Relationship between Dry Weight and Spikelet Number of each Tiller at Heading in Rice Plants

Hiroyuki Shiratsuchi[1], Youichi Ohdaira[2] and Jun-ichi Takanashi

[1] National Agricultural Research Centre, Tsukuba, Ibaraki, Japan 305-8666, narc.naro.affrc.go.jp Email shiratsuch@yahoo.co.jp
[2] National Agricultural Research Centre for Western Region, Fukuyama, Hiroshima, Japan 721-8514, wenarc.naro.affrc.go.jp

Abstract

The relationship among dry weight and nitrogen content of each tiller and spikelet number of the tiller was investigated in order to elucidate the factors determining spikelet number in each tiller of rice. Various treatments were used to change the spikelet number per panicle: three cultivars with different growth duration, 'Mineasahi' (short), 'Hinohikari' (medium) and 'Akebono' (long) were transplanted at two transplanting dates in 1999 and in 2000, 'Hinohikari' was grown with GA_3 application, nitrogen top-dressing, and thinning of the hills at panicle initiation. The slopes of the regression lines of spikelet number on dry weight at heading of each tiller were larger in the short-duration cultivar 'Mineasahi' than in the others. The slopes were not affected by the treatments within each cultivar. The treatments changed the intercepts of the regression lines somewhat within each cultivar. In 'Hinohikari' in 2000, spikelet number of each tiller was also regressed on nitrogen content of the tiller at heading across the treatments. Partial correlation analysis among dry weight, nitrogen content and spikelet number of each tiller at heading suggests that dry weight rather than nitrogen content determines spikelet number of each tiller. Differentiated spikelet number did not affect surviving spikelet number of each main stem. In conclusion, the spikelet number of each tiller was determined by dry weight of the tiller at heading, regardless of differentiated spikelet number. The treatments affected the regression line a little within each cultivar.

Media summary

Spikelet number of each tiller in rice plants was determined by dry weight of the tiller at heading regardless of differentiated spikelet number.

Key Words

Rice, Spikelet number of each tiller, Dry weight of each tiller, Nitrogen content of each tiller, Differentiated spikelet number

Introduction

Increasing spikelet number per unit area is important for higher grain yield in rice (Yoshida 1981). Spikelet number per unit area (spikelet density) is the product of panicle number per unit area and spikelet number per panicle. Spikelet number per panicle, which is determined later (by -5 days after heading (DAH)) than panicle number per unit area (by -18 DAH) (Matsushima 1957), is thought to be the most important trait determining spikelet density. Therefore, the elucidation of factors influencing spikelet number per panicle is important for the development of high-yielding cultivars and cultivation technologies.

The spikelet number of a main stem was positively correlated with the diameters of uppermost internode (Yamagishi et al. 1992; Fukushima 1999a) and growing point at panicle initiation (Yamagishi et al. 1992; Fukushima 1999b, Kobayasi et al. 2002) when examined for a range of genotypes. Within a cultivar, however, there was no correlation between diameter of growing point and differentiated spikelet number of a main stem (Kobayasi et al. 2001). Thus it is still unclear what determines spikelet number per panicle of individual tillers within a cultivar.

To elucidate the factors determining spikelet number of each tiller, we investigated the relationship among dry weight and nitrogen content at heading, and spikelet number measured with individual tiller base under the treatments affecting spikelet number per panicle.

Materials and Methods

In 1999, field experiment was conducted to examine the genetic difference in the effects of transplanting dates on the relationships of spikelet number to dry weight at heading among tillers. "Tiller" in this study includes a main stem. Seedlings of three japonica rice cultivars with different growth duration, namely 'Mineasahi' (short duration), 'Hinohikari' (medium) and 'Akebono' (long) were transplanted at 30?15cm spacings on April 30 (EARLY) and June 16 (LATE) in a paddy field in Chugoku National Agricultural Experiment Station (Fukuyama, Japan, latitude 34?30′N, longitude 133?23′E). Fertilizer was applied at 8 g N/m^2 g, P_2O_5/m^2 and 8 g K_2O/m^2. The experiment was conducted with a split plot randomized complete block design with three replications with the transplanting dates as main plots and the cultivars as subplots.

In 2000, a field experiment was conducted to examine the effects of treatments aiming to increase spikelet number per panicle and to examine the relationships of spikelet number with dry weight or with nitrogen content at heading among the tillers. Seedlings of 'Hinohikari' were transplanted on June 13 at 30?15cm spacing. The basal fertilizer was 8 g N/m^2, 8 g P_2O_5/m^2 and 8 g K_2O/m^2. Four treatments were imposed on July 21 (panicle initiation); Giberellic Acid (GA): 0.5 L/m^2 of 50 ppm GA_3, Nitrogen (N): 2 g/m^2 of N and K_2O, thinning (THIN): hills were thinned to half of the control, and a control (CONT). The experiment was conducted with a randomized complete block design with four replications.

The number differentiated spikelets on each main stem were measured as the sum of degenerated and surviving spikelets. Thirty-two main stems per treatment were harvested at -1 DAH and preserved in a FAA solution. Number of degenerated spikelet was measured under binocular microscope (Matsushima 1957). Dry weight at heading was measured with four main stems per treatment.

Results and Discussion

Spikelet number per panicle of the short-duration cultivar 'Mineasahi' was higher in EARLY transplanting than in LATE transplanting in 1999 (Table 1). Spikelet number per panicle was the highest in THIN (109), followed by GA (90), N and CONT in 2000. These treatments affected spikelet number per panicle significantly.

Table 1. Effects of the treatments on spikelet number per panicle in rice plants.

Year	Cultivar	Treatment	Spikelet Number per panicle		
1999	Mineasahi	EARLY	100	?	3*
		LATE	86	?	1
	Hinohikari	EARLY	85	?	1
		LATE	85	?	2

	Akebono	EARLY	83	?	2
		LATE	86	?	3
2000	Hinohikari	GA	90	?	2b
		N	86	?	1c
		THIN	109	?	1a
		CONT	83	?	2c

Data are shown as mean ? standard error of the mean.
* Indicates significant difference (P<0.05) between the transplanting dates within each cultivar in 1999 according to ANOVA.
Among the treatments in 2000, means followed by the same letter are not significantly different at P<0.05 according to Tukey's test.

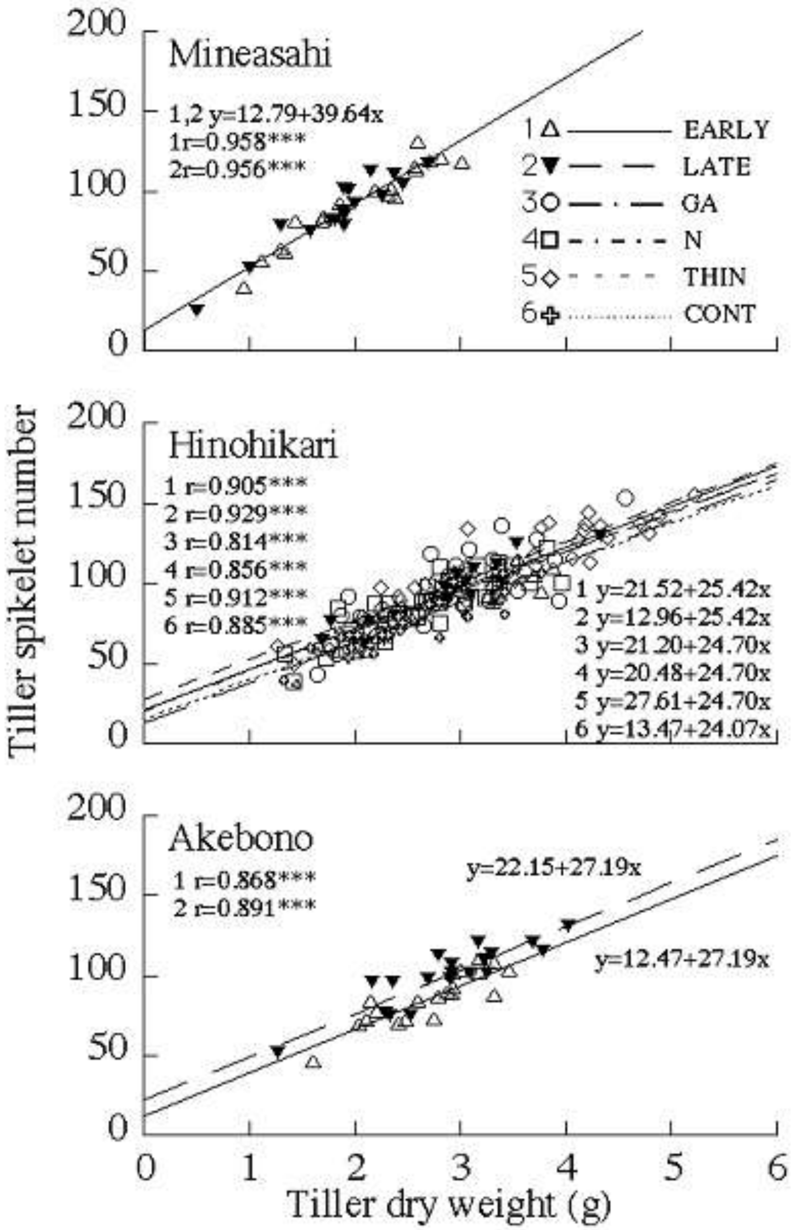

Fig. 1 Effects of the treatments on relationship between dry weight of each tiller at heading and spikelet number of the tiller in the three rice cultivars in 1999 and in 'Hinohikari ' in 2000.

Tiller spikelet number was positively and significantly correlated with tiller dry weight at heading for each cultivar and treatment (r=0.814*** to 0.958***, Fig. 1). A covariance analysis of the data for 'Mineasahi' in 1999 showed that the transplanting dates did not affect the slope of the regression between spikelet number and dry weight of each tiller at heading, though they affected spikelet number per panicle (Table 1). Higher spikelet number per panicle of 'Mineasahi' in EARLY than in LATE was attributed to an increase in tiller dry weight. A covariance analysis of the data for 'Hinohikari' in 2000 showed that the four treatments did not affected the slopes of the regression (Fig. 1), though spikelet number per panicle was significantly more in GA and THIN than in N and CONT (Table 1). There was little difference in the slopes of the regression between 1999 (25.42) and 2000 (24.70). The six treatments slightly affected the intercepts of the six regression lines. The six intercepts ranged from 12.96 in LATE to 27.61 in THIN. Regression lines of spikelet number of each tiller on dry weight of the tiller at heading were different among the cultivars. The slopes of them, however, were similar within each cultivar regardless of the treatments. The slope of the short-duration cultivar 'Mineasahi' was larger than those of the medium-duration cultivar 'Hinohikari' and the long-duration cultivar 'Akebono'.

Tiller spikelet number was also significantly and positively correlated with tiller nitrogen content at heading across the treatments in 'Hinohikari' in 2000 (Fig. 2, r=0.864***). The correlation coefficients for the individual treatments are also shown in the Figure.

Table 2. Partial correlation coefficient among dry weight, nitrogen content and spikelet number of each tiller and correlation coefficient between dry weight and nitrogen content of each tiller at heading in 'Hinohikari' in 2000.

Treatment	$r_{SD.N}$ [a]		$r_{SN.D}$ [b]		r_{DN} [c]		n
GA	0.628	**	0.258		0.592	*	12
N	0.201		0.220		0.951	***	12
THIN	0.505	*	0.316		0.941	***	12
CONT	0.105		0.424	*	0.975	***	12
Total	0.463	**	0.288	*	0.915	***	48

[a]Partial correlation coefficient between spikelet number of each tiller and dry weight of the tiller holding nitrogen content of the tiller fixed.
[b]Partial correlation coefficient between spikelet number of each tiller and nitrogen content of the tiller holding dry weight of the tiller fixed.
[c]Correlation coefficient between dry weight and nitrogen content of each tiller.
*, **, ***Significant at P<0.05, 0.01, 0.001, respectively

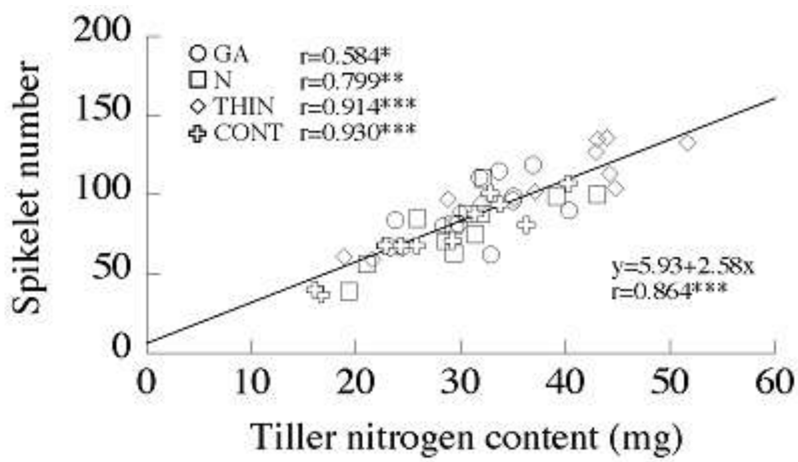

Fig. 2 Relationship between nitrogen content of each tiller at heading and spikelet number of the tiller in rice cultivar 'Hinohikari' in 2000. The regression line in the figure was determined with analysis of covariance.

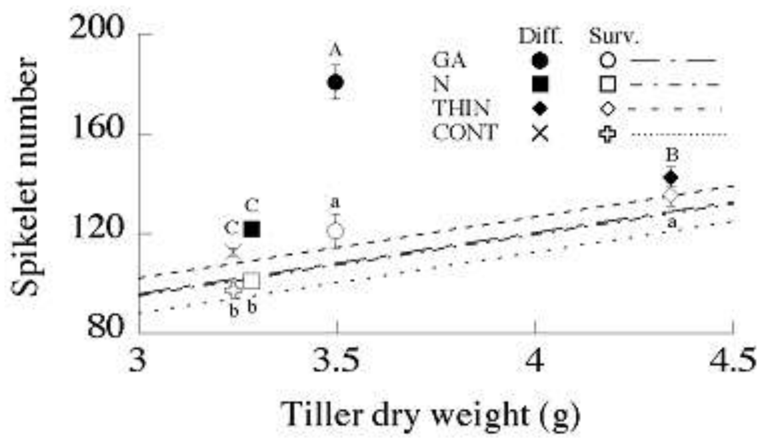

Fig. 3 Effects of the treatments on differentiated and surviving spikelet number of a main stem in 'Hinohikari' in 2000. The lines are the same regression lines in Fig. 1. Data are averaged with standard error among four replications. The same letters indicate that there is no significant difference in spikelet number at 5 % level (Tukey's test); capital: differentiated spikelets; lowercase: surviving spikelets.

Partial correlation coefficient between tiller dry weight and spikelet number of each tiller while holding nitrogen content ($r_{SD.N}$) constant was 0.628** in GA and 0.505* in THIN. These partial coefficients were larger than those between nitrogen content and spikelet number of each tiller holding dry weight ($r_{SN.D}$) constant (Table 2). Over all the treatments $r_{SD.N}$ was 0.463** and larger than $r_{SN.D,\ which}$ was 0.288*. Overall $r_{SD.N}$ was larger than $r_{SN.D}$, though $r_{SD.N}$ in CONT was less than $r_{SN.D}$. These indicate that spikelet number of each tiller was more causally correlated to dry weight of the tiller at heading than nitrogen content. The results suggest that nitrogen content of each tiller seems to indirectly affect tiller spikelet number through dry matter production, though previous studies showed that spikelet density was related to nitrogen content and concentration of canopies during reproductive stage (Hasegawa et al. 1994; Kobayasi and Horie 1994; Kobayasi 2000).

Surviving spikelet number on a main stem was close to the regression lines of tiller spikelet number on tiller dry weight at heading, whereas differentiated spikelet number on a main stem was larger than estimated spikelet number by the regression lines in the four treatments in 'Hinohikari' in 2000 (Fig. 3). Although the number of differentiated spikelets on a main stem was higher in GA than in THIN, actually surviving spikelet number was less in GA than in THIN maybe because of lower dry weight of the main stem in GA than in THIN. This suggests that the surviving spikelet number of each tiller decreases to estimate number by the regression lines regardless of differentiated spikelet number.

Conclusion

Tiller spikelet number was largely determined by tiller dry weight at heading regardless of differentiated spikelet number in rice plants. The slopes of the regression lines of tiller spikelet number on tiller dry weight at heading were almost constant within each cultivar. The slope in the short-duration cultivar 'Mineasahi' was steeper than those in the medium-duration cultivar 'Hinohikari' and in the long-duration cultivar 'Akebono'. The intercepts of the lines differed slightly among the treatments within each cultivar.

References

Fukushima A (1999). Branching structure of panicle with reference to the number of spikelets in rice. Jpn. J. Crop Sci. 68, 71-76 (in Japanese with English abstract).

Fukushima A (1999). Differentiation and development of the branching of panicle with reference to the number of spikelets in rice. Jpn. J. Crop Sci. 68, 77-82 (in Japanese with English abstract).

Hasegawa T, Koroda Y, Seligman NG and Horie T (1994). Response of spikelet number to plant nitrogen concentration and dry weight in paddy rice. Agron. J. 86, 673-676.

Kobayasi K (2000). The analysis of the process in spikelet number determination with special reference to nitrogen nutrition in rice. Bull. Fac. Life Env. Sci. Shimane Univ. 5, 13-17.

Kobayasi K and Horie T (1994). The effect of plant nitrogen condition during reproductive stage on the differentiation of spikelets and rachis-branches in rice. Jpn. J. Crop Sci. 63, 193-199 (in Japanese with English abstract).

Kobayasi K, Nakase H and Imaki T (2001). Effects of planting density and topdressing at the panicle initiation stage on spikelet number per unit area. Jpn. J. Crop Sci. 70, 34-39 (in Japanese with English abstract).

Kobayasi K, Imaki T, and Horie T (2001). Relationship between the size of the apical dome at the panicle initiation and the panicle components in rice. Plant Prod. Sci. 4, 81-87.

Kobayasi K, Horie Y, and Imaki T (2002). Relationship between apical dome diameter at panicle initiation and the size of panicle components in rice grown under different nitrogen conditions during the vegetative stage. Plant Prod. Sci. 5, 3-7.

Matsushima S (1957). Analysis of developmental factors determining yield and yield prediction in lowland rice. Bull. Nat. Inst. Agric. Sci. A5, 1-271 (in Japanese with English summary).

Yamagishi J, Yajima J, Etoh K, Suzuki H and Inanaga S (1992). Relation of number of spikelets per panicle to the characteristics of shoot and the size around growing point at panicle initiation stage in rice varieties. Jpn. J. Crop Sci. 61, 568-575 (in Japanese with English abstract).

Yoshida S (1981). In 'Fundamentals of rice crop science' 213-230, (IRRI, Los Ba?os).