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Effects of Nitrogen Level and Seedling Number on Panicle Structure in Japonica Rice

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ABSTRACT: Four different rice varieties, Sindongjinbyeo, Dongjin #1, Saegyehwabyeo, and Iksan 467, were transplanted under three different nitrogen levels and two different seedling numbers per hill to obtain basic information on panicle traits under different cultural conditions and to propose the ideal panicle structure in Japonica rice. Sindongjinbyeo and Iksan467 were characterized by more primary rachis branches (PRBs) per panicle and more grains on PRB than other cultivars. The two varieties also had fewer secondary rachis branches (SRBs) per PRB and fewer grains on SRB per PRB. These characteristics, consequently, resulted in higher ripened grain rate, contrary to that of Dongjin #1 and Saegyehwabyeo.

In the correlation coefficient analysis, PRB number per panicle and grain number on PRB per panicle were positively correlated with ripened grain rate, while SRB number per panicle, number of grains on SRB per panicle, SRB number per PRB, number of grains on SRB per PRB and grain number per panicle were negatively correlated with ripened grain rate. Therefore, the number of grains on PRB per panicle, SRB number per PRB and the number of grains on SRB per PRB were the appropriate criteria for determining and achieving higher ripened grain rate in rice. High ripened grain rate over 90% was obtainable with over 12.5 PRBs per panicle and 63 grains on PRB per panicle, and with under 1.7 SRBs per PRB, 5 grains on SRB per PRB, 130 grains per panicle, and 14 panicles per hill. The study recommended that for over 90% high ripened grain rate, the critical limiting factors should be under 2 SRBs per PRB, 6 grains per PRB, and 130 grains per panicle, irrespective of the PRB number per panicle and the number of grains on PRB.

Keywords : rice, rachis branch, spikelet number, panicle structure, nitrogen level, seedling number

In rice, it was reported that spikelet number per panicle and panicle structure were greatly controlled by applied nitrogen level, planting density, air temperature, shading of sunlight, phytohormone treatment and water management (Hasegawa *et al.*, 1994, Kobayashi & Horie 1994, Park *et al.*, 2002). Saha *et al.*, (1998) and Park *et al.*,(2002) investigated the effect of application time of top dressing at panicle formation stage on the differentiation and degeneration of spikelet. There were also studies reporting the significant varietal difference in spikelet number and panicle structure (Fukushima & Akita 1997, Lee *et al.*, 1992, Park *et al.*, 1999). Fukushima(1999) reported that panicle structure was determined by the number of primary rachis branches (PRBs), secondary rachis branches(SRBs), and tertiary rachis branches(TRBs). He also added that the number of grains on SRB had the greatest effect on the spikelet number per panicle. Kobayashi & Imaki (1997) classified three different panicle structures as the upper positioned SRB dominance type bearing lots of SRB at the upper part in a panicle, intermediate type, and lower positioned SRB type bearing lots of SRB at the lower part. These panicle structures were classified on the basis of the position type of SRB within a panicle. They found that the panicle structure was an innate trait in rice.

In recent years, Kim *et al.*, (2002) conducted the genetic analysis of PRB and SRB per panicle by half diallel cross.

But there are not many researches on basic information on the useful criteria among panicle traits for the improvement of ripened grain rate in rice. The useful criteria have some requirements such as the variation pattern of panicle traits as affected by cultural conditions, the interrelationship among the traits, and the varietal difference in the traits. Therefore, this study was conducted to investigate the varietal differences and the interrelationship among panicle traits under different nitrogen levels applied and seedling number per hill. Other useful research results were also summarized.

MATERIALS AND METHODS

Four different panicle types of rice varieties, Sindongjinbyeo, Dongjin #1, Saegyehwabyeo, and Iksan 467, were transplanted under three different nitrogen levels and two different seedling numbers per hill with planting density of 30×15 cm on May 30, 2002, 30 days after the seeding date.

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The experiment plots were arrayed with split-split design with main plot of nitrogen application levels of 110, 165 and 220 kg/ha, sub-plot of seedling number per hill of three and one plant and sub-sub plot of four varieties in three replications.

Split application of nitrogen was applied at the rate of 40% as basal fertilizer just before transplanting, 30% at the fouror five-leaf stage, and 30% at the panicle formation stage. A total of 45/ha of phosphorus was applied as basal fertilizer and 57 kg of potassium, with 70% as basal fertilizer and 30% at the panicle formation stage.

The longest five panicles per hill were harvested from ten plants per replication, 55 days after heading and studied according to each panicle trait. The analyzed data were the means of traits drawn from the five panicles.

Phenotypic and genetic correlation coefficients were calculated on the basis of variance and covariance, and path analysis followed Dewey & Lu's method (1959) of hA2+eA2=1 using AGRISP.

RESULTS AND DISCUSSION

Varietal differences of panicle traits as affected by nitrogen level and seedling number per hill

Table 1 shows the analysis of variance for panicle number per hill, number of PRB and SRB, and grains on PRB and SRB per panicle under three different nitrogen levels and two different planted seedling number per hill in four different rice varieties.

But there was no interaction between and among the three factors. It was thought that the individual factor's effect on each panicle trait was greater than the interaction effect of two or three factors, which could not apparently appear.

On the effect of nitrogen level and seedling number on the different rice varieties, panicle number per hill was not affected by nitrogen level but was significantly affected by seedling number per hill (Table 2). There was significant difference among the four rice varieties in order of Saegyehwabyeo>Iksan 467>Dongjin #1>Sindongjinbyeo.

Table 1. Mean squares for panicle traits across nitrogen level and seedling number per hill.

Source	df	No. of rachis branch per panicle		No. of grain on	
		Primary	Secondary	PRB per panicle	SRB per panicle
Replication	2	0.073	9.605	4.234	78.078
Nitrogen level(NL)	2	0.512	26.527	24.297*	232.688
Error	4	0.114	7.780	3.070	88.156
Seedling number(SN)	1	13.524**	639.645**	528.219**	5774.630**
NLSN	2	0.344*	0.598	18.344	26.594
Error	6	0.061	1.285	5.000	16.443
Variety(VAR)	3	3.064**	564.383**	335.885	8659.280
NLVAR	6	0.238	4.751	25.464	34.724
VARSN	3	0.097	1.724	11.615	42.104
NLSNVAR	6	0.185	2.832	11.094	34.010
Error	36	0.263	5.862	12.256	65.786

*, **Significant at the 0.05 and 0.01 probability level, respectively.
PRB: Primary rachis branch, SRB : Secondary rachis branch

Table 2. Difference in the panicle number as affected by nitrogen level and seedling number per hill.

Nitrogen level(NL)	Seedling number(SN) per panicle and variety(VAR)									
	Three					One				
	SDJ	I.467	DJ 1	SGH	Mean	SDJ	I.467	DJ 1	SGH	Mean
	Panicle number per hill									
110	125	128	131	143	132	96	107	98	108	102
165	128	132	135	148	136	100	110	105	115	108
220	138	141	13	162	143	108	111	112	132	116
Mean	130	134	133	151	137	101	109	105	118	109
LSD(5%)	NL(0.34), PD(0.35), VAR(0.28)									

SDJ: Sindongjinbyeo, I.467: Iksan 467, DJ 1 : Dongjin #1, SGH: Saegyehwabyeo

The number of PRB per panicle increased more in one seedling per hill than in three and showed significant varietal difference among the four rice varieties. Sindongjinbyeo had 11.6 and 12.4 PRBs per panicle; Iksan 467, 11.3 and 12.4; Dongjin #1, 11.0 and 11.9; and Saegyehwabyeo, 10.7 and 11.4 under three and one planted seedling number per hill, respectively (Table 3).

Grains on PBR per panicle was affected by seedling number per hill and increased in one seedling per hill than in three. In the varietal difference, Sindongjinbyeo had 67.4 and 70.6 grains on PRB per panicle, which meant that Sindongjinbyeo had 5.8 and 5.7 mean grains per PRB under

Table 3. Difference of PRB number and grains on PRB per panicle as affected by nitrogen level andseedling number per hill.

Nitrogen level(NL)	Seedling number(SN) per hill and variety(VAR)									
	Three					One				
	SDJ	I.467	DJ 1	SGH	Mean	SDJ	I.467	DJ 1	SGH	Mean
	No. of primary rachis branch(PRB) per panicle									
110	112	110	110	104	109	124	121	117	117	120
165	118	114	106	109	112	127	125	120	112	121
220	117	116	115	109	114	121	125	121	113	120
Mean	116	113	110	107	112	124	124	119	114	120
LSD(5%)	NL(0.27), PD(0.14), VAR(0.34)									
	Grains on PRB per panicle									
110	639	636	591	562	607	717	721	636	650	681
165	725	663	568	604	640	730	731	659	635	689
220	657	678	626	587	637	672	739	661	641	678
Mean	674	659	595	584	628	706	730	652	642	683
LSD(5%)	NL(1.40), PD(1.29), VAR(2.32)									
MGNPRB	5.8	5.8	5.4	5.5	5.6	5.7	5.9	5.5	5.6	5.7

SDJ: Sindongjinbyeo, I.467: Iksan 467, DJ 1: Dongjin #1, SGH: Saegyehwabyeo
MGNPRB: Mean grain number in a primary rachis branch(Grain number on PRB/No. of PRB in a panicle)

Table 4. Difference in the SRB number and grains on SRB per panicle as affected by nitrogen level and seedling number per hill.

Nitrogen level(NL)	Seedling number(SN) per hill and variety(VAR)									
	Three					One				
	SDJ	I.467	DJ 1	SGH	Mean	SDJ	I.467	DJ 1	SGH	Mean
	No. of SRB per panicle									
110	205	156	306	230	224	278	207	347	287	280
165	236	179	297	228	235	295	237	365	290	297
220	197	164	284	215	215	256	208	368	271	276
Mean	213	166	296	224	225	276	217	360	283	284
LSD(5%)	NL(2.24), PD(0.65), VAR(1.61)									
	Grain on SRB per panicle									
110	569	385	953	683	648	776	517	1061	858	803
165	647	458	914	689	677	816	603	1145	891	864
220	527	414	872	638	613	733	544	1151	805	808
Mean	581	419	913	670	646	775	555	1119	851	825
LSD(5%)	NL(7.52), PD(2.34), VAR(5.38)									
MGNSRB	27	2.5	3.1	3.0	2.8	2.8	2.6	3.1	3.0	2.9

SDJ: Sindongjinbyeo, I.467: Iksan 467, DJ 1: Dongjin #1, SGH: Saegyehwabyeo
MGNSRB: Mean grain number in a secondary rachis branch(Grain number on SRB/No. of SRB in a panicle)

three and one planted seedling number per hill; Iksan 467 had 65.9 and 73.0 grains setting with 5.8 and 5.9 mean grains; Dongjin #1 had 59.5 and 65.2 grains setting with 5.4 and 5.5 mean grains; and Saegyehwabyeo had 58.4 and 64.2 grains setting with 5.5 and 5.6 mean grains for three and one seedling per hill, respectively.

The number of SRB per panicle increased in one seedling per hill than in three. There was apparent difference among the varieties (Table 4).

Iksan 467, the fewest SRB variety among used varieties, had 16.6 and 21.7 SRB per panicle under three and one seedling number per hill, respectively, while Dongjin #1, the most SRB one among used varieties, had 29.6 and 36.0; Sindongjinbyeo, 21.3 and 27.6; and Saegyehwabyeo, 22.4 and 28.3, respectively.

Grains on SRB per panicle was affected by seedling number per hill but not by nitrogen level and there was significant difference among varieties. Sindongjinbyeo had 58.1 and 77.5 grains on SRB per panicle with 2.7 and 2.8 mean grains per SRB. Iksan 467 had 41.9 and 55.5 grains with 2.5 and 2.6 mean grains; Dongjin #1, 91.3 and 111.9 grains with 3.1 and 3.1 mean grains, and Saegyehwabyeo, 67.0 and 85.1 grains with 3.0 and 3.0 mean grains in three and one seedling number per hill, respectively.

From these results, Sindongjinbyeo and Iksan 467 were characterized by more PRB and more grains on PRB per panicle but fewer SRB and fewer grains on SRB per panicle, while Dongjin #1 and Saegyehwabyeo showed contrary

Table 5. Mean squares for secondary rachis traits per PRB branch across nitrogen level and seedling number per hill.

Source	df	Number of		Grain number per panicle	Ripened grain rate
		SRB per PRB	Grain on SRB per PRB		
Replication	2	0.045	0.298	123.50	8.844
Nitrogen level(NL)	2	0.200	1.767	349.63	95.063
Error	4	0.068	0.729	66.78	11.734
Seedling number(SN)	1	2.457**	23.405**	9685.75**	33.750**
NLSN	2	0.026	0.466	0.87	2.125
Error	6	0.016	0.205	21.875	2.438
Variety(VAR)	3	4.880**	73.305**	382.83**	315.313**
NLVAR	6	0.008	0.087	106.25	7.563
VARSN	3	0.029	0.442	24.54	8.208
NLSNVAR	6	0.027	0.301	64.31	6.240
Error	36	0.035	0.434	95.78	12.168

*, **Significant at the 0.05 and 0.01 probability level, respectively.
PRB: Primary rachis branch, SRB : Secondary rachis branch

Table 6. Differences in the SRB per PRB and grains on SRB per PRB as affected by nitrogen level and planted seedling number per hill.

Nitrogen level(NL)	Seedling number(SN) per hill and variety(VAR)									
	Three					One				
	SDJ	I.467	DJ 1	SGH	Mean	SDJ	I.467	DJ 1	SGH	Mean
	Number of SRB per PRB									
110	18	14	28	22	21	23	17	30	22	23
165	18	16	28	21	21	23	19	31	21	24
220	17	14	25	20	19	21	17	31	20	22
Mean	18	15	27	21	20	22	18	31	21	23
LSD(5%)	NL(0.21), PD(0.07), VAR(0.12)									
	Grains on SRB per PRB									
110	47	36	87	66	59	63	43	90	73	67
165	50	40	87	64	60	64	49	96	80	72
220	45	36	76	58	54	61	43	96	71	68
Mean	47	37	83	63	58	63	45	94	75	69
LSD(5%)	NL(0.68), PD(0.26), VAR(0.44)									

SDJ: Sindongjinbyeo, I.467: Iksan 467, DJ 1: Dongjin #1, SGH : Saegyehwabyeo

results for the four traits.

Table 5 shows the analysis of variance for number of SRB and grains on SRB per PRB, grain numbers per panicle, and filled grain rate as affected by nitrogen level and seedling number per hill and per variety.

The number of SRB and grains on SRB per PRB were not affected by nitrogen level but were significantly affected by seedling number per hill and genotypes. There was no interaction between and among the three factors.

Grain number per panicle and ripened grain rate were not varied among nitrogen levels but significantly different between two planted densities and among the four genotypes (Table 6).

The number of SRB per PRB increased in one than in three seedlings per hill. There were significant varietal differences. Iksan 467 had the fewest SRBs per PRB while Dongjin #1 had the most.

Grains on SRB per PRB increased in one than three seedlings and showed significant varietal difference among the four varieties in the order of Dongjin #1>Saegyehwabyeo>Sindongjinbyeo>Iksan 467.

Grain number per panicle and ripened grain rate were significantly affected by seedling number per hill and genotypes but not by nitrogen level (Table 7).

Grain number of Iksan 467 was 107.8 and 128.5 grains, Sindongjinbyeo, 125.1 and 148.1 grains, Saegyehwabyeo, 125.4 and 149.3 grains, and Dongjin #1, 150.8 and 177.1 grains in three and one seedling per hill, respectively. Ripened grain rate was apparently affected by seedling number per hill and genotype. Iksan 467 had 91.2% and 92.7%; Sindongjinbyeo, 87.1% and 86.9%; Saegyehwabyeo, 84.9% and 86.0%; and Dongjin #1, 80.3% and 83.4% ripened grain rate in three and one seedling per hill, respectively.

Correlation coefficients between panicle traits and ripened grain rate or grain number per panicle

Phenotypic and genetic correlation coefficients between panicle traits and ripened grain rate are shown in table 8.

Ripened grain rate was significantly and positively corre-

Table 7. Changes in the grain number per panicle and ripened grain rate as affected by nitrogen level and seedling number per hill.

Nitrogen level(NL)	Seedling number(SN) per hill and variety(VAR)									
	Three					One				
	SDJ	I.467	DJ 1	SGH	Mean	SDJ	I.467	DJ 1	SGH	Mean
	Grain number per panicle									
110	1208	1021	1544	1245	1255	1493	1238	1697	1508	1484
165	1372	1121	1482	1293	1317	1546	1335	1804	1526	1553
220	1183	1092	1498	1225	1250	1405	1283	1813	1446	1487
Mean	1254	1078	1508	1254	1274	1481	1285	1771	1493	1508
LSD(5%)	NL(6.55), PD(2.70), VAR(6.49)									
	Ripened grain rate									
110	897	922	806	880	876	888	939	868	876	893
165	865	907	794	825	848	882	916	807	858	866
220	850	907	808	842	852	838	926	827	846	859
Mean	871	912	803	849	859	869	927	834	860	873
LSD(5%)	NL(2.75), PD(0.90), VAR(2.31.)									

SDJ: Sindongjinbyeo, I.467: Iksan 467, DJ 1: Dongjin #1, SGH: Saegyehwabyeo

Table 8. Correlation coefficients among panicle traits and ripened grain rate.

Traits	Number of		Number of grains on		Number of		Grain number per panicle
	PRB per panicle	SRB per panicle	PRB per panicle	SRB per panicle	SRB per PRB	Grains on SRB per PRB	
Ripened grain rate	0.209 0.455*	-0.589** -0.881**	0.551** 0.812**	-0.630** -0.887**	-0.638** -0.903**	-0.663** -0.898**	-0.525** -0.830**
Grain number per panicle	0.293 -0.174	0.991** 0.995**	0.015 -0.521**	0.978** 0.989**	0.951** 0.975**	0.936** 0.969**	-

*, **Significant at the 0.05 and 0.01 probability level, respectively.
PRB: Primary rachis branch, SRB : Secondary rachis branch

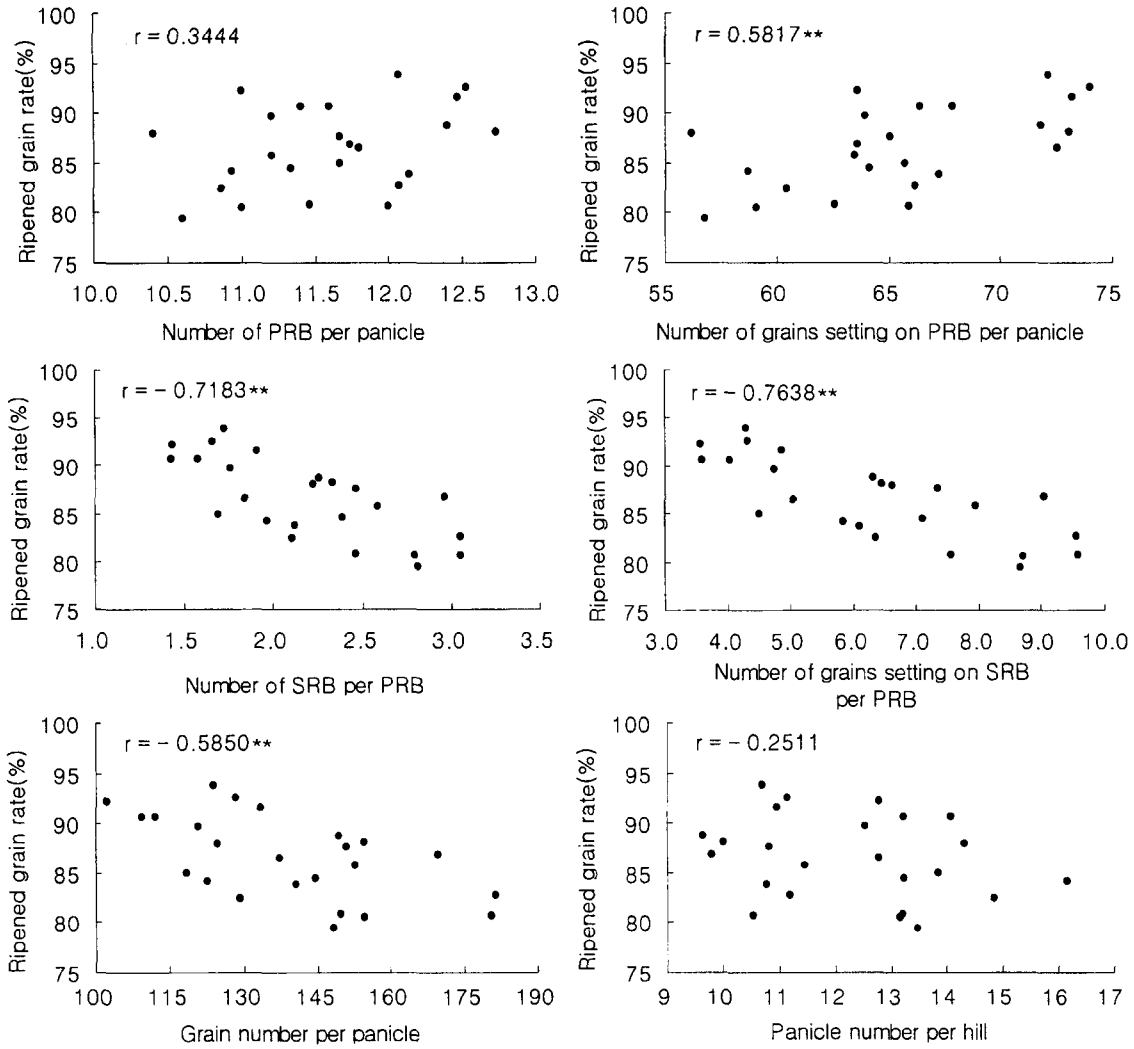

Fig. 1. Scatter diagram between panicle traits and ripened grain rate. PRB: Primary rachis branch, SRB : Secondary rachis branch

lated with grains on PRB per panicle, while it was significantly and negatively correlated with the number of SRB per panicle and PRB, grains on SRB per panicle and PRB in phenotypical and genetical correlation. Grain number per panicle was not negatively correlated with the number of grains on PRB per panicle neither phenotypically nor genetically, while it was significantly correlated with all of SRB traits both phenotypically and genetically. These results were similar to Fukushima's reports (1999). Therefore, the indispensable require-ments for increasing both grain number per panicle and ripened grain rates were to increase the number of grains on PRB per panicle and to decrease SRB number per panicle and number of grains on SRB per panicle.

Interrelationship between panicle traits and ripened grain rate

High ripened grain rate over 90% was obtained with more than 12.5 PRBs per panicle, 63 grains on PRB per panicle, less than 1.7 SRBs per PRB, 5 grains on SRB per PRB, 130 grains per panicle, and 14 panicles per hill (Fig. 1).

The study suggests that the critical limiting factors to attain high ripened grain rate of more than 90% be under 2 SRBs per PRB, 6 grains on SRB per PRB, and 130 grains per panicle.

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