# LATITUDINAL DIFFERENTIATION IN HEADING PHOTOPERIOD SENSITIVITY AND SEED DORMANCY OF *ECHINOCHLOA ORYZICOLA*, AN OBLIGATE WEED IN FLOODED RICE

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*Summary.* Latitudinal differentiation in heading photoperiod sensitivity and seed dormancy of *Echinochloa oryzicola*, an obligate weed in flooded rice, was studied by treating plants of the strains from seven countries with 8, 12 and 16 h photoperiod, and by submerging seeds in water at 4°C. Strains from countries in lower latitudes such as Sri Lanka, Bangladesh and Taiwan headed even under 16 h photoperiod and were identified as having weak photoperiod sensitivity. Strains from countries in higher latitudes had strong photoperiod sensitivity and did not head under the long photoperiod, except for a strain from northern Japan which was weakly photoperiod sensitive. Seeds of strains from Sri Lanka and Bangladesh showed more than 30% germination after 38 days of submergence, but strains from higher latitudes had a stronger dormancy and exhibited little germination after submergence. The significance of latitudinal differentiation in heading photoperiod sensitivity and strength of seed dormancy are discussed with respect to survival strategies of this obligate weed in flooded rice.

## INTRODUCTION

*Echinochloa oryzicola* Vasing. (= *E. phyllopogon* Stapf) is an obligate weed in flooded rice and is widely distributed over temperate and tropical regions of the world (1,3,6,9). It has various characters adaptive as a weed in flooded rice, including its morphological mimicry to rice (1,9), anaerobic seed germinability in flooded soil (4,5,7,9,12), dormancy-germination pattern of soil-buried seeds synchronizing to soil condition in the crop (7,12).

Moreover, *E. oryzicola* is well known to exhibit a geographical cline in heading time in Japan (8,9,10). Heading time of the weed as well as that of rice becomes earlier as the latitude increases, and the time when a local population of the weed initiates heading coincides the heading time of the rice cultivar planted. The coincidence of heading times between crop and weed is an important survival strategy for the weed to escape from hand weeding. Objectives of the experiments reported herein were to study latitudinal differentiation of *E. oryzicola* in heading photoperiod sensitivity and strength of seed dormancy in 12 strains originating in several temperate and tropical countries.

## METHODS

<u>Plant materials</u>. Seeds of 12 strains of *E. oryzicola* supplied by Drs. N. U. Ahmed, L. S. Leu, S. Matsunaka and T. Yabuno were planted in mid July at our experimental field in Kyoto under a natural day length and their identities were confirmed according to Yabuno (9).

<u>Photoperiod sensitivity in heading</u>. Germinating seeds of each strain at 25°C were planted in late July in 1/5,000 are pot and thinned to 3 plants per pot with three replications. They were treated with 8, 12 and 16 h photoperiods in three identical growth chambers at 25°C and 70% relative humidity. Natural day length exceeded 9 h during the experimental period until mid November.

Then, only natural light was used for the 8 h treatment (7:00-15:00). Both natural light and supplemental light (177 µmol/sec/m$^2$) were used for the 12 and 16 h treatments.

Depth of seed dormancy. Plants of each strain were grown under a natural day length in Kyoto. The plants headed from late July to mid September, depending on the strain. Seeds maturing within a month after initial heading were collected, air-dried for 10 days under a room condition, and stored with silica gels at -21°C for maintenance of seed dormancy. Submergence was initiated in late December by placing 20 seeds into a 20 mL bottle with 3 mL of distilled water at 4°C in the dark. Germination of the submerged seeds were periodically tested at 30°C in the light, and the percentages were used as a criterion for the strength of seed dormancy. The experiment was conducted with three replications.

## RESULTS AND DISCUSSION

Photoperiod sensitivity in heading. All of the strains of *E. oryzicola* used appeared to be short day plants. They had an optimum photoperiod for heading at either 8 or 12 h, with heading delayed or prevented at the 16 h photoperiod (Table 1). Strains which headed at 16 h were those from Sri Lanka, Bangladesh, Taiwan and Kamikawa (Japan). There was a negative correlation between the latitudes of original collection sites and the duration from planting to heading under a photoperiod at 12 h ($r=-0.823$, $n=11$, $P=0.01$).

The photoperiod sensitivity of rice cultivars is often determined by the durations of basic vegetative phase (BVP) and photoperiod sensitive phase (PSP), as described elsewhere (13,14). We arbitrarily adopted this concept and calculated the BVP and PSP for each strain of *E. oryzicola* (Table 1). Strains from lower latitudes such as Sri Lanka, Bangladesh and Taiwan had BVP values from 16 to 24 days and PSP from 27 to 36 days, and headed even under the 16 h photoperiod
But strains from higher latitudes such as France, China and Japan had smaller BVP and did not show heading at 16 h, though the one from Kamikawa, Hokkaido District of Japan, showed smaller BVP and greater PSP values as well as heading at 16 h. We classified strains into two groups with weak and strong photoperiod sensitivity in heading. The weakly sensitive strains include those from Sri Lanka, Bangladesh, Taiwan and Kamikawa, whereas the strongly sensitive strains include the ones from France, China, Korea and Japan except the one from Kamikawa.

Seed dormancy. The strength of seed dormancy of *E. oryzicola* was compared among strains by determining germination percentages of the seeds submerged in water at 4°C. Seeds of the two Sri Lanka strains exhibited low germination percentages before submergence and more than 30% germination after 34 days (Table 2). Much greater germination was obtained for seeds of Bangladesh strain with the same duration. Seeds of strains from latitudes at higher than N 30° germinated little before 34 days and reached 50% at either 68 or 111 days. There were negative correlations between the latitudes where strains originated and the germination percentages at 68 days ($r=-0.672$, $n=12$, $P=0.05$). Therefore, we concluded that the strength of seed dormancy increased with latitude in the northern hemisphere.

Table 1. Heading photoperiod sensitivity of various strains of *Echinochloa oryzicola* Vasing

| Country | Collection site | Latitude N° | Photoperiod (hr)[a] | | | BVP[b] | PSP[b] |
|---|---|---|---|---|---|---|---|
| | | | 8 | 12 | 16 | | |
| Sri Lanka (13) | Angunawala | 8 | ND[c] | ND | ND | | |
| Sri Lanka (11) | Gampola | 8 | 45.7 | 71.2 | 81.6 | 20.7 | 35.9 |
| Bangladesh | Dacca | 24 | 41.2 | 53.3 | 68.6 | 16.2 | 27.4 |
| Taiwan | Tauyuen | 26 | 49.3 | 49.3 | 78.6 | 24.3 | 29.3 |
| Korea | Fuyou | 36 | 34.5 | 35.9 | | 9.5 | 100+ |
| China | Beijing | 40 | 32.7 | 35.7 | | 7.7 | 100+ |
| France | Camargue | 47 | 35.2 | 33.4 | | 8.4 | 100+ |
| Japan | Kagoshima | 32 | 36.8 | 31.9 | | 6.9 | 100+ |
| Japan | Nagasaki | 33 | 37.4 | 31.9 | | 6.9 | 100+ |
| Japan | Takatsuki | 35 | 43.1 | 56.7 | | 18.1 | 100+ |
| Japan | Konosu | 36 | 37.5 | 35.2 | | 10.2 | 100+ |
| Japan | Kamikawa | 44 | 29.7 | 29.7 | 76.8 | 4.7 | 47.1 |

[a] The values shown are the mean numbers of days after planting with three replications. Standard errors of the means were smaller than 2.0.

[b] The BVP and PSP are the duration of the basic vegetative and photo sensitive phases in days.

[c] Not determined.

Table 2. Germination percentages of the seeds submerged in water at 4°C

| Country | Latitude N° | Germination percentage after submergence[a] | | | | |
|---|---|---|---|---|---|---|
| | | 0 | 34 | 68 | 111 | 161 |
| Sri Lanka (13) | 8 | 7.5 | 31.7 | 79.3 | 51.7 | 85.9 |
| Sri Lanka (11) | 8 | 2.5 | 36.7 | 71.7 | 59.5 | 91.1 |
| Bangladesh | 24 | 51.0 | 87.3 | 94.0 | 24.0 | 25.6 |
| Taiwan | 26 | 0.0 | 4.0 | 39.0 | 89.0 | 98.0 |
| Korea | 36 | 0.0 | 2.0 | 11.7 | 25.2 | 63.8 |
| China | 40 | 0.0 | 2.0 | 48.7 | 89.2 | 96.3 |
| France | 47 | 2.0 | 1.3 | 25.0 | 70.3 | 94.3 |
| Japan (Kagoshima) | 32 | 1.0 | 6.7 | 45.0 | 48.3 | 70.2 |
| Japan (Nagasaki) | 33 | 3.0 | 1.7 | 37.0 | 44.8 | 50.8 |
| Japan (Takatsuki) | 35 | 7.5 | 6.7 | 32.3 | 39.1 | 40.4 |
| Japan (Konosu) | 36 | 0.0 | 0.7 | 3.3 | 5.3 | 50.5 |
| Japan (Kamikawa) | 44 | 1.0 | 16.7 | 44.7 | 49.6 | 55.3 |
| L.S.D. (0.05) | | 7.9 | 11.1 | 28.3 | 22.7 | 14.8 |

[a] Germination percentages at 30°C for 7 days in the light after the days of submergence indicated.

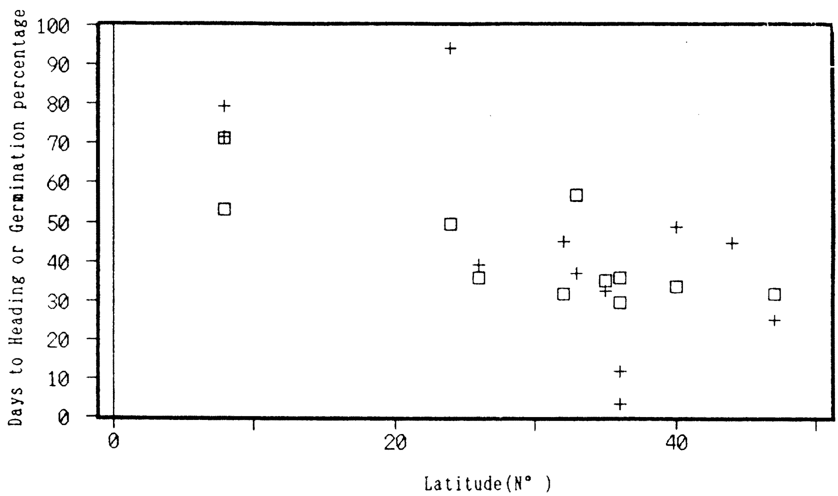


Figure 1. Interrelationship of the heading photoperiod sensitivity at 12 hr (?) and the germination percentages after submergence for 68 days (+) with latitudes of the strains originated.

Photoperiod sensitivity of the rice cultivar planted in a given region is an important determinant to ensure full development and yield from water and temperature stresses at heading and maturity. In most of tropical Asia, rice cultivars traditionally planted had a strong photoperiod sensitivity with heading time coinciding with end of the wet season. But there has been a pronounced reduction in the sensitivity since the extent of irrigation has grown along with the extension of newly bred cultivars since the 1960's (2). The cultivars planted in the northern region of Japan are weaker in photoperiod sensitivity than those planted in the southern region (15). Photoperiod sensitivity of *E. oryzicola* strains used here appears to be in agreement with the sensitivity of rice cultivars where each strain of the weed originated. The strains from France and Kamikawa were classified to be strong and weak in the sensitivity, respectively, though the two collection cites are little different in latitude (Table 1). This is probably related to far higher temperatures in the fall in Camargue. *E. oryzicola* is an obligate weed found exclusively in flooded rice and escapes from hand weeding by means of morphological mimicry before heading (1,9). Yabuno (9) previously pointed out the importance of hand weeding as a selection pressure by verifying a parallel geographic differentiation of Japanese strains in heading time to those of rice.

Seed dormancy is also a significant character for a weed to survive through hostile winter temperatures in a region of high latitude. The weed tended to have stronger seed dormancy in temperate regions. Strains from tropical Asia, where germination temperatures prevail throughout the year, had weaker seed dormancy. In such regions the seeds produced may germinate relatively soon after maturity, with weed infesting fields of flooded rice when water becomes available for germination. Further experiments with a greater number of strains from locations within and between countries and field observation will be required to verify the survival strategies in heading photoperiod sensitivity and strength of seed dormancy of this weed in flooded rice.

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