Analysis of Spatial Variation of Rice Grain Yield and Soil Chemical Properties

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Abstract

This research aims to quantify within-field spatial variability of rice yield response to soil chemical properties under different cultivation methods in Korea. The two paddy fields experiments were carried out for this analysis in the year of 2002 and 2003, the coefficient of variation (CV) result obtained for rice yield was 12.8%. CV for soil variables varied from 2.1% for pH to 19.6% for EC. Among the soil variables, CEC showed the highest correlation to grain yield (r =0.61). Stepwise regression procedure was used to identify the soil variable with the most significant correlation with spatial variability of rice yield among the soil variables. CEC, Clay, Organic matter, Available Si, K and Ca were used in the multiple regression model at significant probability level of 0.05, accounting for as much as 68% of yield variability. The boundary line analysis and the Law of Minimum of the limiting factors were applied for the two year experiments and this analysis accounted for an average of about 48% of within-fields spatial yield variability.

Keywords

Korea, spatial variability, rice yield, soil properties, paddy field

Introduction

Spatial variability of rice yield in a paddy field results from inhomogeneity of management practice and soil properties and their complex interaction (Casanova et al., 2002). To obtain the basic information for site-specific soil management to improve nutrient use efficiency of plants, spatial variability of grain yield response to soil properties should be evaluated. This research was carried out to investigate the causal factors associated with within-field spatial variability of yield under a direct-seeded and transplanted rice culture in Korea.

Materials and Methods

The two paddy fields, assigned as field A: 59m?110m (divided into 65 plots with 10m?10m) and field B: 60m?110m (divided into 66 plots with 10m?10m) located in the experimental farm of National Crop Experimental Station, RDA, Korea, were used for the research. Soil samples in each plot from the surface soil (0 to 15 cm) were collected for the analysis of soil chemical properties. Grain yield for each plot was also measured nearby the soil sampling point of each plot. Several statistical procedures using SAS were applied for the analysis of two years experiment data. Boundary line analysis (Cui and Lee, 2002) and The Law of the Minimum of the limiting factors (Anh et al., 2003) were applied to identify soil variables that significantly influenced the spatial variability of grain yield.

Result and Discussion

1. Descriptive statistics and correlation analysis

The descriptive statistical analysis for soil variables and grain yield is shown in table 1.

Table 1. Descriptive statistics for soil chemical properties and grain yield (*n*=197)

Variable	Mean	Std Dev	Minimum	Maximum	C.V (%)
Yield (kg/ha)	568	73.0	330	758	12.8
CEC ($cmol^+/kg$)	9.44	1.02	7.65	10.4	10.8
Sand (%)	25.2	4.05	16.0	34.0	15.8
Clay (%)	27.9	2.14	22.0	32.2	7.6
Total N (%)	0.120	0.010	0.097	0.148	8.3
Organic matter (%)	21.2	1.603	16.2	25.1	7.56
Available P (mg/kg)	84.6	9.92	66.4	108.4	11.7
Available Si (mg/kg)	103	17.9	72.6	165.4	17.3
EC (dS/cm)	0.326	0.064	0.200	0.590	19.6
pH	5.72	0.123	5.39	6.120	2.1
Mg ($cmol^+/kg$)	0.807	0.079	0.605	0.997	9.7
K ($cmol^+/kg$)	0.991	0.110	0.726	1.256	10.1
Ca ($cmol^+/kg$)	3.681	0.380	2.792	4.471	10.3
Na ($cmol^+/kg$)	0.731	0.088	0.579	1.070	12.0

Simple correlation analysis provided a comparison between grain yield and soil variable and the obtained results showed several soil variables have significant correlations with grain yield. However, the largest correlation was obtained for CEC (r=0.61) followed by OM, Ca, total N, etc.

2. Stepwise regression analysis

Stepwise regression analysis with forward selection was carried out to identify the soil variables with the most significant effect on grain yield for field A and B during the years 2002 and 2003. The following was the equation (1) where selected soil variables are written in increasing order of partial R-square.

$$Yield = -313+76.4CEC+ 6.74Clay+13.6OM+1.0SiO2-114K-84.9Ca \quad r2adj=0.685 \quad (1)$$

The result showed that selected soil variables accounted for about 68% of grain yield spatial variation, while CEC was a most important soil variable accounting for more than 40% of the spatial variability of yield and the other selected variables accounted for about 28% of it. CEC was also reported to be a most influential soil variable associated with rice yield variability in Spain (Casanova et al., 1999).

3. Application of Boundary line analysis and the Law of the Minimum

Boundary line analysis was carried out for the grain yield response to soil variables. This bounrary line was fomulated from the following equation:

$$Y= \alpha.\{1-\beta.\exp(\gamma.X) \quad (2)$$

Where Y is yield, X indicated a parameter such as: soil variable, α, β and γ are constant). If we exclude α from the equation (2), Y value ranges from 0 to 1 and can be used as indices expressing the degree of influences on grain yield. Finally, the

index formula obtained from equation (2) that describe the grain yield response to the variation in the test parameter, where all other factors are close to non-limiting level in terms of grain yield (Table 2). The limitting factor that has the lowest index value was selected for each plot, and regressed to the respective grain yield. That is $Y= a \min[I_{OM}, IA_{.P}, I_{TN},\ldots I_{CEC}]$. The limiting factors accounted for an average of about 48% of spatial yield variability within-field (Fig. 1). Kriged maps were prepared for the spatial variation of grain yield and soil minimum indices (Fig. 2).

Table 2. Boundary line formulation for the grain yield response to soil variables

Parameter	Boundary line formula	Index formula	R^2
CEC ($cmol^+/kg$)	*f*(CEC)=893*[(1-32.9*EXP(-0.5326*CEC)]	I_{CEC}=1-32.9*EXP(-0.5326*CEC)	0.997
Sand (%)	*f*(Sand)=893*[1-2.05*EXP(-0.0987*Sand)]	I_{Sand}=1-2.05*EXP(-0.0987*Sand)	0.963
Clay (%)	*f*(Sand)=893*[1-15.4*EXP(-0.162*Clay)]	I_{Clay}=1-15.4*EXP(-0.162*Clay)	0.981
Total N (%)	*f*(TN)=893*[1-11.2*EXP(-33.7*TN)]	I_{TN}=1-11.2*EXP(-33.7*TN)	0.949
Organic matter (g/kg)	*f*(OM)=893*[1-3.31*EXP(-0.129*OM)]	I_{OM}=1-3.31*EXP(-0.129*OM)	0.995
Available P (mg/kg)	*f*(P)=893*[1-4.52*EXP(-0.038*P)]	I_P=1-4.52*EXP(-0.038*P)	0.995
Available Si (mg/kg)	*f* (Si)=893*[1-2.65*EXP(-0.025*Si)]	I_{Si}=1-2.65*EXP(-0.025*Si)	0.978

Mg ($cmol^+/kg$)	f (Mg)=893*[1-1.89*EXP(-2.75*Mg)]	I_{Mg}=1-1.89*EXP(-2.75*Mg)	0.978
K ($cmol^+/kg$)	f(K)=893*[1-9.33*EXP(-4.23*K)]	I_K=1-9.33*EXP(-4.23*K)	0.932
Ca ($cmol^+/kg$)	f(Ca)=893*[1-2.52*EXP(-0.699*Ca)]	I_{Ca}=1-2.52*EXP(-0.699*Ca)	0.986

* This analysis was carried out using the data from field A (2002 and 2003) and field B (2003) with transplanting cultivation method. The selected boundary line formulation was applied for data of field B (2002) with direct-seeded cultivation method.

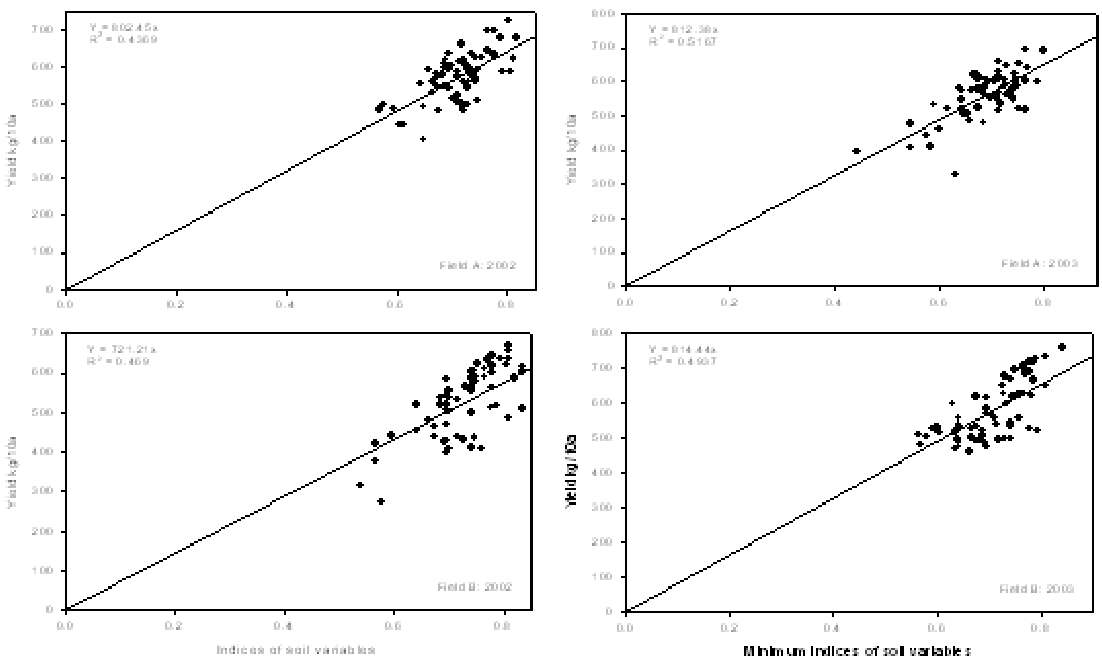
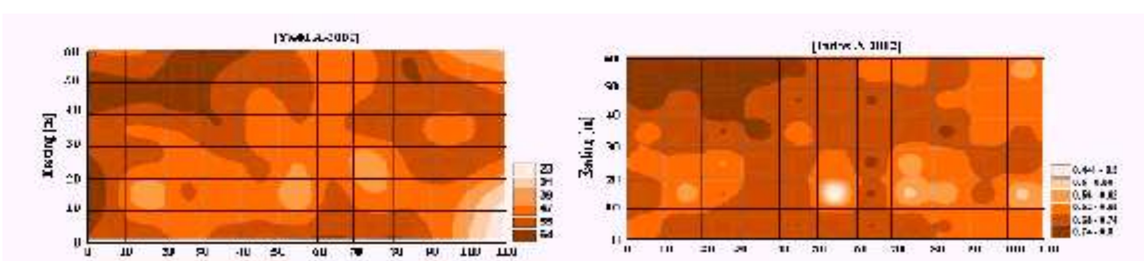


Fig. 1. Relationships between indices of soil variables and yield at field A and field B (2002 and 2003).



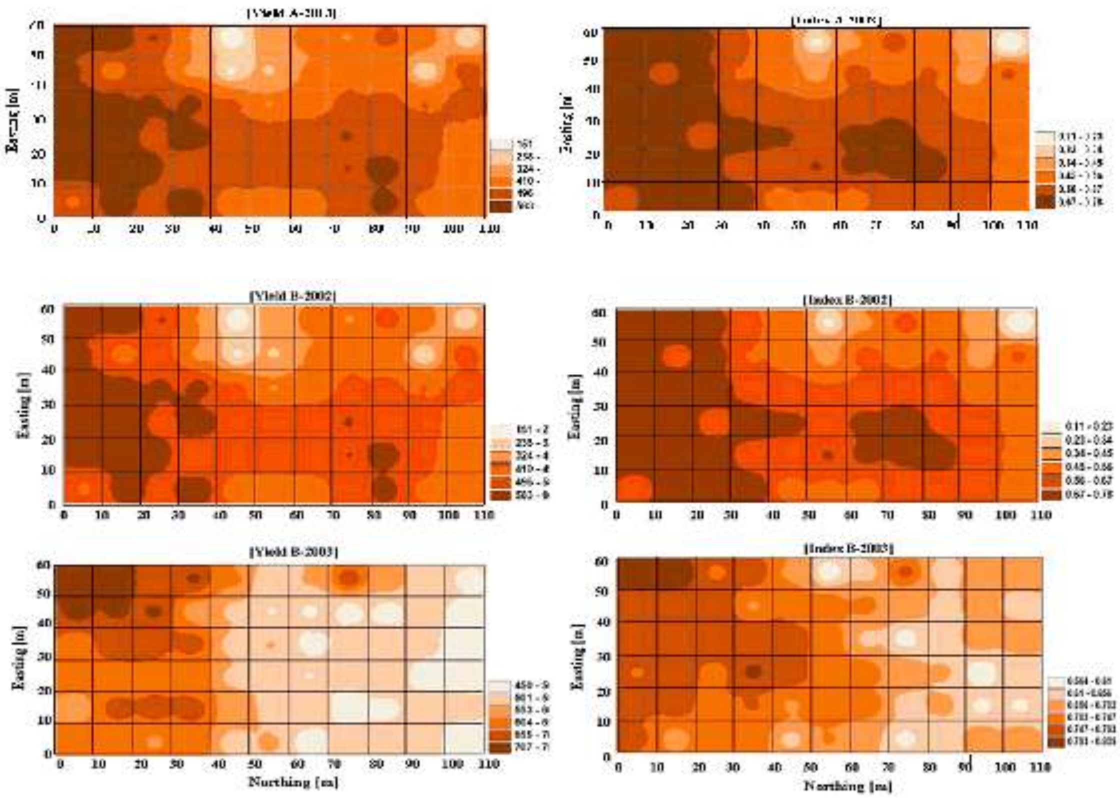


Fig. 2. Kriged map of indices of soil variables and grain yield at field A and field B (2002 and 2003)

Conclusion

The results obtained from a two year experiment indicated that the soil variables CEC, clay, organic matter and silica were significantly correlated with spatial variability of rice yield. Stepwise regression analysis indicated that the selected soil variables accounted for about 68% of spatial variability of rice yield. The boundary line analysis and the Law of Minimum of the limiting factors were applied for the two years experiments and they accounted for an average of about 48% of within-field spatial yield variability.

References

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