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Grain Yield Potential of a Low-Tillering Large Panicle Type in Rice

Je Kyu Kim* and B.S. Vergara**

벼 小蘖 穗重型 草型의 收量性

金帝圭*, 비 에스 벨가라**

ABSTRACT : For the increase of grain yield potential in rice, a low-tillering large panicled type has been suggested as an ideotype. A low-tillering plant type may have different yield potential and needs different cultural practices from that used in a high-tillering type for the maximum yield. This study was conducted to evaluate the grain yield performances of a low-tillering large panicled rice and high-tillering small panicled rice at different plant spacings, nitrogen(N) levels and seedling numbers per hill.

A low-tillering large panicled genotype, IR25588 was compared with a high-tillering small panicled IR58. The grain yield of IR25588 was significantly higher than that of IR58 under a narrow spacing with high N level. The maximum yields of IR58 and IR25588 were reached at about 35,000 and 40,000 spikelets per m², respectively. The increased grain yield in IR25588 was mainly due to the increase in spikelet number per unit area which is the most precise indicator of grain yield in rice.

The optimum spacing for the maximum yield was denser for IR25588 than that for IR58 under high N level. The intra-hill competition of the low-tillering type was lower than that of the high-tillering type. The higher dry matter production and bigger leaf area and culm weight were the main factors for increased grain yield in a low-tillering panicle weight type.

Based on the results, the yield potential of a low-tillering panicle weight type was higher than that of a high-tillering panicle number type, especially under a close spacing with high N level.

Rice yield has greatly increased in the last 25 years mainly through varietal improvement and the accompanying cultural practices. IR8, the first high-yielding rice cultivar released in 1966 by the International Rice Research Institute(IRRI), started the "green revolution" in rice mainly through its ideotype : semidwarf, high-tillering, stiff culm, erect leaves,

* 作物試驗場(Crop Experiment Station, RDA, Suwon 441-100, Korea
** 國際米作硏究所(International Rice Research Institute, P.O.Box 933, Manila, Philippines) 〈접수일자 : 1992. 8. 12〉

photoperiod insensitive and high response to fertilizer nitrogen compared with traditional cultivars. However, rice yields during the last two decades have apparently reached a plateau[4] and subsequent efforts to further improve yielding ability have not resulted in visible gains.

Different types of rice plant are proposed. Morphological characteristics of ideotype of rice plant are generally short and stiff culm, and erect leaves. Yoshida[9] emphasized high-tillering cultivars and Chandler[2] claimed low- to medium-tillering cultivars. Donald[3] proposed a uniculm plant as an ideotype for cereal crops. Recently, Kim and Vergara[6,7] strongly suggested an ideotype of rice plant one with "a low-tillering sturdy culm with large panicled cultivars" for increased grain yield potential since the low-tillering type has been shown to be superior morpho-anatomically and physiologically to a high-tillering type with small panicled cultivar. Low-tillering and high-tillering are synonymous to panicle-weight type and panicle-number type, respectively.

Cultivars with different tillering abilities may have different yield potentials in rice. Increasing the grain yield potential of a low-tillering rice would require different cultural practices from that used in a high-tillering cultivar. Plant spacing, N level and seedling number per hill would affect tillering ability, growth phase and yield of low-tillering type with large panicled cultivars.

This study was conducted at the IRRI in 1988 to evaluate the grain yield performance of low-tillering large panicled rice as an ideotype for increasing yield potential at different plant spacings, N levels and seedling numbers per hill.

MATERIALS AND METHODS

IR25588-7-3-1, a low-tillering advanced breeding line with large panicles, and IR58, a high-tillering cultivar with small panicles were used[5]. Both genotypes have similar plant height(about 88cm) and growth duration (about 103 days) but differ in tillering ability and panicle size. Tillering ability of IR25588 was only 60% of IR58.

The field experiment was conducted using a split-split-plot design with three replications. Four N levels(0, 100, 150 and 200kg/ha) were designated as the mainplot ; the combination of two spacings(10×10 and 20×20cm) and seedling numbers per hill(2 and 6 seedlings) as the subplot ; and the two rice cultivars as the sub-subplot. The size of each sub-subplot was 4×6m.

Pregerminated seeds were sown uniformly on the seedbeds with 80 gr seeds per m^2, and soon after seeding, the seedbeds were topped with fine soil for uniformed germination and were covered with nylon screen mesh to protect the seedlings from green leaf hoppers which are the vactors of tungro virus.

The experimental field was plowed and puddled four times with a hand tractor for better leveling and soil homogeneity for transplanting. Nitrogen was applied at 0, 100, 150 and 200 kg/ha, and phosphorus and potassium were also applied at 40kg/ha each, and they were incorporated into the soil one day before transplanting. Nitrogen was split at 50, 20, 20 and 10% at pretransplanting, 2 weeks after transplanting, during panicle initiation and heading stages, respectively. About 2 to 5cm water depth was maintained. The 14-day-old seedlings were transplanted and dead hills were replanted within 7 days after transplanting(DAT).

Right after transplanting, a 2.5m high screen mesh was placed around the field to protect the plants from green leaf hoppers. Insect and disease control was done as often as necessary. To control the weeds, 2,4-D isopropyl ester(1kg a.i. /ha) was applied at 3 DAT and handweeding was also done when needed.

Leaf area index was determined from five sample hills using the Automatic Leaf Area Meter(Type AAM-5, Japan). Dry matter was determined from the five representative sample hills in each sub-subplot. The plants were uprooted and washed, and were dried at 75℃ for 3 days.

At maturity, a sample of $5m^2$ was taken from each sub-subplot to estimate the yield and yield components. Grain yield was adjusted to 14% moisture content. The panicle number per hill was determined from 50 hills of each sub-subplot. For the spikelet number per panicle, five hills from the average of 50 hills were selected. The number of filled and unfilled spikelets per panicle and 1,000-grain weight were determined from the 5 hills.

All data were analyzed by the least significant difference test or Duncan's Multiple Range Test and simple linear or quadratic regression.

RESULTS AND DISCUSSION

1. Grain yield

The highest grain yield obtained was 7.13 t /ha by low-tillering large panicled IR25588 at 10×10cm spacing with 2 seedling /hill at 150kg N level(Fig. 1). The grain yield of IR58 under the same condition was 6.62 t /ha which was the higest yield for high-tillering IR58. The grain yield of IR25588(7.13 t /ha) was significantly ($P<0.05$) higher than that of IR58(6. 62 t /ha) under the spacing and N level. Grain

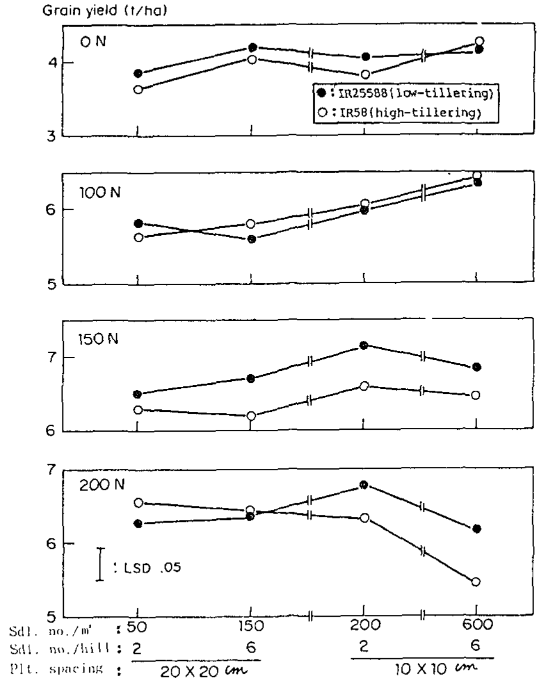

Fig 1. *Grain yield of low-tillering IR25588 and* high-tillering IR58 as affected by different nitrogen levels, planting spaces and seedling numbers per hill.

yield at low N levels(0 and 100 N kg /ha) was not significantly different between the low- and high- tillering cultivars. However, with higher N levels(150 and 200 N kg /ha) and higher plant density(10×10cm), the grain yield of low-tillering IR25588 was always higher than that of high-tillering IR58.

This indicates that with proper cultural management the yield potential of a low-tillering panicle weight type could be higher than that of a high-tillering panicle number type. This result supports the hypothesis of Kim and Vergara[6,7] that the yield potential of "a low-tillering sturdy culm with large panicled cultivar" is higher than that of a high-tillering small panicled cultivar.

Yoshida and Parao[11], and Bhattacharya and Chatterjee[1] reported that high-tillering cultivars can give high yields at narrow spacing as well as wide spacing. However, the plant densities used in their experiments were only 90 to 100 seedlings per m^2 which were relatively lower as compared with 150 to 600 seedlings per m^2 used in this study. Therefore, the plant densities selected by them would not be the optimum plant density to show the advantage of low-tillering cultivars to produce high yield.

With greater use of direct- or broadcast-seeded rice, higher plant density may also require "a low-tillering sturdy culm with large panicled cultivar" to maximize grain yield.

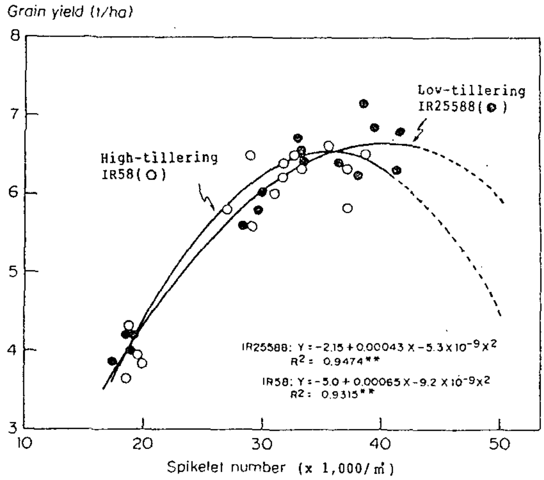

Fig 2. Relationship between grain yield and spikelet number per unit area in IR25588 and IR58.

2. Yield components

Increased grain yield in IR25588 was mainly due to the increase in spikelet number per m^2 of up to about 40,000 spikelets where it formed a plateau(Fig. 2). Grain yield of IR58 also increased with the increased spikelet number of up to about 35,000 spikelets and then decreased. Total spikelet number per unit area is the major factor limiting grain yield of rice and is the most precise indicator of grain yield. At the narrow spacing with higher N levels of 150 and 200kg/ha, IR25588 had more spikelets per m^2 than IR58(Fig. 2) This implies that a

Table 1. Panicle number of IR25588 and IR58 as affected different nitrogen levels, planting spaces and seedling numbers per hill.

Nitrogen applied (kg/ha)	Cultivar	Panicle number (per m^2) 20×20cm		10×10cm		Mean
		2[1]	6[1]	2[1]	6[1]	
0	IR25588	186c	238b	253b	480a	289
	IR58	257d	333c	377b	567a	384
100	IR25588	273d	330c	373b	557a	383
	IR58	403d	443c	513b	583a	486
150	IR25588	296d	358c	430b	520a	401
	IR58	412c	462b	550a	577a	500
200	IR25588	345b	362b	453a	480a	410
	IR58	449b	453b	537a	530a	492
Mean	IR25588	275d	322c	377b	509a	371
	IR58	380d	423c	494b	564a	465

[1]Two or six seedlings per hill
* LSD .05 between the cultivars in each treatment is 38
* Means followed by a common letter in a row are not singificantly different at the 5% level by DMRT.

low-tillering panicle weight type would be better than a high-tillering panicle number type under a narrow spacing with high N level to obtain more spikelets per unit area.

The figure 2 also illustrates that the more the spikelet number per m²(over about 40, 000), the greater the difference between low- and high-tillering types in terms of the grain yield.

Panicle number per m² of IR25588 was always lower than that of IR58(Table 1). However, at a narrow spacing(10×10cm) with 6 seedling /hill, the average panicle number per m² of IR25588 across N levels was around 90% of IR58 regardless of N levels. This indicates that under narrow spacing with high N level, a low-tillering plant type can produce as much panicle number per unit area as that of a high-tillering cultivar.

Spikelet number per panicle in IR25588 was always higher than that in IR58 under all conditions(Table 2). Thus, the low-tillering type compensated for the reduction in panicle number per unit area by producing more spikelets per panicle, resulting in higher total spikelet number per unit area. Therefore, the panicle size(spikelet number per panicle) in a low-tillering plant type is the most important limiting factor for high yield.

Percentage of filled spikelet decreased with increasing spikelet number per unit area in both cultivars, and no varietal differences were detected between the low- and

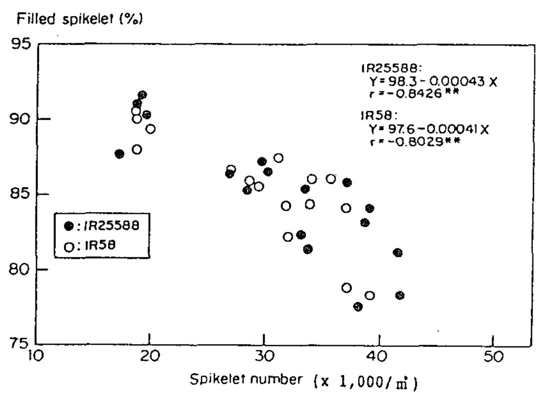

Fig 3. Relationship between filled spikelet percentage and spikelet number in IR25588 and IR58.

Table 2. Spikelet number of IR25588 and IR58 as affected by different nitroen levels, planting spaces and seedling numbers per hill.

Nitrogen applied (kg /ha)	Cultivar	Spikelet number(per panicle)				Mean
		20×20cm		10×10cm		
		2	6	2	6	
0	IR25588	92.6a	80.2b	75.2b	39.5c	71.9
	IR58	72.4a	56.4b	52.5b	33.0c	53.6
100	IR25588	108.9a	85.9b	80.6b	65.6c	85.2
	IR58	71.1a	60.7b	60.5b	49.8c	60.5
150	IR25588	112.5a	92.4b	89.6b	74.3c	92.2
	IR58	81.3a	68.7b	64.4b	58.0c	68.1
200	IR25588	120.3a	92.6b	91.8b	79.0c	95.9
	IR58	85.5a	70.4b	69.0b	66.1b	72.8
Mean	IR25588	108.6a	87.8b	84.3c	64.6d	86.3
	IR58	77.6a	64.0b	61.6b	51.7c	63.7

* LSD .05 between the cultivars in each treatment is 11.2
* Means followed by a common letter in a row are not singificantly different at the 5% level by DMRT.

high-tillering cultivars(Fig. 3).

The 1,000-grain weight of IR25588 was heavier than that of IR58, especially at 10× 10cm spacing with high N level (Table 3). This is probably the morpho-anatomical advantage of the low-tillering type, due to bigger leaf area and heavier culm weight per tiller and more vascular bundles in the stems[6,7].

3. Optimum plant spacing and nitrogen level

The optimum spacing and N level differ with different tillering abilities of rice plant. The optimum spacing for the maximum yield in 0 and 100 N levels was at the highest plant den-

Table 3. 1,000-grain weight of IR25588 and IR58 as affected by different nitrogen levels, planting spaces and seedling numbers per hill.

Nitrogen applied (kg /ha)	Cultivar	1,000 grain weight (g)				Mean
		20×20cm		10×10cm		
		2	6	2	6	
0	IR25588	23.9b	24.5ab	24.6a	24.8a	24.5
	IR58	23.8a	23.4a	23.5a	23.7a	23.6
150	IR25588	24.6c	25.4b	26.0a	25.8ab	25.5
	IR58	24.2a	24.5a	24.6a	24.6a	24.5

* Means followed by a common letter in a row are not singificantly different at the 5% level by DMRT.

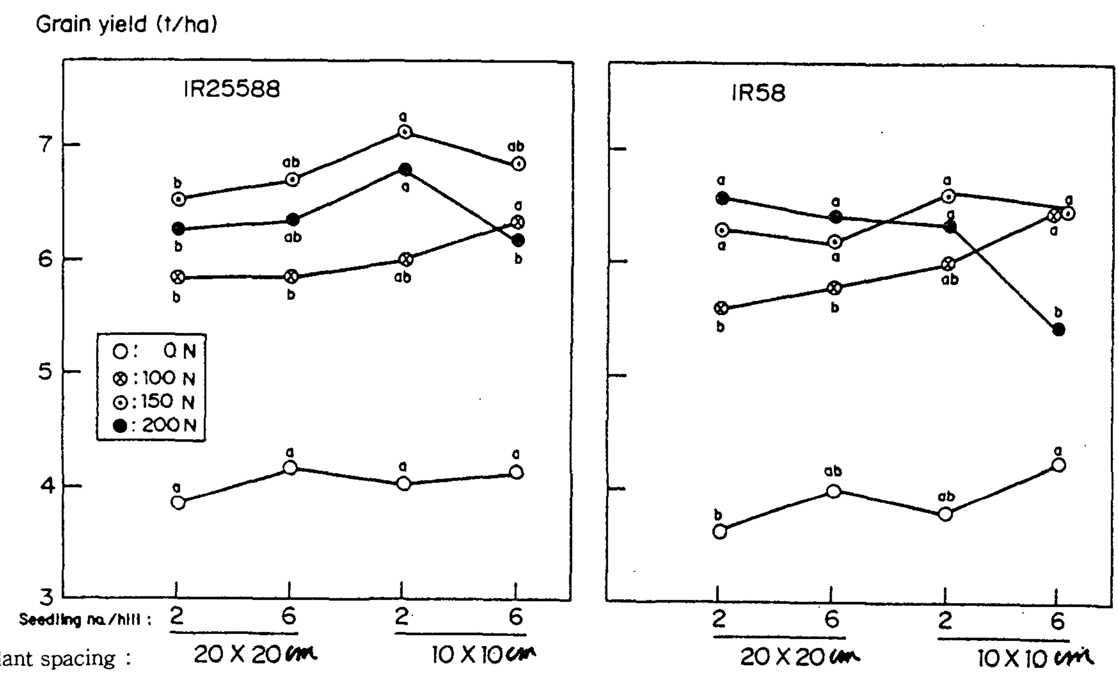

Fig 4. Grain yield of IR25588 and IR58 as affected by different nitrogen levels, planting spaces and seedling numbers per hill. Means with the same letter within a nitrogen level and variety are not significantly different at the 5% level by DMRT.

sity(10×10cm with 6 seedling/hill), while in 150 N level it was of a slightly lower plant density (10×10cm with 2 seedling/hill) in both low- and high-tillering cultivars, although in some cases this was not statistically significant(Fig. 4). At 200 N level, the optimum plant density of low-tillering IR25588 was 10×10cm with 2 seedling/hill, whereas that of high-tillering IR58 was 20×20cm with 2 seedling/hill. This implies that the optimum spacing for the maximum yield is denser for low-tillering cultivars than that for high-tillering cultivars under high N level. This also indicates that the increment of yield by dense planting is greater in a low-tillering type than in a high-tillering type.

On the other hand, grain yields of both cultivars at 10×10cm with 6 seedling/hill in 200 N level decreased significantly as compared with the yield at 2 seedling/hill under the same condition. This shows that seedling number per hill at high plant density with high N level should be lower than that at high N level with wide spacing for higher yield. The decrement of yield from 150 N to 200 N level at 10×10cm with 6 seedling/hill was less in low-tillering IR25588(8.9%) than in high-tillering IR58(13.9%). This indicates that low-tillering cultivars have lower intra-hill competition than high-tillering cultivars. Hence, a low-tillering type should be selected to minimize the intra-hill competition in rice plant.

4. Leaf area and dry matter accumulation

Leaf area index(LAI) was greatly affected by N level and plant spacing. LAI increased markedly with increasing N level, especally at narrow spacing (Fig. 5). Higher LAI values were reached earlier at narrow spacing(10×10cm) than at wide spacing(20×20cm). Generally, there were less varietal differences in LAI between the low- and high-tillering cultivars indicating that the low-tillering type can produce LAI value as much as that of the high-tillering type.

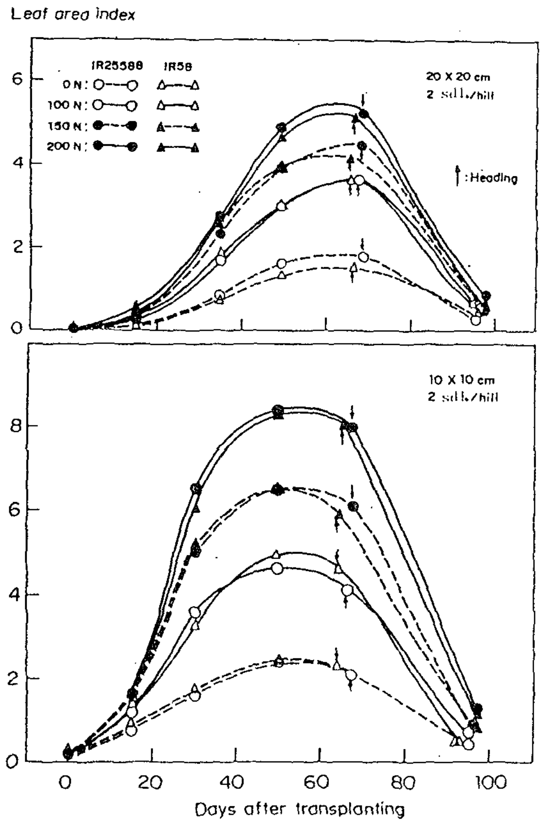

Fig.5. Changes of leaf area index of IR25588 and IR58 as affected by nitrogen level and plant spacing.

IR25588, however, had bigger leaf area per tiller at heading than IR58 in all treatments (Table 4).

The total dry matter accumulated at harvest time increased with increasing N level and plant density. Dry matter accumulation per hectare in IR25588 at high N level with narrow spacing was slightly higher than that of IR58 (Fig. 6). The total dry weight per tiller of IR25588 at heading was also heavier than that

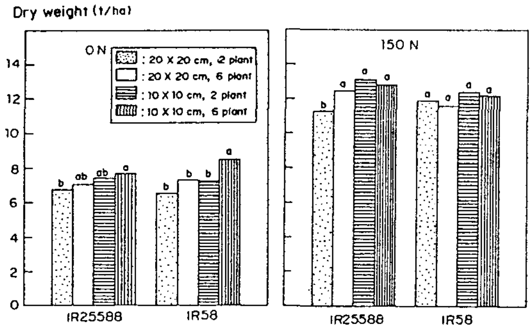

Fig 6. Total dry matter accumulation of IR25588 and IR58 as affected by nitrogen level and plant spacing. Means with the same letter within a cultivar and nitrogen level are not significantly different at the 5% level by DMRT.

of IR58(Table 4).

The grain yields at high N level with narrow spacing were generally higher in IR25588 than in IR58. This was probably due to higher dry matter production, and greater leaf area and dry weight per tiller which resulted in larger panicles. Beside of that, the low-tillering cultivar may have better crop canopy for the utilization of solar energy and better assimilates partitioning through its physio-anatomical advantages. Kim and Vergara[7] reported that a low-tillering panicle weight type had more inner and outer vascular bundles, bigger peduncle diameter and thickness than a high-tillering panicle number type.

5. Relationship between source and sink

Spikelet number per panicle in both cultivars was highly correlated with the total dry weight per tiller and leaf area per tiller at heading. However the correlations of IR25588 were higher than those of IR58 (Fig. 7). And also, both the leaf area and culm weight per tiller of IR25588 were significantly correlated with 1,000-grain weight, but it was not observed in IR58 (Fig. 8) showing the advantage of bigger culms and larger leaves for accumulation more carbohydrates to the grain in the low-tillering type.

Table 4. Leaf area and total dry weight per bearing tiller of IR25588 and IR58 as affected by different nitrogen levels, planting spaces and seedling numbers per hill at heading.

Nitrogen applied (kg/ha)	Cultivar	20×20cm		10×10cm		Mean
		2	6	2	6	
		Leaf area(cm² /tiller)				
0	IR25588	81.9a	74.5a	73.4a	63.1a	73.2
	IR58	57.2ab	63.7a	47.8ab	45.9b	53.7
150	IR25588	127.7a	138.4a	123.9ab	110.8b	125.7
	IR58	89.7a	87.8a	94.7a	90.7a	90.7
		Dry weight. (g/tiller)				
0	IR25588	1.92ab	1.73c	1.80a	1.01c	1.62
	IR58	1.36a	1.38a	1.17ab	1.05b	1.24
150	IR25588	2.38a	2.11b	2.06b	1.78c	2.08
	IR58	1.53a	1.37a	1.44a	1.36a	1.43

* Means followed by a common letter in a row are not singificantly different at the 5% level by DMRT.

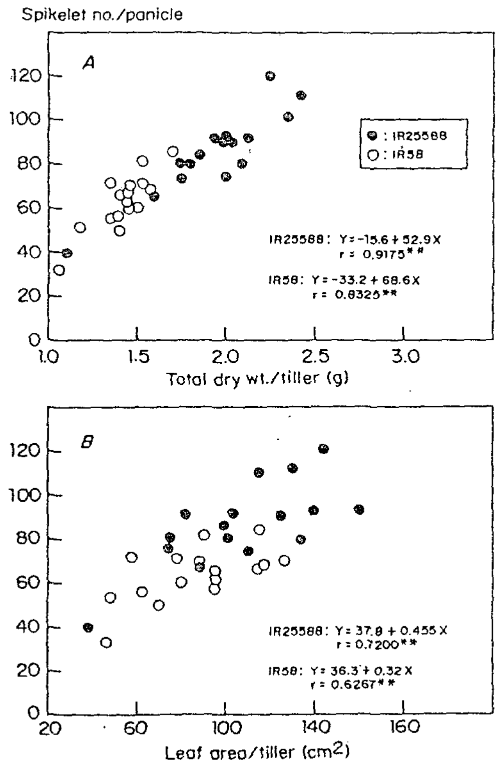

Fig 7. Relationship between spikelet number per panicle and total dry weight and leaf area per tiller at heading.

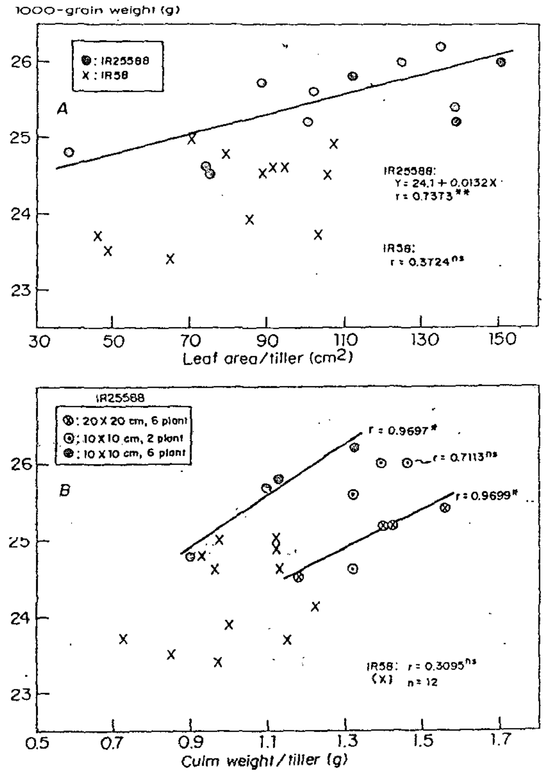

Fig 8. Relationship between 1000−grain weight and leaf area and culm weight per tiller at heading in IR25588 and IR58.

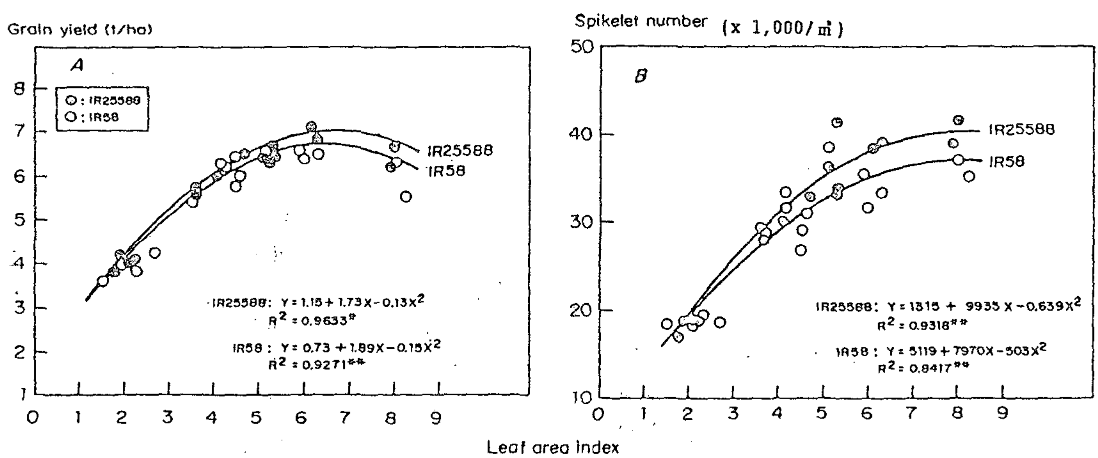

Fig 9. Relationship between leaf area index and grain yield and spikelet number in IR25588 and IR58.
Grain yield(t/ha) Spikelet number(x 1,000/m²) Leaf area index

Therefore, the larger leaves and culms were the main sources for increased grain yield in a low-tillering panicle weight type. Kim and Vergara[6, 7] reported that greater leaf area and culm weight per tiller of a low-tillering cultivar had accumulated more carbohydrates, larger photosynthesizing tissues, and more vascular bundles to promote the transport of assimilates, thus better grain filling. Yoshida and Cock[10] found that 74% of grain carbohydrates was a result of phytosynthesis after flowering and 26% of that was translocated from the accumulated carbohydrates in the plant body. Therefore, the proportion of the former and latter could be increased by larger leaves and culms in a low-tillering panicle weight type.

Grain yield and spikelet number per m^2 were highly correlated with LAI in both cultivars (Fig. 9). LAI values for the maximum spikelet number were about 8 in both cultivars (Fig. 9B), while for the maximum grain yield the LAI values were about 6.5 in both cultivars (Fig. 9A). This implies the possible limitation of source for potential grain yield in both cultivars. Venkateswarlu and Visperas[8] claimed that in japonica rice, sink is the limitation because all spikelets were filled under several favorable conditions, while in indica rice, source is the limitation because a clear gap exists between spikelet numbers and grains in tropical climates.

摘 要

本 試驗은 벼의 收量性을 增加시킬 수 있는 새로운 草型으로서 小蘖·穗重型品種의 潛在收量性을 多蘖·穗數型品種과 比較, 評價하기 위하여 國際米作硏究所(IRRI)에서 1988年에 遂行되었다. 供試品種은 小蘖·穗重型인 1R25588과 多蘖·穗數型인 IR58이었으며, 이들은 分蘖能力과 이삭의 크기는 현저한 差異가 있었으나 다른 特性은 비슷하였다.

1. 小肥條件(窒素 0 & 100kg/ha)에서는 栽植密度에 관계없이 IR255888과 IR58 사이에 收量差異가 없었으나, 多肥密植條件(窒素, 150 & 200kg/ha, 栽植距離 10×10cm)에서는 小蘖·穗重型인 IR2588이 多蘖·穗數型인 IR58보다 有意的으로 收量이 많았다. 最高收量은 窒素 150kg/ha, 栽植密度 10×10cm 그리고 株當苗數 2苗植 處理區에서 나타났으며 IR255888과 IR58이 각각 7.10과 6.60 t/ha이었다. 이는 小蘖·穗重型인 IR255888이 多蘖·穗數型인 IR58보다 收量性이 높다는 것을 나타내었으며, 또한 벼의 潛在收量을 보다 높일 수 있는 理想的인 草型이 "小蘖·強桿·穗重型"이라는 結果를 뒷받침하고 있다.

2. 多肥密植 상태에서 IR255888이 IR58보다 높은 收量性을 나타내었으며, 이는 主로 小蘖·穗重型 草型인 IR255888의 穗當穎花數가 IR58보다 많았기 때문이었다.

3. 單位面積當 穗數는 IR58이 IR255888보다 많았고 穗當穎花數는 IR255888이 IR58보다 많았는데, 收量을 가장 잘 나타내는 單位面積當 穎花數는 IR2588이 IR58보다 많았다.

4. 稔實比率은 두 品種間에 差異가 없었으나, 千粒重은 IR255888이 IR58보다 무거웠다.

5. IR255888과 IR58間에 葉面積指數는 서로 비슷하였으나 總乾物 生產量은 특히 多肥密植 상태에서 IR255888이 IR58보다 많은 경향을 나타내었다. 分蘖當 葉面積과 乾物重은 IR255888이 IR58 보다 월등히 많았는데, 이는 많은 sink(穗當穎花數)를 채울수 있는 source로서 光合成 作用과 同化產物의 蓄積에 크게 寄與할 것이다.

6. IR255888과 IR58 모두 分蘖當 葉面積 및 乾物重은 穗當穎花數와 正의 相關關係를 나타내었는데, 小蘖性品種의 相關關係가 多蘖性品種보다 높았다. 또한, IR255888에서는 分蘖當 葉面積 및 乾物重이 千粒重과 有意的인 相關關係가 있었으나 IR58에서는 關係가 없었다.

7. 收量을 減少시키는 要因 중에 하나인 株內競爭 程度는 小蘖性品種이 多蘖品種보다 적었다. 또한, 多肥密植 상태에서는 多收穫을 위한 株當 苗

數가 適正 栽植密度에서의 株當 苗數보다 적었다.

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