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Ludwigia hyssopifolia emergence and growth as affected by light, burial depth and water management

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ABSTRACT

Experiments were conducted to evaluate the effects of light, seed burial depth, and flooding on germination, emergence and growth of *Ludwigia hyssopifolia*. Germination was strongly stimulated by light, suggesting that seeds of this species are positively photoblastic. Seeds sown on the soil surface gave the greatest percentage of seedling emergence in plastic trays, and no seedlings emerged from seeds buried in soil at depths of $\geq$1 cm. Intermittent or shallow flooding suppressed emergence and growth of *L. hyssopifolia*. Flooding to a depth of 2 cm for 4 days out of 7 days reduced seedling emergence by more than 71% and seedling dry matter by 97% compared to where the soil had not been flooded. Flooding up to a depth of 10 cm however, when delayed to 21 days after sowing, did not significantly suppress growth of this species. This study illustrates the role of seed burial by tillage and flooding as two important tools for the management of *L. hyssopifolia*.

1. Introduction

Germination and emergence of weed species are influenced by several factors including seed burial depth, soil moisture, and light (Chauhan and Johnson, 2008a,b). A better understanding of the germination ecology of problem weed species could help define more precise management interventions for a particular species and facilitate development of effective weed control options. Light requirement for germination, for example, is the principal means by which germination may be restricted to an area close to the soil surface and species requiring light for germination are potentially more likely to be prevalent in reduced or minimum tillage systems. Similarly, knowledge on seedling emergence in relation to soil depth could contribute to the use of tillage systems to reduce emerging weed seedlings. Flooding has long been recognised as the principal means of cultural weed control in lowland rice (Rao et al., 2007). Timing, duration, and depth of flooding however govern the extent of suppression of a weed species by water (Civico and Moody, 1979; Hill et al., 2001). Flooding in the rice field can be continuous, intermittent or deep, depending on rainfall, the availability of irrigation water and the degree of land leveling in the field. The potential of flooding as a component of integrated weed management strategies could be enhanced if the response of weed species to flooding were better understood.

Ludwigia hyssopifolia (G. Don) Exell, Onagraceae, is an erect and annual herbaceous, marshy, or aquatic plant grows up to a height of 1 m (Holm et al., 1997; Johnson, 1997). It is a serious weed of rice in many countries, including India, Malaysia, Philippines, and Sri Lanka (Holm et al., 1997; Moody, 1989). In Asia, irrespective of water level, this weed has been observed season long in both direct-seeded rice as well as transplanted-rice fields (Tomita et al., 2003). Recently, *L. hyssopifolia* has been reported to occur in seven countries in dry-seeded rice and six countries in wet-seeded rice (Rao et al., 2007). In addition to occurring in the crop fields, the weed is also known to frequent pools, shallow ditches, and river edges. Pancho (1964) reported that a single plant of *L. hyssopifolia* grown in rice in the Philippines may yield 75,000 seeds, with 16,000 seeds per g. The seed of *L. hyssopifolia* is about 0.5–0.75 mm long (Holm et al., 1997).

L. hyssopifolia is similar in appearance to two close relatives, *Ludwigia perennis* L. and *Ludwigia octovalvis* (Jacq.) Raven, and young plants may easily be confused until in flower. These species are all weeds of transplanted and direct-seeded rice systems in Asia and Africa (Moody, 1989; Rao et al., 2007). *L. hyssopifolia*, *L. perennis* and *L. octovalvis* can all be problem weed species particularly where the soil is subject only to intermittent flooding in the early stages of the crop. The former species is thought to be an increasing problem in many systems. *L. hyssopifolia* has the C_3 photosynthetic pathway, while some grass and sedge weeds of rice, such as *Echinochloa*

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crus-galli (L.) Beauv., *Echinochloa colona* (L.) Link and *Fimbristylis miliacea* (L.) Vahl are C_4 and hence may be more competitive with rice under conditions of high light, temperature and drought stress (Sage, 2000). Drought however is commonly avoided in lowland rice which may account for why *L. hyssopifolia*, and other C_3 weeds remain competitive with C_4 weeds and with rice (C_3).

This study was conducted to examine the effects of light, seed burial depth, and flooding time, duration and depth on germination, emergence and growth of *L. hyssopifolia*. The results may provide information on the importance of water management in the control of this weed or other species occupying similar ecological niches.

2. Materials and methods

Experiments were conducted in 2007 and 2008 at the International Rice Research Institute, Los Baños, Philippines. Seeds used in this study were collected in November 2007 (first population) and June 2008 (second population) from plants of *L. hyssopifolia* growing as a weed in the transplanted-rice fields around Los Baños (approximately 5 km^2). The crop at the time of seed collection was at maturity stage. For each population, branches of at least 50 plants were spread out on a bench in a greenhouse for 2 d to dry before the seeds were dispersed by shaking the plants. Seeds were cleaned and stored at room temperature (25 °C) until used in the experiments. All experiments were conducted twice with seeds of each population.

2.1. Effect of light on seed germination

Twenty-five seeds were placed in a 9-cm diameter Petri dish containing two layers of Whatman No. 1 filter paper and 5 ml of distilled water. The dishes were then incubated in a growth chamber at 30/20 °C alternating day/night temperature in two light regimes [light/dark (12 h/12 h) and continuous dark (24 h)] with the higher temperature corresponding to the light phase. In a preliminary experiment, the selected temperature was found optimal for seed germination of *L. hyssopifolia* (data not shown). Dishes in the continuous dark treatment were wrapped in double layers of aluminium foil. Germination was determined after 14 d of incubation, at which time the seeds with emerged radicals were considered to have germinated.

2.2. Effect of soil moisture and seed burial depth on seedling emergence

Fifty seeds were sown on the soil surface in plastic trays, and soil moisture was maintained in saturated (water level at soil surface) or aerobic-moist (water level 2 cm below the soil surface) condition. The trays were then placed in a screenhouse (frame building with 2-mm steel mesh sides and overhead transparent plastic cover to prevent rain damage). Sterilized soil with a pH of 6.3 and organic carbon of 0.9% was used in the experiment. Seedling emergence, defined as the appearance of the coleoptile, was counted 28 d after sowing. In another experiment, the effect of seed burial depth on seedling emergence was determined by placing 50 seeds on the soil surface or at depths of 0.5, 1, and 2 cm in plastic trays. The soil moisture was maintained at saturation level in this experiment, and the emergence was determined as described above.

2.3. Effect of duration and depth of flooding on seedling emergence and dry matter

Fifty seeds of *L. hyssopifolia* were sown uniformly on the soil surface in plastic trays. The soil used in this experiment was as described above for the soil moisture experiment. The treatments (after Kent and Johnson, 2001) were three flooding durations (2 d out of 7 d, 4 d out of 7 d, and continuous flooding) and four flooding depths (0, 2, 4, and 10 cm). The treatments were intended to simulate intermittent flooding often found in rice fields, particularly those that are rainfed or where the supply of irrigation water is inadequate, and compare these to continuous flooding. The soil in the trays was initially moistened to saturation using a fine-mist spray, and then the trays with the soil and seeds were transferred to large containers to retain water and maintain the required water levels. To ensure uniformity of water quality and maintain the water level, a continuous water flow was installed for all containers. There was minimal soil disturbance in the trays and no water turbidity throughout the experiments. After 28 d, emerged seedlings were counted, harvested, and oven-dried at 70 °C for 72 h for dry-weight measurements.

2.4. Effect of depth and seedling age at time of flooding on seedling dry matter

Seeds of *L. hyssopifolia* were spread on the soil surface in plastic trays and the soil maintained at saturation level until the flooding was given. The seedlings were thinned at 7 days after sowing (DAS) and 10 plants per tray were maintained. The sowing dates were staggered so that all the plants were flooded at the same time. The flooding times of the plants were at 7, 14, and 21 DAS, and the flooding depths were 0 (saturated soil), 2, 4, and 10 cm. The experiment was carried out as described above. Seedling dry matter was recorded 14 d after flooding.

2.5. Statistical analysis

All experiments were arranged as randomized complete-block designs with three replications, and duplicated with seeds of each population. Data of both populations (a total of 12 replications) were combined for analyses of variance, and as results indicated no significant interaction between experiments and treatments the means of experiments and populations are presented. Treatment means were separated using least significance difference at the 5% level of significance. GENSTAT was used for statistical analysis (GenStat 8.0, 2005).

3. Results

3.1. Effect of light on seed germination

Light strongly stimulated germination and in the dark only treatment, germination of *L. hyssopifolia* seeds was completely inhibited. In the light regime, seeds germinated to a level of $97.7 \pm 0.8\%$.

3.2. Effect of soil moisture and seed burial depth on seedling emergence

Seedling emergence from surface-sown seeds was similar ($P > 0.05$) whether the soil was aerobic-moist ($83.5 \pm 1.9\%$) or saturated soils ($85.3 \pm 2.3\%$). Seed burial depth, however, greatly influenced seedling emergence. The greatest proportion of seeds emerged (84%) from those placed on the soil surface (Fig. 1) and emergence decreased sharply with increasing burial depth. No seedlings emerged from soil depths of 1 cm or greater.

3.3. Effect of duration and depth of flooding on seedling emergence and dry matter

An increase in the duration and depth of flooding significantly reduced ($P < 0.05$) emergence and dry matter of seedlings. Germination in the saturated soil was greater than 95% (Fig. 2).