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Germination Conditions for the Non-dormant Seeds of *Monochoria vaginalis*

Po-Huei Chen[1] and Warren H. J. Kuo[1,2]

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ABSTRACT : Effects of environmental factors on the germination of non-dormant seeds of *Monochoria vaginalis* (Burm.f.) Persil var. *plantaginea* Solms. were investigated. Under anoxia condition the seeds germinated but the subsequent seedling growth was retarded. In hypoxia condition of 6 mm submergence, the seeds germinated readily and the seedlings grew normally. Aerobic condition inhibited germination almost completely. The seeds absolutely required light to germinate. Light intensity saturated at as low as 5 x 10^{-3} mol/m^2/day. No inhibition on germination was found at light intensity of 3 mol/m^2/day. Under waterlogged condition the seeds were prevented from germination by burying in the soil up to 4 mm depth. Percentage germination was inhibited slightly and progressively in deeper depth of soil up to 16 mm, drastically decreased thereafter. Almost no germination occurred at 20 mm depth. No effect of water potential within -0.2 MPa on germination was found. Percentage germination was decreased slightly and progressively between -0.2 to -0.8 MPa, drastically decreased thereafter. The non-dormant seeds germinated well at constant temperature ranging from 22-32℃. Minimum and maximum temperature for germination were approximately 14 and 40 ℃, respectively. Base, optimum and ceiling temperatures of the rate of germination were 12.7, 30.4 and 65.8℃ respectively. Thermal time for 50 % germination was 19.2 and 38.5 degree-day for sub-optimum and supra-optimum temperature respectively. Suitable methods and conditions for germination tests were proposed.

KEY WORDS : ***Monochoria vaginalis*, Seeds, Germination, Temperature, Light, Oxygen, Water potential, Burial depth.**

INTRODUCTION

Monochoria vaginalis (Burm.f.) Persil was listed as a serious weed in six countries, including Indonesia, Japan, and Taiwan (Holm, *et al.*, 1979). Indeed, in Taiwan it is one of the five most serious weeds in paddy field with great damaging capability (Chiang and Leu, 1982). In a recently article, it was rated as a worst weed in Southeast Asia only next to *Echinochloa colona* (Waterhouse, 1993). Although *M. vaginalis* is easily controlled by butachlor during seedling stage (Liu and Tsai, 1986), it remains a serious weed after the extensive use of herbicides. Hence an integrated management (Chiang, 1993) including the application of the knowledge of the seed ecology (Forcella, *et al.*, 1993) should be advanced.

Dormancy cycle of buried weed seed is a major field of seed ecology (Baskin and Baskin, 1985) and a very important factor for successful weed management. Many efforts have been done to investigate the dormancy cycle of the seeds of temperate species. Several patterns of

1. Department of Agronomy, National Taiwan University, Taipei 106, Taiwan, Republic of China.
2. Coresponding author.

dormancy cycle have been proposed (Baskin and Baskin, 1988, 1989).

Although many works on the seed bank ecology of wetland have been documented (Leck, 1989), only a few on seed ecology of paddy weeds were reported. In order to investigate the seed ecology of *M. vaginalis*, the germination requirements of the non-dormant seeds should be established at first. Temperature, light, water and oxygen are the major four environmental factors affecting the germination of seeds both in the laboratory (Bewley and Black, 1994) and in the field (Fenner, 1992). Vast experimental data on this area have been accumulated during past years. However only a few articles contributed to the germination behaviour of the seeds of *M. vaginalis*. Chisaka and Kataoka (1977, cited by Momonoki, 1992) reported that light, low oxygen and ethylene ensured high germination of *M. vaginalis*. Low oxygen requirement was subsequently confirmed by Kataoka and Kim(1978). Morita (1982) illustrated seedling morphology of *M. vaginalis*. Pon (1982) reported the effects of water submergence on the germination of the seeds of *M. vaginalis*. Kim and Mercado (1987) studied the effects of soil burial on seed dormancy and germination, while Momonoki (1992) presented evidences that CO_2 and ethylene promoted germination of dormant seeds of *M. vaginalis*. This article reports some experimental results that can be used to develop germination test methods of this species.

MATERIALS AND METHODS

Seeds

The seeds of *M. vaginalis* (Burm.f.) Persil var. *plantaginea* Solms. were collected on October 1993 from the experimental farm of the National Taiwan University. Empty and/or under-developed seeds were discarded by floating the seed sample in tap water. The remaining seeds were air-dried to about 8.5% wet basis and hermetically stored in a -20 °C chest deep-freeze cabinet.

Non-dormant seeds were prepared either by stratifying the seeds or by burying the seeds. Stratification at 5°C under dark condition broke the dormancy of the seeds of *M. vaginalis* (manuscript in preparation). The non-dormant seeds remained ready germinable for a long period when stored in water of 5°C. Dormancy status of the seeds of *M. vaginalis* changed during burial in the soil. The seeds became non-dormant at February and March (Chen, 1995). Seeds were packed in envelopes made of fine mesh nylon gauze and buried in loam soil of waterlogged condition in November 1993. The depth of burial was approximately 10cm. The buried seeds were exhumed at February 1994, washed, surface blotted and directly taken for experiments.

Germination tests in Petri dish

Except otherwise stated, the following procedures were applied to routine germination tests. Fifty seeds per replicate, four replicates per experiment, were put into 5 cm Petri dish in which two sheets of filter paper were lined and distilled water was added. Ten ml of water were added excepted in the study of gaseous environment. The dishes were then wrapped with one sheet of parafilm and covered to ensure no loss of water during germination test. Germination tests were performed in the incubators of 30/25 °C, with 16 hours of dark period and 8 hours of light period per day. Except in the study of photon dose, light intensity at water surface (6 mm above seed surface) was about 30 μmol/m^2/s, which was provide by

fluorescent tubes. Where dark germination was needed, the dishes were covered by light-proof polyethylene bag.

The seed was considered germinated if the embryo axes had protruded more than 2 mm. The final count was at the 14th day of incubation.

Germination under different gaseous environment

Factorial experiments of both light/dark condition and three levels of aerobic condition were undertaken using stratified non-dormant seeds. Levels of aerobic condition were achieved as followings (Kubota *et al.*, 1994):

(1) aerobic condition: Seeds were laid in the Petri dish with 2ml distilled water and two sheets of filter paper. Water level was below the seed surface.

(2) hypoxia condition: Seeds were laid in the Petri dish with 10ml distilled water and two sheets of filter paper. Water level was 6mm above the seeds.

(3) anoxia condition: Seeds were soaked in a 50ml flask that contained 50ml $Na_2S_2O_4$ solutions at concentration of 0.0364g or 0.1g per litre of water.

Germination under constant temperature

The influences of constant temperature on final germination percentage and germination rate of the stratified non-dormant seeds of *M. vaginalis* var. *plantaginea* were studied by a temperature gradient plate (Murdoch, *et al.*, 1989; Kuo, 1994a,b). Without adjustment of daily temperature shift, the plate provided 14 rows of cells of constant temperature ranging from 16 to 38 °C, with a 1.7 °C increment between two successive rows. The plate was lined with Whatman filter paper. Water level was maintained daily at 2 mm above the seeds to ensure hypoxia condition. A rubber band was put on each cell to confine the seeds in the centre of the cell. Fifty seeds per replicate with four replicates per temperature were tested. Dim light of fluorescent tube was provided 8 hours per day.

Counting of germinated seeds was started at the 12th hours of imbibition. Counting interval was 1 hour for the rapid germination period, and then daily until the 21st day. Mean germination time (MGT) was calculated by the following equation (Ellis and Roberts, 1980) :

(1)

$$MGT = \frac{\sum(t \times n)}{\sum n}$$

where t was the number of incubation days at counting, n was the number of germinated seeds at t day. Mean germination rate was calculated by the reverse of the MGT.

Base temperature or ceiling temperature as well as thermal time (heat sum) of the rate of germination were calculated by the following regression equations (Covell *et al.*, 1986) :

(2)

$$\frac{1}{t} = K_1 + (\frac{1}{\theta_1})T$$

when at sub-optimum temperature, where germination temperatures were smaller than optimum, or

(3)

$$\frac{1}{t} = K_2 - (\frac{1}{\theta_2})T$$

when at supra-optimum temperature, where germination temperatures were larger than optimum temperature.

In the above equations, t was days to 50 % germination, T was germination temperature, K was the intercept of the regression that was lined with the abscissa. θ was thermal time (degree-days) to 50 % germination. Base or ceiling temperature was calculated by multiplying K with θ. Optimum temperature can be derived by extrapolation of the two regressions.

Germination under different photon dose

Exhumed non-dormant seeds were subjected to different photon dose (net number of photons per unit area per day) in the germination tests. A large quantities of light regimes were provided by fluorescent tubes of two incubators. To adjust light intensity, the Petri dishes were put on the different places in the incubators. For high regimes of light intensity, the seeds were exposed to light 8, 4, 2, 0.5 hours or 10 minutes per day. The resultant data were pooled together, since no interaction between light period and photon flux density was observed. The seeds were exposed to light for only one minute per day to create low photon dose regimes. Light intensity on the seed surface of each Petri dish was measured by a photometer (LI-COR, LI-1000 Data Logger). Light periods were controlled by wrapping the Petri dishes with two sheets of aluminium foil during dark period as well as during transferring the samples to the counting room. Counting room was a dark room provided with dim safe green light. The light intensity on the seed surface was 0.005 to 0.01 μmol/m^2/s. Germination tests lasted for 7 days in this experiment.

Emergence under different soil depth

Exhumed non-dormant seeds were used to study the effects of sowing depth on germination. Silt loam soils were ground, passed 1mm sieves, autoclaved and put into container. The soils were flooded with tap water. Water level was 30~50 mm above soil surface. Four replicates of 100 seeds per depth were sown into soil. The depths of burying were 2, 4, 6, 8, 10, 12, 15, 20, 25, and 30 mm. The emergence tests were undertaken at 30/25 °C in the phytotron. Seedlings were daily counted until the 21st days of incubation after which no emergence occurred.

Germination under different water potential

Germination media of different water potentials, ranging from 0 to -1.0 MPa, were prepared by different concentrations of PEG 6000 (polyethylene glycol), base on the table (Kuo and Chu, 1981) that was calculated according to a formula proposed by Michel and Kaufmann. Two hundreds exhumed seeds were put in a 50 ml flask in which 50 ml of PEG solution were added. The flasks were covered to ensure no water loss during experiments. Germinated seeds were examined more closely during the first three days of incubation, then per three days until the 14th day. Data of final total germination were used in this article.

RESULTS

Effects of gaseous environment

The stratified seed samples were highly germinable under hypoxia condition if a dim fluorescent light was provided (Table 1). However, the seeds could not germinate if they were exposed to the air and/or incubated in dark. When the oxygen in water was deprived

almost completely by adding 0.0364 g $Na_2S_2O_4$/l H_2O, the seeds still germinated well, although seedlings were paler than those in hypoxia conditions. Even under excess concentration of the chemical, i.e. 0.1 g/l, there were still some seeds showing early germination, that is, radicle protrusion. The protruded seeds were viable, because normal seedlings developed if the germinated seeds were transferred into water within two days of radicle protrusion. Longer duration of the protruded seeds in the solution killed the seeds, as indicated by tetrazolium test.

Table 1, Effects of gaseous environment on the germination of the non-dormant seeds of *M. vaginalis*. Standard error in parenthesis.

gaseous environment	light germination	dark germination
aerobic	8.5(1.0)	0 (0)
hypoxia	94.5(0.7)	2.0(0.4)
anoxia*		
0.0364 g/l	**90.0(1.1)	3.5(0.9)
0.1 g/l	***22.5(1.4)	4.0(0.7)

* Created by the solutions of $Na_2S_2O_4$.
** Normal germination, the seedlings were paler than those in hypoxia conditions.
*** Embryos protruded only. Normal seedlings developed if the germinated seeds were transferred into water within two days of embryo protrusion.

Germination under constant temperature

The stratified, non-dormant seeds of *M. vaginalis* var. *plantaginea* germinated well among a wide range of constant temperatures (Figure 1). Within 22-32°C, no significant effects of temperature on germination percentage were observed. Beyond these two temperatures however the percentage germination decreased rapidly until 14 or 40°C at which the seeds failed to germinate completely.

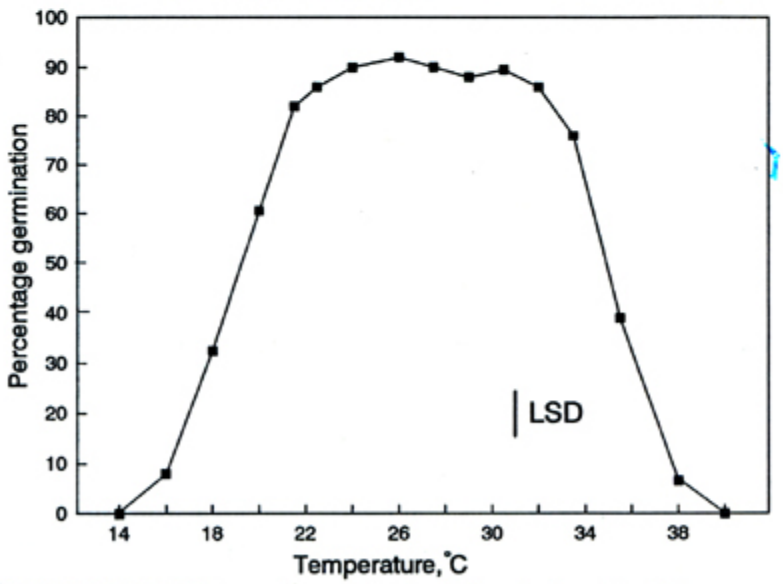

Fig. 1. Percentage germination of the non-dormant seeds of *M. vaginalis* under different constant temperatures.

The non- dormant *Monochoria* seeds germinated quickly at temperature around 30°C. The seeds completed their germination within four days. When the mean germination rates were plotted against incubation temperatures (Figure 2), a positive linear relationship between them was apparent if the temperature was not exceed 30°C. The regression equation was $1/t = -0.66 + 0.052T$ with $r^2 = 0.986$. The thermal time to 50 % germination at sub-optimum temperature was 19.2 degree-days, according to equation 2. On the contrary, above 30°C the relationship was negative, with the equation as $1/t = 1.71 - 0.026T$, $r^2 = 0.986$. The thermal time to 50 % germination at supra-optimum temperature was 38.5 degree-days, according to equation 3. Extrapolation of the two equations estimated 30.4 °C as the optimum temperature for the rate of seed germination. Calculation by equation 2 and 3 indicated that the base temperature for sub-optimum temperature regimes was 12.7 °C and the ceiling temperature for supra-optimum temperature regimes was 65.8°C.

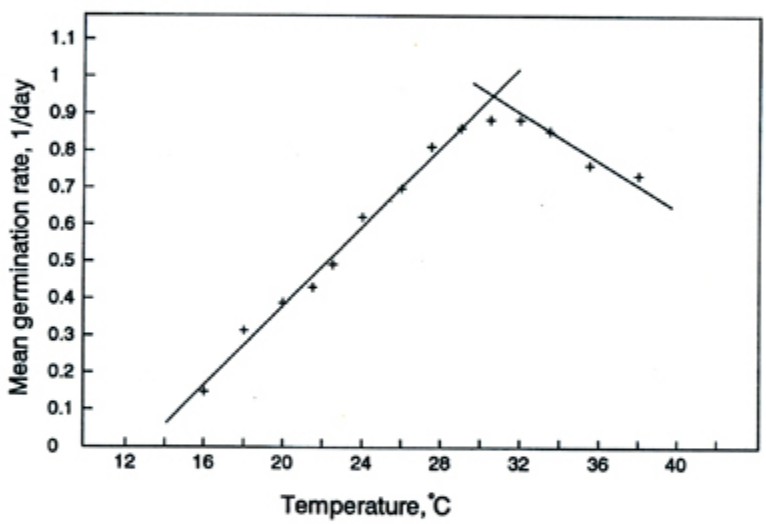

Fig. 2. Relationships between temperature and the mean germination rate of the seeds of *M. vaginalis*.

Germination under different photon dose

While the non-dormant seeds of *M. vaginalis* virtually failed to germinate without light, they responded to light among a wide range of photon dose (Figure 3). In order to revealed the relationship more clearly, photon dose received by seeds in each Petri dish was calculated by the product of photon flux density and duration of the daily exposure to light, i.e. mol/m^2/day, irrespective of the actual exposure times, which might range from 8 hours to only one minute per day. Germination percentages were transformed to probit values. The germination probits were then regressed to the logarithms of the daily photon dose the seeds received. The result showed that between photon doses of 6 to 0.04 mmol/m^2/day, there was a linear relationships ($r^2 = 0.786$) between the probability of germination and the daily light dose on a logarithm scale, that is to say a cumulative log-normal distribution response of the non-dormant seeds to low light intensity. The promotion effects of light on germination were however saturated at photon dose as low as 5 mmol/m^2/day above which more light did not increase germinability ($r^2 = 0.044$, not significant at $p=0.05$) at least until 5 mol/m^2/day.

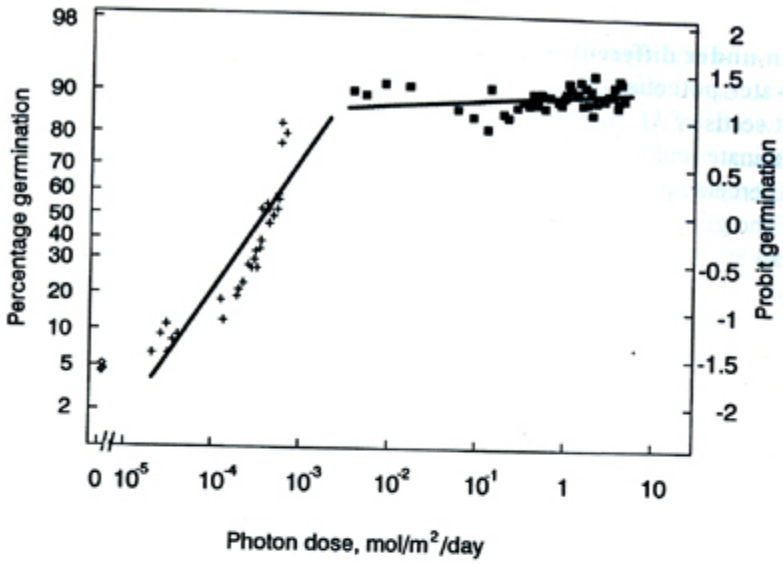

Fig. 3. Relationships between photon dose and the germination of the seeds of *M. vaginalis*. The seeds were subjected to 0.17 to 8 hours of light period per day: ■, one minute of light period per day: +, or dark control: ◊. The determination coeficient (r^2) at higher dose (■) was not significant at $p = 0.05$.

Emergence under different soil depth

The exhumed, non-dormant seeds of *M. vaginalis* germinated readily in the flooded soil, as long as the seeds were sown below soil surface of no less than 12 mm (Figure 4). Within this depth of burial, there was a significant linear relationship ($r^2 = 0.90$) between percentage germination and sowing depth, although the effect of sowing depth on the germination was quite small. The linear relationship existed within the sowing depth from 12mm to 22mm ($r^2 = 0.96$), but the seeds responded to the burial depth drastically. The seeds completely lost their germinability beyond 22 mm, or 21.6 mm as extrapolated by the regression.

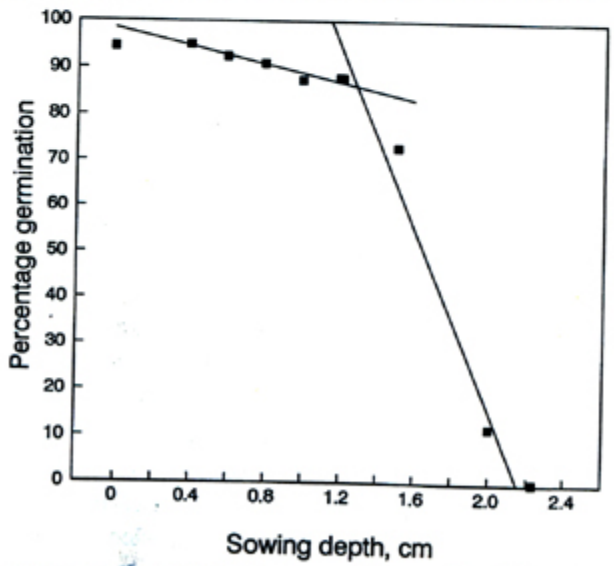

Fig. 4. Effects of sowing depth on the emergence of the seeds of *M. vaginalis*. The soil was flooded throughout the experiment.

Germination under different water potential

Above water potential of -0.2 MPa, no significant reduction in the germinability of the non-dormant seeds of *M. vaginalis* was found (Figure 5). A small part of the seed population failed to germinate under lower water potential. There was a linear relationship between final germination percentage (y) and water potential (x) of -0.8 MPa and above ($y = 100.9+34.2\ x$, $r^2 = 0.926$). The germination however was severely reduced at -0.9 MPa, and no germination occurred at all at -1 MPa.

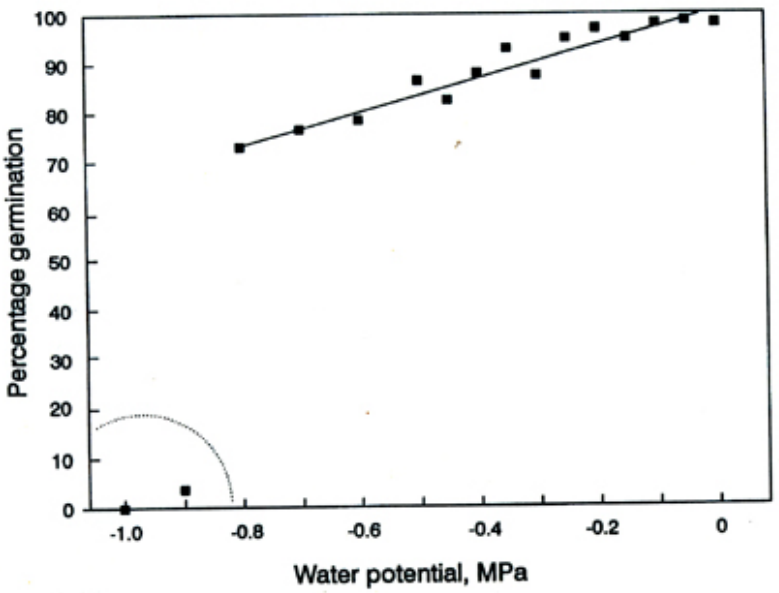

Fig. 5. Effects of water potential on the germination of the seeds of *M. vaginalis*. Data within dot line were not included in the regression analysis.

DISCUSSION

Many seeds failed to germinate when submerged in water. On the other hand, Morinaga found as early as in 1929 that seeds of 43 out of 78 genera could germinate in water. Actually some seeds germinate better in reduced oxygen concentrations than in the air, such as *Alisma plantago*, *Cynodon dactylon*, *Echinochloa turnerana*, *Leersia oryzoides*, *Thypha latifolia*, *Trapa natans* and *Zizania aquatica* (Corbineau and Côme, 1995). The seeds of rice, *Erythrina caffra* and four species of *Ecinochloa* can germinate under anoxia. Momonoki (1992) found that non-dormant seeds of *M. vaginalis* could germinate at 0.2% oxygen. Under aerobic condition the germination was low, which could be relieved by CO_2 or ethylene. The present results add M. vaginalis to the list of anoxia germinater. Complete deprivation of oxygen in water by $Na_2S_2O_4$ does not inhibit germination of the seeds of *M. vaginalis* (Table 1). However, the possibility can not be excluded that there is a very trace of oxygen presented within the seeds and that this trace amount is enough for radicle protrusion. Care must also be taken that germination here is different from subsequently seedling growth, which is completely inhibited by over-dosage of $Na_2S_2O_4$.

In the flooding condition, germination of the seeds of *M. vaginalis* is not significantly reduced in up to 12 mm burial (Figure 4). The results contrast with those of Kataoka and Kim(1978); they observed that *M. vaginalis* could emerge from very shallow depth in the submerged condition, but failed in the soil of more than 2 mm depth. They suspected that the failure might be due to dormancy, because their colleagues in Japan also found that the seeds of this species can emerge from 10 to 15 mm depth. Their notion is supported by present results as well as the experiments of rice seeds. Dormant rice seeds were found to require oxygen for the successful treatment of stratification (Kuo and Chu, 1985). On the other hand, it is possible that there exist ecotypes or accessions in which non-dormant seeds do not germinate in the waterlogged soil of 2 mm depth.

Therefore in the subsequent experiments, submerging the seeds of *M. vaginalis* in water, with water level 6 mm above the seeds is adopted as the standard germination test, although 1 mm of water depth should be enough, as revealed by the temperature experiment (Figure 1). This is not to say that the seeds can not be submerged in deeper depth. As shown in Figure 4, the seeds germinate well in the 4 mm soil plus 30~50 mm of inundated water. In flooded soil, the oxygen concentration may be less than 1% (Gamgbrell *et al.*, 1991, cited by Corbineau and Côme, 1995). This level however is enough for the seeds of *M. vaginalis*, since they germinate (Table 1) under the concentration of $Na_2S_2O_4$ as high as 0.0364g/l, which deprives oxygen almost completely (Kubota *et al.*, 1994). The reduction of germination in deeper soil (Figure 4; Pons, 1982;) must be caused by light rather then caused by oxygen concentration.

Effects of light on seed germination have been well documented. At lower light intensity, so called low fluence response (LFR), the ratio of Pfr to total phytochrome determines whether the seeds germinate or not. At high irradiation reaction (HIR), where the exposure of light for more than one hour, light tends to inhibit germination of seeds of many species. It is caused by a high rate of inter-conversion between Pfr and Pr (Frankland and Taylorson, 1983). In both LFR and HIR, Ellis *et al.* (1986a,b, 1989) proposed that, for seeds of some species, linear relations existed between the logarithm of photon dose of white light and probit germination. Here we also show that in the range of LFR the linear relation also applies to the non-dormant seeds of *M. vaginalis* (Figure 3). The seeds nevertheless absolutely require light to germinate. Under total dark condition, the whole sample virtually remained quiescence.

It is interesting to find that the photon dose saturated at as low as 5 x 10^{-3} mol/m^2/day, the same magnitude of intensity they may receive from one second exposure at full sunlight. This is of agronomic significant, and supports the conclusion that soil tillage can stimulate seed germination. Scopel *et al.* (1994) pointed out that the buried seeds might germinate as long as they had been exposed to daylight for seconds during soil lifting, but buried back in the dark soils again. It also implies the importance of light proof during seed counting in a light-concerned experiment, as well as during transporting of exhumed seeds in a burial experiment. Because in these cases the seeds are so wet that the photoconversion of the phytochrome can occur (Bewley and Black, 1994, p.241).

Germination inhibition of HIR up to 3 mol/m^2/day does not happen to the non-dormant seeds of *M. vaginalis*. This is quite different from the data of Ellis *et al.* (1986a,b, 1989) They showed that at the light intensity proposed by International Seed Testing Association (ISTA) as standard germination test, that is around 0.29 to 0.48 mol/m^2/day, germination of the seeds of all species they tested was inhibited to some extent. They claimed that the ISTA

should consider revising their testing rules. The present data indicate that the seeds of *M. vaginalis* are not light-inhibited at light intensity a normal germination cabinet provides, at least up to 8 hours of light period. Whether this insensitivity to HIR applies to the same seeds on soil surface under natural situation, which provide stronger photon dose, remains an open question. But under these conditions, the seeds may subject to aerobic inhibition as mentioned above. In the glasshouse, the seeds germinated well at soil surface, when the seeds were put below a water curtain of 30~50 mm (Figure 4), indicating the capability of seed germination of this species under high irradiation.

Woolley and Stoller(1978) reported that light could penetrate most soil to induce germination of light-sensitive seeds at a 2mm depth, but not much deeper. Tester and Morris (1987) concluded in a review article that physiologically and ecologically significant amounts of light rarely penetrated more than 4-5 mm through the soil, and might often penetrate much less than this. That is not to say that light can not penetrate more than 4-5 mm of the soil, because maize roots show positive geotropism at depths up to 15 mm of sandy loam (Tester and Morris, 1987). Apparently the seeds of *M. vaginalis* can detect very dim light as maize roots do. Alternatively, flooded condition may enhance germination by changing light composition, since under water, red/ farred ratio is higher (Smith and Morgan, 1981). Irrespective of the reasons, in germination-in-soil experiments, it is suitable to buried the seeds in a soil depth of 5 mm, plus a surplus of water, if light is not a limiting factor.

Water potential in the ordinary unflooded soil can be from -0.03 (aproximately field capacity) to -1.53MPa (permanent wilting point). In germination-in-soil experiments, water content may decrease rapidly on a hot and dry day, which means that water potential can change during experiments. Water potentials from -0.05 to 0.2 MPa do no affect germination of non-dormant seeds of *M. vaginalis* at all (Figure 5). At lower water potentials, i.e. from -0.2 to -0.8 MPa, the inhibition of germination is small, while there is a drastically decrease by -0.9 MPa. The response of seed germination of *M. vaginalis* to water potential is different from two wet-ditch species, *Typha latifolia* and *Scrophularia nodosa*. In a study of wide range of species of different habitats, Evans and Etherington (1990) pointed out that in both wet-ditch species, germination progressively decreased as soil water potential decreased. Even at -0.05 MPa, germination of seeds was inhibited to some extent. Interestingly, the response of *M. vaginalis* is similar to that of *Reseda luteola* and *Teucrium scorodonia*, species of woodland ride and limestone scree respectively. Here the seeds remain high germination, although some small inhibition occurred, in all but the smallest water potential used. The different behaviour of *M. vaginalis* compared with *T. latifolia* may be due to germination media, temperature interaction (Blackshaw, 1992), or other unknown reasons. Ecologically, the less sensitivity of non-dormant *Monochoria* seeds to water potential of -0.2 MPa can explain the emergence of them from unflooded soil (data not shown).

In terms of germination rate, the seeds of *M. vaginalis* germinate quickly at the optimum temperature (Figure 2). Mean germination rate at 30.4 °C is estimated as 0.92 1/day, or they require only 1.09 days for 50 % germination. At 20 °C it would be 0.38 1/day, or 2.63 days for half germination.

Non-dormant seeds of *M. vaginalis* germinate with high percentage at among 22-32 °C (Figure 1). In 10 cm below surface of a flooded soil in the experimental farm of the University, the daily mean temperatures between April and October in 1993-1995 are within this range (Chen, 1995), correspond with the time of field appearance of this species. During

summer, the mean daily soil temperatures are below 30 °C, and the maximum temperatures, which only last for less than 1 hour per day, seldom excess 35 °C. It seems then during summer supra-temperature will be not a problem for this species. The observed minimum temperature for germination is 14 °C, which occurs in the soil during winter when no field emergence of *M. vaginalis* happened. Although the soil temperatures in autumn are high enough for at least some seeds of the population to geminate, in the field the seedlings seldom emerge at this time. It can be due to the completion of the germination of the non-dormant seeds in the soil at the beginning of rice transplanting. On the other hand, the shading of rice leaves, which can be a natural filter of red light (Smith, 1973), may prevent germination of any non-dormant seeds that are remained in the paddy field.

In conclusion, for the non-dormant seeds of *M. vaginalis*, suitable germination test method is the top paper method of the ISTA (1994) with the following modifications. The test should be proceeded in a Petri dish or other suitable containers. During the whole period of tests, the water level should be maintained 2 to 6mm above seed surface. Temperature regime can be 30(light)/25(dark) °C, with light period 8 hours/day and light intensity (fluorescent tube) at seed surface as those prescribed by ISTA, that is 0.3-0.5 mol/m^2/day. For the germination-in-the-soil tests, the seeds can be buried in 4 mm depth soil, with water flooding during the whole period of tests.

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鴨舌草無休眠種子的發芽條件

陳博惠[1]、郭華仁[1,2]

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摘　　要

本試驗旨在探討無休眠鴨舌草種子的適當發芽條件。結果顯示該種子在無氧狀態下可以發芽，但幼苗無法生長。種子浸於水中6 mm的缺氧狀態下發芽甚快，幼苗生長正常。曝露於空氣中則不發芽。鴨舌草種子的發芽絕對需要光照，所需的光量相當低，每天白光照射量達5×10^{-3} mol/m^{2}就已飽合。每天高達3 mol/m^{2}的照射量不會抑制發芽。濕水狀況下埋於土中0.4cm以內不影響發芽，埋土0.4至1.6cm之內時，隨深度的增加發芽率略爲遞減。埋土深度在2cm以上時幾乎不發芽。水勢在 -0.2 MPa以上時不影響發芽，-0.2至-1.2 MPa之內時隨水勢的降低發芽率略爲遞減。水勢在 -0.9 MPa以下時不發芽。無休眠鴨舌草種子在22-32 ℃之間的發芽率皆高，在此範圍外發芽率下降，發芽的最高及最低溫分別約爲40及14 ℃。發芽速率的最適、基礎及高端溫度分別爲30.4、12.7及65.8 ℃。半數發芽所需的積溫就低於最適溫時爲19.2度日，就高於最適溫時爲38.5度日。根據以上的試驗結果，提出無休眠鴨舌草種子發芽試驗的方法及適當條件。

關鍵詞：鴨舌草，種子，發芽，溫度，光，氧，水勢，埋土深度。

1. 國立臺灣大學農藝學系，台北市106，台灣，中華民國。
2. 通信聯絡員。