PRINCIPAL COMPONENT ANALYSIS OF RICE PRODUCTION ENVIRONMENT IN THE RICE TERRACE REGION

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ABSTRACT

Environmental conditions that affect rice production, such as air temperature, relative humidity, solar radiation, effective cation exchangeable capacity (ECEC) of the soil, and total nitrogen in irrigation water, were assessed for 4 paddy fields in Hoshino village, Fukuoka prefecture in Japan. Also, environmental factors that affected rice quality (physicochemical properties of rice grains and cooked rice) were identified using data during the beginning of a ripening period (20 days after heading) by principal component analysis. It was found that air temperature, diurnal range of temperature, solar radiation had major positive effects on rice quality. Also, a large diurnal range of temperature, which was advantageous for rice production, was observed locally in the rice terrace region.

Keywords: rice production environment, rice quality, principal component analysis, rice terraces, farmers' decision support system

INTRODUCTION

Rice terraces are a unique form of land use in mountainous areas. Its landscape is as beautiful as the rice terraces in the Philippines are designated a World Heritage Site. Also, rice terraces have been providing us with various functions, such as food production, land preservation from floods and landslide, amenity, biodiversity, preservation of culture and history, etc, as listed by

Haruyama (2004). On the other hand, conservation of rice terraces is becoming hard due to low market price of rice, low productivity in terms of labor and land, and severe working conditions. Considering the conservation of rice terraces, it is important to produce high quality rice (local brand) through which people in a city can be motivated to visit the mountainous area. Thus, a farmers' decision support system utilizing information technologies has been studied to ensure production of high quality rice.

Information technologies that are expected to be used as a part of a farmers' decision support system have been widely studied. The real-time soil spectrophotometer made it possible to assess spatial variability of soil qualities in a field such as soil moisture, organic matter, nitrate, pH, and EC (I Made Anom *et al* 2002). Chosa *et al* (2004) has developed the yield monitoring system for a Head-Feeding Combine. Fukatsu and Hirafuji (2003) developed the field server that can monitor weather information and crop growth in real time via a Web browser. Also, GIS (geographical information system) has been becoming popular as a tool of managing information on agricultural production. As mentioned above, sensors to acquire information and software to manage the information have been rapidly developed recently in many areas. However, because the relationship between environmental factors on agricultural production, methods of cultivation, and quality of products has not been understood well, useful indications that support a farmers' decision have not been proposed sufficiently.

The objective of this study was to evaluate the effects of environmental factors on rice production for rice terraces in Hoshino village, Fukuoka prefecture in Japan. To achieve the objective, indicators of weather, water quality, and soil quality during a rice growth season were assessed among 4 paddy fields. Also, environmental factors and cultivation methods that potentially affected rice quality were examined by principal component analysis using data during the beginning of a ripening period.

MATERIAL AND METHODS

Experimental fields were located in Hirouchi, Rokuri, Nitasaka, and Fujiyama areas in Hoshino village. Elevation and area of the experimental fields were shown in Table1. Weather information, such as air temperature, relative humidity, and solar radiation, was measured at 4 paddy fields from the middle of July until the beginning of October. Data was logged at an interval of 10 minutes. Effective cation exchangeable capacity (ECEC) of the soil was measured for the samples taken at each paddy field in the middle of May (before rice planting) using atomic absorption spectrometer (Hitachi, Z-2300). Also, concentration of total nitrogen was measured for irrigation water of each paddy field (samples were taken on August 25) by the total phosphorus and nitrogen analyzer (Central Kagaku Corp., HC-1000).

Table 1. Elevation and area of experimental paddy fields

Experimental field	Elevation, m	Area, are
Hirouchi	369	5
Rokuri	415	19
Nitasaka	324	3.4
Fujiyama	445	1.8

Physical and chemical properties of rice were also analyzed for each sample harvested at the 4 experimental fields. Moisture contents of the samples were adjusted in the range from 14.6 to 15.8%. Thousand grain weight of brown rice was measured by the grain grader (Satake, RGQI20A). Protein of polished rice was analyzed by the rice taste analyzer for rice grain (BRAN+LUEBBE, Infraalyzer 260). Also, hardness, stikiness, degree of balance, and taste value were analyzed by the rice taste analyzer for cooked rice (Satake, Rice Taste Analyzer STA1A).

Cultivation information is shown in Table 2. TSUKUSHIROMAN variety was cultivated at all the experimental fields. Information on fertilizer application is shown in Table 3.

Principal component analysis was conducted to investigate relationships between environmental factors, cultivation methods, and physicochemical properties of rice. Generally, production environment during the beginning of a ripening stage significantly affects rice quality (Matsuo, 1990). Thus, data on weather for 20 days after heading was used for the analysis.

Table 2. Cultivation information

Experimental field	Transplant	Heading	Harvest
Hirouchi	6/6	8/25	10/7
Rokuri	6/18	8/25	10/2
Nitasaka	5/29	8/10	9/22
Fujiyama	6/12	8/25	10/7

Table 3. Date and amount of nitrogen fertilizer application

Experimental field	Date	Amount, kg/10a	Date	Amount, kg/10a	Total Amount, kg/10a
Hirouchi	6/4	3.5	7/26	2.0	5.5
Rokuri	6/15	4.4	8/10	1.7	6.1
Nitasaka	5/26	5.3	8/20	2.1	7.5
Fujiyama	6/9	7.0	8/9	1.7	8.7

RESULTS AND DISCUSSIONS

The coefficients of structure on the first principal component are graphically shown in Fig.1. The coefficients were calculated based on the data shown in Table 3, Table4, and Table 5. Here, data on weather conditions shown in Table 3 were average values for 20 days after heading. Because taste value, balance, stickiness, and appearance had a positive coefficient, and hardness had negative coefficients, it was thought that the first principal component indicated rice quality. Rice quality is affected by two main variable groups, which are environment factors and physicochemical properties of rice. The changes in variables were explained by the first component up to 57%.

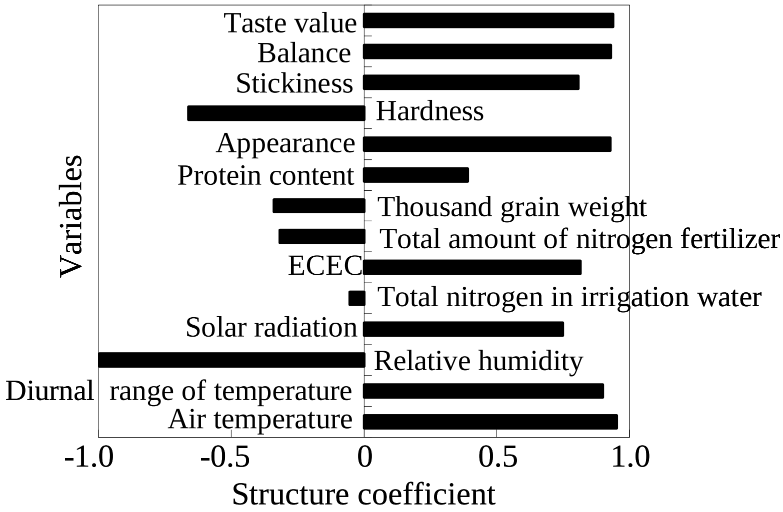

Fig. 1. Structural coefficients of the first principal component

Table 4. Production environment during the beginning of a ripening period

Experi-mental field	Air Temp., ºC	Diurnal range, ºC	Relative humidi-ty, %	Solar radia-tion, MJ/m^2	Total nitro-gen, mg/l	ECEC, $cmol_c$/kg
Hirouchi	24.1	7.8	84	11.75	1.79	8.6
Rokuri	24.1	7.4	84	14.80	3.23	7.2
Nitasaka	26.0	9.6	81	17.50	0.35	25.6
Fujiyama	23.4	7.1	87	13.27	0.61	7.8

Table 5. Physicochemical properties of rice grains

Experimental field	Thousand grain weight, g	Protein, %
Hirouchi	20.9	7.4
Rokuri	22.4	6.7
Nitasaka	21.5	7.5
Fujiyama	22.2	7.1

Table 6. Physicochemical properties of cooked rice

Experimental field	Appearance	Hardness	Stickiness	Balance	Taste value
Hirouchi	8.1	5.9	8.6	8.3	81
Rokuri	8.4	5.5	8.6	8.5	82
Nitasaka	8.5	5.5	8.6	8.6	83
Fujiyama	7.6	5.8	7.7	7.8	77

As Fig. 1 shows, average temperature, diurnal range of temperature, solar radiation, and ECEC had positive effect on rice quality while relative humidity had negative effect. It was examined that temperature and solar radiation had positive effects on rice quality through the translocation of dry matter stored in stem and leaf controlled by enzyme activity and carbon assimilation by photosynthesis. Higher values of temperature and solar radiation had a positive effect in the range of data used for the principal component analysis. Also, it was considered that rice grain was ripened well under a large diurnal range of temperature because high temperature during daytime increased translocation rate while low night temperature decreased the translocation of dry matter (Yang et al., 2005). Namely, it was concluded that a large diurnal range of temperature, which was advantageous for rice production, was observed locally in the rice terraces. On the other hand, it was judged that a negative structure coefficient of relative humidity didn’t mean the direct effect on rice quality but negative correlation with temperature and solar radiation. ECEC had a positive structure coefficient, and the result was brought by relationship between high taste values with large ECEC (N1) and low taste values with small ECEC (F2). However, main reason of high quality in Nitasaka area was considered to be high temperature and sufficient solar radiation during the beginning of the ripening period, and the effect of ECEC have to be further examined.

CONCLUSIONS

Rice production environment was assessed for the rice terraces in Hoshino village, Fukuoka prefecture in Japan. Also, environmental factors and cultivation methods that potentially affected rice quality were examined by principal component analysis. Following conclusions were drawn from this study.

1) Larger values of air temperature, diurnal range of temperature, and solar radiation had positive effects on rice quality in the range of data used for the principal component analysis.
2) A large diurnal range of temperature, which was advantageous for rice production, was observed locally in the rice terrace region.

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