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Effects of early-inundation and water depth on weed competition and grain yield of rice in the Central Plains of Thailand

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Abstract

Rice production is often limited by weed competition. The use of herbicides has aggravated this effect due to the occurrence of herbicide resistance in weeds. This study was conducted to determine the effect of depth of early-inundation and weeding at a critical competitive stage (i.e. between maximum tillering and panicle initiation) on rice-weed competition and grain yield.

Factorial combinations of five depths of water (viz. 0, 2, 4, 6 and 8 cm) and two weeding regimes (unweeded and weeded at a critical competitive stage) were tested together with herbicide based weeding in a randomized complete block design.

The population of rice did not differ between herbicide-based and submerged treatments. The population of grass and sedge weeds decreased significantly with increasing water depth, while broadleaf weeds declined at 6 cm depth. In the submerged treatments, dry matter of broadleaf weeds decreased from 1.4 kg/m^2 at zero cm to 0.01 kg/m^2 at 8 cm depth.

The number of effective tillers per plant was higher with submergence between 2 and 6 cm, but decreased outside this range. The grain yields were 4.1 t/ha in herbicide treated plots. In submerged plots, weeding had little effect (4.1 - 4.4 t/ha), while grain yields were 0 -4.4 t/ha when unweeded and with increasing depth of water.

Keywords: time of inundation, depth of water, rice weeds, water management.

Introduction

The competition of weeds often reduces rice yield. Losses due to weeds in rice have been estimated in several rice-producing countries: India (10%) (De Datta, 1980); Philippines (13%) (Smith, 1983); In general the losses amount more than 15% annually in the U.S. (Smith et al., 1977) and 10% in the world (De Datta, 1980). Time of weed competition is one of the main factors that affects crop yields in many crops. Greater yield losses can occur at times when weed competition coincides with the critical periods of growth of crops (Carbonell, 1982). Over the past decade, scientists have both assessed previous weed control methods and developed many weed control approaches for rice, some of which include tillage, crop rotation, water management, and herbicides, etc. However, no single weed management strategy has so far been successful in solving all weed problems in rice. Weed scientists have attempted to integrate many methods with emphasis on managing rather than eradication of weeds.

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Management of water level in rice field is one of the most successful methods traditionally used by the rice farmers. Williams (1987) in California reported that the level of water in rice field to 5-7 cm prevented the growth of major weeds in rice, but yields were only about 70% compared to herbicide methods. He reported that flooding was the most effective cultural control method of weeds in rice, and flooding to a depth of 10cm had prevented germination of most weed seeds and killed majority of weed seedlings.

Weeds acquire competitive advantage over rice by early germination and emergence along with the crop and growing together. Therefore, transplanting of 14 to 28 day old seedlings followed by field submergence to 10 to 15 cm in depth is practised by rice farmers over generations to suppress weed seed germination and emergence. This method increases cost of production due to nursery management, and uprooting, bundling, transportation and transplanting of seedlings in the field, all to be done manually. Transplanting itself requires approximately 30-40 labour days when compared to broadcasting. Early germination and emergence of weeds curbs the use of low cost direct seeding rice, and which has been resolved with the development of pre-emergence herbicides. However, the use of herbicides has been alarmed with the discovery of herbicide resistant weed ecotypes: herbicide resistant barnyard grass *(Echinochloa crus - galli)* to propanil in Greece (Giannopolitis and Vassiliou, 1989), USA (Baltazar and Smith, 1994) and Sri Lanka (Marambe et al., 1997); and to butachlor and thiobencarb (Huang and Gressel, 1997); jungle rice *(Echinochloa colona)* to propanil in Colombia and Costa Rica (Fischer et al., 1993; Valverde, 1996). This has opened up the needs for developing other sustainable weed management methods for direct seeded rice.

Rice being adapted to submerged environments, the seed germination and emergence would take place even at some water depths. This would provide opportunities to suppress weeds by direct seeding rice in plots impounded with water. This has the potential to eliminate weeds, and thereby avoiding rice-weed competition, and help rice farmers to avoid extra costs incurred on early weed removal, while minimizing or preventing the herbicide pollution of water and the environment. However, there was no information found in the literature related to attempts of suppressing weeds in broadcasted rice.

This study was undertaken to develop a water management-based weed control method for broadcasted (direct seeded) rice. The specific tasks were to determine, a) the depth of water at which rice seeds could germinate and establish a vigorous crop, b) the type and density of weed species that could emerge and compete with rice at different water depths, and c) the growth and development and grain yield of rice at different water depths.

Methodology

This experiment was conducted in Pathumthani, Thailand, during January 2001 to May 2001, and the site is located at $14^0$14'N latitude, longitude $100^0$30'E and elevation of 2.27 m AMSL. Soil type is poorly drained hydromorphic alluvial soils with pH around 6.2. Rainfall in the area is unimodal, and which comes during April to August period. Mean annual rainfall is about 1200mm.

a. Preliminary study:

A preliminary study was conducted in the laboratory. One-hundred seeds each of the rice variety SP90 were kept in beakers at 5 different water depths, viz. 0, 2, 4, 6, and 8cm, and replicated three times. The number of seeds germinated and emerged was counted and percent germination and emergence was computed.

2.2 Field study:

In a split plot deign with three replicates, five water depths (viz. 0, 2, 4, 6 and 8 cm) (assigned to main plots) and two weeding regimes (viz Unweeded and weeded at 35 days after seeding – DAS) (assigned to sub-plots) were tested together with a herbicide based weed control treatment (control). Field was plouged and harrowed, and concrete hume pipes (diameter of 100 cm and 50 cm in height) were buried and leveled with the rest of the soils. Water levels were adjusted by removing the soil from the surface of the hume pipe to the required depth. Basal dressing at the rate of 30 kg N/ha and 37 kg P/ha using diammonium phosphate (16-20-00) was applied and mixed with the soil, and pre-soaked and sprouted seeds of Saphan Buri 90 rice variety were broadcasted into standing water at different levels. At 14 DAS, excess seedlings were thinned out to maintain 75 plants per m^{2}. At 21 DAS, the surrounding area of the rice plots were transplanted with 21 day old rice seedlings. Weeds in the control plot was controlled using butachlor.[N-(butoxymethyl)-2-chloro-2',6'-diethylacetanilide] at the rate of 3.0 kg a.i./ha.

Plots were top dressed with N at the rate of 16 kg/ha at 40 DAS using urea. Pest control was by manual and pesticide methods. The water level in each hume pipe was maintained by pumping water.

Data collection and analysis

Weed counts at 21 DAS as well as at harvesting was recorded. Weed types, i.e. grasses, sedges and broadleaves were separately counted and recorded. At 35 DAS, weed dry weight was recorded. The number of effective tillers per hill and yield and its components were also recorded at harvest.

Analysis of variance (ANOVA) was performed for recorded data, and means were separated using Fisher's protected least significant difference method (Steel and Torrie, 1980).

Results and Discussion

Results

Percent Seed Germination

The preliminary study showed that germination of rice seeds was 100% at both zero and 2 cm water depths, but decreased to 80% with increasing water depths to 4 cm (Fig. 1). Further decrease of water depth to 6 and 8 cm lowered seed germination to nearly 70% and lower, respectively.

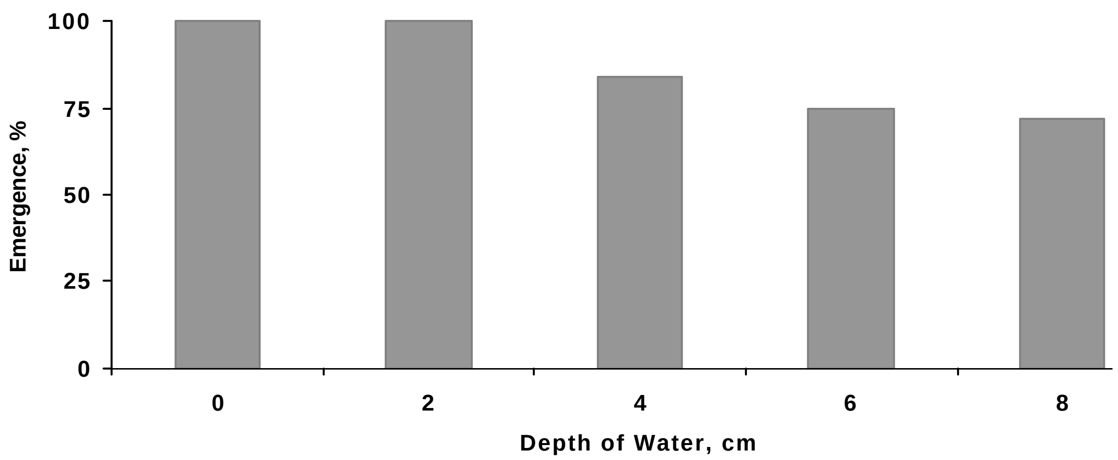

Fig 1. Effect of depth of water on percentage emergence of rice in the preliminary study.

Density of rice

The density of rice seedlings was 269 plants/m^{2} in herbicide treated plots, while it was slightly greater (301 plants/m2) in plots with 0 cm water depth (Fig. 2). The density of rice significantly increased with increasing water depth to 2, 4 and 6 cm, but decreased at 8 cm depth. The decreased density at both herbicide treated and 0 cm depth was attributed to bird damage to seeds as they were exposed. Increased depth of water to 4 and 6 cm gave a protection from the bird damage, which increased the survival of seedlings. The decreased density at 8 cm was due partly to lower anchorage with the soil, but it was later improved with lowering the water level for a few days.

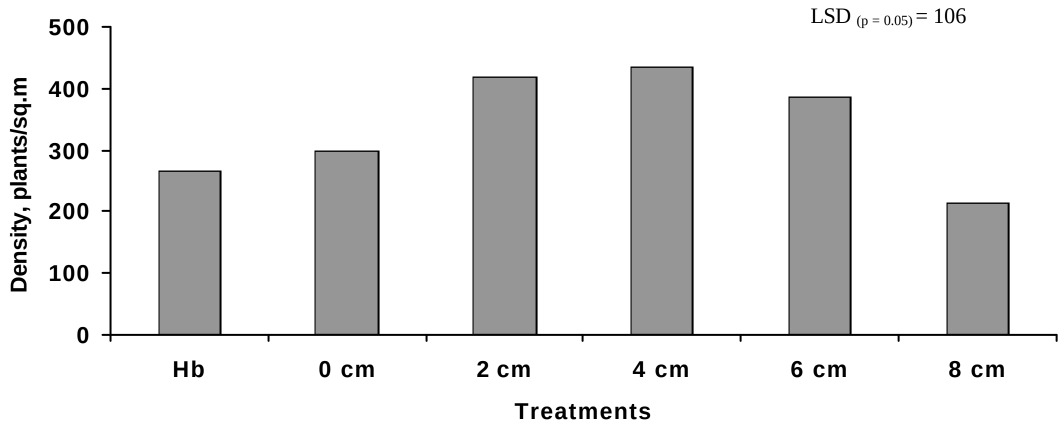

Fig. 2. Effect of water depth on the density of rice.

Density of weeds

Density of weeds at 21 DAS showed no weeds in herbicides treated plots, but had higher weed density in plots having 0 cm water depth (Fig. 3). There were all three weed types in the plots maintained at 0 m water depth. Increasing the water depth to 2 cm reduced the grass density to 6 weeds/plot, while further increase significantly suppressed grass population. The sedge density was suppressed by more than 75% when the water depth was increased to 2 cm and to a very few weeds/m^2 at 8 cm depth. However, the population of broad-leaf weeds showed a significant reduction only at 8 cm water depth. The dominant grass weed was barnyard grass (*Echynocloa crus-galli*), while the broad leaf weed was mainly the *Sphenoclea zeylonica*. There were no weeds until 14 days, but when the water level was lowered in all plots for three days, particularly to promote the anchorage of rice roots in 8 cm water depth, it induced the germination of weed seeds. Although there were large numbers of weeds, they were very tiny even at 21 DAS. Up to 14 DAS, there were no weeds in all plots, except those had 0 cm water depth. This indicated that germination of weed seeds could be suppressed by water management so long as the soil is kept inundated.

Weed dry weight

Herbicide treated plots did not have weeds even at 35 DAS (Fig 4). Combination of inundation with herbicide as used by the farmers caused a overall suppression of weeds. All three types of weeds offered a severe competition at 0 cm water depth. However, increasing the water depth to 2 cm and above lowered weed dry weight. The highest reduction was in the 8 cm water depth. Major contributor to the dry matter was *Sphenoclea zeylonica,* while *Echinocloa crus-galli*, was the second highest. There was a few sedge species, namely, *Cyprus iria* and *Fimbristylis* species among the sedges. Although weed densities were very high, their growth was very much lower, which is displayed by figures 3 and 4.

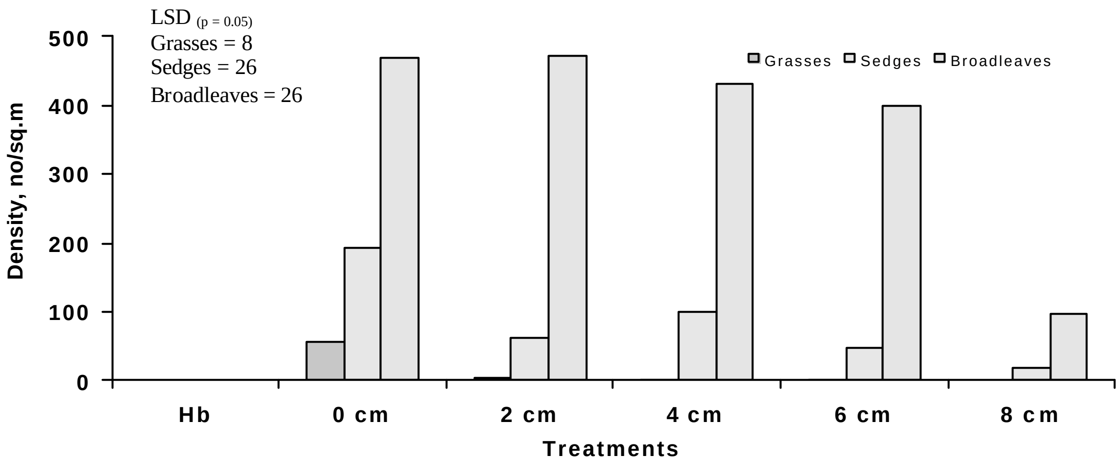

Fig. 3. Effect of water depth on density of different weed types.

Yield and its components of rice

The effective tiller number (i.e. tillers bearing panicles) ranged from one to 3 per plant (Fig 5). Herbicide treated plants had a mean tiller number of 2 per plant. There was a total crop failure (no effective tillers produced) in plots maintained at 0 cm water depth without weeding at 35 DAS. Effective tiller number per plant increased with increasing water depth up to 6 cm (3 tillers/plant) and decreased with further increase. In plots weeded at 35 DAS, effective tiller number remained constant until 6 cm water depth, and decreased at 8 cm depth as observed in unweeded plots.

There were 40 grains per panicle in herbicide-treated plots, where as no grains in plots that had 0 cm water depth and left unweeded during the complete life period (Fig 6). The grain number per panicle significantly increased with increasing water depth until 4 cm. Further increases in water depth did not increase the grain number per panicle. Plots that were weeded at 35 DAS showed no difference in grain number per plant with increasing water depth from 0 to 8 cm.

The 100-grain weight did not significantly differ among treatments. It varied from 2.2 g in the water management treatments to 2.6 g in herbicide treatment. However, there was a total crop failure in the plots that had 0 cm water depth and no weeding adopted at 35 DAS.

The grain yield in herbicide treatment was 4.1 t/ha (Fig 7). There was no grain yield produced by the treatment that had water depth of 0 cm and unweeded at 35 DAS. This was because of severe competition from weeds on rice. However, when the plot was weeded at 35 DAS the rice plants recovered, and hence resulted with a grain yield of 4.0 t/ha, which was not significantly different from yield of the herbicide treatment. Without weeding and increasing the water depth up to 8 cm increased the grain yield up to 4.3 t/ha, but significant increases were found only up to 6 cm (4.26 t/ha). On the other hand weeded plots at 35 DAS resulted in producing yields ranging from 4.0 t/ha (at 0 cm water depth) to 4.4 t/ha (at 8 cm water depth).

Discussion

Water management in rice for the purpose of weed control is a traditional practice among rice farmers. The farmers usually broadcast pre-germinated rice seeds after draining water in the field in order to provide the opportunity to the rice seedlings to emerge and establish. Impounding water in the rice field is usually adopted about a week after broadcasting, in order to ensure that the rice seedlings have reached a height that impounding would not interfere with the growth and development of the rice crop. The period when the soils in the field is exposed to atmosphere and solar radiation facilitate the germination of weeds seeds and emergence of seedlings that offer a severe competition on rice so that both tiller and leaf area production are suppressed. This affects the overall productivity of rice crop. Although, germination of new weed seeds is prevented by subsequent inundation, initial weed population would exert an adequate competition and weaken the rice crop in numerous ways: competition for plant nutrients, sunlight and space (Vega and Paller, 1970) and with allelopathic effects (Smith, 1983), etc. These effects may cause difficulties for the rice plants to acquiring necessary growth resources during later stages and critical growth periods.

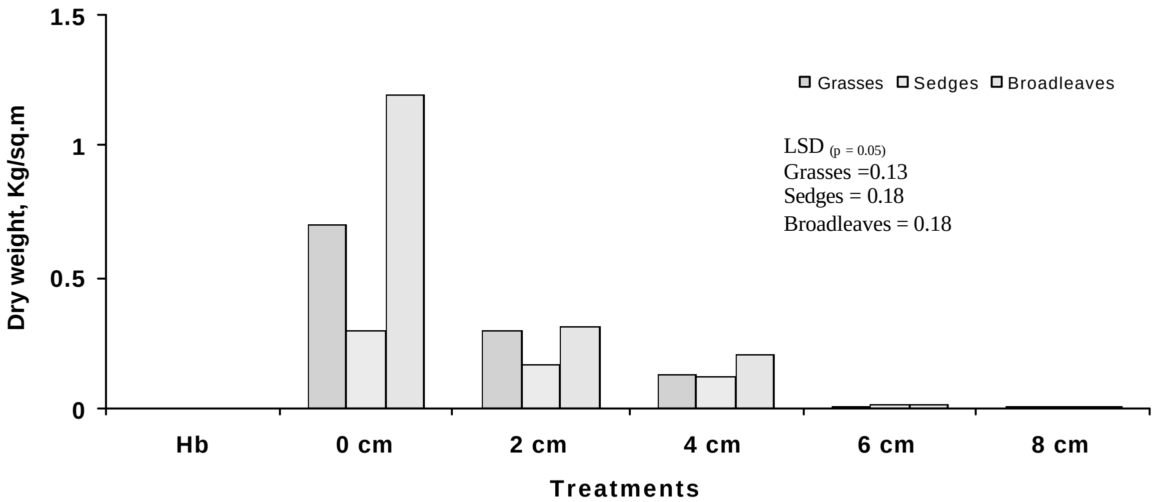

Fig. 4. Effect of water depth on dry weight of different weed types at 35 days after seeding.

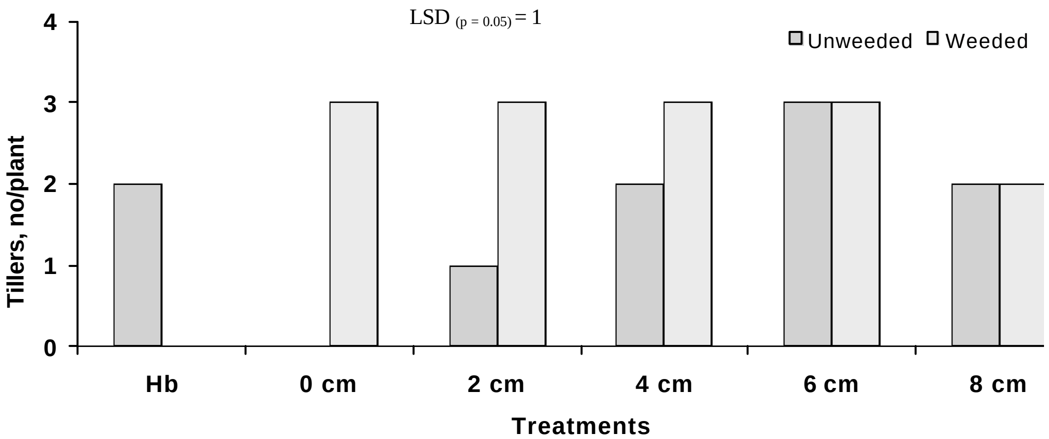

Fig. 5. Effect of water depth and weeding at 35 days after seeding on effective tiller number per planting hill at harvest.

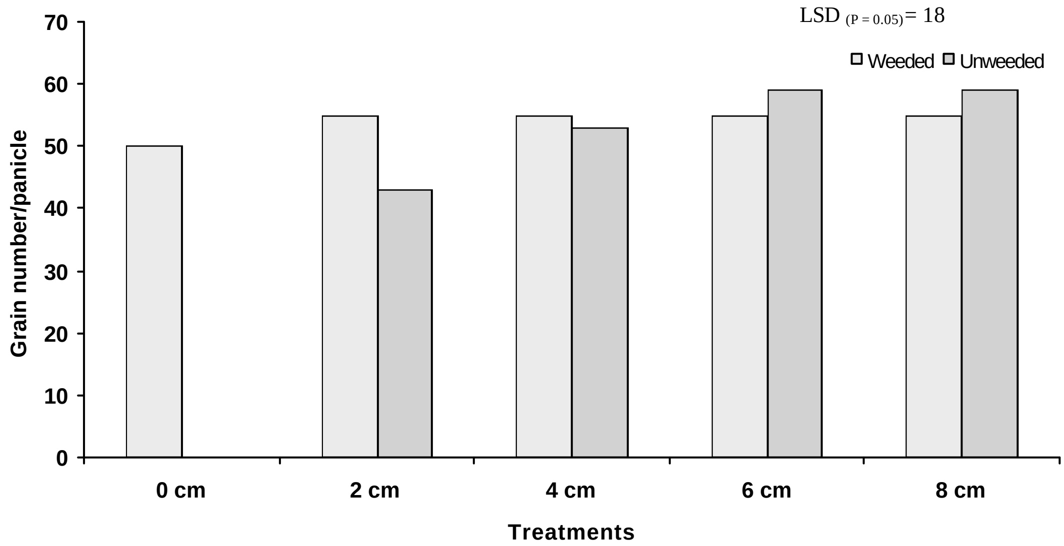

Fig. 6. Effect of water depth and weeding at 35 days after seeding on grain number per panicle at harvest.

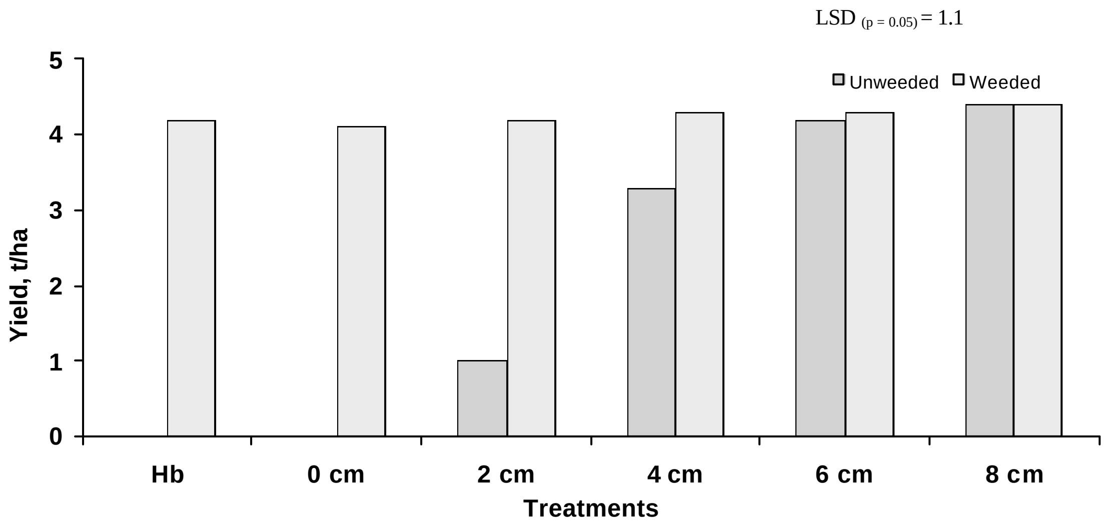

Fig. 7. Effect of water depth and weeding on grain yield of rice.

Increase in grain yield with decreasing weed competition has previously been reported (Noda et al., 1968). Podkin et al. (1983) have reported that sowing rice seeds to flooded fields with a water layer of 10-12 cm deep and then draining out water at the beginning of seed germination could avoid the competition from grass weeds. In this method, germination and emergence of rice seeds is facilitated by aerated condition, and after seedling emergence the field is re-inundated to avoid weed emergence. However, this practice too facilitates weed seed germination and weed emergence along with rice seedlings, and hence nullify the expected advantage. The current studies avoided weed emergence along with rice seedlings, thereby avoiding early and prolonged rice-weed competition.

The Decrease in the growth and tiller production has been reported with increasing water depth (Arai et al., 1954), its effects on the productive tiller number and grain yield have not been prominent until 6 cm depth. This may take place beyond 6 cm as experienced in the current study with 8 cm water depth. Weeding has not played a major role at 6 cm depth of water as shown in figures 5, 6 and 7.

This study revealed the possibilities and its advantage for suppressing weeds from the beginning of the rice crop. Although herbicides suppress weeds effectively, the development of resistant weeds create secondary problems . (Giannopolitis and Vassiliou, 1989; Baltazar and Smith, 1994; Marambe et al., 1997; Huang and Gressel, 1997; Fischer et al., 1993; Valverde, 1996. Inundation of plots to 4 to 6 cm depth and broadcasting pre-sprouted seeds provided an answer to nursery management and transplanting and herbicide resistant population build up, and increases in the cost of production in the rice sector.

It could be concluded that broadcasting pre-germinated rice seeds after inundation the field to an approximate depth between 4 and 6 cm, and maintaining the water level continuously help the farmer to minimize rice-weed competition and harvest about 4.3 t/ha of grains. In situations with post emergent weeds, weeding at 35 DAS while impounding water to a depth of 6 cm would minimize weed growth and its competition, thus increasing the rice grain yield. This provides an opportunity for cost-effective weed control to farmers in areas where water is abundant or during rainy seasons to reduce rice-weed competition.

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