soil was found to be different with different test crops. Besides this, the change of coloration of fungal or bacterial infested *Orobanche* seeds into black was observed.

Pot experiment

Of the 22 crops investigated in pot experiment, the reduction of *Orobanche* seed bank was found to be significant (P=0.05) compared to control pots in cumin (*Cuminum cyminum*), carrot (*Daucas carrota*), fennel (*Foeniculum vulgare*), barley (*Hordeum vulgare*), lentil (*Lens culinaris*), linseed (*Linum usitatissimum*), radish (*Raphanus sativus*) and maize (*Zea mays*) (Table 2). The reduction was highest in lentil (54.27±8.63 in seed density).

The viability of the *Orobanche* seeds before burying in soil was regarded as initial viability and was found to be 86.44%. The viability of buried *Orobanche* seeds after crop harvest was reduced significantly (P=0.05) in all cases (Table 1) except in carrot. Viability loss was recorded highest in pots with radish (56.68%) and it was above 35% in pots with chilli, chickpea, cumin and maize.

Table 1. Percentage reduction in seed bank, viability of *Orobanche aegyptiaca* seeds and its reduction after crop harvest in pot experiments. Same letters followed after the mean ± standard deviation in a column do not differ significantly at P=0.05 according to Duncan's Multiple range tests followed after ANOVA.

Botanical name	Common name	Reduction (%) in seed density	Viability (%) Mean ± Sd.	Viability loss (%)	
				(A)	(B)
Allium cepa L.	Onion	22.00 ± 3.78 ABCD	55.75 ± 5.94B	30.69	6.79
Allium sativum L.	Garlic	15.15 ± 5.08 A	52.56 ± 9.90 B	33.88	9.98
Capsicum furtescens L.	Chili	11.64 ± 0.84 A	50.20 ± 4.02 B	36.24	12.34
Cicer arietinum L.	Chickpea	23.64 ± 2.99 ABCD	51.16 ± 9.55 B	35.28	11.38
Coriandrum sativum L.	Coriander	22.41 ±3.69 ABCD	56.95 ± 4.87 B	29.49	5.59
Cuminum cyminum L.	Cumin	31.29 ± 8.98 DE	49.91 ± 17.20 B	42.81	20.96
Daucas carrota L.	Carrot	29.53 ± 5.47 BCDE	70.07 ± 8.25 BC	16.37	-7.53
Fagopyrum esculentum Moench	Buckwheat	21.86 ± 8.64 ABCD	53.85 ± 13.62 B	32.59	8.69
Foeniculum vulgare Mill	Fennel	37.33 ± 5.91 EF	62.84 ± 3.87 B	23.6	-0.3
Helianthus annus L.	Sunflower	14.62 ± 9.16 A	67.80 ± 7.03 B	18.64	-5.26
Hordeum vulgare L.	Barley	31.33 ± 8.58 DE	57.79 ± 6.23 B	28.65	4.75
Lens culinaris Medic.	Lentil	54.27 ± 8.63 G	51.65 ± 19.47 B*	34.79	10.89
Linum usitatissimum L.	Linseed	30.05 ± 2.84 CDE	62.22 ± 7.28 B*	24.22	0.32
Phaseolus vulgaris L.	French bean	14.49 ± 5.33 A	64.04 ± 8.32 B	22.4	-1.5
Pisum sativum L.	Pea	20.56 ± 3.38 ABCD	57.13 ± 8.02 B	29.31	5.41
Raphanus sativus L.	Radish	42.28 ± 5.29 F	29.76 ± 10.31 A	56.68	32.78
Solanum melongena L.	Egg plant	17.68 ± 10.95 AB	57.01 ± 16.59 B*	29.43	5.53
Solanum tuberosum L.	Potato	19.34 ± 6.08 ABCD	51.70 ± 20.21B*	34.74	10.84
Trigonella foenum- graecum L.	Fenugreek	22.51 ± 0.69 ABCD	52.59 ± 8.85 B	33.85	9.95
Triticum aestivum L.	Wheat	18.79 ± 5.47 ABC	58.68 ± 10.98 B*	27.76	3.86
Vicia faba L.	Faba bean	18.04 ± 5.67 AB	60.57 ± 8.00 B	25.87	1.97
Zea mays L.	Maize	28.05 ± 6.70 BCDE	50.46 ± 14.52 B**	35.98	12.08
Control		15.09 ± 3.47 A	62.54 ± 5.75 B		
Initial Viability			86.44 ± 2.29 C		

* Seeds with black embryo in one pot; ** Seeds with black embryo in two pots

Viability loss due to (A) = soil factors and test crops, (B) = test crops only

Field A

The mean percentage reduction of *Orobanche* seed bank in Field-A was found to be 18.86±6.70. Lowest percentage of *Orobanche* seed bank reduction was recorded in plots with chili (8.20±3.16%) and highest percentage in plots with radish (34.69±9.09). Out of 21 test crops investigated, seed bank was reduced significantly (P=0.05) in onion, chickpea, radish, fennel, lentil and linseed than in control plots (Table 2).

Viability of *Orobanche* seeds buried in soil showed significant decrease (P=0.05) in all cases including fallow in comparison to initial viability. The reduction of *Orobanche* seed viability was highest in plots grown with fenugreek (42.46%), and lowest in plots with buckwheat (68.70%) (Table 2). When data of *Orobanche* seed viability loss in different test crops were compared with that of control plots, it was found that the viability reduced above 35% in plots with onion, chili, pea and fenugreek.

Field B

The mean reduction in *Orobanche* seed bank in the field B was found to be 19.24±7.62% and the reduction was highest in lentil (35.39±1.83%.) and lowest in chili (6.41±5.28%). Out of 21 crops investigated, *Orobanche* seed bank was reduced significantly (P=0.05) in fennel, lentil, linseed, radish and barley compared to control plots (Table 3).

Table 2. Percentage reduction in seed bank, viability of *Orobanche aegyptica* seeds (%) and its reduction after crop harvest in Field-A (Vedabari). Same letters followed after the mean ± standard deviation in a column do not differ significantly at P=0.05 according to Duncan's Multiple range tests followed after ANOVA.

Botanical name	Common name	Reduction (%) in seed bank	Viability (%) Mean ± Sd	Viability loss (%)	
				(A)	(B)
Allium cepa L.	Onion	23.73 ± 3.00 CDEFGH	47.29 ± 19.34 ABC**	39.15	16.26
Allium sativum L.	Garlic	10.47 ± 1.51 AB	53.59 ± 8.18 ABCDE	32.85	9.96
Capsicum frutescens L.	Chili	8.20 ± 3.16 A	44.74 ± 6.06 AB**	41.70	18.81
Cicer arietinum L.	Chickpea	20.72 ± 5,15 BCDEFG	52.65 ± 5.05 ABCDE*	33.79	10.9
Coriandrum sativum L.	Coriander	17.25 ± 7.84 ABCDEF	51.49 ± 5.61 ABCDE	34.95	12.06
Daucas carrota L.	Carrot	19.44 ± 5.85 ABCDEF	61.13 ± 4.74 DEFG	25.31	2.42
Fagopyrum esculentum Moench	Buckwheat	19.17 ± 3.63 ABCDEF	68.70 ± 5.54 G*	17.74	-5.15
Foeniculum vulgare Mill.	Fennel	31.01 ± 9.58 GH	53.63 ± 6.29 ABCDE**	32.81	9.92
Helianthus annus L.	Sunflower	14.22 ± 7.64 ABCDE	55.05 ± 10.17 ABCDEF*	31.39	8.5
Hordeum vulgare L.	Barley	24.22 ± 6.24 DEFGH	56.78 ± 10.10 BCDEF	29.66	6.77
Lens culinaris Medic.	Lentil	26.93 ± 6.34 FGH	53.53 ± 9.61 ABCDE	32.91	10.02
Linum usitatissimum L.	Linseed	25.36 ± 7.51 EFGH	62.51 ± 10.60 DEFG*	23.93	1.04
Phaseolus vulgaris L.	French bean	12.59 ± 6.20 ABCD	63.90 ± 6.92 DEFG	22.54	-0.35
Pisum sativum L.	Pea	15.08 ± 2.37 ABCDEF	49.81 ± 6.7 ABCD**	36.63	13.74
Raphanus sativus L.	Radish	34.69 ± 9.09 H	53.42 ± 5.57 ABCDE	33.02	10.13
Solanum melongena L.	Egg plant	16.49 ± 6.73 ABCDEF	59.44 ± 2.65 CDEFG	27.00	4.11
Solanum tuberosum L.	Potato	20.73 ± 3.15 BCDEFG	68.45 ± 7.57 FG	17.99	-4.9
Trigonella foenum-graecum L.	Fenugreek	16.11 ± 7.17 ABCDEF	42.46 ± 5.06 A**	43.98	21.09
Triticum aestivum L.	Wheat	15.20 ± 4.21 ABCDEF	53.28 ± 8.99 ABCDE	33.16	10.27
Vicia faba L.	Faba bean	11.82 ± 7.85 ABC	65.19 ± 7.34 EFG	21.25	-1.64
Zea mays L.	Maize	18.99 ± 8.00 ABCDEF	58.99 ± 3.50 CDEFG	27.45	4.56
Fallow		12.39 ± 1.54 ABCD	63.55 ± 5.25 DEFG		
Initial Viability			86.44 ± 2.29 H		

*Seeds with black embryo in one plot; **Seeds with black embryo in two plots

Viability loss due to (A) = soil factors and test crops, (B) = test crops only

Orobanche seed viability in Field-B also significantly reduced in all cases as in Field A. including control plots in comparison to initial viability (Table 3). But, reduction of *Orobanche* seeds buried in control plots did not differ significantly from the reduction in plots with most of the crops. The reduction was significant only with chili, fennel, radish, eggplant and maize. (Table 3). Among the different test crop investigated in field B, the reduction in *Orobanche* seed viability was highest in the plots with radish (50.66%) and lowest in onion (70.31%).

Table 3. Percentage reduction in seed bank, viability of *Orobanche aegyptiaca* seeds (%) and its reduction after crop harvest in Field-B (Beldia). Same letters followed after the mean ± standard deviation in a column do not differ significantly at P=0.05 according to Duncan's Multiple range tests followed after ANOVA.

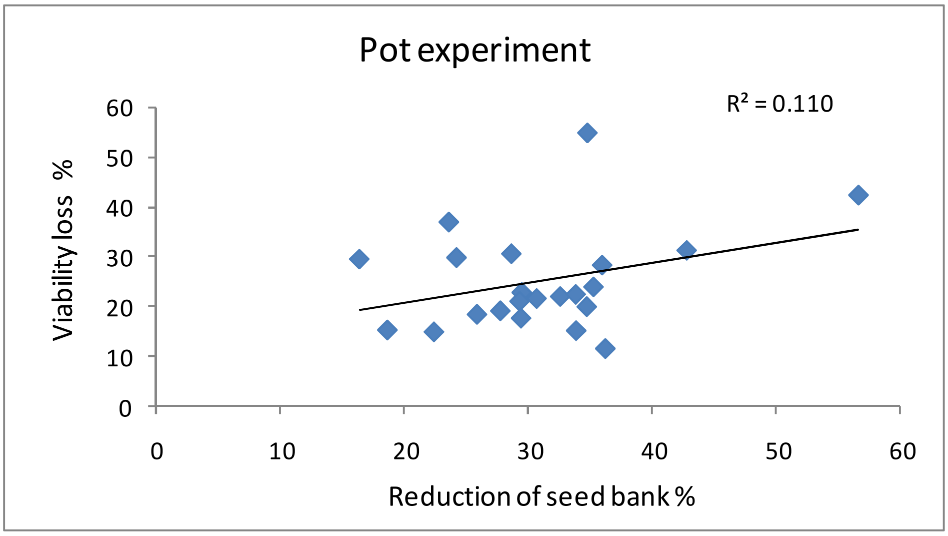
Botanical name	Common name	% Reduction in seed bank	Viability (%) Mean ± Sd	Viability loss (%)	
				(A)	(B)
Allium cepa L.	Onion	17.33 ± 9.99 ABCD	70.31 ± 6.19 F	16.13	-1.31
Allium sativum L.	Garlic	13.47 ± 6.80 AB	68.60 ± 4.47 EF	17.84	0.4
Capsicum frutescens L.	Chili	6.41 ± 5.28 A	58.68 ± 6.65 ABCD**	27.76	10.32
Cicer arietinum L.	Chickpea	22.40 ± 5.81 BCDE	65.12 ± 7.00 CDEF	21.32	3.88
Coriandrum sativum L.	Coriander	19.73 ± 4.96 ABCD	64.88 ± 6.38 CDEF	21.56	4.12
Daucas carrota L.	Carrot	18.98 ± 9.91 ABCD	69.55 ± 4.5 F	16.89	-0.55
Fagopyrum esculentum Moench	Buckwheat	19.89 ± 7.84 ABCD	64.61 ± 4.81 CDEF*	21.83	4.39
Foeniculum vulgare Mill.	Fennel	28.83 ± 9.56 DEF	53.06 ± 10.74 AB*	33.38	15.94
Helianthus annus L.	Sunflower	14.09 ± 7.68 AB	69.40 ± 7.67 F	17.04	-0.4
Hordeum vulgare L.	Barley	27.89 ± 9.62 CDEF	57.18 ± 5.16 ABC	29.26	11.82
Lens culinaris Medic.	Lentil	35.39 ± 1.83 F	57.20 ± 5.99 ABC	29.24	11.8
Linum usitatissimum L.	Linseed	29.26 ± 4.64 DEF	65.65 ± 7.29 CDEF	20.79	3.35
Phaseolus vulgaris L.	French bean	15.08 ± 3.28 ABC	66.04 ± 3.38 DEF	20.4	2.96
Pisum sativum L.	Pea	17.45 ± 8.26 ABCD	63.15 ± 4.29 CDEF	23.29	5.85
Raphanus sativus L.	Radish	34.96 ± 5.00 EF	50.66 ± 6.80 A	35.78	18.34
Solanum melongena L.	Egg plant	11.31 ± 4.60 AB	60.22 ± 4.15 BCD*	26.22	8.78
Solanum tuberosum L.	Potato	15.13 ± 8.04 ABC	68.68 ± 3.97 EF	17.76	0.32
Trigonella foenum-graecum L.	Fenugreek	12.08 ± 9.16 AB	69.00 ± 4.12 F	17.44	0
Triticum aestivum L.	Wheat	16.98 ± 9.01 ABCD	62.84 ± 7.91 CDEF	23.6	6.16
Vicia faba L.	Faba bean	17.64 ± 1.19 ABCD	67.79 ± 6.51 EF	18.65	1.21
Zea mays L.	Maize	13.66 ± 4.89 AB	57.11 ± 7.18 ABC	29.33	11.89
Fallow		15.40 ± 3.02 ABC	69.00 ± 5.75 EF		
Initial Viability			86.44 ± 2.30 G		

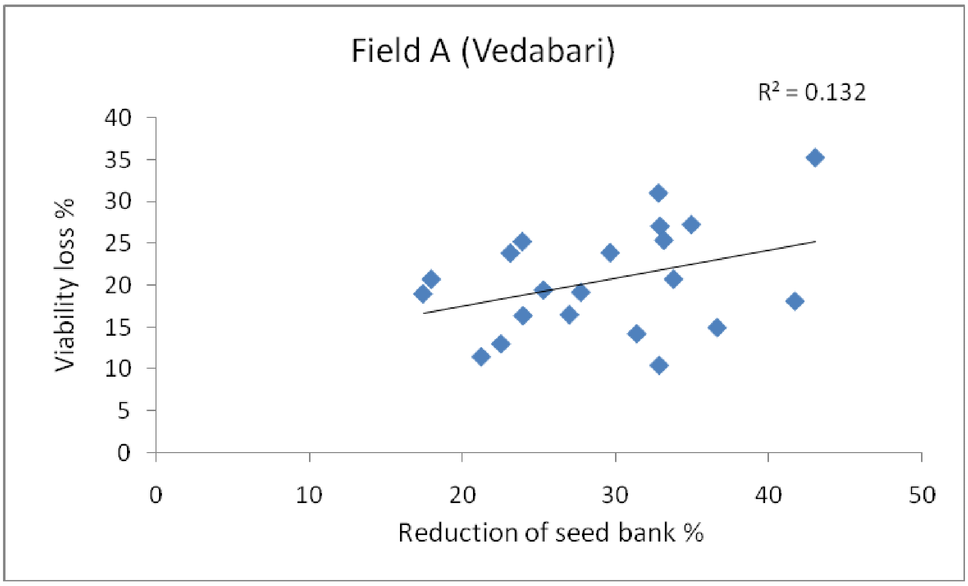
*Seeds with black embryo in one plot; **Seeds with black embryo in two plots

Viability loss due to (A) = soil factors and test crops, (B) = test crops only

Correlation between seed bank reduction and viability loss

When the data of *Orobanche* seed bank reduction and viability loss of the corresponding experimental conditions (pots, Field-A and Field-B) were processed through regression analysis using SPSS 15 statistical programme, it was observed that the reduction in *Orobanche* seed density was positively correlated with seed viability loss (Fig.1). R^2 0btained from the regression analysis of viability loss and seed bank reduction indicated that nearly 11%, 13% and 25% seed viability loss has contributed to the seed bank reduction in pot experiments, Field A and Field B, respectively. Regression analysis on combining data of all three experiments, indicated that the viability loss of *Orobanche* seed contributes only nearly 24% on seed bank reduction. When the viability loss due to soil factors and test crops together was compared with the value obtained in control treatment, it was found that the contribution of edaphic factors was about 75% and that of test crops were about 25%, respectively, for the viability loss.





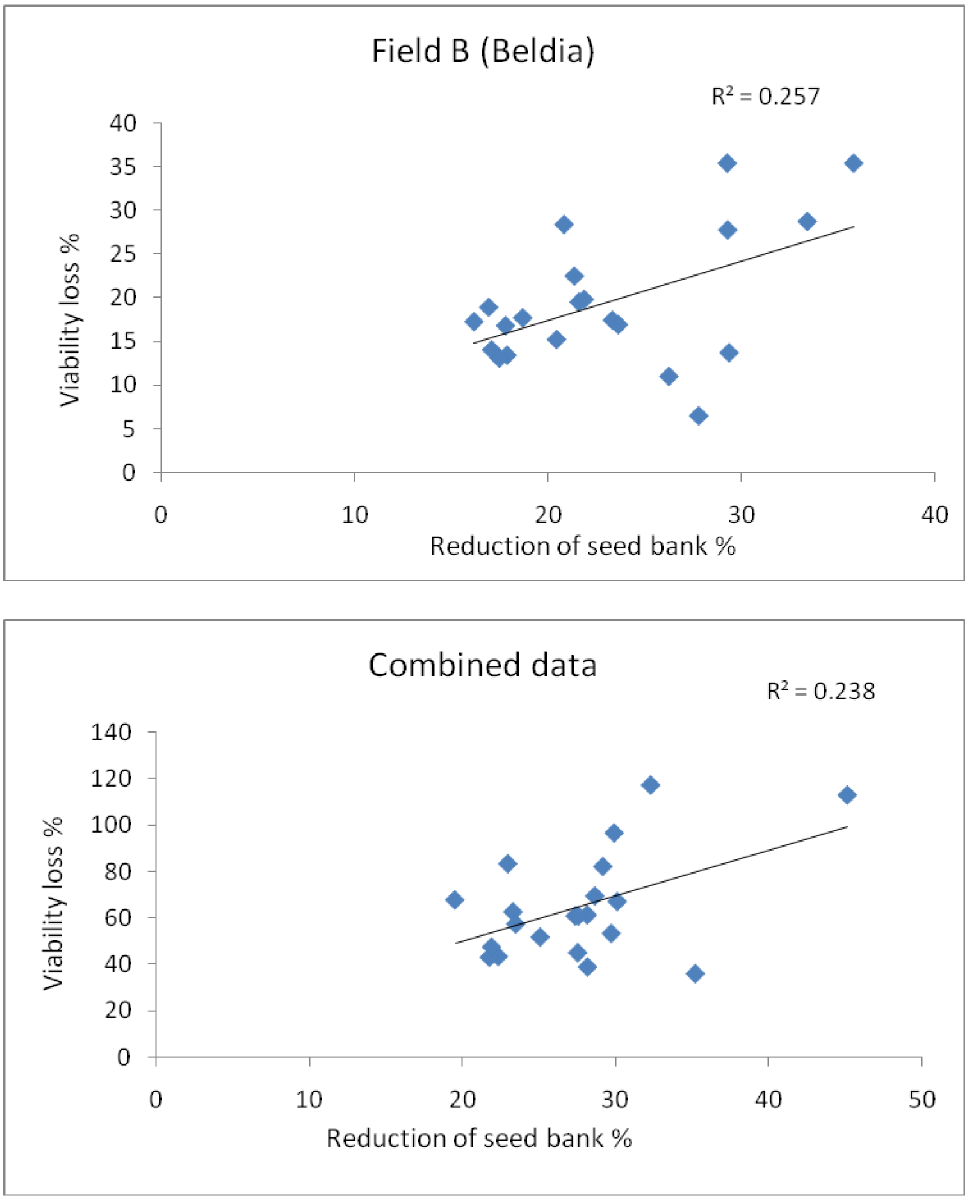


Fig 1. Relation between *Orobanche* seed bank reduction and viability loss in soil under different experimental conditions.

DISCUSSION AND CONCLUSIONS

High seed viability loss of buried *Orobanche* seeds was observed in pots and field A. High root density in the pots must be the reason for highest reduction in seed viability. Possibly the root exudates of the non-host crop must have initiated seed germination but later the germinated seeds could not infest the roots of test crop, as a result the germinated seeds must have died and contributed in seed bank reduction. Similarly more viability loss of buried seed in Field A is due to infection of microorganism in soil, as infected seeds are more observed in Field A than in Field B.

Data have also indicated that both edaphic factors and test crops are responsible for the loss in *Orobanche* seed viability. In this regard it could be assumed that soil microorganisms reduce *Orobanche* seed viability either by infection or by stimulating seed germination as reported by Cezard (1973). The possible role of non-host test crops in reducing *Orobanche* seed viability could be that, i) crops exude stimulant(s) for suicidal seed germination (Chabrolin 1935, Kasasian 1971, Edwards 1972, Krishnamurty *et al.* 1977, Sauerborn 1991), and ii) crops exude chemicals which in association with suitable micro-organisms acquire stimulatory nature for *Orobanche* seed germination as mentioned by Wegmann (1991).

The *Orobanche* seed bank reduction in soil is positively correlated with viability loss in all the experimental conditions. From the regression analysis R^2 value obtained in Field B is higher than in Field A or pot experiment. This indicates the relationship between viability loss (%) and seed bank reduction is higher in Field B (Beldia) than in Field A (Vedabari). The soil type in Field A (Vedabari) is sandy loam and in Field B (Beldia) is loamy soil. Possibly the root exudates of test crop could have retained in loamy soil for longer time than in sandy loam soil and have contributed in higher relationship because of suicidal germination.

ACKNOWLEDGEMENTS

Author like to thank Professor S.C. Srivastava, Associate Professor Dr. G.B. Khattri and Professor M.K. Chettri for their valuable guidance and suggestions. The author also like to thank Campus chief and Head of Department of Botany, Amrit Campus, for providing necessary laboratory facilities.

REFERENCES

Aalders, A.J.G. and R. Pieters. 1986. Plant vigour as a misleading factors in the search for resistance in broad bean to *Orobanche crenata*. In: *Proceedings of a Workshop on Biology and Control of Orobanche*. (ed.) S.J. ter Borg. Lh/VPO, Wageningen, Netherlands, pp. 140-149.

Abbes, Z.Z., M. Kharrat and W. Chaibi. 2008. Seed germination and tubercle development of *Orobanche foetida* and *O. crenata* in presence of different plant species. *Tunisian Journal of Plant Protection* **3(2):**101-109.

Acharya, B.D., A. Bista, G.B. Khattri, M.K.Chettri and S.C. Srivastava. 2003. A method of quantitative estimation of *Orobanche* seeds from infested soil and its reliability test. *Ecoprint* **10(1):**53-57.

Ashworth, L.J. 1976. Quantitative detection of branched broomrape in California tomato soils. *Plant Disease Reporter* **60:**380-383.

Brown, R., A.D. Greenwood, A.W. Johnson, A.G. Long and A.R. Lansdowne. 1951. The stimulant involved in the germination of *Orobanche minor* Sm. Chromatographic purification of crude concentrates. *Journal of Biochemistry* **48:**564-574.

Cezard, R. 1973. Quelques aspect particuliers de la biologie des *Orobanches. Proc. EWRS Symp. Parasitic Weeds*, Malta, pp. 55-67.

Chabrolin, C. 1935. Germination des graines et plantes–hotes de *Orobanche* de la feve (*Orobanche speciosa* D.C.). *C.r. hebd. Seanc. Acad. Sci.*, Paris, **200:**1974-1976.

Cubero, J.I. and M.T. Moreno, 1979. Agronomic control and sources of resistance in *Vicia faba* to *Orobanche* spp. In: *Some Current Researches on Vicia faba in Western Europe*. (eds.) Bond, D.A., G.T. Scarascia Mugnozza and M.H. Poulsen. Commission of The European Communities. pp. 41-80.

Edwards, W.G.H. 1972. Orobanche and Other Plant Parasite Factors. Harborne, J.B. (ed.) *Phytochemical Ecology*, Academy Press. pp. 235-248.

Kadry, A.R. and H. Tewfic. 1956. Seed germination in *Orobanche crenata* Forsk. *Svensk Bot. Tidskr*. **50:**270-286.

Kasaisian, L. 1971. *Orobanche* spp. *PANS* **17:**35-41.

Khattri, G.B. 1997. Some Studies on biology and control of *Orobanche* in *Brassica* crops. A Thesis submitted for the Degree of Doctor of Philosophy in Botany (Faculty of Science) to the B.R.A. Bihar University Muzaffarpur, Bihar, India, 157 pp.

Krishnamurty, G.V.G., R. Lal and K. Nagarjan. 1977. Further studies on the effect of various crops on the germination of *Orobanche* seed. *PANS* **23:**206-208.

Ma, Y.Q., W. Zhang, S.Q. Dong, X.X. Ren, Y. An and M. Lang. 2012. Induction of seed germination in *Orobanche* spp. by extracts of traditional Chinese medicinal herbs. *Sci. China Life Sci.* **55:**250–260, doi: 10.1007/s11427-012-4302-2

Musselman, L.J. 1980. The biology of *Striga*, *Orobanche* and other root parasites. *Ann. Rev. Phytopathology* **18:**463-489.

Parker, C. and C.R. Riches.1993. *Parasitic Weeds of the World: Biology and Control*. CAB International, Wallingford, UK.

Puzzilli, M. 1983. Tobacco broomrape and their control and some useful references to other parasite and host species. *Rev. Agric. Subtropicale e Tropicale* **78:**209-248.

Sauerborn, J. 1991. *Parasitic Flowering Plants, Ecology and Management*. Supra-regional project, GTZ, University of Hohenheim, Institute of Plant Production in the Tropics and Subtropics. Verlag josef margraf Scientific book.

Wegmann, K., E. Von Elert, H.J. Harloff and M. Stadler. 1991. Tolerance and resistance to *Orobanche*. In: *Progress in Orobanche Research*. (eds.) Wegmann, K. and L.J. Musselman. Eberhard Karls Universitat.