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Effect of Planting Density and Nitrogen Level on Growth and Yield in Heavy Panicle Weight Type of Japonica Rice

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ABSTRACT

To investigate the effects of planting density and nitrogen level on growth and yield potential of newly bred heavy panicle japonica rice with large grain (Iksan 435 and Iksan 438) or many spikelets per panicle(HR14022-21-8-4 and HR14022-21-8-6), four heavy panicle type rices and two many panicle type rices(Dongjinbyeo and Donganbyeo) as the checks were planted under standard planting density(30× 15 ㎝) and dense planting density (15×15 ㎝) with two nitrogen levels of standard nitrogen level(110 ㎏ ha^{-1}) and heavy nitrogen level(165 ㎏ ha^{-1}).

Effective tiller rate decreased in dense planting or heavy nitrogen, when compared to standard nitrogen and planting, while leaf area index and top dry weight increased in dense planting or heavy nitrogen. Tiller numbers and panicle numbers were more increased by dense planting than heavy nitrogen, whereas spikelet numbers were more increased by heavy nitrogen than dense planting. Ripened grain ratio was slightly lower only in dense planting. 1,000 grain weight in brown rice was not significantly different in dense planting or heavy nitrogen.

Milled rice yield was highest in heavy nitrogen with standard planting for heavy panicle type rice, while yield for many panicle type rice was highest in heavy nitrogen with dense planting, suggesting that many panicle type rice possesses higher adaptability for dense planting than heavy panicle type rice.

Path coefficient analysis revealed that top dry weight, spikelet number and grain weight were the greatest positive contributors to yield, whereas tiller number was negative to yield.

Keywords : rice, heavy panicle, planting density, nitrogen level, yield, yield component.

In general, maximum sink size per unit area has been proposed as the most important factor determining the yield of cereal crops and the maximum sink size has been obtained by an increase of planted plants per unit area (Gravois & Helms, 1992; Jones & Synder, 1987; Miller et al., 1991; Wells & Faw, 1978). An over-luxuriantly grown rice canopy accompanies the prevention of light transmisation to the lower leaves, the increase of respiration over photosynthesis, the withering of lower positioned leaves, the reduction of ripened grain rate and the occurance of lodging in field, and consequently reduces the rice yield. Therefore, the maximum yield depends on achieving the optimum planting density, as previously reported in rice (Kanda & Kakizaki, 1957a,b; Kato & Takeda, 1996; Kato, 1997; Son et al., 1998; Yamada et al., 1961).

Recently, IRRI's breeders have focused on developing the new plant type of rice with low tiller number and large panicle from the tropical japonica germplasm because low tiller-large panicle rices are characterized by each tiller's high effective contribution to yield per plant and reducing the disadvantage of over-luxuriantly grown rice canopy by having a higher light transmission rate even in dense planting(Peng et al., 1993; Khush, 1995). To obtain the maximum sink size, low tiller-heavy panicle rice with large panicle or large grain has been proposed as an ideal type. However, there have been some difficulties in that many spikelets per panicle accompanies low ripened grain rate and small grain size, and also large grain size accompanies low ripened grain rate and fewer spikelets per panicle(Kato & Takeda, 1996; Kato, 1997).

On the other hand, since 1980s, some Korean rice breeders in National Honam Agricultural Experimrnt Station(NHAES) have tried to develop japonica high yielding cultivars with high grain quality and good palatability from japonica germplasm, and bred some promising rices, namely heavy panicle rice focused on the increase of grain number, grain weight and filled grain rate. The growth and yield responses to planting density and nitrogen level of these rices, however, have not yet been elucidated. The purpose of the present study is to compare the effects on growth and yield traits of different type of japonica heavy panicle rices newly bred in Korea under dense planting and heavy nitrogen conditions.

MATERIALS AND METHODS

Six japonica rice varieties were used: Iksan 435 and Iksan 438 having many spikelets per panicle, high ripened grain rate and large grain size (thereafter,

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arge grain type rices(LGTRs)), and HR14022-B-21-3-4 and HR14022-B-21-8-6 having medium grain size, high ripened grain rate and many spikelets per panicle (thereafter, many spikelet type rices(MSTRs)), and Donginbyeo, a leading variety in the southern plain area of Korea and Donganbye (thereafter, many panicle type rice(MPTR)) as check varieties.

They were cultivated on a silty loam soil at NHAES rice field under the standard planting(30×15 cm) and dense planting(15×15cm) densities with two nitrogen levels of standard nitrogen(110 kg ha^{-1}) and heavy nitrogen (165 kg ha^{-1}). Thirty five-day old seedlings were transplanted with three plants per hill on May 30.

Split application of nitrogen was applied at the rate of 40% as basal fertilizer just before transplanting, 30% at the four to five leaf stage and 30% at the panicle formation stage. A total of 70 kg ha^{-1} of phosphorus was applied as basal fertilizer, and potassium, 70% as basal fertilizer and 30% at the panicle formation stage in which the applied amount was 80kg ha^{-1}.

The experiment plots were arrayed with the split-split-plot design with the nitrogen level as main plot, planting density as subplot and variety as sub-subplot with three replications.

Tiller number was counted at the maximum tillering stage and leaf area and top dry weight were measured at heading stage. Panicle number was measured at twenty days after heading. Yield and yield components were measured at the fully matured stage (fifty days after heading) according to the procedure of the Rural Development Administration (RDA).

Path coefficients analysis followed Dewey and Lu's Method(1959).

RESULTS AND DISCUSSION

Plant growth habit

Table 1 shows mean squares for plant growth related traits across two planting densities and two nitrogen levels. Tiller number and leaf area index (LAI) differed significantly by nitrogen level. Tiller number, effective tiller rate, LAI and top dry weight were different by planting densitiy. And almost all of the traits except for the effective tiller rate were significantly different among rice varieties. The interaction by planting densitiy and variety was significant only for tiller number.

Table 2 shows the variation of plant growth related traits under two planting densities and two nitrogen levels. Tiller number increased in the order of standard nitrogen with standard planting, heavy nitrogen with standard planting, standard nitrogen with dense planting and heavy nitrogen with dense planting, showing that tiller number in all of rice varieties were significantly increased by dense planting but not, by heavy nitrogen, while tiller number in four heavy panicle type rices (HPTRs) differed apparently by the interaction of planting density and nitrogen level but that of MPTRs was not affected. It was lower in HPTRs than in MPTRs under the four conditions.

Effective tiller rate was lowered by heavy nitrogen or dense planting. There was not a significant difference in the effective tiller rate between LGTRs and MPTRs, while MSTRs were lower than any other rice type and more decreased in dense planting, but they were increased higher by heavy nitrogen.

LAI in MPTRs and MSTRs was high in the order of heavy nitrogen with dense planting, heavy nitrogen with standard planting, standard nitrogen with dense planting and standard nitrogen with standard planting, while that in LGTRs was much higher at dense planting or heavy nitrogen. MSTRs with the lowest tillering ability had the lowest LAI among rice types under the four conditions.

Top dry weight in all of rice varieties was increased by dense planting or heavy nitrogen. Two MPTRS and two LGTRs were increasingly affected more by heavy nitrogen than by dense planting, while MSTRs

Table 1. Mean squares for plant growth related traits across two planting densities and nitrogen levels.

Source	df	Tiller number m^{-2}(No.)	Effective tiller rate(%)	Leaf area index	Top dry weight (g m^{-2})
Replication	2	12390.0	59.41	0.07	448
Nitrogen level(NL)	1	160352.0*	697.28	13.43**	230448
Error	2	3215.0	59.10	0.13	13896
Planting density(PD)	1	1090280**	1944.42**	8.61**	140564**
NL×PD	1	834.0	61.73	0.01	26976
Error	4	5323.5	25.66	0.15	4590
Variety(VAR)	5	33970.4**	6.35	3.55**	20988**
NL×VAR	5	1260.8	18.58	0.12	1946
VAR×PD	5	4376.0*	89.89	0.23	4482
NL×PD×VAR	5	1792.4	11.51	0.13	799
Error	40	1739.1	12.46	0.13	2179

*, ** Significant at the 0.05 and 0.01 probability level, respectively.

Table 2. Changes of plant growth related traits as affected by planting density and nitrogen level.

Nitrogen level	Planting density	Varieties and lines					
		Dongjin byeo	Dongan byeo	Iksan 435	Iksan 438	HR14022-21-8-4	HR14022-21-8-6
(kg)	(cm)	Tiller number m^{-2}(No.)					
11.0	30×15	465b	486b	419d	430c	367c	363c
	15×15	730a	754a	628b	601ab	622b	630b
16.5	30×15	564b	601b	533c	515bc	427c	415c
	15×15	819a	794a	776a	723a	722a	739a
		Effective tiller rate(%)					
11.0	30×15	64.3a	64.2a	65.3a	62.2a	66.3a	64.7a
	15×15	54.0b	54.1b	54.8b	56.2ab	47.1c	47.7b
16.5	30×15	53.9b	52.9b	53.3b	56.5ab	60.2b	61.7a
	15×15	49.5b	52.6b	46.0c	50.3b	44.8c	44.1b
		Leaf area index					
11.0	30×15	4.6c	4.9c	5.0c	4.9c	3.8b	3.8b
	15×15	5.4b	5.3bc	5.8b	5.7b	4.4ab	4.7a
16.5	30×15	5.7ab	6.0ab	5.4bc	5.5b	5.0a	4.6a
	15×15	6.2a	6.3a	6.6a	6.8a	5.3a	5.1a
		Top dry weight(g.m^{-2})					
11.0	30×15	738b	750b	813b	784c	745b	724c
	15×15	877a	823ab	918ab	925b	887a	887b
16.5	30×15	918a	887a	1,014a	939b	854ab	853b
	15×15	920a	885a	1,030a	1,021a	944a	963a

Means followed by the same letter within a column are not significantly different at 5% probability level by DMRT.

were increased more by dense planting. HPTRs had heavier top dry weight than MPTRs in heavy nitrogen with dense planting.

Milled rice yield and yield components

Table 3 shows mean squares for rice yield and yield components across two planting densities and nitrogen levels. Panicle number, spikelet number and milled rice yield were significantly different by nitrogen level. And by planting density, panicle number, ripened grain ratio and 1,000 grain weight of brown rice were significantly different. All of the traits were significant among rice types. The interaction of planting density and nitrogen level was significant only for 1,000 grain weight in brown rice, and that by nitrogen level and variety, only for ripened grain ratio, and that by variety and planting density, for panicle number, ripened grain ratio and milled rice yield.

Table 4 shows the variation of yield and yield components under two planting densities and nitrogen levels.

Panicle number was increased only by dense planting in MPTRs and LGTRs, while that in MSTRs was increased by dense planting and the interaction by dense planting and heavy nitrogen. The result indicates that low tillering HPTR should have a limitation on increasing panicle number per unit area up to the level of MPTR. There was another possibility for the increase of spikelet number per unit area through the development of a new rice type having many panicles per plant with many spikelets per panicle, if it is possible.

There were varietal differences for spikelet number. Spikelet number of MPTRs increased as many at dense planting as at heavy nitrogen and increased by interaction of two factors. But that in HPTRs increased more at heavy nitrogen than dense planting but was not different between two planting densities under heavy nitrogen. Therefore, it is inferred that the effect of dense planting on the increment of spikelet number is greater in MPTR than in HPTR.

Ripened grain ratio of MPTRs and LGTRs was decreased by dense planting, and the interaction of planting density and nitrogen level was significant but was not affected by heavy nitrogen, while that of MSTRs was not affected by dense planting or heavy nitrogen but was decreased by the interaction of planting density and nitrogen level.

These above mentioned results were similar to that as planting rates increased, panicle density increased significantly and filled grain per panicle decreased significantly, as an indication of the compensatory

Table 3. Mean squares for rice yield and yield components across two planting densities and nitrogen levels.

Source	df	Panicle number m^{-2}	Spikelet number m^{-2}	Ripened grain rate(%)	1,000 grain weight(g)	Yield (MT/ha)
Replication	2	627.75	7.89	1.41	0.25	0.02
Nitrogen level(NL)	1	5225.50*	73.01*	2.75	6.55	1.76*
Error	2	121.50	2.04	0.38	1.02	0.03
Planting density(PD)	1	102755.0**	8.26	50.06**	1.24*	0.02
NL×PD	1	215.00	0.07	0.81	0.79*	0.12
Error	4	44.75	3.12	1.13	0.06	0.02
Variety(VAR)	5	14407.10**	37.60**	11.49**	36.36**	1.26**
NL×VAR	5	109.00	0.75	1.43*	0.24	0.04
VAR×PD	5	756.40**	3.09	3.63**	0.34	0.12*
NL×PD×VAR	5	33.70	0.38	0.19	0.08	0.02
Error	40	172.25	1.84	0.43	0.16	0.04

*, ** Significant at the 0.05 and 0.01 probability level, respectively.

Table 4. Changes of yield and yield components as affected by planting density and nitrogen level

Nitrogen level	Planting density	Varieties and lines					
		Dongjin byeo	Dongan byeo	Iksan 435	Iksan 438	HR14022 -21-8-4	HR14022 -21-8-6
(kg)	(cm)	Panicle number m^{-2}(No.)					
11.0	30×15	299b	312b	273b	267b	243c	235c
	15×15	390a	402a	342a	335a	292b	301b
16.5	30×15	304b	318b	284b	290b	257c	256c
	15×15	404a	418a	357a	356a	323a	326a
		Spikelet number m^{-2}(×1,000)					
11.0	30×15	21.1b	24.0a	22.9b	22.6b	26.0a	25.1b
	15×15	22.3ab	23.9a	21.9b	22.3ab	24.9a	25.6ab
16.5	30×15	22.7ab	24.6a	23.5a	23.3ab	26.6a	27.0a
	15×15	23.3a	24.9a	23.1a	23.5a	26.4a	26.9a
		Ripened grain ratio(%)					
11.0	30×15	98.0a	94.7a	94.0a	95.0a	93.3a	93.7a
	15×15	94.7c	92.7b	91.7b	92.7b	93.3a	92.3ab
16.5	30×15	96.3b	94.0ab	93.7a	94.7a	93.3a	93.0ab
	15×15	93.0c	92.7b	92.7ab	92.7b	93.3a	92.0b
		1,000 grain weight in brown rice(g)					
11.0	30×15	24.6a	24.2a	27.6a	28.0a	24.3a	24.9a
	15×15	25.1a	24.3a	27.3a	27.9a	24.4a	24.4ab
16.5	30×15	23.8b	23.4a	27.5a	28.0a	24.2a	24.4ab
	15×15	23.8b	23.3a	26.8b	26.9a	23.7a	23.9b
		Milled rice yield(MT/ha)					
11.0	30×15	5.0b	5.4b	6.1b	6.0a	5.8bc	5.7b
	15×15	5.3ab	5.5ab	6.0b	5.9a	5.8c	5.7b
16.5	30×15	5.4a	5.6ab	6.4a	6.4a	6.2a	6.2a
	15×15	5.5a	5.8a	5.9b	6.1a	6.1ab	6.1a

Means followed by the same letter within a column are not significantly different at 5% probability level by DMRT.

nature between these two traits (Gravois & Helms, 1992; Gravois & Mecnew, 1993).

1,000 grain weight in brown rice did not vary significantly among rice types by dense planting or heavy nitrogen.

Milled rice yield did not vary significantly by planting density or nitrogen level. But there was the trend that the yield in MPTR was highest in heavy nitrogen with dense planting, while the yield in HPTR was highest in heavy nitrogen with standard planting. It was higher in HPTRs than in MPTRs under the four conditions.

Despite that MSTRs had more spikelets than LGTRs, milled rice yield in MSTRs was lower, owing to the larger effect of grain weight than grain number per panicle on the increase of milled rice yield. These results did not agree to the previous report that variation of sink size was more related to the variation in spikelet number per plant than in grain weight because of the negative correlations between two traits (Kato & Takeda, 1996). These imply that both spikelet number and grain weight are the most important factors and the latter is the larger influencing factor than the former on maximizing rice yield per unit area.

Path coefficient analysis of some traits on yield

The results of path coefficient analysis of growth traits and yield components on milled rice for nitrogen level, planting density and rice type are shown in Table 5.

For MPTRs, only panicle number had the larger direct effect to the positive direction than indirect effect, and tiller number and 1,000 grain weight, to the negative direction. For LGTRs, top dry weight had the larger positive direct effect, and LAI and 1,000 grain weight, the negative one than indirect effects. For MSTRs, tiller number showed the larger positive direct effect and panicle number, negative one than indirect effect. And for all of the three types, spikelet number, 1,000 grain weight and top dry weight had the larger positive direct effect, and tiller number and panicle number, the negative one. These results were in good agreement with the previous report that 1,000 grain weight had the positive direct effect on yield of which the value was small (below one) but was larger than any other indirect effect (Gravois & Helms, 1992).

Therefore, it is suggested that across all of the planting densities, the nitrogen levels and the rice types, 1,000 grain weight, spikelet number and tiller number should be the most important factors for increasing rice yield, focusing on the increase of top dry weight, 1,000 grain weight and spikelet number and the decrease of tiller number.

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Table 5. Path coefficient analysis of yield and yield components for nitrogen level, planting density and rice variety types.

Traits	Rice types			All of Three types
	Many panicle	Large grain	Many spikelet	
1. Tiller number m^{-2}	-2.184	-0.190	4.046	-0.328
Indirect effect via 3	-0.110	-0.628	0.238	0.004
2. Effective tiller rate	-1.012	-0.267	2.809	-0.119
Indirect effect via 3	0.115	0.450	-0.209	-0.002
Indirect effect via 1	1.772	0.169	-3.899	0.271
3. LAI	-0.180	-0.827	0.403	0.006
Indirect effect via 1	-1.339	-0.144	2.389	-0.205
4. Top dry weight	0.024	0.691	0.457	0.186
Indirect effect via 1	-1.171	-0.112	3.250	-0.175
5. Panicle number m^{-2}	1.540	-0.225	-1.974	-0.088
Indirect effect via 3	-0.089	-0.667	0.266	0.004
6. Spikelet number m^{-2}	0.588	-0.055	-0.208	0.482
Indirect effect via 4	0.006	0.395	0.189	0.059
Indirect effect via 1	-1.230	-0.068	0.937	-0.035
7. Filled grain rate	-0.022	-0.394	0.186	-0.190
Indirect effect via 3	0.108	0.425	-0.132	-0.001
Indirect effect via 6	-0.432	0.006	0.106	-0.290
Indirect effect via 1	1.612	0.116	-2.039	0.126
8. 1,000 grain weight	-0.358	-0.133	-0.034	0.325
Indirect effect via 1	0.267	0.108	-1.807	0.058
R Square	0.909	0.644	0.727	0.673

1~8 is the direct effect of each trait on yield

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