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Effect of Seeding Depth and Flooding on Emergence of *Malva parviflora, Rumex dentatus* and *R. spinosus*

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ABSTRACT

Pot studies were carried out in the screen house for three years (2006-07 to 2008-09) to assess the role of seeding depth and flooding durations on the emergence of *Malva parviflora, Rumex dentatus* and *R. spinosus*. Seeding depths of 0, 0.5, 1, 2, 4, 8 and 16 cm and flooding durations of 0, 5, 10, 20, 40 and 80 days were maintained with three replications. Maximum emergence was recorded from 1 cm depth which significantly decreased with increasing depths of 4 cm and higher, data averaged over species. Emergence of *R. spinosus* was significantly more compared to *M. parviflora* and *R. dentatus* from deeper depths. *R. dentatus* emergence was significantly reduced at 2 cm depth and there was no emergence beyond 4 cm unlike *R. spinosus* which was able to emerge even from 16 cm, though in reduced numbers. *M. parviflora* emergence was significantly reduced at 0, 4 and 8 cm, and had no emergence from 16 cm depth. Both species of *Rumex* showed good emergence when the seed was placed on soil surface (0 cm depth), though emergence was significantly less for *M. parviflora* compared to 0.5 to 2 cm depths. Flooding encouraged *M. parviflora* emergence, but inhibited *R. spinosus* and had no significant reduction in the emergence of *R. dentatus* except 40 days flooding. Increasing the flooding duration from 0 to 80 days increased the emergence of *M. parviflora* from 37 to 67%, whereas five days flooding period decreased emergence of *R. spinosus* by 54% compared to no flooding and no emergence was recorded after 40 days flooding. On the other hand, a flooding duration of 80 days resulted in lowering the emergence of *R. dentatus* by 46% only. The emergence and growth of *R. dentatus* was not suppressed by flooding duration except 80 days period. All the three species behaved uniquely to seeding depths and flooding durations and need characteristically different strategies for their management under field infestations. The greater propensity of *R. dentatus* to emerge from shallow depths can be exploited by tillage manipulations. Allowing the seed on the surface after crop harvest for its predation, greater emergence in the next growing season from surface and its killing by pre-seeding herbicide application or tillage can lower the soil seed bank. Placing seed deeper than 4 cm by tillage operations will also render the seed to lower and delayed emergence posing no competition to crops. Similarly, lower emergence of *M. parviflora* from surface and susceptibility of *R. spinosus* to flooding can be exploited to lower their menace.

Key words : Weed biology, germination, soil moisture, management strategy

INTRODUCTION

Seed germination is a complex physiological process that responds to many environmental signals, including temperature, moisture, light, seeding depth and other factors (Bewley and Black, 1994; Baskin and Baskin, 1998). Seed dormancy and survival are controlled by soil temperature fluctuations that differ with soil depth and seed appears to have season-sensing and burial-depth detecting mechanisms based upon temperature fluctuations. Seed dormancy has an important role in weeds continued existence due to differential germination patterns which is affected by light (seeding depth) and other environmental conditions (temperature and moisture) in the immediate surrounding of the seed. Since light does not usually penetrate the soil beyond a few centimeters, the seed dormancy cycle is mostly determined by temperature fluctuations (Baskin and Baskin, 1994) which differs with soil depth (van Assche and Vanlerberghe, 1989) and moisture (Richard and Street, 1984). Seedling emergence is not possible when the seed is buried deep (Benvenuti *et al*., 2001; Tamado *et al*., 2002; Singh *et al*., 2007). Soil moisture also affects weed seedling recruitment. The impact of soil moisture on germination and emergence is highly variable among weed species, and moisture conditions vary within a field. An anaerobic condition is created by flooding; lowering the oxygen availability to the seed to undergo metabolic changes (Gould and Rees, 1964; Ehrenshaft and Brambl, 1990) and can induce dormancy (Benvenuti and Macchia, 1995, 1997; Benvenuti *et al*., 2001). Not only the enzymatic activities are responsible for weed seed germination initiation and emergence are restricted by flooding, but flooding also restrict diffusion of toxic metabolites into surrounding environment, affecting seed germination (Benvenuti and Macchia, 1995) and reduced respiratory capacity of seed leading to seed mortality (Hendry, 1993).

Rumex spinosus a broadleaf weed with deep and strong tap root is a major weed of wheat in several districts of Punjab which not only competes strongly with crop affecting its yield adversely, but also interferes in manual harvesting due to spiny seed and is poorly controlled by 2,4-D (Walia *et al*., 1997; Sidhu *et al*., 2000). A single plant/m^2 of *R. spinosus* reduced wheat yield by 11.4% and increased population of 30 plants/m^2 resulting in 61% lower wheat yield compared to weed free crop (Walia and Singh, 2005). *R. spinosus* was not a serious weed of wheat in Haryana during 1990 (Singh *et al*., 1995), but recent surveys have revealed its increased infestations in the light soils where wheat is rotated with cotton or millets.

Singh *et al*. (1995) reported 45% wheat fields infested with *Rumex maritimus* (syn. *dentatus*) in the eastern zone (rice-wheat rotations) of Haryana compared to 15% occurrence in the western zone (non rice-wheat rotations). Increased dependence on ACCase inhibitor herbicide after the evolution of resistance in *Phalaris minor* to isoproturon in north-west India resulted in further dominance of *R. dentatus* as these herbicides were broadleaf friendly. Wheat crop dominated by *R. retroflexus* weed caused 43% reduction in yield (Balyan and Malik, 2000). Dhawan (2005) reported that *R. maritimus* mature plants in the fields (160 tall) had on an average 10-12 primary and secondary branches and 16000 fruits/seed per plant. In cropped areas where no herbicides are used, the infestation level may vary from 8-20 plants/m^2 which could add approximately 3,20,000 seed. With this high seed rain and no dormancy, the weed could be a serious threat to crop. Seed lying at a depth and with their seed coat intact may not germinate, but those lying on the surface and without the fruit wall possess a fairly good chance of establishment.

Similarly, *M. parviflora* was not a serious weed of wheat in the nineties (Singh *et al*., 1995). This has gained prominence only after the adoption of zero till wheat plantation in the rice-wheat areas. Earlier it was growing in wasteland, near farmyard manure pits, roadside area, field bunds and then moved into wheat crop fields. *M. parviflora*, a weed of wasteland crops, and pastures throughout Australia (Michael *et al*., 2004) has become a serious weed in zero till fields (Chauhan *et al*., 2006a, b). Freshly harvested seed of this weed from Australia was dormant and storage of 13 months resulted in 47% emergence only; germination was insensitive to light and needed scarification for germination (Chauhan *et al*., 2006b). This has become a serious weed of wheat and is not effectively controlled by many broadleaf weed herbicides (Singh *et al*., 2008) including sulfosulfuron (Chhokar *et al*., 2007) and sulfosulfuron pre-mixed with metsulfuron, under field conditions. It is abundant seed producer and thrives best under moist field conditions of rice-wheat rotation areas.

Not much is known about the biology of *R. dentatus, R. spinosus* and *M. parviflora*. A better understanding of seed emergence pattern within the soil profile and variable moisture levels would increase our ability to plan management strategies for these species and to predict their response to significant changes in management practices under field conditions. Therefore, the objective of this study was to investigate the effect of seeding depth and flooding durations on the emergence of *M. parviflora, R. dentatus* and *R. spinosus*.

MATERIALS AND METHODS

Screen house experiments were conducted at CCS Haryana Agricultural University, Hisar during 2006-07, 2007-08 and 2008-09 using plastic pots of 25 cm height and top dia with 10 kg soil capacity for seeding depth and medium sized pots of 20 cm height and top dia containing 5 kg soil for flooding period studies. Field soil free from *Malva* and *Rumex* spp. seed and herbicide application for the last three years was used by mixing in 2 : 1 : 1 ratio of field soil, dunal sand and vermi-compost with three replicate pots for each species and experiment. The soil was sandy loam in texture, low in organic carbon and available N, medium in P_2O_5 and high in K_2O with a pH of 8.4. Previous year harvested seeds of *M. parviflora* L., *R. dentatus* L. (collected from rice-wheat rotation areas) and *R. spinosus* (L.) Campd. (from cotton-wheat rotation areas) of Haryana state were buried in nylon bags of 100 m pore size at 10 cm depth in pots, a month prior to experiment. This was done to overcome the germination problem with *M. parviflora* due to its hard coat and dormancy and *R. dentatus* which showed poor germination under lab conditions. Twenty-five seeds of *R. dentatus* and *R.*

spinosus and 30 seed of *M. parviflora* were placed at surface (0 cm), 0.5, 1.0, 2.0, 4.0, 8.0 and 16 cm depths in large plastic pots for seeding depth studies and at 1 cm depth in medium sized pots for flooding duration studies. Pots were watered as requirement except for flooding durations where a water layer of 3-5 cm was maintained continuously for 0, 5, 10, 20, 40 and 80 days of seeding. After the specified flooding durations, holes were made at the bottom of pots and seed was allowed to grow normally. Periodic observations on emergence were recorded and final observation was made 105 days after sowing (25 days after last flooding period). Data on number of plants emerged per pot were converted for per cent emergence and pooled data from the three years' observation were subjected to ANOVA using SPSS Software. One-way ANOVA was done to separate means with Student-Newman-Keuls test. Per cent emergence data are presented in figures with standard error of means.

RESULTS AND DISCUSSION

Effect of Seeding Depth

The three species exhibited markedly different response to seeding depths. Maximum emergence of 60% was recorded with *R. spinosus* which was significantly higher than R. *dentatus* (32%) and *M. parviflora* (22%), when data were averaged over seeding depths (Figs. 1 to 3). Greater emergence was observed from 0.5 to 1 cm which was statistically similar to emergence from surface and 2 cm depths, data averaged over species. Increasing the seeding depths to 4 and 8 cm or higher resulted in greater reduction in emergence.

Emergence of *M. parviflora* was maximum from 0.5 cm, but similar to 1 and 2 cm depths (Fig. 1). Increasing the seeding depths to 4 and 8 cm resulted in 42 and 89% lower emergence, respectively, compared to 0.5 cm depth and no seed emerged from 16 cm depth. Similarly, seed placed on surface took longer time to emerge and there was 53% lower emergence compared to 0.5 cm depth. A polynomial relationship was observed for the emergence of *M. parviflora* from different seeding depths ($y = 0.833x^3 - 12.68x^2 + 50.84x - 21.11$ with $R^2 = 0.98$).

R. spinosus had maximum emergence of 89% from 1 cm depth which was significantly higher than emergence from 0.5 and 2 cm depths (Fig. 2). Emergence of *R. spinosus* was reduced significantly with increasing depths of 4, 8 and 16 cm depths by 26, 45 and 98%, respectively, over 1 cm depth. Similarly, 33% lower emergence was recorded from surface compared to 1 cm depth. The emergence data were regressed to a polynomial relationship ($y = -0.185x^3 - 3.226x^2 + 27.03x + 36.71$ with $R^2 = 0.98$).

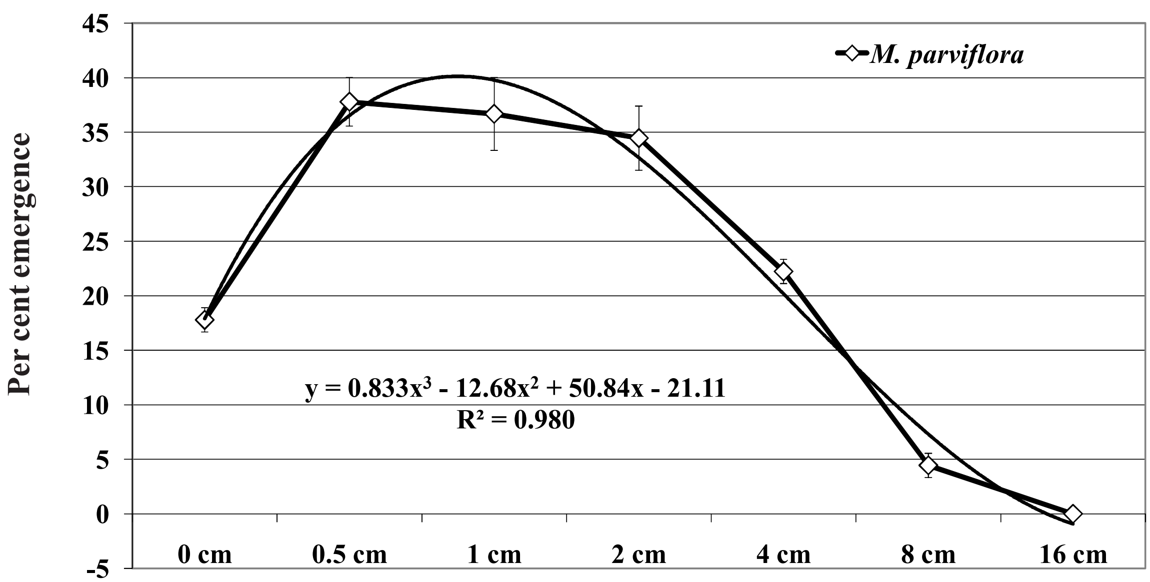

Fig. 1. Effect of seeding depth on emergence of *M. parviflora* (bars indicate SEm).

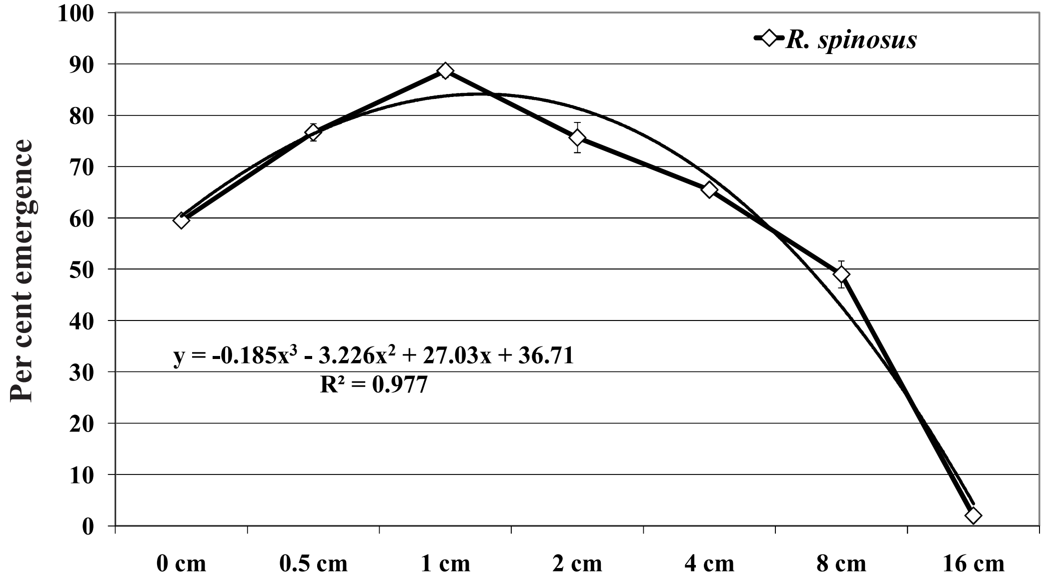

Fig. 2. Effect of seeding depth on emergence of *R. spinosus* (bars indicate SEm).

Emergence of *R. dentatus* was similar from 0 to 1 cm depths (61-70%), but decreased significantly at 2 cm depth and only 3% seed emerged from 4 cm depth and no emergence from deeper depths of 8 and 16 cm (Fig. 3). Maximum emergence was recorded from surface which was 112% more than from 2 cm depth. The emergence data showed polynomial regression of third order with R^2 value of 0.98 (y=1.4074 x 3- 16.905 x 2 + 45.116x + 30.476).

Among the three species, *R. spinosus* could resist more to increasing depths of seeding as 49% emergence was recorded from 8 cm depth compared to only 4% for *M. parviflora* and no emergence in case of *R. dentatus*. Highest emergence of *Malva pusilla* and *M. parviflora* was recorded from 0.5 to 2.0 cm depths (Blackshaw, 1990; Chauhan *et al*., 2006b). A higher emergence of *M. parviflora* (62%) was observed by Chauhan *et al*. (2006b) as they used scarified seed,

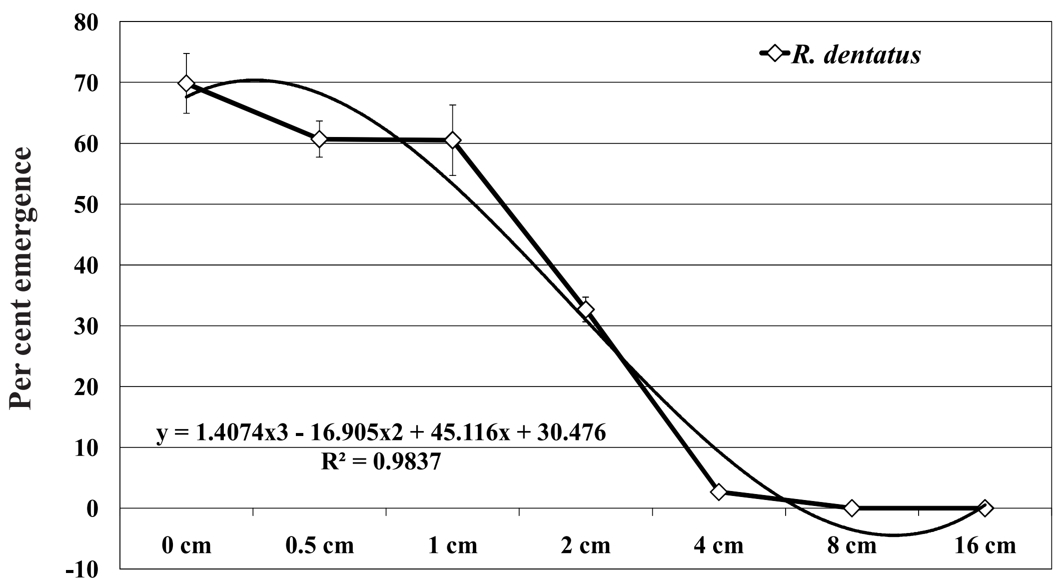

Fig. 3. Effect of seeding depth on emergence of *R. dentatus* (bars indicate SEm).

whereas in the present study a lower emergence was observed (38%) which may be due to seed dormancy as one month soil burial time may not be sufficient to break dormancy for 100% seed germination and emergence. Chauhan *et al*. (2006b) did not record any emergence from 8 cm depth, but in the present study 4% seeds were able to emerge from 8 cm depth, which could be due to variation in soil type or growing conditions. Weaver and Cavers (1979) reported that *R. crispus* had maximum emergence when seed was at or near soil surface and even a seeding depth of 1 cm significantly reduced its emergence. This is similar to *R. dentatus* where maximum emergence of 70% was observed from 0 cm depth and only 33% emergence from 2 cm depth. Dhawan (2005) reported that *R. maritimus* (syn. *dentatus*) emergence decreased from 40 to 6% when seeding depth was increased from 2 to 4 cm. *R. dentatus, R. spinosus* and *M. parviflora* exhibited 70, 60 and 18% emergence, respectively, from soil surface (Figs. 1-3) which is quite remarkable as the seed of many species when placed on surface had little or no emergence (Yenish *et al*., 1996; Singh *et al*., 2007). Most of weed species emerge from shallow depths of 0 to 4 cm (Cousens and Moss, 1990). The environmental factors such as light, temperature and oxygen may be limiting at deeper depths and an unfavourable growth condition may not be able to provide signals for weed seeds to germinate. Lower oxygen levels at deeper soil depths may also result in seed decay and reduced germination (Benvenuti and Macchia, 1995). Seed weight and length of coleoptiles also contribute to emergence from deeper depths. Weed seed with higher test weight have larger capacity to emerge from deeper depths due to more reserved carbohydrates compared to small sized seed (Baskin and Baskin, 1998). In the present study, higher seed weight of *R. spinosus* (12. 24 g test weight) compared to *R. dentatus* (2.56 g test weight) may explain the differential response to seeding depths by these two species. *M. parviflora* with similar test weight to that of *R. dentatus* (2.57 g) was able to emerge in decreased number from 4 cm depth.

The intra- and inter-specific competition varies with the plant stand of weed and crop and the relative emergence time of both. *R. dentatus* is very competitive and has the capacity to smother wheat crop. Plant height of *R. dentatus* was 15, 10, 8 and 5 cm, 45 days after sowing (DAS), whereas at 115 DAS it was 58, 81, 92, 125 and 19 cm from 0, 0.5, 1, 2 and 4 cm, respectively. *R. dentatus* plants at maturity are generally 30-50 cm taller than wheat; plant height of 160 cm is very common with dozens of branches and abundant seed production (Dhawan, 2005). The greater height of plants emerging from 2 cm depth in the pots could be due to lower number of emerged plants and less competition among them compared to surface emerged plants. The significant fact that plants emerging from 4 cm depth were not only few but poorly growing and may not be able to compete vigorously with crop plants compared to those emerging from shallow depths. The differences in plant height of *R. spinosus* emerging from different depths were less compared to *R. dentatus*, but deeper depths reduced the number and growth of *M. parviflora* plants. Both *R. spinosus* and *M. parviflora* are very competitive with wheat and can lower the yield of crop significantly as reported earlier (Makowski and Morrison, 1989; Walia *et al*., 2004).

The emergence pattern of these species (*Malva* and *Rumex*) from different depths can best be utilized in decreasing their soil seed bank by manipulating tillage practices. For surface germinating weed seed (shallow depth), these can be left on soil surface after crop harvest allowing for predation, planting by zero tillage with minimum soil disturbance and subsequently early emergence of these seeds in the winter season which can be killed by pre-seeding herbicide or by tillage practice thus reducing crop-weed competition. Also deep burial will reduce their emergence particularly for *R. dentatus* and *M. parviflora* which are very competitive with wheat. Delayed emergence of seed from deeper depths will lower their vigour offering less competition to crop and more amenable to control measures. Delayed emergence of *M. parviflora* from deeper depths and also poor growth of *R. dentatus* compared to shallower depths can be utilized for lower crop-weed competition.

Effect of Flooding Duration

Flooding duration stimulated emergence of *M. parviflora*, but adversely affected *R. spinosus* and had no significant effect on *R. dentatus* (Figs. 4-6). When data were averaged over flooding duration, maximum emergence of 51% was recorded for *R. dentatus* which was significantly higher than *R. spinosus* (29%) and similar to *M. parviflora* (50%). Submergence of 40 and 80 days reduced the emergence significantly compared to no flooding, data averaged for three species.

M. parviflora emergence was increased by 81% with 80 days flooding compared to no flooding (Fig. 4).

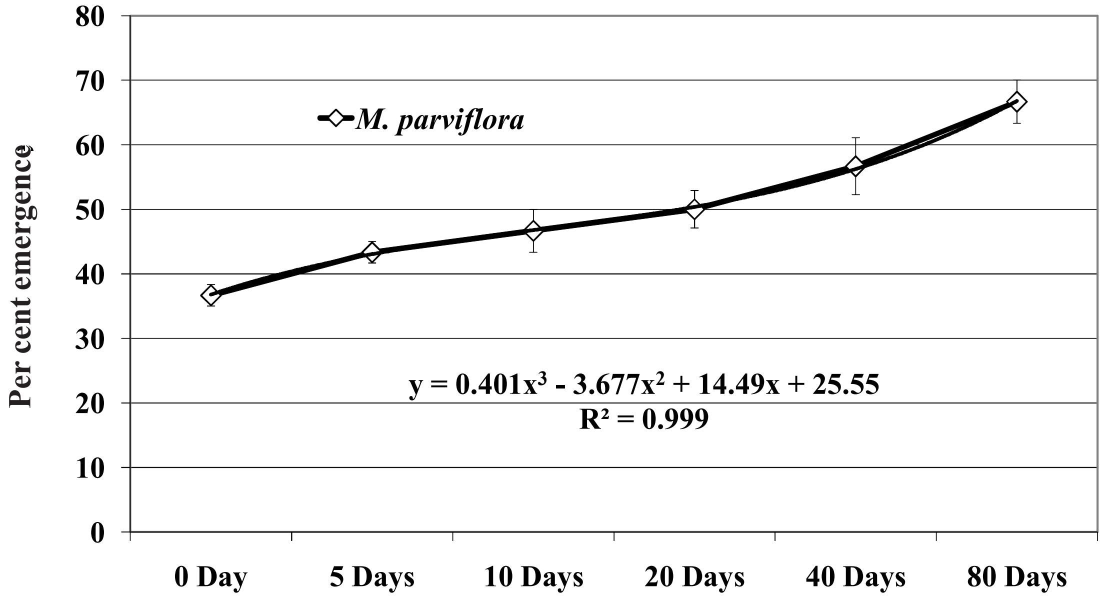

Fig. 4. Effect of flooding duration on emergence of *M. parviflora* (bars indicate SEm).

Increasing flooding duration increased the emergence, but significant differences were observed with 20 days flooding duration compared to no flooding. Maximum emergence of 67% was recorded with 80 days flooding which was significantly higher than 40 days flooding (56%). The emergence data followed a non-linear cubic polynomial regression ($y = 0.401x^3 - 3.677x^2 + 14.49x + 25.55$ with R^2 of 0.999).

A flooding duration of five days reduced the emergence of *R. spinosus* from 87 to 40% and a further flooding duration of 20 days resulted in 18% emergence only (Fig. 5). No seed was able to emerge from 40 or 80 days flooding durations. The emergence data were regressed with a polynomial model ($y = -0.925x^3 + 13.25x^2 - 70.26x + 142.2$ and R^2 of 0.97).

Emergence of *R. dentatus* decreased with increased flooded durations, but significant reduction was recorded only with 40 days flooding (Fig. 6). A

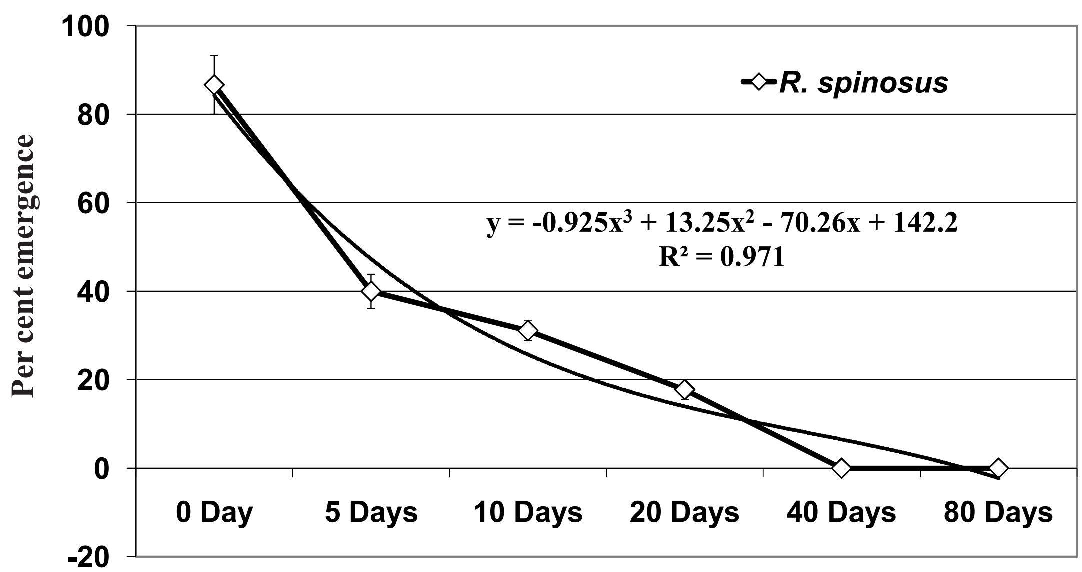

Fig. 5. Effect of flooding duration on emergence of *R. spinosus* (bars indicate SEm).

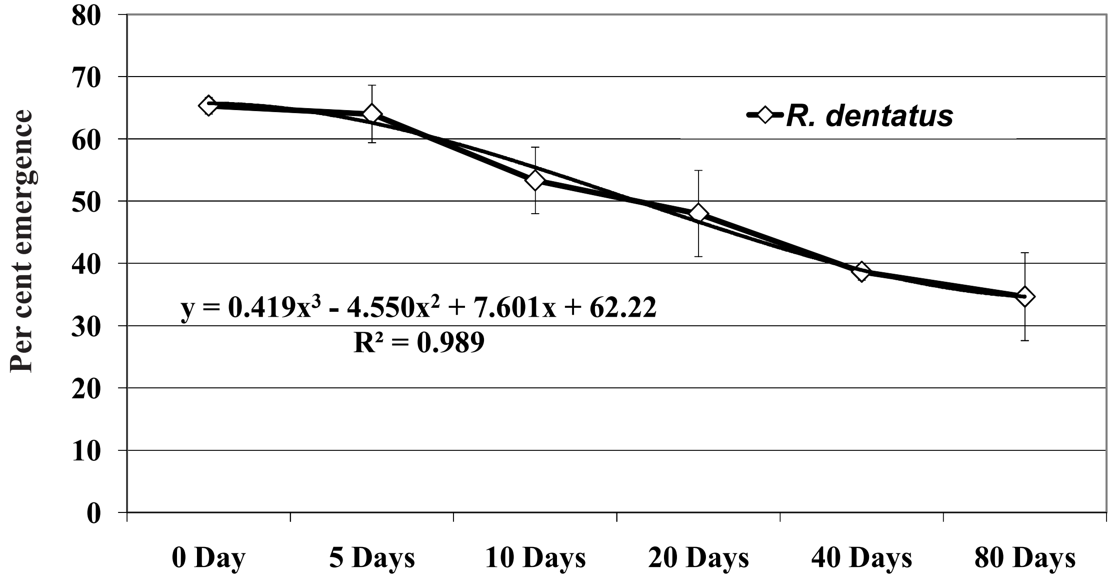

Fig. 6. Effect of flooding duration on emergence of *R. dentatus* (bars indicate SEm).

flooding duration of 80 days reduced the emergence from 65 to 35% over no flooding. The growth of *R. dentatus* was not checked with 80 days flooded conditions, but lowered its emergence by 46%. *R. dentatus* was able to emerge in standing water, rather than emerging after the removal of flooded conditions. A non-linear polynomial regression of third order best fitted the model for the emergence data ($y=0.419x^3 - 4.550x^2 + 7.601x + 62.22$ with R^2 of 0.989).

Kaur *et al*. (2008) found that under high moisture conditions emergence and growth of *M. neglecta* was more compared to dry conditions. *M. parviflora* responded more to increased flooding duration, which might have helped in breaking the dormancy and increasing germination/emergence. Higher germination of *Malva* species has been reported under scarified than unscarified conditions owing to dormancy (Chahuan *et al*., 2006b; Kaur *et al*., 2008). The high moisture requirement of *M. parviflora* might be the reason for its increased infestation under rice-wheat rotation areas. Under the prevailing conditions in rice-wheat rotation areas, flooding in rice may not help in decreasing the emergence of *M. parviflora*, but being a small seeded weed, tillage operations can be employed to lower its preponderance.

R. dentatus was least affected by flooding and plants were able to emerge even in flooded conditions in the pots. Furthermore, the increased occurrence of *R. dentatus* in rice-wheat (high moisture conditions) compared to other rotations might be the contributing factor for its proliferation. The seed survives flooded conditions in paddy and the puddling process might bring the seed on surface from where it can emerge in great number in the next wheat crop season. Under flooded conditions, *R. palustris* plants accumulated ethylene due to decreased gas-exchange and continued ethylene production during submergence (Rieul *et al*., 2005). Ethylene has been shown to influence many processes in plants such as germination, root-hair initiation, flower senescence, and fruit ripening. Flooding may not help in lowering the emergence of *R. dentatus*, but deep tillage to bury the seed may lower its capacity to emerge from deeper depths (4 cm). The seed may survive long time in soil as still not much is known about its longevity under Indian conditions, care should be taken not to frequent tillage operation to bring back the seed from deeper soil profiles.

Interestingly *R. spinosus* was not able to withstand flooding conditions and even a short duration of five days significantly lowered its emergence by 54% (Fig. 5). Singh *et al*. (2007) reported that flooding duration of four days reduced the emergence of *Desmodium tortuosum* by 33%, but four days flooding period had no effect on *Sida spinosa* which required 16 days flooding to lower its emergence by 94%. Similarly, one day flooding significantly reduced the emergence of *Morrenia odorata* (Reddy and Singh, 1992). There was no dormancy as the seed of *R. spinosus* emerged from deeper depths (8 cm), where light and oxygen might be limiting. Flooding might have checked metabolic activities or some enzymatic changes leading to seed decay. Gould and Rees (1964) reported that anoxic conditions may limit the activity of a-glactosidase which increases after germination of mustard as raffinose and sucrose levels decline. Limiting the activity of enzymes which ultimately release sugars for growth and development can also retard seedling development. Benvenuti and Macchia (1995) reported that oxygen deficiency in soil due to burial depth or flooding also restricts diffusion of toxic metabolites into surrounding environment affecting seed germination. *R. spinosus* seed under flooded conditions was not examined for seed viability after the study.

The primary sources of seed bank exhaustion include germination, predation and decay, which respond to the management practices. Seed predation by vertebrate and invertebrate granivores may cause high rates of seed mortality in a wide range of cropping systems when the seeds are left on the surface after harvest, but seed burial, may limit the overall effect on the seedbank as many seeds in the soil can persist for long duration without loosing viability. It has been observed that decay may be less responsive to management than germination and likely predation, though many seeds serve as a source of energy to soil microbes. The objective is to reduce the seedbank size and decreased losses from weeds by effectively reducing the size of the seedbank through manipulation of available biological tools. The differential response of *M. parvilfora, R. dentatus* and *R. spinosus* to seeding depths and flooding durations provided insight of their emergence pattern under these conditions and the information can be utilized effectively for their management depending upon the infestation of these weeds in the field.

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