연구보문

Comparison of Growth, Yield and Yield Components among Rice Cultivars for Organic Farming in No-tillage Paddy

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Organic farming system in rice paddy is rapidly expanding in Korea. This study was to find out optimum japonica rice cultivars for organic farming. A field research was conducted to evaluate the characteristics of japonica rice cultivars under no-tillage paddy at Doo-ryangmyeon, Sacheon, Gyeongsangnam-do, Korea. The experimental soil was Juggog series (silty clay loam: 56.0% silt, 31.2% clay and 12.8% sand). In experiment, ten lines of Japanese rice cultivars were tested under no-tillage amended with rye (NTR) and no-tillage without cover crop treatment (NTNT). In addition, two Korean japonica rice cultivars as check cultivars were used in this study. The grain yield in NTR was significantly higher in 6.13 Mg ha^{-1} for Kinuhikari, 5.30 Mg ha^{-1} for Komekogane, 5.25 Mg ha^{-1} for Kosihikari, 5.22 Mg ha^{-1} for Mazizbare and 5.12 Mg ha^{-1} for Akitakomachi compared to two Korean rice cultivars (4.57 Mg ha^{-1} for Hwayoungbyeo and 4.00 Mg ha^{-1} for Ilmibyeo) in that order. While, grain yield in NTNT was significantly higher in 4.90 Mg ha^{-1} for Akitakomachi 3.81 Mg ha^{-1} for Hinohikari, 3.74 Mg ha^{-1} for Umezkusi, 3.67 Mg ha^{-1} for Kosihikari and 3.54 Mg ha^{-1} for Dondokuri compared to 3.02 Mg ha^{-1} for Ilmibyeo and 2.36 Mg ha^{-1} for Hwayoungbyeo, respectively. The number of panicle per m^2 and grain number per panicle were indispensible for increasing the yield of rice. These results were able to find out optimum japonica rice cultivar Akitakomachi for organic farming in no-tillage paddy.

Key Words: No-tillage paddy, Organic farming, Principle component analysis, Rice cultivar

INTRODUCTION

Rice is a main source of food for more than half of the world's population, especially in Asia and Latin America. It is grown on approximately 153 million hectares globally, of which 134 million hectares are in Asia (Rao et al., 2007). Area of organic farming in Korea is increasing rapidly from 450 ha in 2001 to 12,033 ha in 2008 (NAQS, 2010). Cultivar improvement is often recognized as one of the most important factor contributing to the regional crop yield (Hasegawa et al., 1991). Major five rice breeding strategies were eating quality, grain quality, resistance to disease and insect, adaptability for direct seeding and yield (Park, 2005). Actually, the previous studies about rice cultivation for organic farming were reported such as insecticide resistance (Bughio and Wilkins, 2004), physical and chemical environment (Chauhan and Johnson, 2009; Naklang et al., 1996; Wade et al., 1999; Zhang et al., 2007) and reducing methane (Aulakh et al., 2002; Mitra et al., 1999). However, these reports have very few of optimum rice cultivars for organic farming. In no-tillage paddy, grain yield of rice was significantly affected by soil tillage and applied organic matters (Lee et al., 2009). Furthermore, the management practices with rye applications in no-tillage paddy improved the physical and biological properties of soils (Lee et al., 2010).

Therefore, this research was performed to select of optimum japonica rice cultivars for organic farming in no-tillage paddy using certified high quality cultivars from consumers.

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Materials and Methods

Experimental site description

This study was performed at the rice paddy fields in Sacheon, Gyeongsangnam-do, Korea which located at 35°06′33″N latitude and 128°07′07″E longitude. Annual average temperature and precipitation in the study area were 19.1℃ and 1,423 mm, respectively, during the experimental period. Soil in the study sites was Juggog series (silty clay loam: 56.0% silt, 31.2% clay and 12.8%) that classified fine-silty mixed, mesic Fluvaquentic Eutrudepts. Selected soil chemical properties in the experimental sites ranged 5.9 for pH (1:5), 0.17 dS m^{-1} for electrical conductivity, 19.0 g kg^{-1} for soil organic matter content, 37 mg kg^{-1} for available phosphorus concentration, 0.16, 6.0 and 1.9 $cmol_c$ kg^{-1} for exchangeable K^+, Ca^{2+} and Mg^{2+} concentrations, 4.1 mg kg^{-1} for NH_4^+-N content, and 127 mg kg^{-1} for available SiO_2 content, respectively.

For sustainable agricultural point of view, Japonica rice cultivars could be focused instead of recommended high yielding cultivars. In the experiment, ten of Japanese rice cultivars were tested under no-tillage amended with rye (NTR) and no-tillage without cover crop treatment (NTNT) which all treatments were performed without chemical compounds and two Korean japonica rice cultivars as high quality rice cultivars (Bum et al., 2006; Choi et al., 2006; Roh et al., 2007) were used in this study (Table 1). All of the treatments were conducted by a randomized complete block design with three replications. The size of each experimental plot was 12 m^2 (3 m × 4 m) and submerged in June to middle of July, and August to middle of September of the study years.

Analysis of soil and organic matter

Seeds of rye (80 kg ha^{-1}) were sown at late September and shoot of rye were harvested at early May and spread on the surface of soil after chopping into 10 cm length. The rye and dominant weeds grown in untreated plot, were collected before submerging the experimental fields, washed with tap water and then rinsed with deionized water. The samples were dried in an air-forced drying oven at 70℃ for 72 hrs and weighed. The dried samples were ground using a grinding mill (RM100 Mortar Grinder, Retsch, Germany). Selected nutritional chemicals were determined using methods proposed by NIAST (2000) and results were presented in Table 2.

Statistical analyses

Statistical analyses were conducted using SAS software version 9.1.3 for Window (2006). The results of each parameter in all three applications were subjected to analysis of variance. Means of cultivars and treatments were performed using the Duncan's multiple range test (DMRT) and Tukey's studentized range test for significance at the 0.05 level of probability, respectively. For each yield and yield components were analyzed by principal components analysis (PCA)

Table 1. Japonica rice cultivars and obtaining regions

No.	Cultivars	Obtaining regions	No.	Cultivars	Obtaining regions
1	Kosihikari	Chunan	7	Hinohikari	Haenam
2	Hitomebore	Daejeon	8	Dream rice	Hwasun
3	kinuhikari	Bosung	9	Komekogane	Yeoju
4	Dondokui	Yongin	10	Mazizbare	GNARES†
5	Akitakomachi	Yangpyung	11	Ilmibyeo	GNARES
6	Umezkusi	Haenam	12	Hwayeongbyeo	GNARES

†GNARES : Gyeongsangnam-do Agricultural Research and Extension Services.

Table 2. The concentrations of chemicals in organic matter applied

Green manure applied	Dry weight	T-N	P_2O_5	K_2O	C:N ratio
	---------- kg ha^{-1} ----------				
Rye	4,927	23	16	97	103
No treatment (weeds)	796	6	3	15	60

to determine the optimum japonica rice cultivars for organic farming.

Results and Discussion

The results of growth, yield and yield components from cultivars and treatment showed in Table 3 and 4. The SPAD values of rice cultivars at heading stage were the highest in Kinuhikari for NTR and Akitakomachi for NTNT. Usually, SPAD values of NTR were significantly higher than those of NTNT. In reported Lee et al. (2006), SPAD values were positively related grain

Table 3. Growth characteristics of cultivars at heading stage under NTR and NTNT in no-tillage paddy

Cultivars	SPAD values			Height (cm)			No. of tillers per m^2		
	NTR†	NTNT	Mean	NTR	NTNT	Mean	NTR	NTNT	Mean
Kosihikari	43.9ab‡	35.6de	40.4	128a	116abc	124	502abc	384e	446
Hitomebore	43.1abc	37.9abcd	40.5	127a	113abc	120	422de	434cd	423
Kinuhikari	46.4a	36.0cde	40.8	127a	119ab	122	524ab	414de	436
Dondokui	39.8cde	33.6ef	38.9	116ab	110abc	115	484abc	412de	466
Akidakomazi	41.1bcd	39.4a	38.9	120a	109abc	118	444cde	472ab	458
Umezkusi	37.7def	36.6bcd	37.0	115ab	121a	118	494abc	486a	459
Hinohikari	36.3ef	36.5bcd	38.4	115ab	110abc	114	466bcd	424d	421
Dream rice	37.9def	37.5abcd	40.2	119a	115abc	120	470bcd	444bcd	467
Komekogane	42.5bc	38.1abcd	40.0	128a	113abc	121	502abc	458abc	453
Mazizbare	38.3def	32.8f	37.3	118a	104bc	112	542a	458abc	453
Ilmibyeo	35.3f	38.8ab	37.6	102c	107abc	106	398e	306g	369
Hwayoungbyeo	41.2bcd	38.4abc	41.9	105bc	102c	107	416de	348f	374
Mean*	40.6[a]	36.2[b]	38.8	119[a]	112[b]	117	482[a]	416[b]	437

†NTR: no-tillage amended with rye and NTNT: no-tillage without cover crop treatment.
‡Values within a column followed by the same letter are not significantly different at 5% level by DMRT.
*Values within a column followed by the same letter are not significantly different at 5% level by Tukey's studentized range test.

Table 4. Grain yield and yield components of japonica rice cultivars as affected by NTR and NTNT in no-tillage paddy

Cultivars	Yield (Mg ha^{-1})			Ripened grain (%)			No. grains $panicle^{-1}$			No. panicles m^{-2}			1000 grain weight (g)		
	NTR†	NTNT	Mean	NTR	NTNT	Mean	NTR	NTNT	Mean	NTR	NTNT	Mean	NTR	NTNT	Mean
Kosihikari	5.25b‡	3.67bcd	4.72	84cd	78bc	82	78.3a	73.5abc	82.0	291abc	229bcd	253	27.4ab	28.0a	27.7
Hitomebore	4.71cd	3.43def	4.07	87abc	86abc	81	75.2a	69.7bcd	74.3	260bcd	220bcde	255	27.6a	26.0ab	26.4
Kinuhikari	6.13a	3.23fgh	4.50	86bcd	82abc	82	82.7a	78.7a	82.4	306a	186ef	239	28.2a	26.8a	27.9
Dondokui	3.64[f]	3.54cde	4.32	86bcd	75c	80	71.0a	76.2ab	73.5	213e	228bcd	264	28.0a	27.2a	28.2
Akidakomazi	5.12bc	4.90a	4.53	86abc	87abc	85	81.6a	79.5a	73.7	269abc	269a	265	27.1ab	26.4ab	27.3
Umezkusi	4.42de	3.74bc	4.09	87abc	84abc	83	73.2a	63.5d	69.1	260bcd	253ab	263	26.7ab	27.7a	27.1
Hinohikari	4.40de	3.81b	4.40	82d	81abc	79	78.9a	71.3abcd	81.3	256cde	246ab	265	26.5ab	26.8a	25.9
Dream rice	4.60d	3.47def	4.94	86bcd	84abc	85	79.3a	66.7cd	79.0	250cde	238abc	266	26.9ab	26.0ab	27.4
Komekogane	5.30b	3.07gh	4.76	84cd	87abc	84	80.5a	64.5d	80.8	302ab	195de	262	25.9ab	28.0a	26.9
Mazizbare	5.22b	3.31efg	4.52	88abc	92a	84	78.8a	71.7abcd	79.1	266abc	206cde	256	28.3a	24.4b	26.5
I lmibyeo	4.00ef	3.02h	3.51	89ab	88ab	86	82.3a	63.5d	69.6	219de	210cde	230	24.9b	25.8ab	25.6
Hwayoungbyeo	4.57d	2.36i	4.21	91a	83abc	84	73.3a	65.0cd	81.1	250cde	161f	221	27.4ab	27.1a	27.9
Mean*	4.79[a]	3.50[b]	4.37	85[a]	84[a]	83	76.4[a]	70.1[b]	76.6	271[a]	222[b]	253	27.1[a]	26.6[a]	27.3

†NTR: no-tillage amended with rye and NTNT: no-tillage without cover crop treatment.
‡Values within a column followed by the same letter are not significantly different at 5% level by DMRT.
*Values within a column followed by the same letter are not significantly different at 5% level by Tukey's studentized range test.

Table 5. A correlation between yield and yield components of japonica rice cultivars (n=72)

Parameter	Ripened grain	Grains per panicle	Panicles per m^2	1,000 Grain weight
Yield	0.144	0.648***	0.870***	0.257*
Ripened grain	-	0.044	0.127	-0.089
Grainsper panicle	-	-	0.561***	0.187
Panicles per m^2	-	-	-	0.275*

yield. SPAD value of NTR was increased in Kinuhikari, Kosihikari, Hitomebore and Komekogane compared to two Korean rice cultivars while that of NTNT was increased in Akitakomachi only compared to two Korean rice cultivars. Plant height of japonica rice cultivars in NTR at heading stage were the longest in Kosihikari and Komekogane. Plant heights of Ilmibyeo in NTNT and Hwayeongbyeo in NTNT were significantly lower than other rice cultivars. Tiller numbers of japonica rice cultivars were the highest in 542 tillers per m^2 for Mazizbare in NTR and 486 tillers per m^2 for Umezkusi in NTNT. Usually, tiller number of NTR was significantly higher compared to NTNT and that of Ilmibyeo and Hwayeongbyeo was decreased compared to Japanese rice cultivars.

Grain yield and yield components were presented in Table 4. The grain yield in NTR was significantly higher in 6.13 Mg ha^{-1} for Kinuhikari, 5.30 Mg ha^{-1} for Komekogane, 5.25 Mg ha^{-1} for Kosihikari, 5.22 Mg ha^{-1} for Mazizbare and 5.12 Mg ha^{-1} for Akitakomachi compared to two Korean rice cultivars (4.57 Mg ha^{-1} for Hwayoungbyeo and 4.00 Mg ha^{-1} for Ilmibyeo) in that order. While, grain yield in NTNT was significantly higher in 4.90 Mg ha^{-1} for Akitakomachi 3.81 Mg ha^{-1} for Hinohikari, 3.74 Mg ha^{-1} for Umezkusi, 3.67 Mg ha^{-1} for Kosihikari and 3.54 Mg ha^{-1} for Dondokuri compared to 3.02 Mg ha^{-1} for Ilmibyeo and 2.36 Mg ha^{-1} for Hwayoungbyeo, respectively. These results were in accord with previously report by Choung et al. (2007) under low fertilizer application in paddy soil. Usually, grain yield in NTR was observed higher than that of NTNT due to significantly higher number of panicle per m^2 and grain number per panicle (Table 4). According to previous reports, number of panicle per area and grain number per panicle were indispensible for increasing the yield of rice (Reuben and Katuli, 1989; Sardana et al., 1989; Yoshida, 1981). Ripened grain rate was significantly higher in two Korean rice cultivars compared to Japanese rice cultivars while number of panicles per m^2 was significantly higher in Japanese rice cultivars than that of two Korean rice cultivars (Choung et al., 2008).

A correlation of yield and yield components was presented Table 5. Yield of japonica rice cultivars was significantly correlated with number of panicles per m^2 (r=0.870, p<0.001) and number of grains per panicle (r=0.648, p<0.001). Also, number of grains per panicle was positively correlated with number of panicles per m^2 (r=0.561, p<0.001). These results were agreed with Lafitte et al. (2006), Bum et al. (2006) and Song and Cho (2008).

PCA could clearly visualize the difference in yield and yield components between the japonica rice cultivars and soil managements (Fig. 1). The eigenvalues for PC1 (50.5%) and PC2 (21.6%) were both greater than 1.0 and their cumulative proportion was 72.1%. PCA was positive in either of the PC1 or PC2, meaning that at least one of the major components would express a general performance of japonica rice cultivars. The PC1 in yield and yield components contained three positive factor loadings for yield (0.59), number of panicles per m^2 (0.57) and number of grains per panicle (0.50) while PC2 in those contained one positive factor loading for ripened grain (0.82) and one negative factor loading for 1,000 grain weight (-0.57). Especially, Akitakomachi both NTR and NTNT treatment was closely positive in PC1. These results were expected to provide optimum japonica rice cultivar Akitakomachi for organic farming in no-tillage paddy.

A new crop production system to improve economic, environmental and production efficiency is an uttermost priority. Particular concern has been given to an integrated cropping system involving recycling of crop residues for organic farming. Above results, the application of selected japonica rice cultivars in no-tillage cropping system will be a one-in-a-million chance to improve the sustainable crop production system which is able to reduce labor and fertilizer amount at large scale.

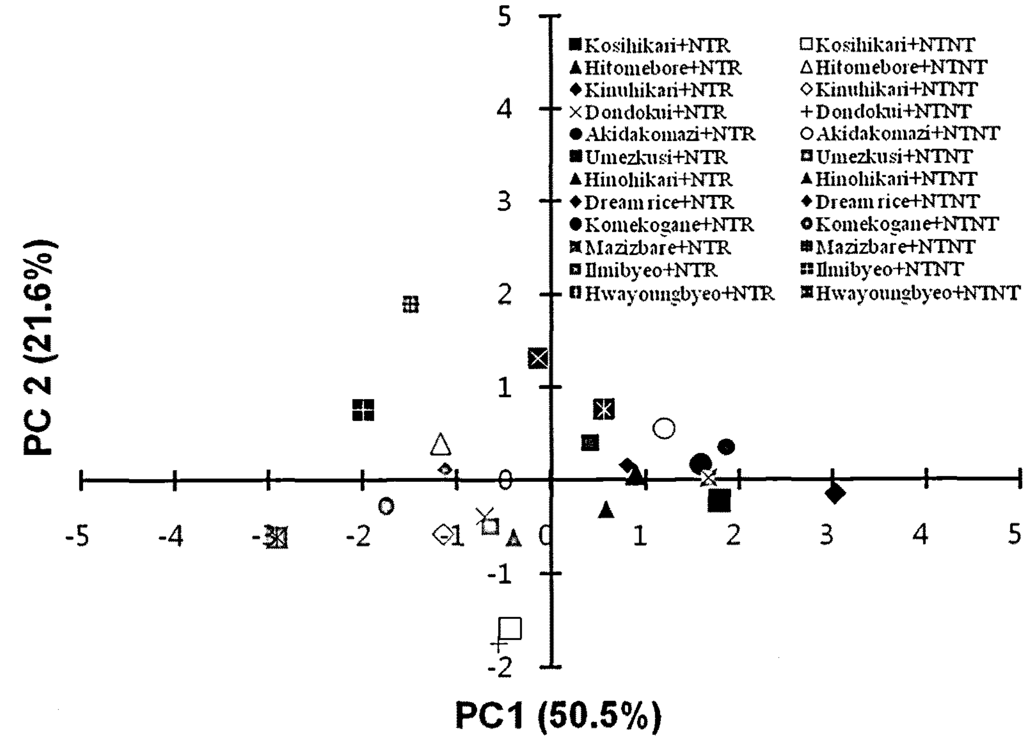

Fig. 1. Principal components analyses of yield and yield components of japonica rice cultivars. The variance explained by the each principal component (PC) axis is shown in parentheses. NTR: no-tillage amended with rye and NTNT: no-tillage without cover crop treatment.

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