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Prediction of Seedling Emergence and Early Growth of *Monochoria vaginalis* and *Scirpus juncoides* under Elevated Temperature

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상승된 온도 조건에서 물달개비(*Monochoria vaginalis*)와 올챙이고랭이(*Scirpus juncoides*)의 출아 및 초기생장 예측

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ABSTRACT This experiment was conducted to investigate seedling emergence and early growth of *Monochoria vaginalis* and *Scirpus juncoides* in the controlled-environment chamber maintained at different temperatures. Non-linear regression analyses of observed data against effective accumulated temperature (EAT) with the Gompertz and logistic models showed that the Gompertz and logistic models worked well in describing seedling emergence and early growth of both weed species, respectively, regardless of temperature. EATs required for 50% of the maximum seedling emergence and the maximum leaf number of *M. vaginalis* were estimated to be 69.3 and 131℃, respectively, while those of *S. juncoides* were 94.8 and 137℃, respectively. Models developed in this study thus were used to predict seedling emergence and early growth under elevated temperature condition. If rotary tillage with water is made on 27 May under +3℃ elevated temperature condition, dates for 50% of the maximum seedling emergence and 4 leaf stage were predicted to be 1 June and 15 June for *M. vaginalis* and 3 June and 14 June for *S. juncoides*, respectively. As compared with current temperature, these dates are 1-2 days earlier for the seedling emergence and 3 days earlier for the early growth, suggesting that earlier application of herbicides is required for effective control of *M. vaginalis* and *S. juncoides* under elevated temperature condition in the future.

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INTRODUCTION

IPCC (2007) reported that atmospheric temperature increased by 0.74℃ during last century and will further increase by 1.4~4.0℃ in this century. Increasing temperature will affect not only crops but also weeds. Many studies have been conducted to investigate eco-physiological effects of elevated temperature and CO_2 on crops (e.g. Jones *et al.* 2003; Tubiello *et al.* 2002) but not many on weeds. Although some studies dealt with weeds considering climate change (Moon *et al.* 2004; Kim *et al.* 2010), more works are required as there are so many weeds threatening crop production.

Monochoria vaginalis is an annual paddy weed distributed in China, Japan and Korea and known to be the most dominant paddy weed in Korea (Park *et al.* 2002). Although its competition effect on rice is not so high as compared with *Echinochloa crus-galli* (Moon 2010), it is still regarded as much important as *E. crus-galli*, particularly due to its resistance to sulfonylurea (SU) herbicides in Korea and Japan. Since its first report on herbicide resistance in Korea (Kwon *et al.* 2000), all the one-shot herbicides newly developed had to include herbicide which can control SU resistant *M. vaginalis*. *Scirpus juncoides* is a perennial sedge weed because it can overwinter in southern Korea and Japan. However, its main propagation is by seeds, so it can also be regarded as an annual weed. Like *M. vaginalis*, some of its biotypes were also reported to be resistant to SU herbicide (Ma *et al.*, 2002). Therefore, it still remains as one of troublesome weeds in Korea and Japan although it is not strong competitor as compared with other perennial sedge weed *Eleocharis kuroguwai* (Moon 2010).

Leaf stage of target weed is one of the most important factors in weed management. If we could expect a specific leaf stage of the target weed, we can make a right decision for herbicide application in advance (Kim *et al.* 2010). Seedling emergence and early growth is affected by various factors complicatedly, but air temperature is most important factor (e.g. Steinbauer and Grigsby 1957; Pyon *et al.* 1990). Many studies of improving relationship between leaf stage and effective accumulated temperature (EAT) were conducted for effective and reasonable expecting of leaf stage (e.g. Morita 2000). EATs for 2 leaf stage of *E. crus-galli* and *Aneilema keisak*, the major annual paddy weeds in Korea was127-128℃ and 110-120℃, respectively (Moon *et al.* 2004). Recently, EATs for seedling emergence and early growth of *E. kuroguwai* was also estimated by using the Gompertz model and observed field data (Kim *et al.* 2010). If such models using EAT can be developed, they can be utilized to predict seedling emergence and early growth under various temperature scenarios, so that timing for weed control can be advised appropriately.

Therefore, this study was conducted to predict seedling emergence and early growth of *M. vaginalis* and *S. juncoides* using a mathematical model based on EAT in order to advice appropriate timing for *M. vaginalis* and *S. juncoides* control in Korea based on IPCC's A1B scenario.

MATERIALS AND METHODS

Data generation

This experiment was conducted in the controlled-environment chamber (Conviron, Canada) at NAAS, RDA, Suwon in 2007. Seeds of *M. vaginalis* and *S. juncoides* were sown in a tray containing paddy soil. Pots were placed in the chamber maintained at 15/25, 16.5/26.5 and 18/28℃ (day/night). Water depth was maintained to be 1 cm by regular top irrigation. Seedling emergence and early growth were recorded daily until 20 days after sowing. The experiment was consisted of three replicates in a completely randomized design.

Model development and prediction

The seedling emergence model describes mathematically the emergence pattern of seedlings, which is expressed as the time course of cumulative emergence. Although several models have been developed, the simplest and widely used model is Gompertz (1825) curve (e.g. Cussans *et al.* 1996; Kim *et al.* 2006),

$$Y_{(T)} = \frac{C}{e^{e^{-B(T-M)}}} \qquad (1)$$

where ***Y*** is the accumulated seedling emergence at days (***T***) after sowing. ***C*** is the maximum seedling emergence, ***B*** is the rate of increase of seedling emergence once it is initiated and ***M*** is a time lag to reach 50% of the maximum seedling emergence. In this case, parameters will be affected by air temperature, particularly parameters ***M***. Therefore, the later the planting date, the earlier the seedling will be as later planting will allow sown seeds to be exposed to higher temperature in a given period of time than earlier planting. However, if EAT is used instead of days after sowing as an independent variable, parameters may be no or less affected by planting date. Therefore eqn 1 can be rewritten by using EAT (***t***) as follows,

$$Y_{(t)} = \frac{C}{e^{e^{-B(t-m_e)}}} \qquad (2)$$

where m_e is a EAT required to reach 50% of the maximum seedling emergence.

The logistic model has also been widely used to describe many biological events including soil depth effects on seedling emergence (Kim *et al.* 2006), herbicide effects (Streibig 1980; Kim *et al.* 2002) and early growth of plants.

$$Y_{(t)} = \frac{C}{1+\left(\frac{t}{m_g}\right)^{B}} \qquad (3)$$

where ***Y*** is the growth of plant in number of leaf, plant height or dry matter, ***t*** is the EAT after sowing, ***C*** is the maximum leaf number, ***B*** is the rate of increase of plant growth once it is initiated and m_g is a time lag to reach 50% of the maximum leaf number.

Statistical analysis

Non-linear regression analysis was conducted to fit the Gompertz model to observed seedling emergence and the logistic model to observed leaf number. All the statistical analyses were conducted by using Genstat 5 release 4.1 (Genstat 5 Committee, 1997).

RESULTS AND DISCUSSION

Seedling emergence

Seedling emergences of both weed species were plotted against days after sowing, showing that the higher the air temperature, the earlier their seedling emergences are (Fig. 1). When seedling emergence

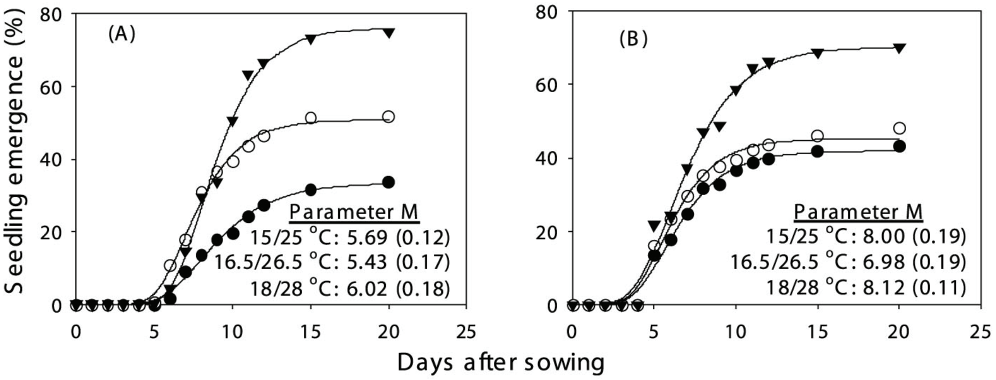

Fig. 1. Seedling emergence (%) of *M. vaginalis* (A) and *S. juncoides* (B) at 15/25 (●), 16.5/26.5 (○) and 18/28℃ (▼) of day/night temperature regimes. The continuous lines are fitted seedling emergence versus days after planting by using the Gompertz model and their parameter estimates. The parameter ***M*** indicates the time lag to reach 50% of the maximum seedling emergence.

Table 1. Parameter estimates for the seedling emergence of *M. vaginalis* and *S. juncoides* for the Gompertz model. The numbers in parentheses are standard errors.

Weed species	Parameter estimates			R^2
	B	M	C	
Monochoria vaginalis	0.0335 (0.0032)	69.3 (1.9)	56.4 (1.7)	0.880
Scirpus juncoides	0.0316 (0.0035)	94.8 (2.4)	60.5 (2.5)	0.857

was modelled with the Gompertz model by plotting seedling emergence versus days after planting, parameter ***M*** (a time lag to reach 50% of the maximum seedling emergence) was fluctuated with temperature (Fig. 1). To minimize such fluctuations in parameter *M* with temperature, EAT was used as an

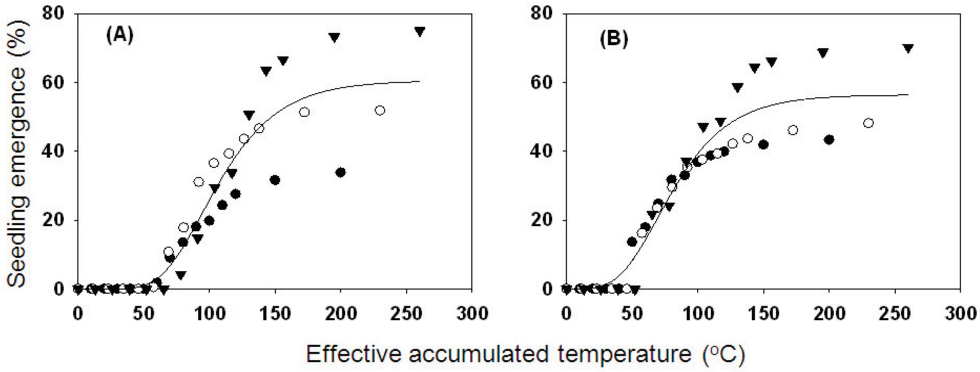

Fig. 2. Seedling emergence (%) of *M. vaginalis* (A) and *S. juncoides* (B) at in 15/25 (●), 16.5/26.5 (○) and 18/28℃ (▼) of day / night temperature regimes. The continuous lines are fitted seedling emergence versus days after planting by using the Gompertz model and their parameter estimates in Table 1.

Table 2. Parameter estimates for the early growth in leaf number of *M. vaginalis* and *S. juncoides* for the logistic model. The numbers in parentheses are standard errors.

Weed species	Parameter estimates			R^2
	B	M	C	
Monochoria vaginalis	0.0297 (0.0012)	131.1 (2.0)	3.7 (0.06)	0.923
Scirpus juncoides	0.0270 (0.0008)	137.4 (1.8)	5.3 (0.08)	0.953

independent variable to model seedling emergence of *M. vaginalis* and *S. juncoides* at different temperature regimes. Seedling emergence of *M. vaginalis* and *S. juncoides* against EAT was well explained by the Gompertz model with less changes in the parameter m_e (EAT required to 50% of the maximum seedling emergence) with temperature as compared with plotting against days after sowing (Fig. 2). The parameter m_e values (EATs required for 50% of the maximum seedling emergence of *M. vaginalis* and *S. juncoides*) were estimated to be 69.3 and 94.8℃, respectively (Table 1).

Number of leaf

Leaf number was also fitted to the logistic model with EAT to model early leaf development of *M. vaginalis and S. juncoides* at different temperature regimes. The logistic model also well described the early leaf development of *M. vaginalis* and *S. juncoides* with EAT. The parameter m_g (EATs for 50% of the maximum leaf number) was estimated to be 131.1 and 137.4℃ for *M. vaginalis* and *S. juncoides*, respectively (Fig. 3). Based on the model and its parameter estimates, EAT required for a specific leaf stage of *M. vaginalis* and *S. juncoides* can be estimated. For example, EATs required for 4 leaf stage were estimated to be 247 and 234℃, respectively (Table 2). These estimated EAT can be used to predict dates reaching the specific leaf stage under various temperature conditions.

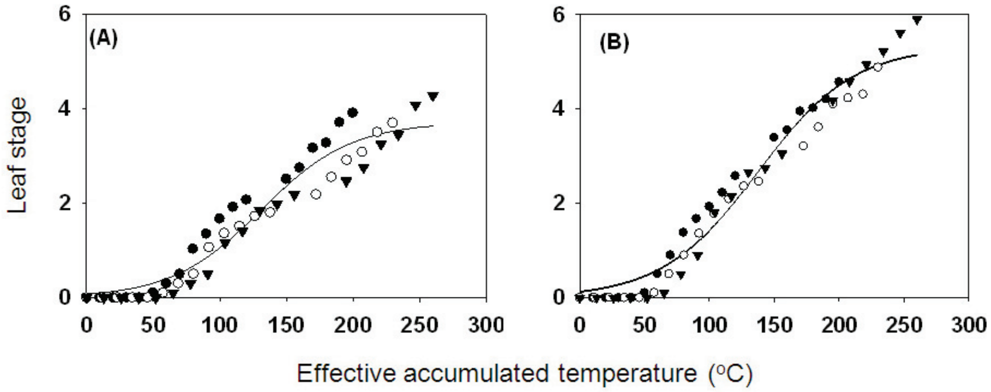

Fig. 3. Leaf stage of *M. vaginalis* (A) and *S. juncoides* (B) at 15/25 (●), 16.5/26.5 (○) and 18/28℃ (▼) of day / night temperature regimes. The continuous lines are fitted leaf stage by using the logistic model and their parameter estimates in Table 2.

Table 3. Estimated dates for 50% of the maximum seedling emergence and 4 leaf stage of *M. vaginalis* and *S. juncoides* under current and +3℃ elevated temperatures in Suwon if rotary tillage with water is made on 27 May.

Target stage	Temperature	Weed species	
		Monochoria vaginalis	*Scirpus juncoides*
50% of the max. seedling emergence	Present	2 June	5 June
	+3℃	1 June	3 June
	Difference*	▽1	▽2
4 leaf stage	Present	18 June	17 June
	+3℃	15 June	14 June
	Difference*	▽3	▽3

Prediction of seedling emergence and early growth under elevated temperature

Based on seedling emergence and leaf growth models from this experiment, dates reaching 50% seedling emergence and 4 leaf stage were predicted in present and 3℃ elevated temperature condition (Table 3). For example, if rotary tillage with water of paddy field is made on 27 May, *M. vaginalis* and *S. juncoides* will reach 50% of their maximum seedling emergence by 1 June and 3 June under 3℃ elevated condition, respectively, which is about 1 and 2 days earlier than current temperature condition. They will also grown up to 4 leaf stage by 15 June and 14 June under 3℃ elevated condition, respectively, which is about 3 days earlier than current temperature condition. Therefore, these results suggest that weed control measure should be made earlier under elevated temperature condition in the future as both seedling emergence and early growth of *M. vaginalis* and *S. juncoides* will be facilitated.

Our study confirmed that elevated temperature affected both seedling emergence and early growth of both weed species. However, when we make a decision for herbicide application timing, we need to consider herbicide activity as elevated temperature may also affect herbicide activity against these weed species. In general, herbicide activity improves with increasing temperature (e.g., Ichizen *et al.* 1996) although there are some exemptions (e.g., Lee *et al.* 2006). As shown in Table 3, herbicide application needs to made earlier under elevated temperature. However, further works must be conducted to investigate the effects of elevated temperature on herbicide activity against these weeds and rice grown elevated temperature prior to making a final decision when to apply herbicide.

In conclusion, our work clearly demonstrates that seedling emergence and early growth of both weed species were well described by the Gompertz model and the logistic model, respectively, by plotting them against EAT. The models developed will be utilized for predicting dates for seedling emergence and early growth under elevated temperature, which will help to make a decision for herbicide application timing.

요 약

일년생 잡초인 물달개비 및 올챙이고랭이의 출아와 초기생장을 예측하기 위한 모델 구축을 위하여 온도조건을 달리한 식물생장상에서 포트실험을 수행하였다. 이들 잡초의 출아 및 초기생장과 유효적산온도와의 관계를 비선형회귀로 분석한 결과 온도조건에 상관없이 각각 Gompertz 모델 및 logistic 모델로 설명이 잘 되었다. 물달개비 및 올챙이고랭이의 최대

출아율의 50%에 필요한 유효적산온도는 각각 69.3 및 94.8℃이었으며, 4엽기에 이르는데 필요한 유효적산온도는 각각 247 및 234℃이었다. 본 연구에서 개발된 모델로 분석한 결과 평균 기온이 3℃ 상승하게 되면 이들 잡초의 50% 출아는 물달개비의 경우 1일, 올챙이고랭이의 경우는 2일 빨라지고, 4엽기에 다다르는 날짜는 이들 잡초 모두 3일이 빨라질 것으로 예측되었다. 따라서 온도상승조건에서 물달개비 및 올챙이고랭이를 효과적으로 방제하기 위해서는 현재의 처리시기보다 약 2-3일 빨라져야 할 것으로 예상된다.

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REFERENCES

Cussans, G. W., S. Raudonius, P. Brain and S. Cumberworth. 1996. Effect of depth of seed burial and soil aggregate size on seedling emergence of *Alopecurus myosuroides*, *Galium aparine*, *Stellaria media* and wheat (*Triticum aestivum* L.). Weed Res. 36:122-142.

Gompertz, B. 1825. On the nature of the functions expressive of the law of human mortality, and on a new mode of determining the value of life contingencies. Philos. Trans. 115:513-585.

Genstat 5 Committee. 1997. Genstat 4 Release 4.1 : Reference manual supplement to Genstat 5 Committee (1993) Genstat 5 Reference manual Release 3. Numerical Algorithms Group, Oxford, UK.

Ichizen, N., T. Takeuchi, H. Omokawa, M. Knnnai and T. Takematu. 1991. Effect of soil type, water depth, water leakage and temperature of flowable and granular formulations of herbicides. Weed Res. Jpn. 36(4):338-342.

IPCC. 2007. Special report of the Intergovernmental Panel on Climate Change, CD-ROM.

Jones, P. G., and P. K. Thornton. 2003. The potential impacts of climate change on maize production in Africa and Latin America in 2055. Global Environ. Change. 13:51-59.

Kim, D. S., P. Brain, E. J. P. Marshall and J. C. Caseley. 2002. Modelling herbicide dose and weed density effects on crop : weed competition. Weed Res. 42:1-13.

Kim, D. S., Y. W. Kwon and B. W. Lee. 2006. The experiment was consisted of three replicates in a completely randomized design. Kor. J. Crop Sci. 51(4):362-368.

Kim, J. W., B. C. Moon, S. H. Lim, J. H. Chung and D. S. Kim. 2010. Prediction of seedling emergence and early growth of *Eleocharis kuroguwai* Ohwi under elevated temperature. Kor. J. Weed Sci. 30(2)(in press).

Kwon O. D., S. J. Koo, J. S. Kim, D. J. Lee, H. J. Lee, T. S. Park, Y. I. Kuk and J. O. Guh. 2000. Herbicide response and control of sulfonylurea-resistant biotype of *Monochoria vaginalis* in paddy fields in Chonnam province, Korea. Kor. J. Weed Sci. 20(1):46-52.

Lee, J. N., D. S. Kim, K. H. Hwang and S. J. Koo. 2006. Environmental factors affecting the herbicide performance of flucetosulfuron. Kor. J. Weed Sci. 26(1):1-9.

Ma S. Y., S. L. Ko and S. S. Han. 2002. Resistance of *Scirpus juncoides* Roxb. biotype to sulfonylurea herbicides. Kor. J. Weed Sci. 22(4): 334-342.

Moon, B. C., J. S. Park, I. Y. Lee, J. U. Park, O. D. Kwon and Y. I. Kuk. 2004. Effect of several temperature conditions on germination and leaf development response of paddy weeds. Kor. J. Weed Sci. 24(3):206-213.

Moon, B. C. 2010. Modelling weed competition and herbicide effects on rice and decision-making for weed control in transplanted rice cultivation. PhD thesis, Seoul National University, Korea.

Morita, H. 2000. Forecast of leaf emergence by accumulated efficient air temperature in barnyardgrass. Kor. J. Weed Sci. 20(supplement 1):19-26.

Park J. E., I. Y. Lee, B. C. Moon, C. S. Kim, T. A. Park, S. T. Lim, J. R. Cho, S. M. Oh, I. B. Im, J. B. Hwang and Y. C. Ku. 2002. Occurrence characteristics and dynamics of weed flora in paddy rice field. Kor. J. Weed Sci. 22(3):272-279.

Pyon, J. Y., T. G. Kang, C. W. Park and K. S. Kang. 1990. Effect of soil temperature and planting depth on emergence and growth of perennial paddy weeds. Kor. J. Weed Sci. 10(3):197-201.

Steinbauer G. P., and B. Grigsby. 1957. Interaction of temperature, light, and moistening agent in the germination of weed seeds. Weeds 5(3): 175-182.

Streibig, J. C. 1980. Models for curve fitting herbicide dose response data. Acta Agric. Scandi. 30:59-64.

Tubiello, F. N., C. Rosenzweig, R. A. Goldburg, S. Jagtap and J. W. Jones. 2002. Effects of climate change on US crop production : simulation results using two different GCM scenarios. Part I : Wheat, potato, maize, and citrus. Climate Res. 20:259-270.