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THE EFFECT OF FLOODING ON SEED GERMINATION OF WEEDY RICE (*ORYZA SATIVA* COMPLEX, LOCALLY CALLED PADI ANGIN) UNDER PLANT HOUSE CONDITION

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Abstrak: Kajian di dalam rumah tumbuhan telah dilakukan untuk menentukan kesan-kesan daripada masa dan kedalaman pembanjiran terhadap kemandirian dan pertumbuhan biji benih *Oryza sativa* complex (padi angin). Data menunjukkan bahawa masa dan kedalaman pembanjiran memberikan kesan yang signifikan ke atas kemandirian dan pertumbuhan padi angin. Percambahan biji benih tertinggi diperoleh apabila biji benih ditanam dalam keadaan tepu dan dengan kedalaman pembanjiran 2.5 cm pada 21 Hari Lepas Tabur (HLT). Namun, hampir semua rawatan menunjukkan pengurangan yang signifikan terhadap kedalaman pembanjiran. Apabila pembanjiran dilewatkan sehingga tujuh hari, hanya ketinggian tumbuhan menunjukkan pengurangan yang signifikan terhadap semua rawatan. Jelas bahawa pengurusan air yang bersesuaian terutamanya terhadap masa dan kedalaman pembanjiran merupakan faktor-faktor yang mustahak untuk mengawal pertumbuhan padi angin dalam ekosistem sawah padi. Ini akan membantu perancangan prosedur yang teratur dalam pengurusan rumpai berkenaan serangannya terhadap padi angin di sawah padi yang merupakan langkah terawal untuk mengatasi masalah ini.

Abstract: Plant house experiment was carried out to determine the effects of time and depth of flooding on the survival and growth of weed *Oryza sativa* complex (weedy rice). Data showed that time and depth of flooding had significant effects on the survival and growth of weedy rice. Moist and saturated soils favored the survival and growth of weedy rice. Higher seed germinations were found when the seed grew under saturated and 2.5 cm depth of flooding at 21 Days After Seeding (DAS). However, almost all treatments were significantly reduced by depth of flooding. When flooding was delayed until seven days, only plant height was significantly lower at all treatments. A further delay of flooding showed a similar trend of all treatments. Evidently, appropriate water management particularly on timing and depth of flooding are very important factors for controlling weedy rice growth in rice ecosystem. This will help to plan for a proper procedure in weed management due to its infestation in ricefields, and initial step to overcome it.

Keywords: Weedy Rice, Time of Flooding, Water Depth, Germination

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INTRODUCTION

Water is essential to the growth and the production of yield for plant. However, continuous flooding during the cropping period is associated with rice populations' growth rate particularly in direct seeded rice. However, weeds of lowland rice are primarily those that can adapt under some waterlogging condition at some stage in their life cycle. The duration, depth of standing water, stage of development of the weeds (De Datta 1981; Akobundu 1987), weed species (Smith & Fox 1973; De Datta 1981) and seeding depth of the weeds (De Datta 1981; Pons 1982) are the factors affecting the efficacy of water management and flooding to control weed species richness. Evidently, weed populations decrease as the depth of water increases.

Based on the morphological and physiological characteristic of weedy rice, the species is similar with *Oryza sativa* (rice plant). In fact it is a strain of rice plant. Due to artificial evolution taking place in the ricefield ecosystem, individual and populations have came out as a resistant strain, although the species is *O. sativa*. Therefore, there is a difficulty in controlling the weedy rice growth by using herbicide. Currently, under direct seeded condition, herbicide application is the only practical method for grassy weed control. Therefore, cultural practices such as water management or flooding might be possible to reduce and to control of weedy rice growth in ricefields especially during the rice-seeding stage. Akobundu (1987) suggested that in order to get maximum benefit from flooding, it should be done when weeds are at the seedling stage and water depth of 10 to 20 cm should be maintained. Sonnier (Baker *et al.* 1986) has studied the effect of water management on weedy rice problem and found that, while draining the fields did indeed overcome the stand establishment problem, it is also allowed more weedy rice to become establishment than if the fields were not drained. It is also reported that if the interval of the drainage period was 3 days to 7 days, the stand establishment problem could be minimized with less weedy rice establishment rather than with a drainage period greater than 14 days. As a result, there was less weedy rice suppression compared to a continuous flood condition.

According to De Datta (1981) and Baltazar *et al.* (1995), flooding in the rice fields can be continuous, intermittent or deep, depending on the available irrigation system in the field. Soil moisture content or flooding depth in the field influenced the germination and the type of weeds. Therefore, the aim of this study was to determine the effects of various water depths and time of flooding as a part of the methods to control the germination of weedy rice seeds.

MATERIALS AND METHODS

This experiment was carried out at the plant house of School of Biological Sciences, Universiti Sains Malaysia, Pulau Pinang, from May 2005 to June 2005. Some environmental data were also recorded at the plant house by using LX-101 Lux meter (light intensity) and Higro-Thermometer (air temperature and relative humidity). In the morning and afternoon, mean temperature ranged from 27^{o}C to

30^{o}C, mean relative humidity ranged from 73% to 87% and light intensities ranged from 55,400 lux to 58,100 lux; whereby during midnight, the temperature and relative humidity remained the same as aforementioned, but light intensities ranged from 1 lux to 2 lux.

There were 14 treatments and the four interval number of days after seeding were arranged in 14 × 4 factorial in a completely randomized design (CRD) and replicated four times. The list of the treatments tested is shown as below:

i. moist soil with 80% of water holding capacity
ii. saturated soil with 100% of water holding capacity
iii. flooded with 2.5 cm water depth at 0 DAS
iv. flooded with 2.5 cm water depth at 7 DAS
v. flooded with 2.5 cm water depth at 14 DAS
vi. flooded with 2.5 cm water depth at 21 DAS
vii. flooded with 5.0 cm water depth at 0 DAS
viii. flooded with 5.0 cm water depth at 7 DAS
ix. flooded with 5.0 cm water depth at 14 DAS
x. flooded with 5.0 cm water depth at 21 DAS
xi. flooded with 10.0 cm water depth at 0 DAS
xii. flooded with 10.0 cm water depth at 7 DAS
xiii. flooded with 10.0 cm water depth at 14 DAS
xiv. flooded with 10.0 cm water depth at 21 DAS

Each plastic bucket with the diameter of 24 cm and 23 cm height was filled with 2 kg of soil. The soil used was collected from Guar Chempedak ricefield which was clay (65% clay, 30% silt and 5% sand) of Guar Chempedak Soil Series with pH 4.75 which was free from weedy rice seeds (first season of 2004 of seed bank study). The soil contained 0.26% N, 0.14% P, 582.34 ppm K and 1.74% organic matter. This soil was air dried and sieved through 250 µm. Weedy rice seeds were collected from mature plants near the Guar Chempedak ricefields. In each plastic tray, 100 pre-germinated seeds of weedy rice were put on the soil surface for germination. All the soils were watered daily to maintain a moist condition (80% of water-holding capacity, 1,000 g of dried soil plus 800 ml of water; for 100% of water-holding capacity, 1,000 g of dried soil was poured with 1,000 ml of water) whereas for flooding treatments, the water depth was maintained continuously according to each tested treatment. Percentage of seed germination, number of seedlings (from 100 seeds), plant height, root length and dry weights of roots and shoots were recorded at 7, 14, 21 and 28 DAS.

Statistical analysis of the data was carried out using Statistical for Analysis System (SAS) Released 6.1 computer program. Significant differences between means were determined by Duncan Multiple Range Test (DMRT) tests at the 5% level as suggested by Gomez and Gomez (1984).

RESULTS

Seed Germination

The result of seed germination is shown in Table 1. During the first seven days, high percentage of seed germinations was recorded in all treatments. Higher seed germinations were found when the seed grew under saturated condition and 2.5 cm depth of flooding at 21 DAS which was conducive for seeds to germinate and to survive with the values of 97% and 86%. The treatments of 10.0 cm water depth at 0 DAS showed that the value was significantly lower than those in other treatments. Therefore, flooding with these treatments was effective to kill and to reduce the number of seedlings.

There was no significant difference between moist soil, saturated soil and 2.5 cm flooding depth at 0 DAS for 14 DAS and 21 DAS. As the time of flooding was delayed, until 7 DAS the chances of survival increased and deeper flooding was needed to control and kill weedy rice. The highest and lowest number of germination under plant house condition at 28 DAS were grown under saturated soil and 10.0 cm depth of flooding at 21 DAS, with values of 96.75% and 9.00% respectively.

Plant Growth

The effect of plant heights under different times and depths of flooding was shown in Table 2. The saturated soil favoured the survival and growth of weedy rice but its stand was significantly reduced by flooding to a depth of 2.5 cm at 0, 7, 14 and 21 DAS. Except for moist soil and 2.5 cm flooding depth for 0 DAS there was significant difference between saturated soil and other treatments. The highest of plant height of weedy rice occurs under saturated and moist conditions, with heights of 58.10 cm where the lowest was 32.60 cm height under 10.0 cm depth of flooding at 7 DAS.

Except for 10.0 cm depth at 14 DAS and 21 DAS, all treatments showed similar trend where increased from 7 DAS until 28 DAS. Observation at 7 DAS, there were significant differences between moist soils and flooded at either 5.0 cm depth or 10.0 cm depth. However, at 28 DAS the treatments of moist, flooding with 2.5 cm at 0 DAS, 5.0 cm at 0 DAS and 5.0 cm at 21 DAS were the highest with lengths more than 10.0 cm (Table 3).

Table 1: Percentage (%) of *O. sativa* complex seed emergence under different times and depths of flooding.

Water depth (cm)	Time of flooding (DAS)			
	7	14	21	28
moist soil	76.50b	80.50ab	80.50ab	80.50bc
saturated soil	93.75a	95.50a	96.75a	96.75a
2.5 cm depth of flooding at 0 DAS	38.50e	53.00def	55.75cde	56.00def
2.5 cm depth of flooding at 7 DAS	53.00d	62.75cde	66.25bcd	69.25cd
2.5 cm depth of flooding at 14 DAS	56.25bc	64.25bc	70.25ab	86.25ab
2.5 cm depth of flooding at 21 DAS	61.25e	64.25bc	70.25ab	86.25ab
5.0 cm depth of flooding at 0 DAS	35.50e	37.50ef	52.25def	52.25def
5.0 cm depth of flooding at 7 DAS	32.75e	39.25fg	43.50efg	44.25efg
5.0 cm depth of flooding at 14 DAS	36.00e	55.00def	56.00cde	56.00def
5.0 cm depth of flooding at 21 DAS	45.50e	49.25g	68.00g	68.25cd
10.0 cm depth of flooding at 0 DAS	23.25e	31.00g	36.50fg	37.75g
10.0 cm depth of flooding at 7 DAS	29.75e	34.50def	38.00cde	38.50g
10.0 cm depth of flooding at 14 DAS	31.00cd	37.25bcd	39.50bc	39.00g
10.0 cm depth of flooding at 21 DAS	38.25e	47.25h	50.50h	51.00def

In column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Table 2: Effect of plant heights (cm) of *O. sativa* complex under different times and depths of flooding.

Water depth (cm)	Time of flooding (DAS)			
	7	14	21	28
moist soil	13.225ab	29.775a	40.350a	58.100a
saturated soil	14.125a	33.725a	40.475a	58.100a
2.5 cm depth of flooding at 0 DAS	12.550abc	16.375c	30.175cd	51.150b
2.5 cm depth of flooding at 7 DAS	11.400bcd	13.625c	36.900abc	44.575bc
2.5 cm depth of flooding at 14 DAS	11.725bcd	13.625c	37.725ab	45.175bc
2.5 cm depth of flooding at 21 DAS	10.625cde	12.925c	33.975abcd	41.250c
5.0 cm depth of flooding at 0 DAS	9.650def	17.625c	37.275ab	44.375bc
5.0 cm depth of flooding at 7 DAS	8.700ef	17.425c	31.525bcd	46.425bc
5.0 cm depth of flooding at 14 DAS	11.000bcde	23.850b	37.550ab	50.675b
5.0 cm depth of flooding at 21 DAS	0.575cde	16.250c	29.550d	47.975bc
10.0 cm depth of flooding at 0 DAS	9.575def	15.375c	38.925a	44.650bc
10.0 cm depth of flooding at 7 DAS	9.425def	15.425c	30.175cd	32.600d
10.0 cm depth of flooding at 14 DAS	8.675ef	18.725c	34.300abcd	34.075
10.0 cm depth of flooding at 21 DAS	8.100f	17.600c	22.500e	34.050d

In column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Table 3: Effect of root lengths (cm) of *O. sativa* complex under different times and depths of flooding.

	Time of flooding (DAS)			
Water depth (cm)	7	14	21	28
moist soil	8.200a	7.475ab	8.600ab	8.800cd
saturated soil	8.000a	6.150bcd	7.400ab	15.375a
2.5 cm depth of flooding at 0 DAS	8.375a	7.725ab	6.500ab	12.750ab
2.5 cm depth of floodingat 7 DAS	8.600a	5.850bcd	6.625ab	8.725cd
2.5 cm depth of floodingat 14 DAS	8.425a	7.625ab	7.075ab	9.625bcd
2.5 cm depth of floodingat 21 DAS	8.025a	6.550abcd	6.550ab	9.450bcd
5.0 cm depth of floodingat 0 DAS	5.100bc	8.850a	6.675ab	10.550bc
5.0 cm depth of floodingat 7 DAS	4.850bc	6.875abcd	8.975a	8.725cd
5.0 cm depth of flooding at 14 DAS	6.225b	7.300abc	8.300ab	8.900cd
5.0 cm depth of flooding at 21 DAS	4.825bc	6.175bcd	5.850ab	10.875bc
10.0 cm depth of flooding at 0 DAS	3.800c	4.450d	5.875ab	7.650cde
10.0 cm depth of flooding at 7 DAS	3.900c	4.875cd	5.475b	4.650ef
10.0 cm depth of flooding at 14 DAS	4.950bc	5.550bcd	5.150b	4.000f
10.0 cm depth of flooding at 21 DAS	5.600bc	5.225bcd	6.925ab	6.175def

In column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Table 4: Effect of dry weight (g) of roots of *O. sativa* complex under different times and depths of flooding.

	Time of flooding (DAS)			
Water depth (cm)	7	14	21	28
moist soil	0.0126b	0.0055ab	0.0057bc	0.0283ab
saturated soil	0.0339a	0.0054ab	0.0113a	0.0422ab
2.5 cm depth of flooding at 0 DAS	0.0047b	0.0050abc	0.0078b	0.0296ab
2.5 cm depth of flooding at 7 DAS	0.0037b	0.0051abc	0.0039cd	0.0218b
2.5 cm depth of flooding at 14 DAS	0.00398b	0.00648a	0.00363cd	0.0161b
2.5 cm depth of flooding at 21 DAS	0.00293b	0.0051abc	0.0036cd	0.0148b
5.0 cm depth of flooding at 0 DAS	0.0051b	0.00363bcd	0.0057bc	0.0292ab
5.0 cm depth of flooding at 7 DAS	0.0044b	0.0030cd	0.0087ab	0.0248b
5.0 cm depth of flooding at 14 DAS	0.0032b	0.0043bcd	0.0065bc	0.0213b
5.0 cm depth of flooding at 21 DAS	0.0040b	0.0036bcd	0.0059bc	0.0865a
10.0 cm depth of flooding at 0 DAS	0.0025b	0.0024d	0.0059bc	0.0865a
10.0 cm depth of flooding at 7 DAS	0.0023b	0.0031cd	0.0026d	0.0055b
10.0 cm depth of flooding at 14 DAS	0.0031b	0.0034bcd	0.0024d	0.0032b
10.0 cm depth of flooding at 21 DAS	0.0037b	0.0026d	0.0021d	0.0036b

In column, means followed by a common letter are not significantly different at the 5% level by DMRT.

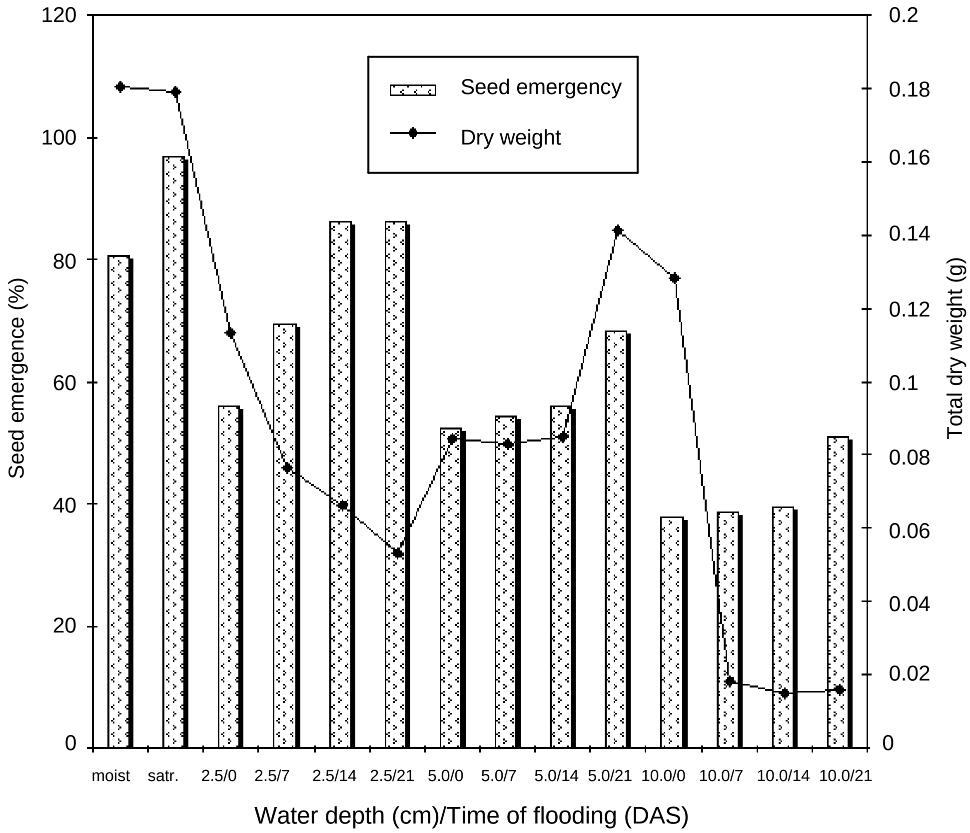

Figure 1: Effect of water depth and time of flooding on seed emergence and total dry weight of weedy rice at 28 DAS.

The effect of dry weight of roots and shoots are shown in Table 4 and Table 5. Evidently, dry weight of roots and shoots of weedy rice were also significantly affected by the tested treatments. The same trend was also observed in dry weights of roots and shoots compared to plant heights. Saturated condition was the highest values of dry weights of roots with value of 0.042 g. Dry weight of shoots in moist condition was higher compared to other treatments, with the value of 0.152 g. Figure 1 and Table 6 show the effect of water depth and time of flooding on seed emergence and total dry weights of weedy rice. There were no significant differences between moist and saturated conditions ($p < 0.05$) but both treatments were significantly different with other treatments grown at 28 DAS.

Table 5: Effect of dry weight (g) shoots of *O. sativa* complex under different times and depths of flooding.

Water depth (cm)	Time of flooding (DAS)			
	7	14	21	28
moist soil	0.0073b	0.0204a	0.0378b	0.1519a
saturated soil	0.1836a	0.0210a	0.0502a	0.1374a
2.5 cm depth of flooding at 0 DAS	0.0049b	0.0088b	0.0169cd	0.0835b
2.5 cm depth of flooding at 7 DAS	0.0049b	0.0058cde	0.0216c	0.0546cd
2.5 cm depth of flooding at 14 DAS	0.0050b	0.0058cde	0.0240c	0.0503cd
2.5 cm depth of flooding at 21 DAS	0.0037b	0.0056cde	0.0212c	0.0384d
5.0 cm depth of flooding at 0 DAS	0.0039b	0.0062bcde	0.0199c	0.0553cd
5.0 cm depth of flooding at 7 DAS	0.0039b	0.0058cde	0.0208c	0.0580cd
5.0 cm depth of flooding at 14 DAS	0.0043b	0.0073bc	0.0215c	0.0636c
5.0 cm depth of flooding at 21 DAS	0.0037b	0.0066bcd	0.0194c	0.0546cd
10.0 cm depth of flooding at 0 DAS	0.0033b	0.0041de	0.0177c	0.0419cd
10.0 cm depth of flooding at 7 DAS	0.0033b	0.0054cde	0.0107de	0.0125e
10.0 cm depth of flooding at 14 DAS	0.0039b	0.0060bcde	0.0100e	0.0118e
10.0 cm depth of flooding at 21 DAS	0.0041b	0.0037e	0.0091e	0.0123e

In column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Table 6: Effect of total dry weight (g) of *O. sativa* complex under different times and depths of flooding.

Water depth (cm)	Time of flooding (DAS)			
	7	14	21	28
moist soil	0.0199b	0.0259a	0.0435b	0.1802a
saturated soil	0.2175a	0.0264a	0.0615a	0.1792a
2.5 cm depth of flooding at 0 DAS	0.0096b	0.0138b	0.0247c	0.1131bc
2.5 cm depth of flooding at 7 DAS	0.0086b	0.0109bc	0.0255c	0.0764bcd
2.5 cm depth of flooding at 14 DAS	0.0090b	0.0123bc	0.0276c	0.0664bcd
2.5 cm depth of flooding at 21 DAS	0.0066b	0.0107bc	0.0248c	0.0532cd
5.0 cm depth of flooding at 0 DAS	0.0090b	0.0098cde	0.0256c	0.0845bcd
5.0 cm depth of flooding at 7 DAS	0.0083b	0.0088cde	0.0295c	0.0828bcd
5.0 cm depth of flooding at 14 DAS	0.0075b	0.0116bc	0.0280c	0.0849bcd
5.0 cm depth of flooding at 21 DAS	0.0077b	0.0102bcd	0.0253c	0.1411bcd
10.0 cm depth of flooding at 0 DAS	0.0058b	0.0065de	0.0236c	0.1284ab
10.0 cm depth of flooding at 7 DAS	0.0056b	0.0085cde	0.0133d	0.0180d
10.0 cm depth of flooding at 14 DAS	0.0070b	0.0094cde	0.0124d	0.0150d
10.0 cm depth of flooding at 21 DAS	0.0078b	0.0063e	0.0112d	0.0159d

In column, means followed by a common letter are not significantly different at the 5% level by DMRT.

DISCUSSIONS

Germination was significantly reduced by the flooding particularly treated in 10.0 cm water depths at 0 DAS which could submerge the weeds seed. Therefore, this condition could reduce seed germination and inhibited weedy rice growth particularly in controlling the weeds in the ricefields especially when applied during the early growth stages (7 DAS). This study revealed that moist and saturated conditions created a conducive condition for the germination of seeds. Similar result was reported by Pane (1997) for *Leptochloa chinensis*. Besides, Bhagat *et al.* (1996) reported that moist or saturated soils favour the emergence of grasses and sedges. Once established, these weeds are difficult to control by flooding. However, flooded conditions during and after transplanting or wet seeding (broadcasting of sprouted seeds) suppress grasses, but encourage sedges to dominate (De Datta 1981; Mabbayad *et al.* 1983). The amount of weeds emergence in submerged plots was about 30% of that in saturated plots (moisture content 80%–90%) and as low as about 17% of that in upland plots (moisture content of 40%–60%) (Arai *et al.* citing in Bhagat *et al.* 1996). The amount of water also influences the periodicity of weed germination because many weeds cannot germinate under flooded conditions. Excessive water in the soil serves an effective means of weed control (De Datta 1981). Therefore, maintenance of a few centimeters of water over soil surface can thus be used to suppress weed emergence in rice soils (Bhagat *et al.* 1996).

The flooding of ricefields is the most effective cultural practice for weed control. A continuous water depth of (7.5 cm to 15.0 cm) prevents the germination of most weed seeds and kills the majority of weed seedlings which emerge, while improving the effectiveness of rice herbicides and allowing crop competition to aid in weed management. In addition, continuous submergence to 5.0 cm depth resulted in a minimum number of grassy weeds (Venkataraman & Gopalan 1995). Maintaining a water depth of 6 to 8 inches for 21 to 28 days after planting can provide partial control of *Echinochloa crus-galli* (Monaco *et al.* 2002). While the flood provides weed control and its primary action is to stop weed seed germination. Although the flood will control some actively growing weeds, most weeds will survive if they have grown taller than depth of flood (Kendig *et al.* 2003).

Flooding is an important factor in delaying seedling emergence and minimizing weed populations in ricefields (Moody & De Datta 1982; Kent & Johnson 2001). Smith and Fox (1973) observed that few or no seedlings of *E. crus-galli* emerged when the soil was flooded. Seeding depth and flooding reduced germination, survival and growth of *E. glabrescens* (Diop & Moody 1989). However, from observation showed that once weedy rice became established at 21 DAS and 28 DAS, 5.0 cm flooding depth has less effect to control this weed. Constant flooding to a depth of 10.0 cm could check the build-up of weedy rice. Therefore, it is recommended that 10.0 cm flooding depth was applied and apparently more effective.

The biomass of weedy rice was significantly decreased when flooded with 5.0 cm and 10.0 cm water depth. This finding is similar to that of Bernasor and De Datta (1983), who reported that water depth of 7.5 cm gave less weed biomass and yield higher than 2.5 cm. From this study, when flooding was delayed until 7 days, the growth of seedlings was not affected by 2.5 cm water depth. In the field situation, as the time of flooding was delayed the chances of survival increased and more water was needed until the seedlings submerged and kill the weeds. Similar results have been reported for *Digitaria setigera* and *Cyperus iria* by Civico and Moody (1979). Therefore, the time of flooding after rice seeding affects weed emergence. *E. glabrescens* was found to dominate when flooding of the ricefield was delayed for 5 days to 10 days after seeding. Also, delay in flooding for up to 12 days increased the density and dry weight of *E. glabresecens* and significantly decreased the yield of wet-seeded rice (Drost & Moody 1982). Ismail and Hossain (1996) also studied when flooding was delayed, the dry weight of the seedlings *E. crus-galli*, *E. colona*, *Ludwigia hyssopifolia*, *C. iria*, and *Rhyncospora corymbosa* were greater than when flooded with 10.0 cm water depth was done immediately after transplanting. The results of this study emphasize the importance of early flooding for the suppression of weedy rice in direct-seeded rice. Hence, appropriate water management particularly on timing and depth of flooding are necessary prerequisites in controlling weed growth in ricefields weed management.

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