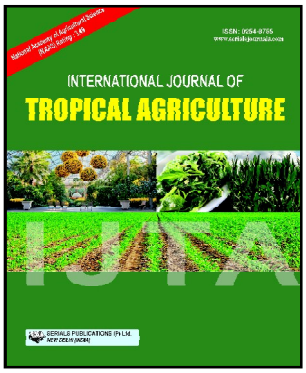

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Factors Affecting Germination *Medicago denticulata* and *Vicia sativa* under Different Environmental Conditions

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Abstract: Laboratory and screen house experiments were conducted to evaluate the effect of temperature, salinity, osmotic potential, light/dark periods, seeding depth and flooding on germination and emergence of *M. denticulata* and *V. sativa*. Maximum germination of *M.denticulata* (61%) was recorded at 20^{O}C whereas the germination of *V. sativa* was 78% that was maximum at 15^{O}C. With decrease and increase from optimum temperature decrease in germination was noted. Germination of these two weeds was observed maximum with distilled in comparison to salty solution. *M. denticulata* germination (15%) took place up to the conc. of 100 mM NaCl, whereas, *V. sativa* (5%) germinated even at high conc. of 200 mM NaCl. The effect of osmotic potential on germination was declining in nature, as the osmotic potential was lowered from 0 to -0.8 MPa the germination decreased drastically. The osmotic potential of -0.8 MPa reduced the germination of *M. denticulata* and *V. sativa* to zero. Light was not prerequisite for the germination of any of the two weed species because there was no significant difference in germination under different levels of light exposure. Optimum depth for the germination of *M.denticulata* and *V.sativa*was 2.0cm where corresponding germination was 61and 69%. Reduction in germination and growth was recorded with increase and decrease from optimum depth.*V. sativa* germinated even from a depth of 8.0 cm while*M. denticulata* cannot able to germinate beyond 4cm depth. *M. denticulata* was very sensitive to flooding, even a flooding of 5 days completely restricted the germination of *M. denticulata* while *V. sativa* tolerated even 20 days of flooding and then germination took place.

Key words: *[1]Medicago denticulata*,*Vicia sativa,*temperature, salinity, osmotic potential, light, depth, flooding

INTRODUCTION

Weed management has been the object of considerable attention and study ever since crops have been cultivated. Despite this prolonged efforts and the more recent, but significant activity of incredible herbicide technology, weed still thrive in cropping systems. As weeds are part of dynamic agricultural ecosystem, knowledge of weed biology is essential for sustainable weed management system that could be environmentally safe and ecologically viable.

Medicago denticulata is a weed of winter season crops infesting wheat, barley, mustard, chickpea etc. and is commonly known as medic or toothed bur clover, belonging to genus *Medicago*, family Leguminosaeand native to the Mediterranean basin in which the greatest species diversity occurs (Piano and Francis, 1992). Some 33 species of annual *Medicago* are recognized (Lesins and Lesins, 1979), of these, *M. polymorpha* syn. *M. denticulata* is considered to be ubiquitous and is found throughout the world. *Vicia sativa* is commonly called as common vetch also known as tare or simply "the vetch" is a dicot weed having the ability of nitrogen fixation and belongs to Leguminosae family. It is trailing type or climbing annual herb which grow up to a height of 1.5 m and leaves are 2–10 cm long.Occurrence of *Medicago denticulata* and *Vicia sativa* were 51and 10%, respectively in the eastern zone of Haryana and preponderance of some of these were also found in western zone (Singh *et al.,* 1995). These weeds have become vigorous competitor in the winter season crops thus causing significant yield losses.Loss in yield of 10% in USA by weeds cost $ 7 billion and that too after herbicide use and without herbicides it would have been much more than $20 billion per year. In India losses by weeds were estimated at Rs. 50,000 crores in 2007. In general, weeds cause approximately 33% loss in production system. For the country like India where food and nutritional security is still a big question, the long term management by detailed study of weeds can contribute much towards achieving the potential yield by reducing the weed losses.

As of today, there are 195 weed species resistant to at least one herbicide mode of action group (Heap, 2010**)** and there is good reason to believe that this number will continue to steadily increase. So, it is desirable to unravel and exploit the intricacies of weed biology and ecology that limits our ability to effectively manage weeds.

The biology of weed is concerned with their taxonomy, genetics, establishment, growth and reproduction. The ecology of weed is concerned with the development of a single species within a population of plants and the development of all populations within a community on a given site. The numerous factors of the environment have a pronounced influence on all of these processes and systems. The environment and the living community are considered to be an ecosystem and in an agricultural situation this ecosystem is considered an agroecosystem. Knowledge of weed biology and environmental management practices makes it possible to shift plant populations and communities in desired directions. This is the principle behind crop production that theoretically optimizes the growth environment of the crop but minimizes the potential of unacceptable weeds. Understanding the basic biology of weed plants i.e. the way it responds to its environment (ecosystem) can provide needed insight to weed managers on specific practices to reduce weed influences under given situations.

MATERIALS AND METHODS

General information

Experiments ontwo weeds i.e. *Medicago denticulata*L.and *Vicia sativa* L.were conducted at CCS Haryana Agricultural University during 2009-10 under screen house and laboratory conditions. There were six factors at different levels at which

germination and growth were studied. Pot studies were carried out to study the effect of sowing depth and flooding duration under screen house conditions and the rest of the factors were studied in weed science laboratory. Screen house experiments were conducted using plastic pots of 25 cm height and top diameter of 15 cm with 10 kg soil capacity. Soil used for filling the pots was in the ratio of 3:1:1 with field soil, dunal sand and vermicompost. The field soil was sandy loam in texture containing 0.45% organic carbon, 27 Kg/ha P_2O_5 and 542 Kg/ha K_2O with pH value of 8.0 and was collected from fields where no herbicides were used for the last four years. Seed were treated with 0.1% sodium hypochlorite immediately before each experiment for 30 minutes and washed 3-4 times with distilled water so as to ensure disease free seeds.In all studies, each treatment included four replications (four Petri dish in case of lab and four plastic pots in case of screenhouse) per treatment and each experiment was conducted twice in the same season and data for one experiment is taken for analysis.All the experiments were conducted in completely randomized block design and experimental data were analyzed using software SPSS version 7.5.

Effect of Temperature

To determine the effect of temperature on germination of the above mentioned weed species, twenty seed of each weed were placed uniformly between two layers of filter papers (Whatman No. 1) of 90 mm in Petri dishes of 100 mm diameter (Borosil glass) and moistened with distilled water and then incubated at 5, 10, 15, 20, 25, 30 and 35°C ± 1.5°C in seed germinators (Khera Instruments (P) Ltd, Azadpur, Delhi-110033). The filter paper and seed were kept moist throughout the period by regular application of deionized water. Temperatures were maintained constant in incubator without any diurnal fluctuations in temperature and germination was determined periodically.

Effect of Salt Stress

To determine the effect of salt stress on germination, the seed were incubated in 0, 25, 50, 100 and 200 mM sodium chloride (NaCl) solution. The solution of 200 mM concentration was prepared first as stock solution and subsequent solutions were made by dilution.

Effect of Osmotic Potential

Aqueous solutions with osmotic potential of 0, -0.2, -0.4, -0.6 and -0.8 MPa were prepared by dissolving 0, 105.64, 161.29, 204.44 and 240.97 g of polyethylene glycol (PEG 8000) in distilled water as described by Michel (1983). Disinfected seed were incubated in the Petri dish filled with 10 ml of freshly prepared solution and germination was determined as previously described.

Effect of Light

To evaluate the effect of light on germination, seed were placed in Petri dish with 10 ml/Petri dish deionized water applied and kept under six regimes of light periods (0, 3, 6, 12, 24 and 48 hour). After a given light hour the Petri dishes were immediately wrapped with double layer aluminium foil to ensure no light penetration. Wrapped Petri dish were kept for seven days undisturbed and then were unwrapped to observe germination and then kept under natural day and light conditions. Germination was finally determined as described previously.

Effect of Sowing Depth

The effect of sowing depth on seedling emergence was studied in a screen house (a chamber framed with 3 cm iron mesh to prevent rain and bird damage). Pots were filled with a 3:1:1 mixture of field soil, dunal sand and vermicompost. Twenty seed of each weed species were placed on the soil surface or covered to a depth of 0.5, 1.0, 2.0, 4.0, 8.0 and 16.0 cm with the same soil. Pots were sub irrigated

initially to field capacity. Emergence counts were recorded at weekly interval. Plants were considered emerged when a cotyledon could be visibly discerned.

Effect of Duration of Flooding

Twenty seed of each species were sown 1 cm deep in plastic pots. There were six level of flooding durations maintained for 0, 5, 10, 20, 40 and 80 days. Flooding was maintained by keeping the pot without hole at the bottom up to the desired days and watering the pots twice a day up to the top of the pot. The holes were made at the bottom after 0, 5, 10, 20, 40 and 80 days, respectively. The observations were made at weekly interval after making the holes i.e. after draining the standing water over the soil surface.

RESULTS AND DISCUSSION

Laboratory experiments

Effect of temperature on germination

Maximum germination of *Medicago denticulata* was observed at 20 °C which significantly differed from 5 and 35 °C (Table 1). Germination at this temperature was 55, 59 and 61%, respectively, 1, 2 and 3 week after sowing (WAS), and thereafter no further increase in germination was observed (Table 1). The germination rate first increased from 5 °C to 20 °C and then gradually decreased with increase in temperature. The minimum germination (29%) was observed at 5^{O}C 4 WAS (Fig.1). These results are consistent with that of Gresta *et al.* (2007) on different species of *Medicago* where 20^{O}C was found optimum for germination. In contrast, Aulakh *et al.* (2006) reported the differences in germination of *Leptochloa chinensis* (L.) Nees. were non-significant due to temperature variations. A temperature of 15 °C resulted in maximum germination of 78% in *Vicia sativa* 4 WAS (Fig. 1). Seed germination in case of *Vicia sativa* was highest at 15 °C. Higher germination of *V. sativa* (78%) was observed than that of the *M. denticulata* (61%) at 15 °C 3WAS (Table 1). Minimum germination of *V. sativa* was similar to the *M. denticulata*at 5 °C. The decline in germination of *V. sativa* was observed beyond 15 °C (78%) (Fig. 1),even though the Fig.1 showed that germination at temperature of 10, 20 and 25 °C was also comparable to 15 °C. This result clearly indicates that *V. sativa* can germinate well under a wide range of temperature conditions. Similar results were also reported by Gresta *et al.* (2006) on *Scorpiurus subvillosus* (L.), where mature scarified seeds tested at 5 to 25 °C had similar germination. Many researches proved that 20-30 °C is suitable for seed germination of tropical plants, even 35 °C is suitable for some of them (Stubbendieck and McCully, 1976). Lu *et al.* (2006) also reported that Crofton weed(*Eupatorium adenophorum*) seed also germinated over a range of 10-30 °C temperature. Labouriau and Agudo (1987) suggested that cardinal temperatures are important for the understanding of plant species occurrences. Similarly Shimono and Washitani (2004) reported that higher temperature induces secondary dormancy in some seed.

Effect of NaCl on germination

The ability of weeds to tolerate the salinity at the time of germination varied significantly from distilled water to 200 mM/L NaCl concentration (Table 2). Seed germination was significantly affected by salinity levels in *M. denticulata*. Germination of *M. denticulata* was inversely related to NaCl concentrations, where maximum germination occurred (60%) in distilled water and complete inhibition of germination observed at 200 mM salt concentration. Seed germination was substantially reduced with all concentrations of NaCl (salinity) level above 25 mM. Germination of *M. denticulata* was more than 30 % at 50 mM NaCl concentrations and was lowest (15%) at 100 mM NaCl.Salinity significantly suppressed germination of *V. sativa* also at all concentrations however, 200 mM NaCl concentration led to the

Table 1
Effect of temperature regimes on germination (%) of different weed species

	1 WAS		*2 WAS*		*3WAS*	
Temperature	*M. denticulata*	*V. sativa*	*M. denticulata*	*V. sativa*	*M. denticulata*	*V. sativa*
5°C	14(22)	0(6)	29(32)	13(21)	29(32)	13(21)
10°C	40(39)	38(38)	45(42)	64(53)	51(46)	64(53)
15°C	53(46)	68(55)	56(49)	75(60)	59(50)	78(62)
20°C	55(48)	65(54)	59(50)	65(54)	61(52)	65(54)
25°C	54(47)	60(51)	56(49)	63(52)	56(49)	63(52)
30°C	38(38)	30(33)	38(38)	30(33)	38(38)	30(33)
35°C	30(33)	20(26)	30(33)	20(26)	30(33)	20(26)
Mean	40(39)	40(37)	45(42)	47(43)	46(43)	47(43)
CD (5%)	(10)	(8)	(10)	(9)	(8)	(9)

complete inhibition of seed germination in the first week but at 2 and 3 WAS as low as 5 % germination was observed (Table 2). Germination was > 50 % up to 50 mM NaCl in *V. sativa* andthen decreased to 20 and 5 % at 100 and 200 mM, respectively (Table 2). The germination of *V. sativa*,significantly decreased from 70% to 5% with increase in NaCl concentration (Table 2). This observation is in line with the work of Shaddad *et al.* (1990) who reported that salinity has adverse effect on the germination of *Lupinous termis* and *V. faba* which are also non-halophytic leguminous plants similar to *M. denticulata* and *V. sativa*. Similar findings were reported by Koger *et al.* (2004) also that even at high soil salinity of 160 mM NaCl, *Caperoniapalustris* seed could germinate. In this study, the germination of *V. sativa* occurred over a relatively broad salinity range from 0 to 200 mM NaCl (Table 2). This result is similar to the findings of El-keblawy (2004) who showed that the seed germination of *Panicum turgidum* was greatly reduced by increasing the salt concentration and completely inhibited at 300 and 400 mM NaCl and KCl.

The effect of salinity on germination is usually attributed to either osmotic effects due to declining solute potential or to toxicity effect due to uptake

Table 2
Effect of NaCl (mM) on germination (%) of different weed species

	1 WAS		*2 WAS*		*3 WAS*	
NaCl Conc.	*M. denticulata*	*V. sativa*	*M. denticulata*	*V. sativa*	*M. denticulata*	*V. sativa*
0 mM	50(46)	80(54)	60(49)	80(54)	60(51)	80(55)
25 mM	40(44)	70(51)	45(46)	70(51)	45(46)	70(51)
50 mM	30(36)	55(49)	30(36)	55(50)	30(36)	55(50)
100 mM	15(28)	20(29)	15(28)	20(29)	15(28)	20(29)
200 mM	0(6)	0(6)	0(6)	5(14)	0(6)	5(14)
Mean	27	45	30	46	30	46
CD (5 %)	(5)	(7)	(5)	(8)	(5)	(8)

and/or accumulation of some ions in weed seed as sodium and chloride (Poljakoff-Mayber *et al.,* 1994, Khan *etal.,* 2001, Tobe *et al.*, 2001). High internal sodium and chloride ion levels can be toxic to plants as they compromise enzyme function and disrupt metabolic processes (Baldwin *et al.*, 1996). In addition, toxicity of NaCl during seed germination is usually associated with a significant decrease in the seed K^+ content, which could reduce metabolic functions and ultimately reduce germination and seedling growth (Rehman *et al.*, 1996).It was clear from the logarithmic model of *M. denticulata* ($y = -36.3\ln(x) + 64.78$ and $R^2 = 0.947$) and polynomial model of *V. sativa* ($y = 2.083x^3 - 20.89x^2 + 42.02x + 56$ and $R^2 = 0.989$) that germination was adversely affected with increase in NaCl (Fig. 2).

Effect of osmotic potential on germination

Substantial decrease in germination occurred when water potential decreased from 0 to -0.8 MPa. The germination of *M. denticulata* at -0.2 MPa did not differ from the non-stressed control (0 MPa) (Table 3). Germination of *M. denticulata* was inhibited at lower level of osmotic stress, *M. denticulata* did germinate (15%) at -0.6 MPa and germination reduced to negligible when osmotic potential lowered to -0.8 MPa (Table 3). Although, germination of *Vicia sativa* was more than double to that of *M. denticulata* at -0.6 MPa, no germination was recorded with further lowering the osmotic potential (Table 3).Similar to *M. denticulata* and *V. sativa* some other weeds are also sensitive to low osmotic potential such as trumpetcreeper (*Campsis radicans*) (Chachalis and Reddy 2000), Texasweed [*Caperonia palustris* (L.)] St. Hil. (Koger *et al.*, 2004) and Cadillo (Wang *et al.,* 2009).

No germination of weeds occurred when the osmotic potential was -0.8 MPa. When water potential was 0 MPa, germination was maximum i. e. 65 and 75% in *M. denticulata*and*V.sativa,* respectively, 3 WAS (Table 3). Germination of *M. denticulata* decreased from 65 to 15% as osmotic potential lowered from 0 to -0.6 MPa, and germination did not occur at -0.8 MPa. Similar trend of decreasing germination was observed in *V. sativa* where more than 50% reduction was noted at -0.6 MPa as compared to deionized water.

According to Bradford (1990) seed germination is a process of growth of a previously quiescent or dormant seed starting with the imbibition of water. Seed imbibition rate and germination level normally decreases as the surrounding water potential decreases, the critical hydration level for seed germination is species-specific (Evans and Etherington, 1990). Similar to*V. sativa* some hairy

Table 3
Effect of osmotic potential (MPa) on germination (%) of different weed species

	1 WAS		*2 WAS*		*3WAS*	
Osmotic Potential (MPa)	*M. denticulata*	*V. sativa*	*M. denticulata*	*V. sativa*	*M. denticulata*	*V. sativa*
0	64(53)	70(57)	65(54)	75(60)	65(54)	75(60)
-0.2	60(51)	62(52)	60(51)	67(55)	60(51)	67(55)
-0.4	33(35)	43(41)	33(35)	44(41)	33(35)	44(41)
-0.6	15(22)	33(35)	15(22)	33(35)	15(22)	33(35)
-0.8	0(6)	0(6)	0(6)	0(6)	0(6)	0(6)
Mean	34	41	35	44	35	44
CD (5 %)	(5)	(7)	(4)	(6)	(4)	(6)

beggerticks seed germinated (3%) at a water potential of -0.75 MPa (Reddy and Singh 1992). Germination over a broad range of osmotic potential indicated that *V. sativa* could emerge and compete under low soil moisture conditions.A polynomial regression of *M. denticulata* ($y = 2.083x^3 - 19.53x^2 + 36.38x + 46.6$ and $R^2 = 0.993$) and *V. sativa* ($y = -0.583x^3 + 2.535x^2 - 15.88x + 89.8$ and $R^2 = 0.985$) showed that the germination was decreasing with lowering the osmotic potential from 0 to -0.8 MPa (Fig. 3).

Effect of light periods on germination

When the seed of *M. denticulata* and *V. sativa*were exposed to different light periods and then put under complete darkness for 7 days, and after that when the aluminium foil was unwrapped most of the seed was found germinated in each level of light exposure. Results indicated that light was not a prerequisite for germination of these weeds. These results are similar to sicklepod (*Senna obtusifolia*) which was not responsive to light (Norsworthy and Oliveira, 2006) while dissimilar to *Celosia argentea* which was stimulated by light for higher germination (Chauhan and Johnson, 2007). Seed germination response to light varies from species to species. Seed of some species require light to germinate (Chauhan and Johnson, 2008a; Chauhan and Johnson,2008b) and others can germinate equally in light and dark (Chauhan and Johnson, 2008c). Effect of light on germination is an indicator to conform whether seed can germinate from deeper depths. Higher germination under both conditions i.e. light and dark shows that these weeds can germinate from deeper depths

B. SCREENHOUSE EXPERIMENT

Effect of sowing depth on germination

Emergence of *M. denticulata* was maximum (61%) for seed placed at a depth of 2 cm which was statistically similar to emergence from 1 and 4 cm deep placed seed (Table 4). Increasing the placement depth beyond 4 cm resulted in drastic reduction of seedling emergence. Emergence of *M. denticulata*seedlings was increased with increasing planting depth from 0 cm to 2 cm and then gradually decreased to 29% at 4 cm depth in first week (Table 4). The emergence of *M. denticulata* from 0.5, 1, 2 and 4 cm did not changed further 3 WAS. No seedlings of *M. denticulata* emerged from 8 and 16 cm depths. *M. denticulata*seed germinated only up to 4 cm depth. Maximum emergence (61%) of *M. denticulata* was from 2 cm placement depth 3 WAS (Table 4). *M. denticulata* seed germination from surface was 44% though it was significantly lower than maximum but higher in comparison to *V. sativa.*

V. sativa was also favoured by 2 cm depth for maximum emergence (69%) which was statistically similar to the emergence from 0.5 and 1 cm depths and then reduction in emergence was noted with further increase in seeding depths (Table 4). Although the emergence was delayed but it was noted even from 8 cm depths 3 WAS in *V. sativa* (Table 4). Larger seed with greater carbohydrate reserves can emerge from greater depths of burial (Baskin and Baskin, 1998). *M. denticulata* seed is small, therefore, having less carbohydrate reserves needed for emergence at greater depths, no seedling emerged from a planting depth beyond 4 cm. Whereas, *V. sativa* seed being larger than *M.denticulata*(having more carbohydrate reserves) had 49% emergence from 8 cm planting depth (Table 4).

Seed on the soil surface had reduced emergence compared with seed placed just below the surface. Limited soil to seed contact, light conditions on the surface and water availability may be some environmental conditions limiting germination of seed on the soil surface (Ghorbani *et al.,* 1999). Seed placed just below the surface receive adequate water for germination initiation and emergence (Ghorbani *et al.,* 1999; Webb *et al.,* 1987).

The reduced emergence with increased seeding depth could be caused by poor gas exchange created by the oxygen consumption of germinating seed as demonstrated by Benvenuti (2003). Thus, deep tillage operation might be needed to invert the soil and bury the seeds deeper than 8 cm, where seed would be unable to germinate.

Table 4
Effect of seeding depth (cm) on emergence (%) of different weed species

	1 WAS		*2 WAS*		*3WAS*	
Depth (cm)	*M. denticulata*	*V. sativa*	*M. denticulata*	*V. sativa*	*M. denticulata*	*V. sativa*
0 cm	25(30)	0(6)	44(41)	3(6)	44(41)	13(18)
0.5 cm	31(32)	28(30)	58(49)	43(41)	58(49)	59(51)
1.0 cm	41(40)	19(26)	54(47)	46(43)	59(50)	61(52)
2.0 cm	44(41)	18(24)	54(47)	51(46)	61(52)	69(56)
4.0 cm	29(32)	9(17)	51(46)	45(42)	60(51)	53(46)
8.0 cm	0(6)	0(6)	0(6)	0(6)	0(6)	49(44)
16 cm	0(6)	0(6)	0(6)	0(6)	0(6)	0(6)
Mean	24	10	37	27	46(43)	47(43)
CD (5%)	(11)	(9)	(7)	(14)	(8)	(9)

M. denticulata ($y = -10.93x^2 + 50.11x$ and $R^2 = 0.828$) and *V. sativa* ($y = -0.368x^2 + 26.10x$ and $R^2 = 0.891$) followed a quadratic response to increasing depth, with increasing germination from surface to optimum depth of 1.0 and 2.0 cm and then decreasing germination with increasing depth (Fig. 4).

Effect of flooding on germination

*M. denticulata*seedlings under continuous flooding failed to emerge. It did not emerge even after the termination of flooding period. Moreover, it did not survive as minimum as five days of flooding duration. Not even a single plant emerged when pots were submerged ≥ 5 days of flooding. The plants emerged only from 0 days of flooding i.e. controlled pot. Sixty-six percent seedling of *M. denticulata*emerged in controlled pot 3WAS (Table 5). Flooding condition adversely affected emergence of weed seed, but the response was different with different species and duration. Flooding had adverse effect on weed germination and therefore weeds seed germination inhibited during flooding period and germination took place only when water was drained from the pot in case of *V. sativa* (Table 5) (Fig. 5). It was observed thatdrastic reduction of emergenceof *V. Sativa* was noted when duration of flooding was > 5 days for *V. Sativa*. The per cent germination under flooding was reduced probably as a result of the anaerobic conditions created by the flooding. According to Opic (1980), artificial prolongation of natural anaerobiosis leads to death in a few days of the seeds of some species though it can be endured by others.

The decreased seedling emergence under flooding was due to reduced oxygen level and accumulation of certain toxic substances due to anaerobic decomposition (Smith and Fox, 1973**).** Poolkumlung *etal.* **(**2001) concluded from their laboratory experiments that water management could control *L. chinensis* by keeping submerged condition in their early stages for 7 to 10 days. The result might be helpful for the control of *M. denticulata* which could

Table 5
Effect of flooding durations on emergence (%) of different weed species

	1 WAS		*2 WAS*		*3WAS*	
Flooding durations	*M. denticulata*	*V. sativa*	*M. denticulata*	*V. sativa*	*M. denticulata*	*V. sativa*
0 days	32(34)	50(45)	33(35)	63(53)	66(54)	63(53)
5 days	0(6)	20(27)	0(6)	23(29)	0(6)	27(31)
10 days	0(6)	13(21)	0(6)	13(21)	0(0)	17(24)
20 days	0(6)	8(17)	0(6)	8(17)	0(6)	13(21)
40 days	0(6)	0(6)	0(6)	0(6)	0(6)	0(6)
80 days	0(6)	0(6)	0(6)	0(6)	0(6)	0(6)
Mean	5	15	6	18	11	20
CD (5%)	(1)	(5)	(1)	(6)	(0.4)	(6.5)

not sustain even 5 days of flooding duration. Duration of five days reduced the emergence from 66 to 0 % in *M. denticulata*. Benvenuti and Macchia (1995) reported that oxygen deficiency in soil due to flooding also restricts diffusion of toxic metabolites into surrounding environment affecting seed germination.

The emergence data were regressed with polynomial model of degree 2 for *M. denticulata* ($y = 5.892x^2 - 50.67x + 99$ $R^2 = 0.785$) and *V. sativa* ($y = 3x^2 - 32.42x + 88$ $R^2 = 0.951$) and found that the emergence decreased with increase in flooding days (Fig. 5).

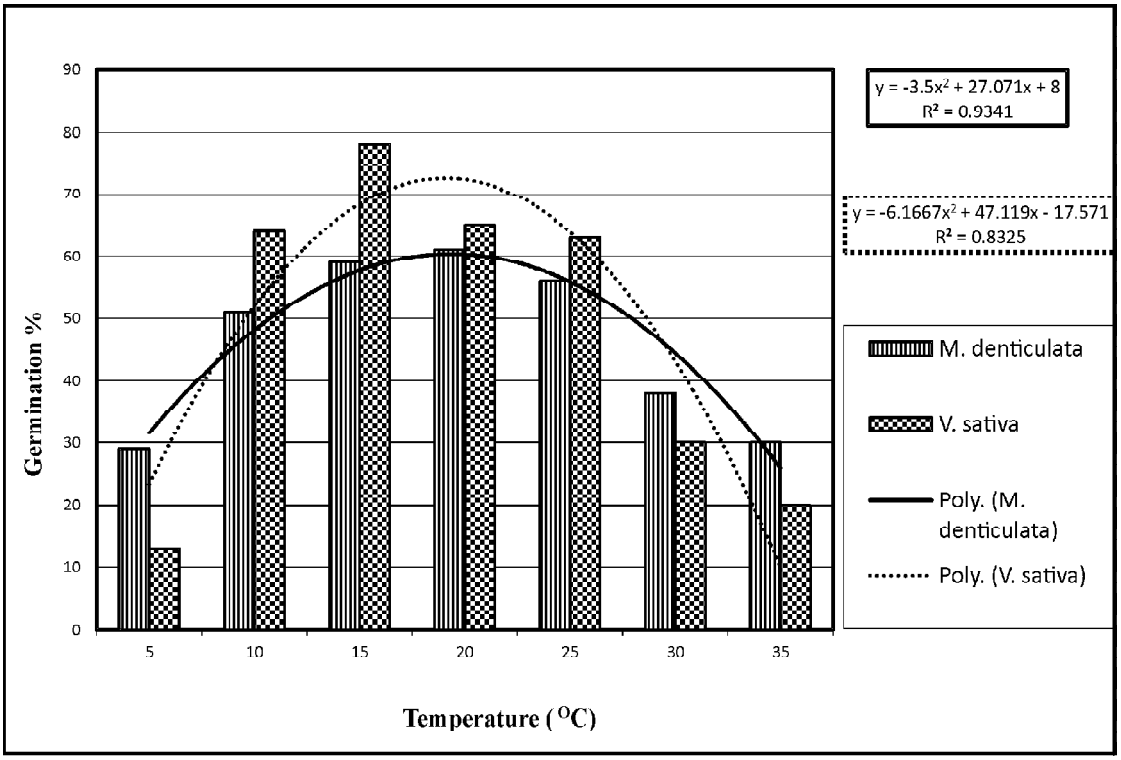

Figure 1: Effect of temperature regimes on germination (%) of different weed species 4 WAS

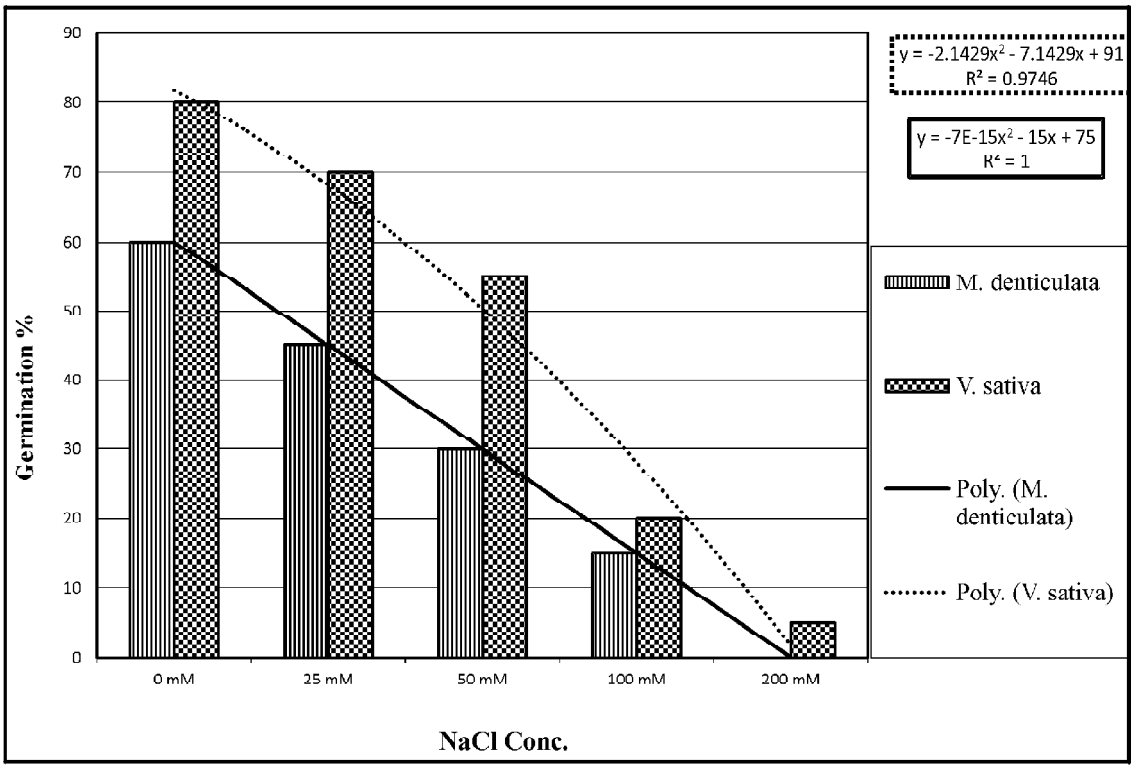

Figure 2: Effect of NaCl (mM) on germination (%) of different weed species 4 WAS

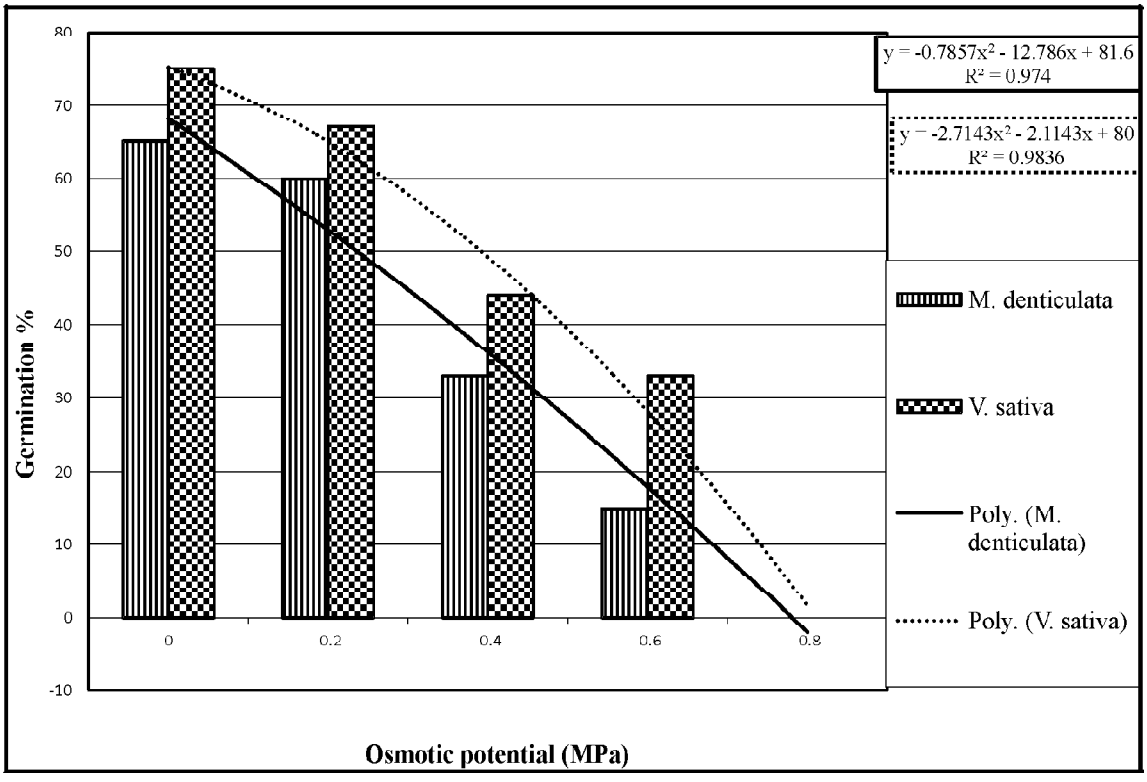

Figure 3: Effect of osmotic potential (MPa) on emergence (%) of different weed species (4 WAS)

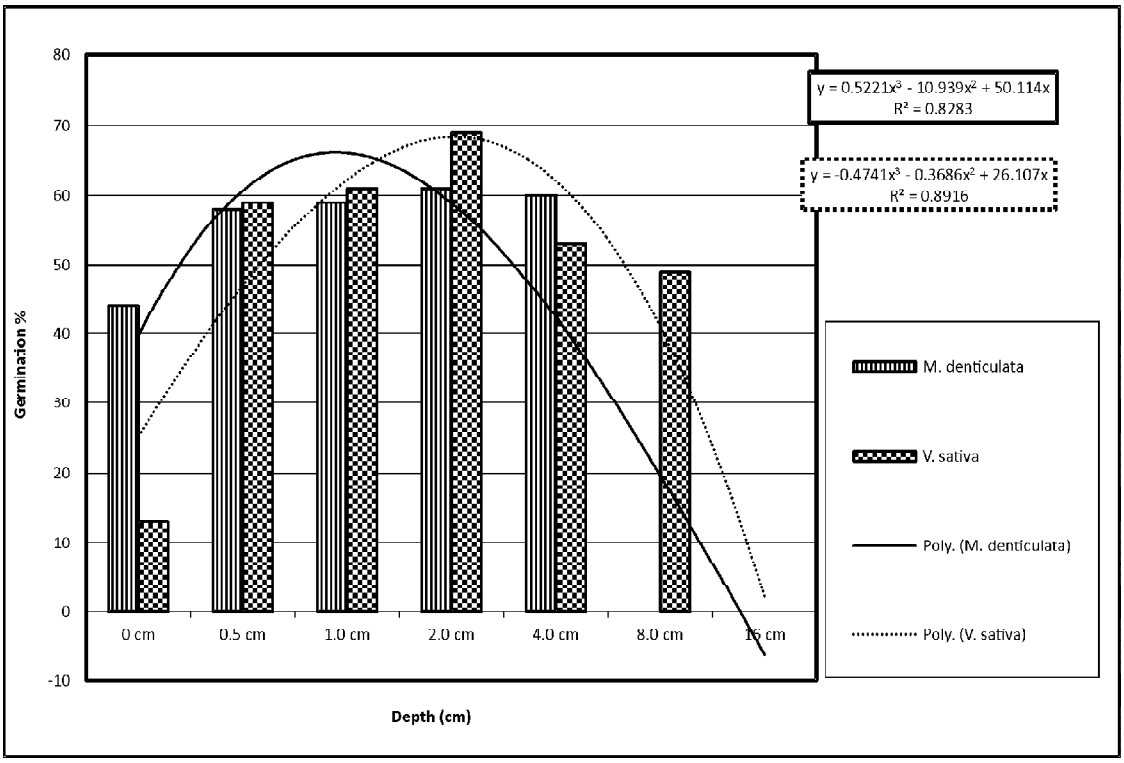

Figure 4: Effect of seeding depth (cm) on emergence (%) of different weed species (4 WAS)

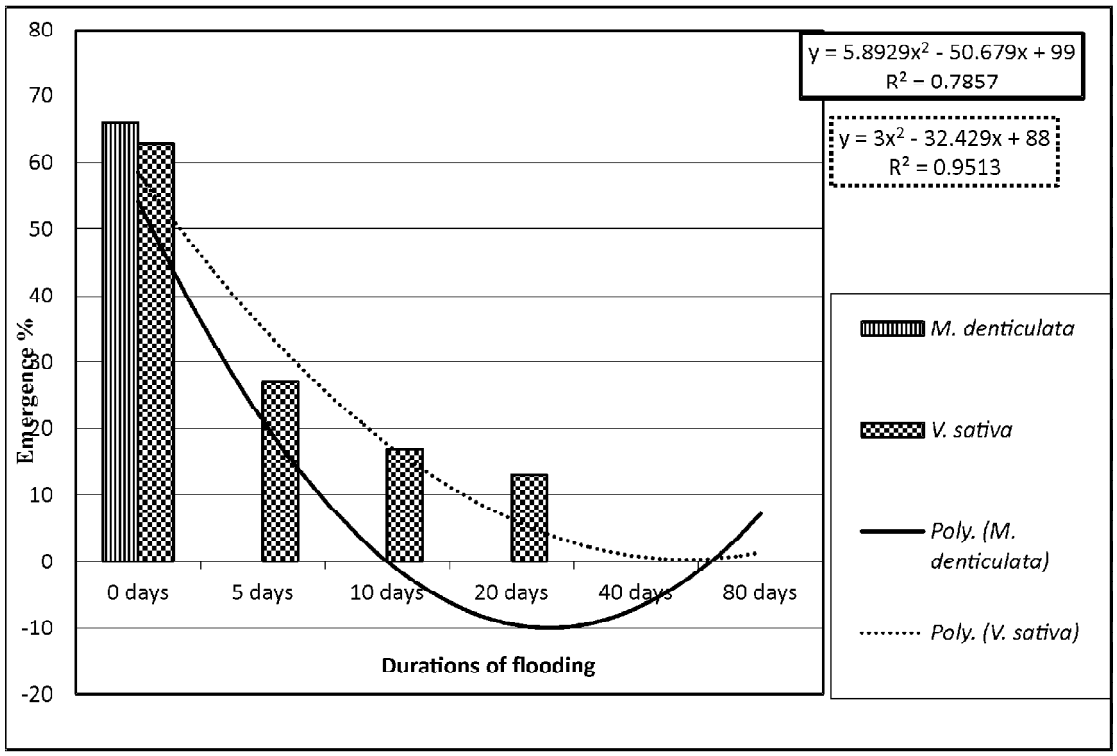

Figure 5: Effect of flooding durations on emergence (%) of different weed species (4 WAS)

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