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https://doi.org/10.5109/14065

出版情報：九州大学大学院農学研究院紀要. 54 (1), pp.231-233, 2009-02-27. Faculty of Agriculture, Kyushu University

J. Fac. Agr., Kyushu Univ., **54** (1), 231–233 (2009)

Development of an Intelligent Robot for an Agricultural Production Ecosystem (IV) – Experiments on Growth and Competition of Rice Plants against Weeds –

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(*Received November 14, 2008 and accepted December 5, 2008*)

This researching addressed to develop an agricultural production ecosystem robot, we carried out experiments in lots of the rice production ecosystem at Kyushu University Farm in order to get the Lotka–Volterra's parameters for the competition between of rice plants, small umbrella sedge well knew in Japan as Tamagayatsuri (*Cyperus difformis* L.) and non superior weeds without predation by golden apple snails for different stages of the growing season. A Verhulst logistic model was successful to estimate the carrying capacities and intrinsic rates of the rice plants and weeds. The competition coefficients were obtained by experience, and we constructed and solved the Lotka–Volterra equations of the species in competition by the method of Runge–Kutta.

INTRODUCTION

The modeling of an agricultural ecosystem estimates the prediction equations of Lotka–Volterra for interactions of competition among rice plants, Tamagayatsuri and weeds (Luna *et al*., 2008a). The parameters are, N_i: dried biomass for rice plant, Tamagayatsuri (a superior weed) and non superior weeds, r_i: intrinsic rate for each species, α_{ij}: competition coefficient between species, K_i: carrying capacity for each species. In this study, we will establish several experiments in order to obtain the parameters and estimate the biomass of rice plants, Tamagayatsuri, non superior weeds without predation by golden apple snail during the rice crop season. The date of models during the time of season should be introduced into the memory of the agricultural production ecosystem robot and the robot will able to remove a suitable amount of snails from paddy.

MATERIAL AND METHODS

Experimental site

In order to estimate the parameters of Lotka–Volterra–type competition models for three species (rice plants (Oryzae Sative L. hinohikari) Tamagayatsuri and non superior weeds) 6 experimental plots (4×5 m) were prepared in Kyushu University Farm on June 20th, 2008. The treatments consisted of 2 plots only for weeds, 2 plots only for rice plants (Figure 1a and 1b) and 2 plots for rice plants and weeds (Figure 1c and 1d). Figure 1d shows the weeds found after picking up the rice plant.

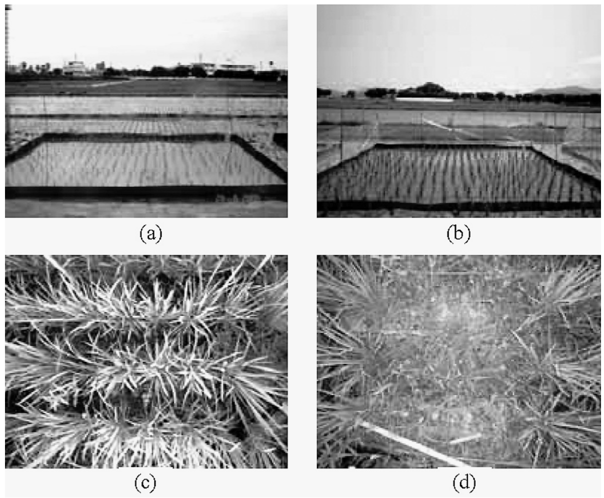

Fig. 1. Experimental plots at Kyushu University Farm for the carrying capacity of rice plants (a and b) on June 29th and July 8th, 2008, respectively and experimental plots for rice plants and weeds (c and d) on July 25th and July 31th, 2008.

Measuring biomass

We measured the biomass, lengths from rice plants and weeds sampled from June 20th to October 7th, 2008. The plants were cut from over ground using a sick tool. A sample of 24 rice plants per each lot was taken and placed into the dryer for 24 hours under 85 Celsius degrees in order to obtain the dried weights of biomass. The dry weight of weeds found out in the lots were also determined using the above procedure. We estimated the logistic biomass rate by the equation of Verhulst (Vandermeer, 1990).

$$N(t) = \frac{K}{1+Ce^{-rt}} \quad (1)$$

where, $N(t)$: biomass of plants in $t=0$, K: carrying capacity, r: intrinsic rate of plants and $C=(K/t(0))-1$.

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RESULTS

Figure 2 shows the lengths of the rice plants measured in the lots II, III and V. The average curve was fitted significantly by the logistic model with a correlation coefficient r=0.995 at 99% of confidence level. The severe predation by snails occurs in paddy in early growth before rice plants reach the length of 400 mm after transplanting and from the average sigmoid curve we can see that length of 400 mm was reached at 30 days after transplanting.

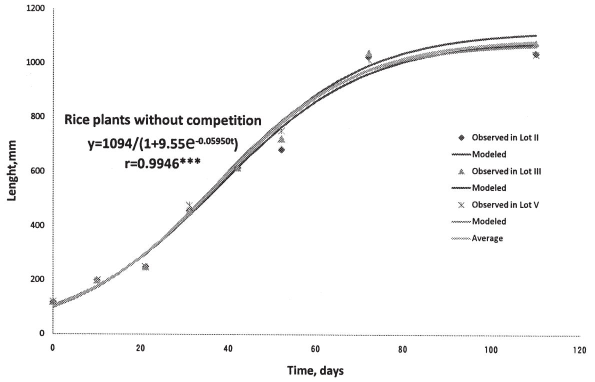

Fig. 2. Lengths of rice plants without competition by weeds in the experimental plots II, III, V and the average curve.

The raw data of biomass of rice plants for three lots containing only rice plants were fitted to the logistic equation (with a correlation coefficient r=0.996 at 99% of confidence level) in order to estimate the carrying capacity and intrinsic rate of rice plants. In Figure 3, we can see three sigmoid curves and the average curve. The carrying capacity and intrinsic rate for rice plants were 2025 and 0.0721 respectively.

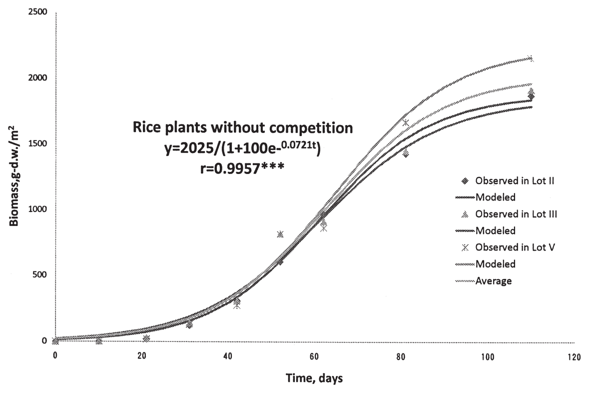

Fig. 3. Biomass rate curves of rice plants without competition by weeds in the experimental plots II, III, V and the average curve.

The competition between rice plants and weeds has a negative effect on the growth rate both species rice plants and weeds. We can observe from the Figure 4 that from day 1 to day 55 the biomass of rice plants competed by weeds was from 19.31 to 171.92 g (dry weight) under the biomass of rice plants without competition.

In Figure 5 we can observe the biomass rate curves of the species in competition. From the logistic equations for each biomass curve we obtained the carrying capacities and intrinsic rates for rice plants, Tamagayatsuri and non superior weeds always without Tamagayatsuri (Table 1).

The competition coefficients were proposed by experience and were as follows, α_{12}: Tamagayatsuri to rice plants competition coefficient=0.0023, α_{13}: non superior weeds to rice plants competition coefficient=0.07, α_{21}: rice plants to Tamagayatsuri competition coefficient=0.0023, α_{23}: non superior weeds to Tamagayatsuri competition coefficient=0.03, α_{31}: rice plants to non superior weeds competition coefficient=0.07, and α_{32}: Tamagayatsuri to non superior weeds competition coefficient=0.03. The Lotka–Volterra equations were,
Equation for biomass rate of rice plants.

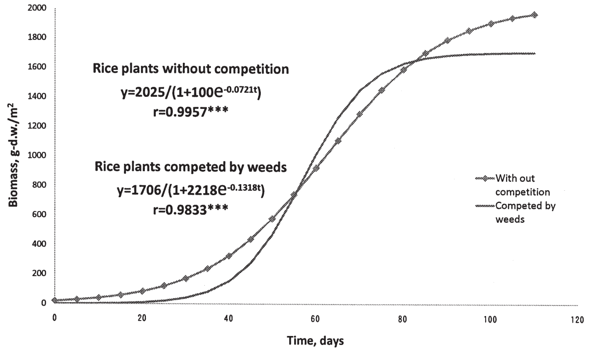

Fig. 4. Biomass rate curves of rice plants without any competition and rice plants competed by weeds.

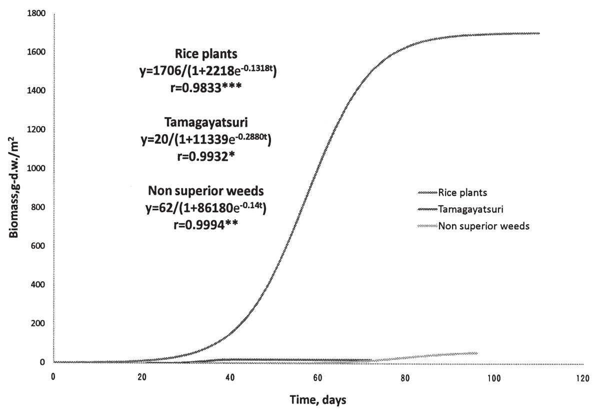

Fig. 5. Biomass rate curves obtained from the competition of rice plants, Tamagayatsuri and non superior weeds in plot VI.

Table 1. Carrying capacities and intrinsic rates for rice plants, weeds and non superior weeds obtained by the logistic equations of biomass rate curves

Parameter	Rice plants	Tamagayatsuri	Non superior weeds
a. Carrying capacity (K)	1706	20	62
b. Intrinsic rate (r)	0.1318	0.2880	0.14

$$\frac{dN_1}{dt} = 0.1318N_1\left(1- \frac{N_1+0.0023N_2+0.07N_3}{1706}\right) \quad (2)$$

Equation for biomass rate of Tamagayatsuri.

$$\frac{dN_2}{dt} = 0.2880N_2\left(1- \frac{N_2+0.0023N_1+0.03N_3}{20}\right) \quad (3)$$

Equation for biomass rate of non superior weeds.

$$\frac{dN_3}{dt} = 0.14N_3\left(1- \frac{N_3+0.07N_1+0.03N_2}{62}\right) \quad (4)$$

The ordinary differential equation system was solved by the method of Runge–Kutta using the following initial conditions: N_1=0.7689, N_2=0.001 and N_3=0.001. We obtained the chart shown in Figure 6.

The biomass curves of Tamagayatsuri and non superior weeds shown in Figure 7 had differences in relation to those shown in the Figure 6 due to the Lotka–Volterra model includes the coefficients of competition.

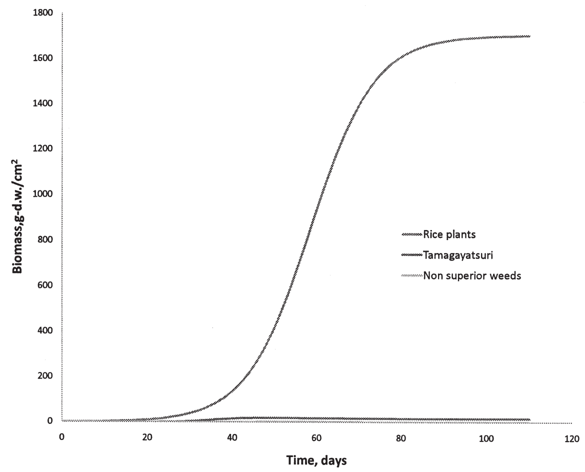

Fig. 6. Biomass rate curves obtained by Lotka–Volterra equations about the competition of rice plants, Tamagayatsuri and non superior weeds in plot Ⅵ.

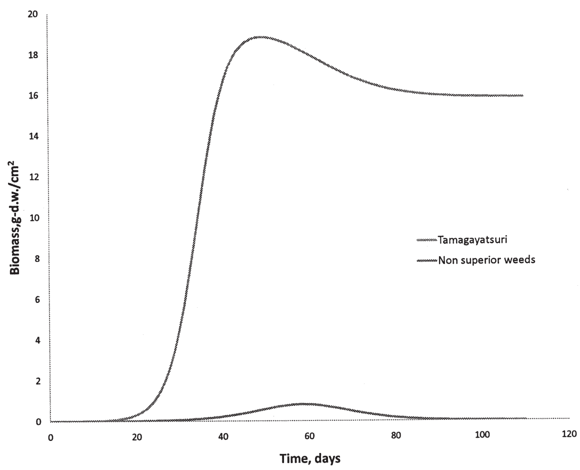

Fig. 7. Enlarged biomass rate curves of Tamagayatsuri and non superior weeds obtained by Lotka–Volterra equations in plot Ⅵ.

DISCUSSION

The weeds did not grow up in the experimental plots considered only weeds; therefore we estimated the carrying capacities and intrinsic rates of weeds from plot Ⅵ. In plot Ⅳ for rice plants and weeds, the weeds did not show up and we used that lot as a replication for only estimation of parameters of rice plants. On the other hand, we considered Tamagayatsuri as a superior weed because its high density and long period of life in the crop season of 2008. The non superior weeds consisted of weeds such as Azena, Himemisohagi, Tainube, Azegaya and Hideriko with a low density and short period in the growing season. The Verhulst logistic model was applied successfully to estimate the biomass curves, carrying capacities and intrinsic rates of the rice plants and weeds. We also solved the system Lotka–Volterra equations for the species in competition by Runge–Kutta method and therefore the dala obtained can be introduced to the memory of robot via personal computer.

CONCLUSION

Our agricultural production ecosystem is stable and the models generated (biomass and lengths curves for rice plants and weeds) can be transferred into the agricultural production ecosystem robot; therefore the robot will be able to make decisions according the scenarios of competition among rice plants and weeds in the ecosystem and remove the appropriate number of snails from the soil.

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