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Yield Potential of Improved Tropical Japonica Rice under Temperate Environment in Korea

Kyu-Seong Lee*†, Jae-Kwon Ko**, Jong-Seok Kim**, Jae-Kil Lee**, Hyun-Tak Shin**, and Soo-Yeon Cho**

ABSTRACT

Rice production in Korea has markedly increased during the last two decades due to newly developed high yielding varieties and improved production technology. This experiment was conducted to determine the potential of tropical japonica germplasm in enhancing the yield of temperate japonica. The yield performance of two tropical japonicas (IR 65597-29-3-2 and IR66154-52-1-2) and one temperate japonica (Dongjinbyeo) was compared at different plant densities and nitrogen levels under Korean environmental conditions. Although tropical japonicas showed low tillering habit and large panicles, they had similar leaf area index and dry weight at heading stage to Dongjinbyeo of the high tillering type indicating that there was not much difference between tropical and temperate japonica in terms of biomass production. The highest milled rice yield of 6.15 t/ha was obtained from Dongjinbyeo at a high nitrogen level with less planting density (220 kg N/ha and 30 × 15 cm). However, those of the two tropical japonicas were 5.36 t/ha at the condition of 165 kg N/ha and 30 × 10 cm planting density and 5.06 t/ha at the condition of 165kgN/ha and 15 × 15 cm planting density, respectively. Ripened grain of tropical japonicas ranged from 65 to 87%, while that Dongjinbyeo ranged from 82 to 97% under Korean conditions.

Keywords : temperate environment, tropical japonica, yield potential.

Rice production during last two to three decades has increased at a slightly higher rate than the human population. However, the rate of increase in rice production has slowed down and is now lower than the rate of increase in the number of rice consumers. To keep up with population growth for next 20-25 years, the average yield of Asian irrigated rice land must increase by 60% over the next 30 years from 4.9t/ha in 1990's to 8t/ha in 2025's to meet the increasing demand due to rapid population growth (IRRI, 1995). Breeding new cultivars with higher yield potential is one way to enhance actual yield and production of rice.

Yield potential is the grain yield obtained when growth is not limited by nutrients, water, and insects and pests. The high yield can be achieved by either increasing biomass production or harvest index. The modern cultivars of high yield had a great biomass production rather than a higher harvest index (Akita,1989; Amano et al., 1993).

The new plant type (NPT) proposed by IRRI scientists to break the yield potential barrier is to use Bulus or Javanicas from Indonesia which have low tiller numbers, large panicles and sturdy stems. At present, several NPT lines are being evaluated for yield response under different seasons, nitrogen, spacing and environment. Resistance to insects, pests and diseases are still being incorporated in the NPT breeding programs at IRRI. The main constraint in increasing yield in NPT lines is poor grain filling in relation to low biomass production, lower canopy photosynthesis and early flag leaf senescence. These are continuously being studied with the goals of breaking the yield barrier and germplasm diversification (Khush and Peng, 1996). The objective of this study is to determine the adaptability of tropical japonica to Korean environmental conditions for the future utilization in developin g high yielding varieties.

MATERIALS AND METHODS

The field experiment was conducted at the National Honam Agricultural Experiment Station, Iksan, Korea, during the rice growing season of April to October, 1997. Two tropical japonicas, IR65597-29-3-2 and IR66154-52-1-2, which have low-tillering habit and a high number of spikelets per panicle were compared with Dongjinbyeo, a japonica variety as the check.

The experimental design was split-split plot design with three replications. Three nitrogen levels of 110, 165 and 220 kg per hectare were designated as the mainplot; three planting densities of 30 × 15 cm, 30 × 10 cm and 15 × 15 cm as the sub-plot, and the three

* International Rice Research Institute, P.O.box 3127, MCPO, 1271 Makati city, Philippine (kslee@cgiar.org). ** National Honam Agricultural Experiment Station, P.O.box 5, Iksan, Korea. *† Corresponding author : (E-mail) kslee @ cgiar.org (Phone) +82-63-2-845-0563. Recieved 15 Mar., 1999.

Table 1. General characteristics of temperate and tropical japonicas used in the experiment.

Var./Line	Heading date	Culm length (cm)	Panicle length (cm)	Tillering ability	No. of spikelet /panicle	1,000(g) grain weight	Plant type[1]
Dongjinbyeo	Aug.15	82	20	High(14)	81	25.1	TMJ
IR65597-29-3-2	Aug.14	65	24	Low(9)	128	25.3	TRJ
IR66154-52-1-2	Aug.13	72	25	Low(8)	198	20.2	TRJ

[1] TMJ : Temperate Japonica
TRJ : Tropical Japonica

rice cultivars as the sub-subplot.

The seeds of the three varieties were heat-treated at 45℃ for three days in a forced draft oven to break the dormancy. The seeds were then surface-sterilized with 0.1% $HgCl_2$ for 2-3 minutes and rinsed thoroughly with distilled water. The sterilized seeds were soaked in water for 24 hours and germinated in a germination tank for 48 hours at 30°C. The pregerminated seeds were sown uniformly on the seedbed at the amount of 60 g per m^2 with three replications. The seedbeds were covered with fine soil and then with a plastic film tunnel for sustaining the proper temperature for germination.

There were split applications of nitrogen at pre-transplanting (40%), mid-tillering (40%), and panicle initiation stage (20%), respectively. Phosphorus at 70 kg per hectare was applied at pre-transplanting and there was a split application of potassium at 80 kg per hectare at pre-transplanting (70%) and panicle initiation stage (30%), respectively.

The 35-day-old seedlings were transplanted at a hill spacing of 30 × 15, 30 × 12, and 15 × 15 cm with three seedlings per hill. Water depth of 5 to 10 cm was maintained until the maturing stage except for a week after the maximum tillering stage. Weeds, insects, and diseases were controlled as required to avoid yield loss.

To estimate the yield and yield components, a sample of 5 m^2 was taken from each plot at maturity. Grain yield was adjusted to 14% moisture content. Panicle number per hill was determined from 20 hills of each plot. The spikelets per panicle, ripened grain percentage and 1,000 grain weight were determined from these samples.

RESULTS AND DISCUSSION

Significant differences among varieties, spacings and nitrogen levels were observed for the panicle numbers per square meter, number of spikelets, percentage of ripened grain, 1,000 grain weight and yield (Table 2). Differences among nitrogen treatments were significant in number of panicle per square meter, number of spikelets, 1,000 grain weight, and percentage of ripened grain. Differences among plant densities was significant in the number of panicle per square meter and number of spikelets. Significant varietal differences were found for yield and yield components. The effect of nitrogen x variety interaction was significant for the number of panicles per square meter, 1,000 grain weight, and yield. Interaction of variety x spacing was significant for number of panicles per square meter and yield. However, the effect of nitrogen x spacing x variety interaction was found to be highly significant only for milled rice yield.

Effective tiller, leaf area and dry matter weight

Tillering ability differed with variety and environment. The development of tillers was greatly influenced by plant density, nitrogen level, planting method, temperature and solar radiation among other factors. In this experiment, the percent of effective tillers was higher in Dongjinbyeo, a high tillering type, than tropical japonica lines under any nitrogen levels and planting densities. As plant density and nitrogen level increased, the productive tiller percentage rapidly decreased, particularly at high nitrogen levels (220 kg, N/ha) in all genotypes (Fig. 1).

Varietal differences in leaf area index (LAI) at heading stage were not great between high and low tillering varieties, indicating that the low tllering type can produce LAI value as much as that of the high tillering type (Fig. 2). Similarly, Kim and Vergara (1992) reported that there were little differences in LAI between the low- and high tillering variety in general. However, they found that IR25588, tropical japonica of low tillering habit, had bigger leaf area per tiller at the heading stage than IR58, indica variety of high tillering in tropical conditions.

Dry matter weight at the heading stage also showed a similar trend to leaf area index that showed no significant difference among varieties, indicating that the two tropical japonicas could produce dry matter as much as that of the high tillering variety due to a broad and thick leaf, although it has the low-tillering habit (Fig. 3).

Table 2. Analysis of variance for yield components and yield as affected by variety, nitrogen fertilizer and plant density.

Source of variation	DF	Mean Square				
		No. of panicle/m^2	No.of spikelet	% Ripened grain	1,000 grain weight	Yield
Replication	2	316.8**	9.8	24.1	0.359	657.0
Nitrogen	2	12195.0**	4269.1**	92.5*	6.481**	336.0
Error	4	14.0	53.8	47.6	0.140	94.5
Spacing	2	17462.8**	203.6*	277.6	0.754	555.0
N×S	4	661.3*	144.6	86.8	0.069	961.0*
Error	12	98.3	49.4	27.9	0.126	153.3
Variety	2	245182.0**	95468**	3862.3**	160.3**	69219.0**
N×V	4	1280.0**	179.7	7.6	0.822*	1337.5*
V×S	4	2596.4**	28.7	26.5	0.330	1608.5*
N×S×V	8	240.3	42.0	24.0	0.102	786.5**
Error	36	132.1	70.3	23.1	0.140	138.9
Total	80					
C.V (Main-plot)		6.0	5.8	10.3	7.0	10.6
(Sub-plot)		4.1	2.1	7.9	6.6	7.3
(Sub-subplot)		6.1	6.6	7.2	7.0	8.4

*Significant at $P < 0.05$, **Significant at $P<0.01$

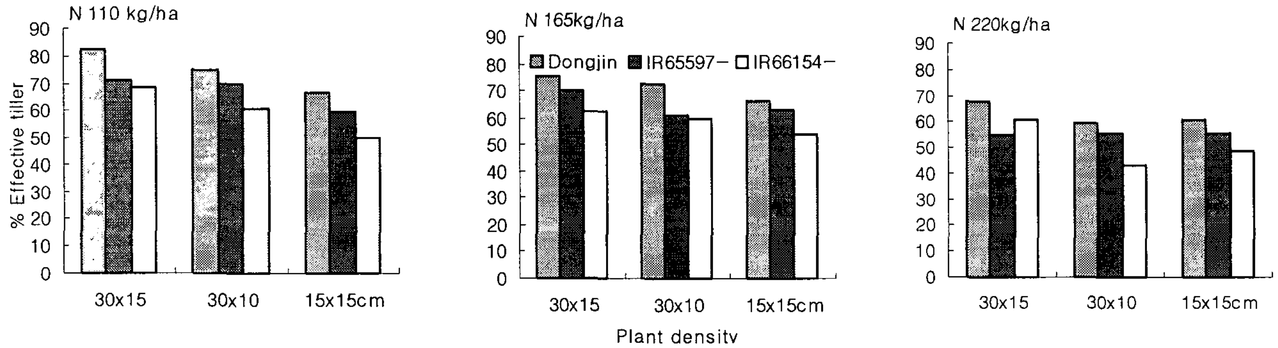

Fig. 1. Percentage of effective tiller in temperate and tropical japonicas as affected by nitrogen level and plant densities.

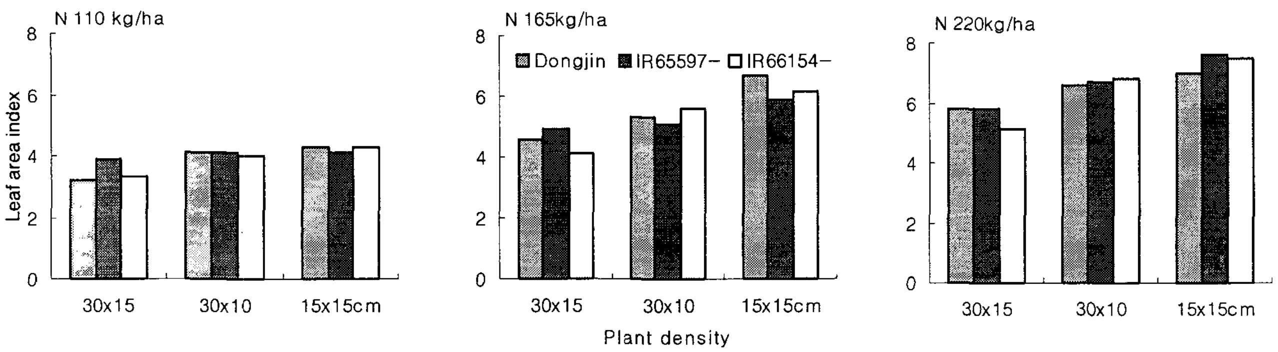

Fig. 2. Leaf area index at heading stage in temperate and tropical japonicas as affected by nitrogen level and plant densities.

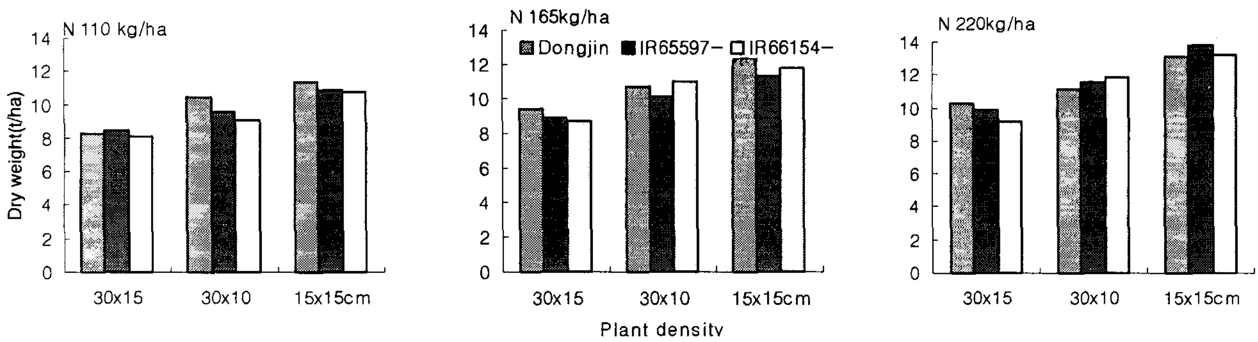

Fig. 3. Dry matter weight at heading stage in temperate and tropical japonicas as affected by nitrogen level and plant densities.

Yield components

All three genotypes showed increase in panicle number at planting densities, particularly at the 30x10cm density but in nitrogen level, the two tropical japonicas showed a slight increase with higher amounts of nitrogen fertilizer, while a temperate japonica, Dongjinbyeo showed the highest increase of panicle numbers per square meter at the nitrogen level of 220kg per hectare among genotypes (Table 3).

This seems that two tropical japonicas of low-tillering habit cannot produce as many panicle numbers per unit area as that of the high tillering variety, Dongjinbyeo unless the number of seedlings per hill and planting density were increased. Kim and Vergara (1992) reported that IR25588, a low-tillering type, always showed smaller numbers of tillers than that of IR58, of a high tillering variety. However, at a narrow spacing with 6 seedlings per hill, it produced around 90% of IR58 regardless of N levels under tropical conditions.

Tropical japonicas characterized as low-tillering plant type have higher spikelet numbers per panicle than the high-tillering type under the same nitrogen level and plant density. In general, spikelet numbers per unit area is the most important factor for increasing yield in low-tillering rice plants. All three genotypes increased the spikelet numbers per unit area with increased amounts of nitrogen, but there was not a significant difference among planting density. IR66154-52-1-2 showed the highest number of spikelets per unit area at the spacing of 30 × 10 cm and at the nitrogen amount of 220kg per hectare.

The improved tropical japonica, IR65597-29-3-2 and IR66154-52-1-2 showed a lower percentage of ripened grain than Dongjinbyeo regardless of the nitrogen level and planting densities. The temperate japonica, Dongjinbyeo, has a high percentage of ripened grain in all conditions except at spacing of 15 × 15 cm at the nitrogen level of 220 kg per hectare

Table 3. Panicle number per unit area of temperate and tropical japonicas as affected by nitrogen and planting densities.

Nitrogen level(kg/ha)	Var./Line	No. of panicle/m^2			LSD (5%)
		30 × 15 (cm)	30 × 10	15 × 15	
110	Dongjinbyeo	324b	333b	358c	19
	IR65597-29-3-2	184d	204d	215e	11
	IR66154-52-1-2	169d	198d	200e	28
165	Dongjinbyeo	327b	374b	409b	22
	IR65597-29-3-2	209c	240cd	253d	24
	IR66154-52-1-2	171d	216d	209e	20
220	Dongjinbyeo	358a	408a	482a	36
	IR65597-29-3-2	216c	264c	272d	35
	IR66154-52-1-2	175d	227d	231de	28

[1] Means followed by a common letter in a column are not significantly different at the 5% level by DMRT.

Table 4. Spikelets number per unit area of temperate and tropical japonicas as affected by nitrogen and planting densities.

Nitrogen level(kg/ha)	Var./Line	No. of spikelet(× 1,000/m^2)			LSD (5%)
		30 × 15 (cm)	30 × 10	15 × 15	
110	Dongjinbyeo	24.95e	24.31f	23.63e	3791
	IR65597-29-3-2	24.47e	24.43f	24.73e	2308
	IR66154-52-1-2	32.96b	36.48b	35.01b	3472
165	Dongjinbyeo	28.45d	28.23e	27.81d	2036
	IR65597-29-3-2	28.84d	30.48d	30.61c	2132
	IR66154-52-1-2	36.25a	40.95a	38.64a	2850
220	Dongjinbyeo	30.43c	29.20e	28.64d	2241
	IR65597-29-3-2	27.86d	32.09c	28.02d	1234
	IR66154-52-1-2	35.02ab	41.58a	39.27a	918

[1] Means followed by a common letter in a column are not significantly different at the 5% level by DMRT.

due to lodging (Table 5). Dongjinbyeo, a temperate japonica has only 81 spikelets per panicle and it was observed that there were only a few unfilled spikelets at the bottom part of the panicle compared to the top portion. Meanwhile IR65597-29-3-2 and IR66154-52-1-2, which had 128 and 198 spikelets per panicle, respectively, showed a distinct increase in half-filled and unfilled spikelets from the top to the bottom part of the panicle which corresponds to a decreasing percent of ripened grain. Khush and Peng (1996) reported that the spikelets of the lower portion of panicles were at a disadvantage in terms of carbohydrate availability and grain filling.

Varietal differences in 1,000 grain weight was observed. Dongjinbyeo and IR65597-29-3-2 showed a reduction of grain weight when the nitrogen level was 220 kg per hectare, probably due to field lodging in Dongjinbyeo. A tropical japonica, IR66154-52-1-2 showed the same grain weight in both plant densities and nitrogen levels (Table 6).

This implies that tropical japonica has no morpho-anatomical advantage for grain filling even though it has a larger leaf area and heavier culm weight per tiller and more vascular bundles in the stem (Kim and Vergara, 1991b).

Milled rice yield

IR65597-29-3-2 produced the maximum yield of 5.36 t/ha at the 165 kg nitrogen level per hectare with 15 × 15 cm plant spacing condition. The maximum yield of IR66154-52-1-2 was 5.06 t/ha at the 165 kg nitrogen level per hectare with a 30 × 10 cm plant spacing. Dongjinbyeo as a check variety, however, showed 6.15 t/ha which was the highest yield at the 220 kg nitrogen level per hectare at 30 × 15 cm plant spacing condition (Table 7). Moreover, Dongjinbyeo has always the highest yield than that of low tillering

Table 5. Percentage of ripened grain of temperate and tropical japonicas as affected by nitrogen and planting densities.

Nitrogen level(kg/ha)	Var./Line	% ripened grain			LSD (5%)
		30×15(cm)	30×10	15×15	
110	Dongjinbyeo	96a	97a	95a	2.0
	IR65597-29-3-2	87b	83b	86b	5.1
	IR66154-52-1-2	70d	72c	76c	7.0
165	Dongjinbyeo	97a	96a	96a	3.5
	IR65597-29-3-2	79c	79bc	81b	4.3
	IR66154-52-1-2	75cd	74c	70cd	3.7
220	Dongjinbyeo	96a	91a	82b	7.5
	IR65597-29-3-2	75cd	76c	71c	9.9
	IR66154-52-1-2	71d	67d	65d	5.7

[1] Means followed by a common letter in a column are not significantly different at the 5% level by DMRT.

Table 6. 1,000 grain weight of temperate and tropical japonicas as affected by nitrogen and planting densities.

Nitrogen level (kg/ha)	Var./Line	1,000 grain weight(g)			LSD (5%)
		30×15(cm)	30×10	15×15	
110	Dongjinbyeo	25.1a	25.1a	24.4a	0.4
	IR65597-29-3-2	25.3a	25.3a	25.1a	1.1
	IR66154-52-1-2	20.2c	20.1c	20.5c	0.6
165	Dongjinbyeo	24.8a	24.7a	24.3ab	0.7
	IR65597-29-3-2	25.1a	25.2a	24.7a	0.9
	IR66154-52-1-2	20.8c	20.6c	20.5c	1.1
220	Dongjinbyeo	23.9b	23.5b	23.4b	0.6
	IR65597-29-3-2	24.1b	24.2ab	23.7b	1.0
	IR66154-52-1-2	19.9c	20.2c	20.1c	1.0

[1] Means followed by a common letter in a column are not significantly different at the 5% level by DMRT.

Table 7. Yield performance of temperate and tropical japonicas as affected by nitrogen and planting densities.

Nitrogen level(kg/ha)	Var./Line	Milled rice yield(t/ha)			LSD (5%)
		30×15(cm)	30×10	15×15	
110	Dongjinbyeo	5.66c	5.44b	5.34c	41
	IR65597-29-3-2	4.85e	4.83d	5.09d	31
	IR66154-52-1-2	4.71f	4.69de	4.87d	35
165	Dongjinbyeo	5.90b	5.84a	5.85a	33
	IR65597-29-3-2	4.93de	5.14c	5.36c	25
	IR66154-52-1-2	4.75f	5.06c	4.57e	37
220	Dongjinbyeo	6.15a	5.95a	5.58b	31
	IR65597-29-3-2	5.05d	5.22bc	4.97d	25
	IR66154-52-1-2	4.82ef	4.64e	4.62e	38

[1] Means followed by a common letter in a column are not significantly different at the 5% level by DMRT.

lines of tropical japonica under any nitrogen level and spacing in Korean environmental conditions. Bhattacharya and Chatterjee (1973) reported that the high tillering types of cultivar produced high yield under any planting spacing. However, Kim (1988) reported that low-tillering, large panicle types produce higher grain yield than high-tillering types under high amounts of nitrogen and higher plant densities under tropical conditions.

This result indicates that the tropical japonica lines cultured in Korean conditions have no yield advantage compared to temperate japonica as long as the percentage of ripened grain is not increased. Based on the experiment, we can infer that there are two main factors limiting yield increase in tropical japonica under temperate conditions. First, the tropical japonica with low tillering type has less number of panicles per unit area even under narrow spacing compared with high-tillering temperate japonica. This means that the percentage of effective tillers in the high tillering type is still higher than low tillering type under the same planting densities. Second, tropical japonica with large panicles (spikelets/panicle) has lower ripened grain percentage (70~81%, N165/ha, densities; 30 × 15, 30 × 10, 15 × 15) than temperate japonica with high tillering type (96~97%, N165/ha). This is probably due to the observation that the flag leaves of tropical japonica lines senesced faster than temperate japonica because of low temperatures at the late maturing stage. This leads to limitations for carbohydrate source causing poor grain filling under temperate conditions.

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