(Korean J. Crop Sci.) 44(1) : 32~37(1999)

Weed Emergence as Affected by Burying Depth and Water Management

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ABSTRACT

The experiment was conducted to investigate emergence response of lowland weeds at different soil moisture contents, burying depths and upon changes in soil moisture. Rice germination was over 50% at all burying depths under aerobic condition, but the emergence rate of the soil surface placed seeds in saturated and flooded conditions decreased by 19% and 29%, respectively, as compared with that of aerobic condition. Rice seeds at burying depth of over 3 cm did not emerge at all.

The emergence rate of *Echinochloa crus-galli* (L.) Beauv. in aerobic condition was lower than 30%, but the emergence pattern of *E. crus-galli* (L.) Beauv. at different soil moisture contents and seeding depths was similar to that of rice. Emergence behavior of *Ischaemum rugosum* Salisb., *Ludwigia octovalvis* (Jacq.) Raven and *Sphenoclea zeylanica* Gaertn. which are dominant lowland weed species in the Philippines also differed depending on soil moisture conditions and burying depths. *Ischaemum rugosum* Salisb. emerged at all burying depths under aerobic condition, whereas *Ludwigia octovalvis* (Jacq.) Raven emerged only at 0 cm deep under saturated and aerobic condition and *Sphenoclea zeylanica* Gaertn. at 0 cm deep under flooding condition.

Weed seeds planted at 1, 3, and 5 cm deep in continuous flooded and saturated condition did not emerge at all, but upon a change of soil moisture condition from saturated to drainage (S→D) and flooded to drainage (F→D), grass weeds began to germinate again and the average emergence rate in S→D and F→D were 26% and 5% for *E. crus-galli* (L.) Beauv., 9% and 8% for *I. rugosum* Salisb., respectively.

Weed seeds buried in soil in the pot showed great emergence at S→D but did not emerge under continuous flooded condition. The diversity index accounting for dominance degree and occurrence aspect of weed, was the lowest at F→D.

Key words : weeds, emergence rate, soil moisture, burying depth.

Grass weeds and broad leaf weeds reduce not only rice yield but also grain quality. Farmers frequently use a combination of herbicides, mechanical and cultural practices to control weeds in rice fields.

Since rice is grown in water, management of standing water is an important tool to control weed growth (Pons & Schroder, 1986). Many weeds can be controlled with little or no herbicide by effective water management. The effect of water culture on the germination and growth of weeds has been studied by many scientists in Japan and the United States (Smith & Fox, 1973). *E. crus-galli* (L.) Beauv. is a troublesome weed in all direct-seeded rice areas, competing vigorously with the crop from the early growth stages. The depth from which *E. crus-galli* (L.) Beauv. emerges depends upon the soil moisture content (Azim, 1996).

Management of water could inhibit germination of many weeds, but *Scirpus juincoides* Roxb. shows peculiar behavior in that maximum germination does not occur at the surface of aerobic soil in the absence of a water cover, but 1 or 2 cm below the surface (Pons, 1982). Hence, this species must be capable of germinating under anaerobic conditions or at least under very low oxygen concentrations. Several aquatic species are known to have this capability (Pons & Schroder, 1986).

The essential factor regulating seed survival is soil moisture condition during the off-season (Masuji et al, 1989). Takahashi & Lida (1995) reported that the longer the duration of upland cropping during 3 years, the fewer lowland weeds emerged after being converted to paddy fields again. By understanding the population dynamics of weeds affected by a change of soil moisture, it is possible to determine the factors that govern weed abundance and predict the weed's response to various control measures and cropping programs.

For this reason, this experiment was initiated to obtain basic information on the emergence response of rice and weeds to soil moisture conditions, burying depth and the change of soil moisture conditions.

MATERIALS AND METHODS

The experiment was conducted in a glass house at IRRI (International Rice Research Institute) in Los Banos, Laguna, Phillippines on November 10 1996. Test seeds used in this study were rice (Hwaoyeongbyeo) from Korea, two grass weeds (*Echinochloa crus-galli* (L.) Beauv., *Ischaemum rugosum* Salisb.) and two broad leaf

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Received 5 Dec. 1998.

weeds (*Ludwigia octovalvis* (Jacq.) Raven, *Sphenoclea zeylanica* Gaertn.). Soil moisture condition were aerobic, saturated and flooded condition and burying depths were 0, 1, 3 and 5 cm deep, respectively.

For soil preparation, finely ground upland clay-loam soil was filled up to the brim in plastic trays (30 cm×25 cm×10 cm) and then slightly compacted by hand. After the trays were watered and excessive water was allowed to drain freely, soil in the tray was dug out to the depth of 0, 1, 3 and 5 cm from soil surface and the seedbed was made evenly. Each weed seed was planted in 3 rows with a spacing of 2 cm per weed seed and the number of seeds used per 3 rows was 100 seeds for *E. crus-galli* (L.) Beauv., *I. rugosum* Salisb. and *Oryza sativa* L. and was 03 g (about 1500 seeds) for *S. zeylanica* Gaertn. and was 0.75 g (about 900 seeds) for *L. octovalvis* (Jacq.) Raven. The seeds were covered with fine upland soil up to the brim in plastic trays. Trays were placed in cooling benches to maintain uniform soil moisture. For flooded condition, water on the surface of the soil was 3 cm deep and for saturated condition, water table even with the soil surface was maintained and for aerobic condition, 50ml of water was sprayed every day to prevent soil from cracking. The trays were arranged into split plot design with soil moisture condition as the main plot and the burying depth as sub plots. Each experiment contained four replicates.

Investigation items were germination percent and coefficient of germination velocity. After completing the investigation on weed emergence, two among 4 replicates of each saturated and flooded conditions were continuously maintained and the others were completely drained 20 days after seeding. The emergence response of weed seeds which were not emerged at burying depth of over 1 cm in continuous saturated or flooded condition was investigated. At the same time, the occurrence of weed seeds buried in soil used was investigated 40 days after drainage. Diversity index (DI) was calculated as; $DI = \Sigma Ni^2$, where Ni is the ratio of dry weight of each weed species to total weeds occurred.

RESULTS AND DISCUSSION

Effect of soil moisture condition and burying depth on weed emergence

Emergence response of rice and weeds to soil moisture conditions and burying depths varied greatly as shown in Table 1. Rice germinated over 50% at all burying depths under aerobic condition. However, the emergence rate of the soil surface placed seeds under saturated and flooded condition decreased by 19% and 29%, respectively, as compared with that of aerobic condition. Rice at a burying depth of over 3 cm did not emerge at all under these conditions.

Emergence rate of *E. crus-galli* (L.) Beauv. in aerobic condition was less than 30%, but the germination pattern of *E. crus-galli* (L.) Beauv. to different soil moisture conditions and seeding depths was similar to that of rice.

Emergence of *I. rugosum* Salisb., *L. octovalvis* (Jacq.) Raven, and *S. zeylanica* Gaertn, which were dominant lowland weed species in the Philippines, greatly differed depending on soil moisture conditions and burying depths. *I. rugosum* Salisb. emerged at all the burying depth of aerobic condition, whereas it scarcely emerged in saturated and flooded conditions. *L. octovalvis* (Jacq.) Raven emerged at only 0 cm deep under aerobic and saturated condition and *S. zeylanica* Gaertn. at only 0 cm deep under flooded condition. Estorninos and Moody (1982) reported that *I. rugosum* Salisb. had the highest abundance in dry direct-seeded rice and was increasing in importance as a rice weed in the Philippines.

Table 1. Emergence response of rice and weeds to burying and flooding depth.

Soil moisture	Burying depth (cm)	Germination rate (%)			No. of germinated weed	
		O. sativa	*I. rugosum*	*E. crus-galli*	*R. octovalvis*	*S. zeylanica*
Aerobic condition	0	67	19	24	12	0
	1	70	27	28	2	0
	3	55	31	22	0	0
	5	50	9	15	1	0
Saturated condition	0	51	2	15	31	6
	1	26	0	4	3	0
	3	1	0	1	0	0
	5	0	0	0	0	0
Flooded condition	0	41	3	8	0	32
	1	33	0	1	0	9
	3	0	0	0	0	1
	5	0	0	0	0	0
Soil moisture (F)		··· 167.5^{***} ···	··· 29.6^{***} ···	··· 62.9^{***} ···	··· 1.6^{NS} ···	··· 2.2^{NS}
Burying depth (D)		··· 70.7^{***} ···	··· 1.6^{NS} ···	··· 8.2^{***} ···	··· 3.1^{*} ···	··· 1.8^{NS}
F*D		··· 6.2^{***} ···	··· 1.8^{NS} ···	··· 2.3^{NS} ···	··· 1.3^{NS} ···	··· 1.1^{NS}

Table 2. Coefficient of velocity of rice and weeds as affected by burying depth and soil moisture.

Soil moisture	Burying depth (cm)	Coefficient of velocity				
		O. sativa	*E. crus-galli*	*I. rugosum*	*L. octovalvis*	*S. zeylanica*
Aerobic condition	0	12.1	11.5	11.3	11.2	–
	1	11.3	10.8	11.1	10.7	–
	3	10	10.4	10.2	8.8	–
	5	9.6	9.9	10.2	8	–
Saturated condition	0	11.9	11.1	11.8	12.3	–
	1	10.1	9.1	9.8	9.1	–
	3	8.7	9.1	–	–	–
	5	–	–	–	–	
Flooded condition	0	11.8	10.4	8.2	–	11.3
	1	11.2	9.9	–	–	9.7
	3	–	–	–	–	8.8
	5	–	–	–	–	–

Coefficient of velocity (CV) as affected by burying depths and soil moisture conditions was shown in Table 2. Generally, coefficient of velocity increased as more seeds germinated and with shorter germination time (Scott et al, 1984). CV by different soil moisture contents was faster in the order of aerobic, saturated and flooded conditions in the case of grass weeds such as *I. rugosum* Salisb. and *E. crus-galli* (L.) Beauv. and *O. sativa* L.. CV of each plants to burying depths at different soil moisture contents increased more as burying depth was lowered. This means that emergence of weeds is faster in aerobic condition and in shallower burying depth with proper oxygen and moisture to germinate. Earlier experiments have shown that emergence of some grass weeds were greatly inhibited under water and the main factor involved with germination inhibition of weeds under water is the response of seeds to oxygen (Pons et al, 1986).

Occurrence of weeds as influenced by complete drainage from continuous saturated and flooded condition

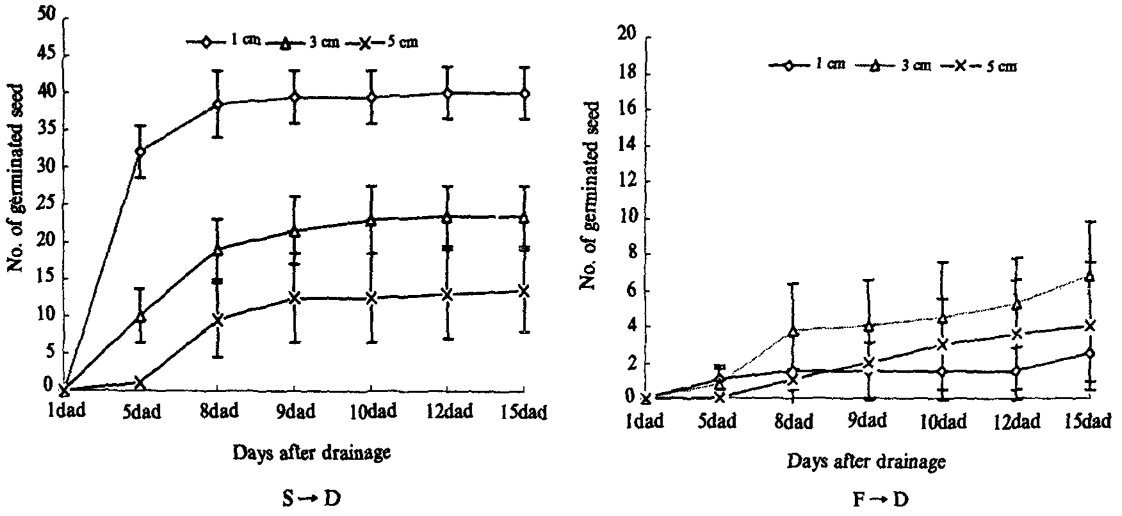
Emergence response of weed seeds under complete drainage from saturated and flooded conditions differed greatly as shown in Table 3. Weed seeds planted at depths of 1, 3 and 5 cm in continuous saturated and flooded conditions did not emerge at all. However, with a change of water management from flooded condition to drainage (F→D) and saturated condition to drainage (S→D), grass weeds such as *E. crus-galli* (L.) Beauv. and *I. rugosum* Salisb. began to emerge, but *O. sativa* L., *L. octovalvis* (Jacq.) Raven and *S. zeylanica* Gaertn. did not emerge at all.

Emergence rate of *E. crus-galli* (L.) Beauv. were 40%, 24% and 14% at 1, 3 and 5 cm deep for S→D and 3%, 7% and 4% at each depth for F→D, respectively. Emergence rate of *E. crus-galli* (L.) Beauv. was lower in F→D than that in S→D. Emergence of *E. crus-galli* (L.) Beauv. at different burying depths upon change of soil moisture decreased as burying depth increased in S→D, but did not show the same tendency in F→D. Emergence of *I. rugosum* Salisb. was different from that of *E. crus-galli* (L.) Beauv. and was 10% less under both S→D and F→D and the emergence rate at different burying depths upon change of soil moisture content was not different. Average emergence rate was the highest (26%) in S→D for *E. crus-galli* (L.) Beauv. and the lowest (5%) in F→D for *E. crus-galli* (L.) Beauv.

Time-course of emergence after drainage was different as shown in Figure 1. Though *E. crus-galli* (L.) Beauv. and *I. rugosum* Salisb. did not emerge under continuous saturated and flooded conditions as shown in Table 3. These weeds began to germinate from 5 to 8 days after complete drainage. The first emergence after drainage was the fastest in S→D and at 1 cm deep among burying

Table 3. Emergence of weeds at different burying depths and change of soil moisture.

Burying depth(cm)	*E. crus-galli* (L.) Beauv.				*I. rugosum* Salisb.			
	Saturated	Saturated →Drained	Flooded	Flooded →Drained	Saturated	Saturated →Drained	Flooded	Flooded →Drained
1	1	40a	1	3a	0	9a	0	12a
3	1	24b	0	7a	0	9a	0	5b
5	0	14c	0	4a	0	9a	0	7b
Mean		26	0	5	0	9	0	8



(*Echinochloa crus-galli (L.) Beauv.*)

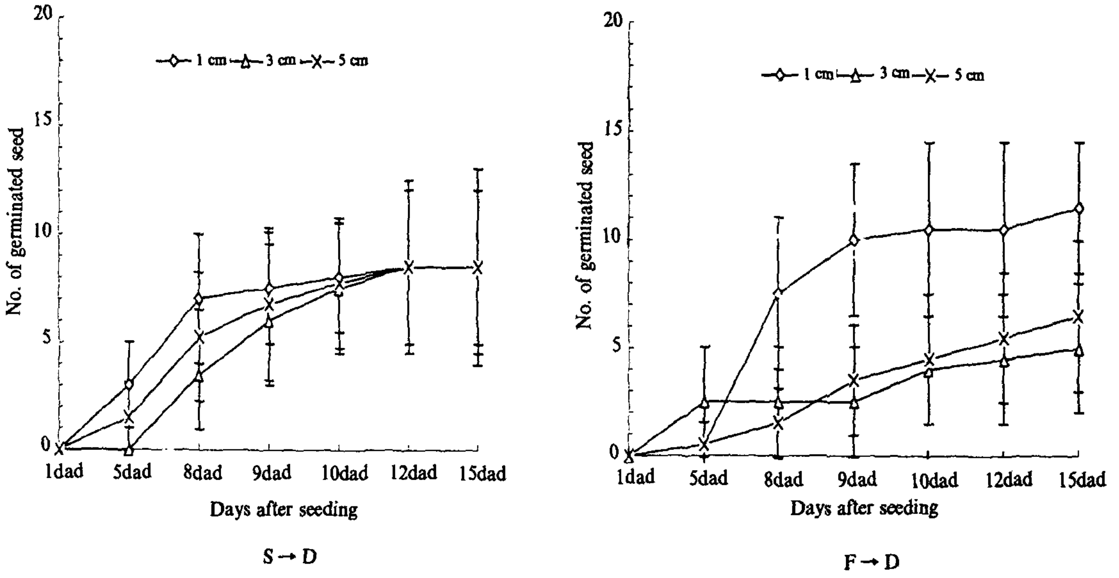


Fig. 1. Time-course of emergence of *E. crus-galli* (L.) Beauv. and *I. rugosum* Salisb. by change of soil moisture from saturated condition to drainage (S→D) and from flooded condition to drainage (F→D) on 20 days after seeding.

depths in S→D, but emergence response to burying depths in F→D was not different.

From the above results, we found that some grass weeds which did not emerge under continuous flooded condition might emerge again upon conversion to soil moisture condition with proper oxygen in the paddy field. Accordingly, longevity of weed seeds once buried into cultivated soil has become a significant factor to be considered in order to choose the kind of herbicides and to determine whether herbicides must be applied or not to each field (Masuji et al, 1989).

Effect of change of water management on occurrence of weeds buried in soil

Occurrence of weed seeds buried in used soil differed greatly by change of soil moisture as shown in Table 4. Weeds occurred the most frequently in S→D and the least freguently under continuous flooded condition. *Hedyotis corymbosa, Ipomoea triloba,* and *Lindernia*

Table 4. Weed occurrence as affected by change of water management to drainage from saturated and flooded condition.

Weed species	Saturated[†]→ Drainage		Flooded[†]→ Drainage		Saturated		Flooded	
	No. /m²	D.W. (g /m²)	No.	D.W.	No.	D.W.	No.	D.W.
Hedyotis corymbosa	830	22.4(62)[‡]	170	1.8(17)	690	4.9(59)	–	–
Cyperus compressus	30	1.2(3)	30	0.5(5)	–	–	–	–
Lindernia crustacea	80	1.4(4)	60	3.1(29)	40	1.0(12)	60	0.5(71)
Ipomea triloba	10	0.2(1)	–	–	–	–	–	–
Portulaca oleracea	210	0.6(2)	20	0.2(2)	–	–	–	–
Murdannia nudiflora	10	0.1(0)	10	0.6(5)	–	–	–	–
Lindernia hirta	120	8.2(23)	90	2.0(19)	60	2.0(24)	–	–
Lindernia anagallis	50	1.8(5)	50	2.3(22)	20	0.4(5)	30	0.2(29)
Total	1,150	36.0	420	10.5	810	8.3	90	0.7
Diversity index		0.446		0.2078		0.4234		0.5918

[†] Maintained during 20 days after seeding.
[‡] The numbers in the parentheses are importance value.

anagallis were dominant weeds in dry direct-seeded rice ecosystems in the Philippines (Moody et al, 1996). The diversity index accounting for dominance degree and occurrence aspects of the weed was lowest in F→D. It means that weeds including lowland and upland weeds in F→D occurred uniformly. Aspect of weed occurrence by water management might differ greatly. Emergence of some weeds were greatly inhibited under continuous flooded condition, but these weeds might greatly increase upon drainage from flooded and saturated condition.

Arai et al. (1955) reported that distribution of weed species and their growth vary with soil moisture conditions. Change in weed occurrence has taken place with a change of flooded condition in the production system and the chief factor that encourages the germination of such weeds is sufficient aeration (Moody et al, 1996). Under dry land (40~60% of maximum moisture capacity conditions), C4 species accounted for more than 90% of the total dry weight compared with only 10% under submerged (6 cm standing water) conditions (Tanaka, 1976).

Water flooding seeded culture curtails problems with certain grass weeds and broad leaf weeds, but it may cause other problems like abundance of aquatic weeds (Smith & Fox, 1973). Accordingly, a better understanding about weed population dynamics influenced by a change of soil moisture content will enable us to predict ecological changes and facilitate an adjustment of treatments to prevent undesirable shifts that could make control more difficult.

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