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EFFECT OF DIFFERENT CROPPING CONDITIONS, DEPTH OF BURIAL, AGE OF SEEDS, AND ALLELOPATHIC EFFECT OF DIFFERENT CROPS ON THE GERMINATION BEHAVIOR OF LITTLE SEED CANARY GRASS (*PHALARIS MINOR* RETZ.) SEEDS

ABSTRACT

Pot culture experiments were conducted to find out the effect of different cropping conditions, depth of burial and age of seeds on the survival of little seed canary grass (*Phalaris minor* Retz.) seeds. The results indicated that the soil temperature modifications through the flooding or filed capacity moisture status of the soil influenced the germination and viability of the buried weed seeds rather than the crops *per se*. It was observed that the seeds lost their viability because of the anaerobic conditions and high temperatures and through increased membrane permeability of the seeds. The *P. minor* Retz. seeds were found to be sensitive to anaerobic conditions. The longevity of seeds buried in rice-wheat system and Flooding-wheat system was found low when compared to those buried under soybean-wheat and field capacity-wheat conditions. The *in situ* effect of rainy season (*kharif*) crops was found to confine to influencing the initial germination (vigor) of the little seed canary grass with cowpea, groundnut, soybean and sunflower inhibiting the initial germination of little seed canary grass. This inhibition was absent at the end of germination counts taken after twenty days after keeping for germination. The residual effect of cowpea, rice, soybean and sunflower was observed. The application of pearl millet and rice residues has considerably reduced the little seed canary grass germination, plant height, seedling fresh weight and leaf area at thirty days after sowing.

Key words: allelopathic effect, anaerobic conditions, crop residues, depth of burial, germination, membrane permeability, rice-wheat cropping system

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INTRODUCTION

Rice-wheat cropping system is the most important cropping systems in India, both in terms of food security and dependency of large number of farmers and secondary sectors on it. For the last several years, this system is showing symptoms like low input response and problems like deterioration of soil and water resources. Among many problems identified, increased incidence of insect pests and domination of little canary grass (*Phalaris minor* Retz.) were shown to be important (Paroda, 1998). Apart from this, *P. minor* Retz. is considered as one of the most predominant and troublesome annual grassy weeds of wheat in India (Ram and Malik, 2000). Many efforts went into understanding its resistance to isoproturon and developing new chemical alternatives for its control (Yaduraju and Sing, 1997). Very small amount of research work was done for understanding its biology and none on its survival mechanism in rice-wheat system in India. Parasher and Singh (1985) studied its physiological basis for anaerobic conditions and hypothyzed that the seeds were entering into secondary dormancy on exposure to anaerobic conditions and were having ability to use nitrate as an alternative electron acceptor during anaerobic respiration. *P. minor* Retz. required an after ripening period of approximately two months before which they don't germinate even at favorable conditions (Yaduraju *et al.*, 1984). *P. minor* Retz. seeds germinate well between 10°C and 20° C and no germination above 30°C and below 5°C (Bhan and Chaudhary, 1976). Mehra and Gill (1988) gave a temperature range of 10-25°C for its satisfactory germination. The research review indicates that not enough work was carried out to find its longevity under flooding conditions of rice crop and field capacity conditions.

The term allelopathy, first introduced by Molisch 1937, refers to biochemical interactions among plants, including those mediated by microorganisms. Allelopathy is an important mechanism of plant interference mediated by the addition of plant-produced phytotoxins to the plant environment. Although the allelopathic suppression of crops by weeds has been well documented (Gill and Sandhu, 1994), the research on allelopathic effect of crops on weeds has been very limited. Putnam and Duke (1974) first explored the possibility of utilizing allelopathic crops to dominate or inhibit weed growth in agricultural sites. The toxicity of *Lupinus albus* and *Zea mays* to weed growth is also reported in the literature (Dzubenko and Petrenko, 1971). Residues of barley, oats, wheat, rye and sorghum were very effective in reducing weed population in several vegetable crops (Putnam and De Frank, 1983).

Little seed canary grass (*Phalaris minor* Retz.) is major weed in rice-wheat cropping system in the Indo-Gangetic Plains. Many efforts were made to tackle this menace but with little success. Heavy dependence on chemical control has lead to resistance to isoproturon (Yaduraju and Singh, 1997). Hence, there is a need to look for non-chemical methods of its management. Exploring the allelopathic potential of various crops will help in using this potential in cropping systems.

With the above background in view, investigations were carried out with an aim to find out the longevity of *P. minor* Retz. seeds under anaerobic conditions and field capacity conditions and for exploring the allelopathic effect of different crops on *P. minor* Retz. at Indian Agricultural Research Institute, New Delhi, India.

MATERIALS AND METHODS

To ascertain the objectives mentioned above, this study involved four experiments that include:

- Pot culture experiment with three factors involving cropping and moisture conditions
- Experiment on direct effect of rainy season crops on in situ buried little seed canary grass seeds
- Experiment on residual effect of rainy season (*kharif*) crops on *P. minor* Retz. during winter season (*rabi*)
- Experiment on crop residues and their effect on the germination of *P. minor* Retz. seeds

Experimental Details

Pot culture experiment with three factors involving cropping and moisture conditions

The pot culture experiment was carried out at Indian Agricultural Research Institute, New Delhi involving three factors. First factor being cropping conditions such as Flooding + Rice, Flooding + No crop, Field capacity + Soybean, Field capacity + No crop. The second factor tested was depth of burial of *P. minor* Retz. seeds in these cropping conditions. The seeds were buried at 5 cm, 15 cm and 25 cm. Two ages of *P. minor* Retz. seeds were included in the studies, two-year-old seeds and fresh seeds of 1999. The *P. minor* Retz. seeds were collected from naturally growing and mixed populations growing in the fields of Indian Agricultural Research Institute during the *rabi* seasons of 1997 (two year old) and 1999 (fresh). The so collected seed were cleaned of debris and stored in cloth bags at the room temperatures until they were used for the burial experiments.

Pots of 30 cm height and 30 cm diameter were used for establishing the experiment. The *P. minor* Retz. seeds (approximately 0.5 g) contained in nylon mesh bags (10 x 10 cm), with a gauge smaller than the seed so that the seed will not escape, were buried at 5, 15 and 25 cm depths, while filling the pots. Each bag was tagged using an aluminum foil indicating the age of the seed. The seeds were buried in the soil just before the crop was sown. The rice crop was transplanted using 31 days old seedlings of the cultivar Pusa basmati. Three seedlings per hill were transplanted at a rate of four hills per pot. A fertilizer dose 120-60-60 kg N, P_2O_5 and K_2O on per hectare soil weight basis with a schedule of half of nitrogen while filling the pots and 25% at 30 days after transplanting (DAT) and rest 25% at 60DAT. Entire P_2O_5 and K_2O was applied at the time of filling pots.

Soybean crop was sown with the seeds of cultivar PK 327 at a rate of six plants per pot. A fertilizer dose of 40-60-60 kg N, P_2O_5 and K_2O on per hectare basis was calculated per pot on soil weight basis and was applied. The pots were regularly irrigated to maintain soil moisture satisfactorily near about field capacity.

Soil temperatures in the pots were monitored twice a day i.e., at 6.00 hr and at 13.00 hr as minimum and maximum temperatures respectively at 5, 15 and 25 cm depths. For this purpose, soil thermometers were used.

The seeds were retrieved at 30, 60 and 90 days intervals and subjected to germination tests under standard conditions of temperature and relative humidity. Results were compared with the non-buried seeds of the same age stored at the room temperature.

One set of pots consisting three replications of each treatment were kept undisturbed, after the completion of *kharif* experiment and were sown with wheat crop in the subsequent *rabi* season in order to study the effect of cropping system on the germination of *P. minor* Retz. seeds. Thus, for the second continuing experiment, the treatments were

- Cropping systems: Rice crop with flooding – wheat
- Only flooding – wheat
- Soybean crop with field capacity – wheat
- Field capacity + No crop– wheat
- Age of the seeds: Two-year-old seeds (1997) and fresh seed (1999)

The wheat crop was grown to full maturity and harvested. The seed packets were retrieved and washed free of soil and subjected to germination tests as of the *kharif* experiment.

Direct effect of rainy season crops on in situ buried little seed canary grass seeds

Pots of 30 cm height and 30 cm diameter were taken and filled with sandy loam soil. Nylon seed packets, containing approximately 0.5 g of *P. minor* Retz. seeds, were buried at 10 cm depth. The crops sown were maize (variety Ganga Safed 2), pearl millet (variety Raj-121), sorghum (variety MSH-51) sunflower (variety MSFH-8), groundnut (variety SG-84), soybean (variety PK-327), pigeonpea (variety UPAS-120), black gram (variety T-9), green gram (variety Asha) and cowpea (variety C-152). The crops were grown to their full maturity. The buried seeds were retrieved, washed free of soil and were sterilized by dipping in 0.1% mercuric chloride solution. They were immediately subjected to germination tests under standard conditions described below.

Residual effect of rainy season crops on P. minor Retz. during rabi

After harvesting, the crops grown in the above experiments the pots were kept undisturbed until *rabi* when the sowing of *P. minor* Retz. was taken up.

During *rabi,* soil in the pots were stirred and refilled in the same pots. Each pot was sown with 50 seeds of *P. minor* Retz. to study the allelopathic influence of previous rainy season (*kharif*) crops. The germination percentage of the *P. minor* Retz. was noted at seven days for the first time and after 21 days for final counts. Vigor of the seedlings was measured by taking fresh weight of the five seedlings after 30 days of germination.

Crop residues and their effect on the germination of P. minor Retz. seeds

The crop residues of maize, green gram, soybean, sunflower, pearl millet, pigeonpea and rice were investigated for their allelopathic potential. Hundred grams of finely powdered finally harvested crop residue was directly applied to the round earthen pans, of 50 cm diameter and 15 cm height, containing 10 kg of soil. The soil was obtained from long-term fallow fields. A control without application of crop residue was also maintained. One hundred seeds of *P. minor* Retz. were counted and sown in each pot and were watered thoroughly. The last germination counts were taken 30 days after sowing. Apart from the germination percentage, vigor of the seedlings was also measured by taking the height of the seedlings and seedling fresh weight.

Germination procedure

All germination tests were carried out at a constant temperature of 20 ±0.5°C, as prescribed in the International Seed Testing Association (ISTA)-International Rules for Seed Testing, Rules 1999, given for *Phalaris arundinacea.* Standard conditions were followed, unless otherwise stated, for conducting germination tests as given below.

One hundred and fifty seeds were counted at random from the retrieved and sterilized seed. Care was taken so that there is no selection of seeds thus causing biased results. Three replicates of 50 seeds each were used. The seeds were spaced apart on the filter paper to minimize the effect of adjacent seeds on seedling development. The filter paper was changed frequently to avoid infestation of any disease.

Paper substrate (two layers of Whatman No. 1 filter papers of 9 cm diameter) was used for germination tests. The top of paper method was adopted in transparent petri dishes. 3 ml of distilled water per petri dish was added at the beginning of the test and maintaining near saturation humidity in the germinator minimized evaporation.

A light source of 20-watt cool-white fluorescent tubes provided light requirements. 14/10-h light/dark cycle was followed throughout the test period. No light preventing procedures were adopted while counting seeds and processing before and after burial and retrieval of the seed. Seeds were surface sterilized by dipping in 0.1% mercuric chloride solution for a minute.

The germination tests were evaluated at weakly intervals. The seeds were assumed germinated when the radicle protruded from the seed coat. All infected and rotten seeds were separated periodically and counted as dead seeds.

The first count was taken on the seventh day after keeping for germination, at fourteenth day and the last count on 21st day. The seeds un-germinated at the end of the test period were assumed dormant and transferred to dormancy breaking treatment. Dormancy breaking treatment was given by using the 0.2% KNO_3 solution. The subsequent moistening was done by distilled water. The seeds not responding to the dormancy braking treatment were assumed dead.

The results of the germination test were calculated as the average of three fifty seed replicates. It was expressed as a percentage by number of normal seedlings.

RESULTS AND DISCUSSION

Effect of cropping and moisture conditions

Soil temperatures

Results indicated that the soil temperatures were considerably affected by cropping conditions (Fig. 1). The soil temperature was low in Flooding + Rice and Flooding + Soybean treatments when compared to the Flooding + No crop and Field capacity + No crop treatments. Field capacity + Soybean recorded higher temperatures when compared to Flooding + Rice. The difference between maximum and minimum soil temperatures was small in Flooding + Rice followed by Field capacity + Soybean. The highest difference was observed in Flooding + No crop situation. The difference was almost not there at 25 cm depth.

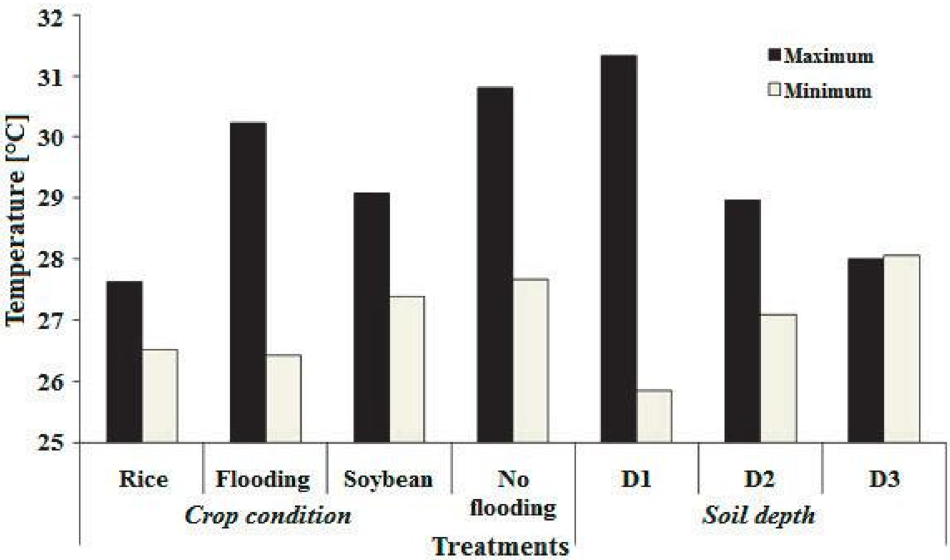

Fig. 1. The average soil temperatures (°C) across the cropping conditions and soil depths

Germination and viability

In general, the germination percent of seeds reduced as the duration of burial increased from thirty to ninety days. Germination of seeds retrieved at thirty days after burial from Flooding + No crop recorded significantly lower compared to all other treatments (Table 1). This was followed by Flooding + Rice (41.5 %). The germination was highest in seeds retrieved from Field capacity + Soybean. This trend was observed throughout the samplings at 60 and 90 days after burial. The response to KNO_3 treatment was not significant at thirty days after burial. The response was highest in seeds buried in Field capacity + Soybean and Field capacity + No crop which were at par. At 90 days after burial, the seeds buried in Flooding + Rice and Field capacity + Soybean responded to KNO_3 similarly and was the same in the case of Flooding + No crop and Field capacity + No crop.

Table 1

Main effects of cropping conditions, depth of burial and age of seeds on the germination (arc sine of % values) of *P. minor*

Treatment		30 DAB*		60 DAB		90 DAB	
		21 DKG**	Response to KNO_3	21 DAK	Response to KNO_3	21 DKG	Response to KNO_3
Cropping condition	Flooding + Rice	41.53	13.62	19.94	14.09	18.74	15.53
	Flooding + No crop	21.94	12.74	17.93	14.08	18.87	12.80
	FC + Soybean	59.34	13.01	47.31	19.96	31.60	16.71
	FC + No crop	51.86	12.84	46.89	22.14	31.61	12.02
	LSD (P: 0.05)	7.09	NS	6.03	3.05	3.20	2.74
Depth of burial [cm]	5	51.01	15.29	39.57	19.25	29.12	14.65
	15	36.38	11.65	28.77	17.14	22.37	12.64
	25	43.62	12.23	30.71	16.31	24.13	15.50
	LSD ($P_{0.05}$)	6.14	2.48	5.22	NS	2.78	NS
Age of seed	Two years	37.93	10.60	29.45	14.58	22.32	13.15
	Fresh	49.41	15.50	36.58	20.55	28.09	15.38
	LSD ($P_{0.05}$)	5.01	2.02	4.26	2.16	2.27	1.94

*DAB: days after burial; **DKG: days after keeping for germination

The seeds buried at 5 cm depth showed higher germination, while the seeds buried at 15 and 25 cm depths were largely at par, throughout the study. The seeds buried at 5 cm depth showed higher response to KNO_3 at thirty days after burial. The response was not significant at 60 and 90 days after burial. The survival of seeds seems to be greatly affected by the age of the seeds at the time of burial. Fresh seeds showed higher germination upon retrieval and significantly higher dormancy (as observed from their higher response to KNO_3 treatment) than their older counterparts. The response was highest at 60 days after burial and declined at 90 days after burial.

Table 2

Untransformed *in situ* seedling count* (average of three replications) of *P. minor* taken at sixty days after sowing wheat crop

Treatment	*P. minor* seedling count (Number)	Sem ±
Flooding + Rice-Wheat	172.33	17.17
Flooding + No crop-Wheat	163.00	22.61
FC + Soybean –Wheat	225.00	15.14
FC + No crop-Wheat	274.00	20.53

*Data was not subjected to statistical analysis

When the buried seeds were left undisturbed after the harvest of rice and were allowed to germinate in the pots during *rabi,* the *in situ* germination of *P. minor* Retz. was higher from Field capacity + No crop treatment (Table 2) followed by in Field capacity + No crop treatment. The least germination was observed from Flooding + No crop. When the buried seeds were retrieved at the end of wheat crop and subjected to germination tests, the seeds buried in Field capacity + No crop germinated higher followed by in Flooding + No crop (Table 3). The germination was poor from 'cropped' treatments.

Table 3

Main effects of cropping system, depth of burial and age of seeds on the germination (arc sine of % values) of *P. minor* after the harvest of wheat crop

Parameter	Cropping conditions*				Depth [cm]			Age [years]	
	C1	C2	C3	C4	5	15	25	2	Fresh
Germination [%]	1.29	3.24	1.53	6.45	0.41	5.59	3.39	0.40	5.85
LSD ($P_{0.05}$)	2.41				2.09			1.71	

*C1: Flooding + Rice-Wheat, C2: Flooding + No crop-Wheat, C3: FC + Soybean-Wheat, C4: FC + No crop-Wheat

Membrane permeability

The membrane permeability studies on the seeds retrieved after different durations of burial (Table 4) revealed that the seeds buried in Flooding + No crop showed significantly higher membrane permeability values and was followed by Field capacity + No crop. The seeds buried in 'cropped' treatments showed significantly less membrane permeability than their cropped counterparts. The seeds buried at 5 cm depth showed least permeability compared to the ones buried at 25 cm. The older seeds showed significantly higher membrane permeability when compared to younger seeds.

Table 4

Main effects of cropping conditions, depth of burial and age of seeds on the membrane permeability (mS/cm/g) of *P. minor*

Treatment		30DAB*	60 DAB	90 DAB
Cropping condition	Flooding + Rice	1.90	2.90	3.40
	Flooding + No crop	2.20	3.59	4.26
	FC + Soybean	0.84	3.00	3.00
	FC + No crop	1.79	3.30	3.68
LSD ($P_{0.05}$)		0.20	0.39	0.55
Depth of burial [cm]	5	1.53	2.91	3.16
	15	1.70	3.04	3.34
	25	1.83	3.70	4.10
LSD ($P_{0.05}$)		0.18	0.34	0.47
Age of seed	Two years	1.90	3.58	3.94
	Fresh	1.47	2.81	3.12
LSD ($P_{0.05}$)		0.10	0.27	0.39

*DAB: days after burial

Direct and residual effect of rainy season crops on the germination of P. minor Retz. seeds

The results indicated (Table 5) that all buried seeds gave significantly lower initial germination counts compared to the control. The slowest germination was observed in the seeds retrieved from the soybean, sunflower and groundnut grown pots, which were at par. This group was followed by cowpea, sorghum, black gram, green gram, pearl millet and pigeonpea. However, the differences were found to be non-significant at 21 days after keeping for germination (DKG).

Table 5

Germination (arc sine of % values) of buried *P. minor* Retz. seeds as effected by the rainy season crops

Treatment	7 DKG*	21 DKG
Black gram	41.18	62.91
Cowpea	35.23	56.38
Green gram	43.04	65.18
Groundnut	27.54	52.01
Maize	47.73	61.20
Pearl millet	43.04	68.91
Pigeonpea	43.78	62.91
Sorghum	38.22	60.30
Soybean	27.49	55.72
Sunflower	28.38	70.03
Control	59.79	69.91
LSD ($P_{0.05}$)	9.43	NS

*DKG: Days after keeping for germination

Table 6

Residual effect of rainy season crops on the germination (arc sine of % values) and growth of *P. minor* Retz

Treatment	Germination [%]		Plant height [cm]	Dry weight (5 seedlings)
	7 DAS*	21 DAS		
Black gram	5.11	62.80	8.03	0.05
Cowpea	0.57	51.20	7.71	0.04
Green gram	6.75	67.32	9.22	0.05
Groundnut	11.03	62.84	13.19	0.13
Maize	5.11	67.58	14.09	0.15
Peal millet	8.24	66.26	12.33	0.09
Pigeonpea	0.57	74.70	7.09	0.03
Rice	14.70	58.96	15.60	0.12
Sorghum	0.57	70.37	9.69	0.07
Soybean	3.09	53.56	8.97	0.06
Sunflower	11.27	57.91	11.31	0.09
Control in lab	46.53	72.15	-	-
LSD ($P_{0.05}$)	11.11	8.43	3.15	0.051

DAS: Days after sowing

The residual effect of rainy season crops on the subsequent germination of *P. minor* Retz. seeds was found to be significant (Table 6). No germination was observed at seven days after sowing in the pots of sorghum, pigeonpea and cowpea grown pots followed by pearl millet, black gram, green gram, groundnut, maize, rice, soybean and sunflower which were at par. All the treatments resulted in significantly lower initial counts when compared with the laboratory check. The final counts taken at 21 DAS revealed that cowpea, rice, soybean and sunflower significantly 'continued' to inhibit germination when compared to the laboratory check and were significantly lower than the germination in maize, pigeonpea and sorghum grown pots, they in turn were at par with the laboratory check. The plant height at 30 days after sowing was significantly lower in the pots grown with black gram, cowpea and pigeonpea and these were significantly lower than pearl millet, maize and rice grown pots. The least dry weight of the seedlings was observed in the pots grown with pigeonpea and was at par with pearl millet, black gram, green gram, sorghum, soybean and sunflower. *P. minor* Retz. seedlings from the pots of groundnut, maize and rice showed vigorous growth.

Effect of crop residues on the germination of P. minor Retz. seeds

The observations made on the germination of *P. minor* Retz., as given in the Table 7, reveals that all the crop residue reduced the germination significantly except pigeonpea, which was found to be at par with the control. The seeds sown in rice straw incorporated pots have shown much lower germination of 26.3%, which is at par with pearl millet, and green gram residue applied pots.

As a measure of seedling vigor observations were also made on the initial plant height, seedling fresh weight and leaf area at 30 DAS (Table 7). Results have indicated that the plant height was significantly higher with pigeonpea residue applied pots compared to the rest of the treatments. However, all the crop residues resulted in reduced plant height compared to the control. Seedling fresh weight gave a satisfactory estimate of seedling vigor and it was found that *P. minor* Retz. seedlings germinating in pigeonpea residue applied pots were much higher than rest of the residue treatments. It recorded a 78% higher fresh weight than soybean and sunflower residue applied pots. The least fresh weight was observed in the pearl millet residue pots with a reduction of 76%. Similar effects can be observed on the leaf area of the seedlings.

The allelopathic potential of rice has been widely documented (Olofsdotter, 1999). Lee 1997, reported the presence of allelochemicals in rice straw. These reports corroborate our present findings. Saxena *et al.* (1995) reported the auto-allelopathic effects of pearl millet on the subsequently grown crop. Similarly, the allelopathic potential of sunflower was widely reported in the literature (Tongma *et al.,* 1998 and Macias *et al.* 1998).

Table 7

Effect of different crop residues on the germination (arc sine of % values), plant height (cm), seedling fresh weight and leaf area (cm^2, total of 10 seedlings) of *P. minor* Retz. at 30 days after sowing

Treatment	Germination [%]	Plant height area [cm]	Seedling fresh weight	Leaf area [cm^2]
Green gram	28.84	4.53	0.19	4.93
Maize	30.29	4.19	0.16	3.10
Pearl millet	27.03	3.14	0.09	1.20
Pigeonpea	35.39	6.40	0.47	12.92
Rice	26.26	3.60	0.18	3.00
Soybean	31.93	3.92	0.14	2.60
Sunflower	30.37	3.31	0.14	2.99
Control	40.01	7.08	0.37	10.71
LSD ($P_{0.05}$)	4.69	0.98	0.06	1.06

CONCLUSIONS

From these results, it can be observed that the seeds were more affected by the moisture conditions (Flooding and Field capacity) than the crops *per se.* The seeds buried under flooded conditions lost viability and gave less germination when compared to those buried under field capacity conditions. The reason for the low germination of the seeds buried in Flooding + No crop and Field capacity + No crop when compared to the their cropped treatments might be due to the higher soil temperatures recorded in these treatments (Figure 1). These treatments also have recorded larger differences between maximum and minimum soil temperature. Such large fluctuation does lead to the ageing affect on the seeds underlying in the soil. The Flooding + Rice and Field capacity + Soybean cropped treatments not only recorded less soil temperatures but also the small difference between maximum and minimum temperatures. The loss of viability of seeds in the non-cropped treatments can be explained by using the observations on membrane permeability of the buried seeds. The higher membrane permeability of seeds buried in ‘non-cropped’ treatments indicates the vulnerability of *P. minor* Retz. seeds to higher temperatures. Arora and Yaduraju (1998) reported that the *P. minor* Retz. seeds were sensitive to higher soil temperatures resulted from soil solarization. The observation that the seeds undergo dormancy with exposure to higher soil temperatures along with moisture (Simpson, 1990) confirms our finding. It can be observed that the seeds buried in the Field capacity moisture conditions have recorded higher response to KNO_3 treatment. These are the treatments, which have recorded higher soil temperatures too, when compared to 'flooding'. The seeds buried in flooding conditions have showed higher loss of membrane permeability and was higher in seeds buried under Flooding + No crop conditions. It should be remembered that this treatment recorded higher soil temperatures than the Flooding + Rice and with larger difference between maximum and minimum temperatures. The seeds retrieved from field capacity moisture conditions, in general, recorded higher dormancy and lower membrane permeability values, which corroborate the findings of Navtial *et al.* (1997). They reported that the dormant seeds show less membrane permeability than the non-dormant seeds. In the present studies the older age seeds recorded higher membrane permeability and least germination when compared to the young seeds. This finding is in line with that of the observations made by Kalpana and Rao (1997).

- The susceptibility of *P. minor* Retz. seeds to anaerobic conditions can be seen from the lower *in situ* germination in the wheat, after 60 days after sowing. The lower germination from 5 cm depth might be due to the reason that some of the seeds buried at this depth might have germinated, as observed from the *in situ* germination counts taken at 60 days after sowing of wheat.
- From these studies it can be concluded that *P. minor* Retz. seeds are susceptible to anaerobic conditions and soil temperatures. The reduction in germination can be attributed to the increased membrane permeability due to the prevailing anaerobic conditions.

Further, from this study it can also be concluded that there existed an allelopathic affect of different crops on *P. minor* Retz. However, there is a need to test their efficacy in the field conditions, after that only their utility in managing *P. minor* Retz. can be thought of. A long-term study involving various field crops in rotation with wheat might definitely give an answer to this problem.

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