Tillering Patterns and the Contribution of Tillers to Grain Yield with Hybrid Rice and Wide Spacing

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The reported success of SRI is based on the synergetic development of both the tillers and roots. With more vigorous root growth, plants can become both fuller and taller and get better access to the nutrients and water they need to produce more tillers and more yield. The practices of SRI include: early transplanting, wide spacing and planting one plant per hill, with application of compost, frequent weeding, and less use irrigation water in order to capture the full potential for tillering and root growth (Uphoff, 2001).

In recent years, planting practices in China have been shifting from close spacing to wider spacing in high-yielding cultivation, especially for hybrid rice varieties. This improves the canopy's photosynthesis, increases the percentage of productive tillers, and the spikelet number per panicle. At same time, in combination with less irrigation water, pests may be better controlled and lodging prevented (Zhu, 2002).

However, there is little knowledge available about the contributions of tillering to yield and what are reasonable numbers of productive tillers per plant to aim for with wider spacing so as to get the best rice production. In this paper, the results of several studies on the pattern of tillering and the contributions of greater tillering to yield with wide spacing are reported.

Materials and Methods

Experiment 1

Spikelet numbers per panicle according to tillers from different orders (sequences) was studied in 2000 using hybrid rice varieties 65002 and Shanyou 63 in pot experiments. The pot size was 20 cm in diameter and 30 cm in height. Single plants with tillering in the fourth phyllochron were transplanted into pots containing clay soil, with 20 plants of each variety planted in this way.

The emergence of primary, secondary and tertiary tillers was recorded separately, and each tiller was marked with a plastic label every second day. Twenty replications per variety were harvested at 5 days after heading. Panicles from different tiller orders were separated carefully, and the spikelet numbers for each panicle in different tiller orders were determined.

Experiment 2

The effects of having a different numbers of productive tillers per plant on spikelet numbers per panicle were studied also in 2000. The same hybrid rice varieties, 65002 and Shanyou 63, were used in pots sized 20 cm in diameter and 30 cm in height. Single seedlings with tillering in the fifth phyllochron were transplanted in each pot. By removing late small tillers every 3 days, tillers per plant were controlled to be 3, 6, 9, 12 and 15. The experiment had ten replications. At harvest, the ten replications were harvested, and spikelet number per panicle was counted.

Experiment 3

An experiment was done under field conditions in 2001 with different spacings and three replications. Two hybrid rice varieties, Xieyou 9308 and Youming 8, were used. Plant density was 7, 9, 11 and 13 hills per m^2. One 21-day seedling per hill was transplanted. (Note that this is older than the recommended seedling age with SRI practices — 8-12 days old, with a maximum of 15 days.) The results of this experiment would not necessarily reveal much about tillering dynamics with SRI methodology, but it is interesting in any case to know more about tillering patterns. The plot size was 3 by 4 m.

Tiller numbers in each plot were counted every 4 days from 12 sampled plants between transplanting and heading. Only tillers that had at least one green leaf were counted. The percentage of productive tillers was calculated as panicle number divided by the maximum tiller number per plant. At maturity, a sample of $5m^2$ was harvested from each plot. The panicles were threshed, dried and weighed, and grain yield was adjusted to 14% moisture content.

Results and Discussion

Components of different types of tillers and spikelet number

The numbers of tillers that emerged from the main tiller and subsequent tillers according to respective tiller orders (main, primary, secondary, tertiary) reflecting their sequence of emergence are indicated in Figure 1. The number of total tillers and tertiary tillers increased exponentially as the number of *phyllochrons* (often referred to as leaf number) advanced.[1] It was the growth in number of tertiary tillers that drove the total number up so sharply.

The number of primary and secondary tillers increased more linearly with the advance of phyllochrons (the number of periods of tiller emergence). The first primary tiller emerges from the main tiller in the fourth phyllochron, with additional primary tillers up to six in the next five phyllochron periods. The first secondary tiller comes out later, from the base of the first primary tiller, in the seventh phyllochron, while the first tertiary tiller emerges from the base of the first secondary tiller in the tenth phyllochron.[2]

[1] *Phyllochrons are a regular interval or period of plant growth observable for all gramineae species. These 'growth cycles' can be as short as 5 days (under ideal growth conditions) or up to 10 days (with less favorable conditions). During each phyllochron beyond the third, one or more phytomers (a unit of tiller, leaf and root) are produced from the plant's apical meristematic tissue. They are particularly important for rice, which is a potentially high-tillering plant provided that its root system is intact and the root system and canopy are not constrained by crowding. Between 6 and 12 phyllochrons may be completed before panicle initiation, when vegetative growth stops and the plant goes into its reproductive phase. The most detailed discussion of phyllochrons in rice in English language is by Nemoto et al. (1995), though they were first identified and analyzed by a Japanese researcher, T. Katayama, about 75 years ago. In 1995, a special issue of the journal Crop Science (Vol. 35, No.1) was devoted to phyllochrons, though mostly with respect to wheat. For more on phyllochrons, see Moreau (1976) and Matsuo et al. (1997: 223-226). [Editors.]*

[2] *The detailed work on phyllochrons by Fr. de Laulanié (1993), who developed SRI, found somewhat different numbers. He agrees that the first primary tiller emerges in the 4th phyllochron, but according to his observations, the first secondary tiller emerges in the 6th phyllochron, and the first tertiary tiller in the 8th phyllochron. A total of 84 tillers should be possible by the end of the 12th phyllochron according to Laulanié's calculations (a) if that many could be completed before panicle initiation, (b) if the plant has not lost much of its root system due to hypoxia and (c) if its root and tiller growth is not constrained by close planting. [Editors.]*

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The distribution of different types of tillers at the various phyllochron stages is indicated in Figure 2. The percentage of primary tillers among total tillers decreased with the increase of phyllochron. The peak percentage of secondary tillers occurs in the tenth phyllochron; after that, the percentage decreases slowly.

Figure 1. Theoretical numbers of different types of tillers produced in successive phyllochrons

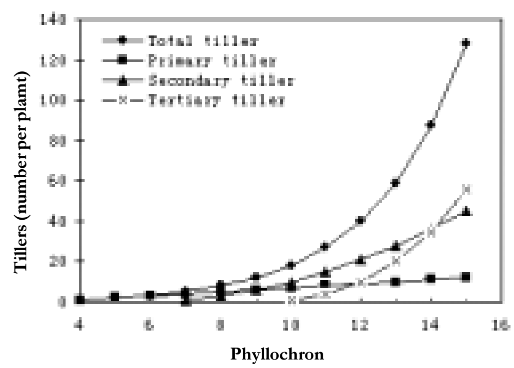
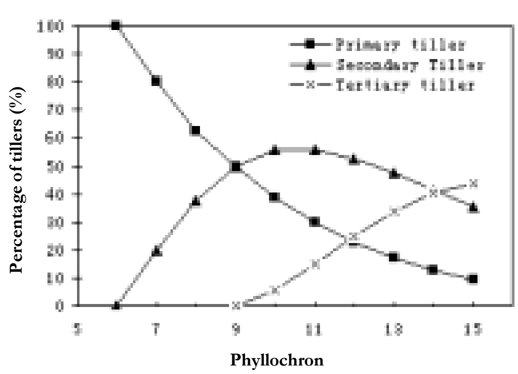


Figure 2. Components of different types of tillers calculated theoretically according to increasing number of phyllochrons



The percentage of teritary tillers increases from the ninth phyllochron by about 5% in the increase of each phyllochron. Therefore, after the ninth phyllochron, the percentage of tertiary and secondary tillers among total tillers increases. Theoretically, with the advance of phyllochrons, especially after the ninth period, small and late emergent tillers will occupy a large portion of the total number of tillers in the rice plant. Reasonable tiller number should be a consideration in assessing the components of panicle performance for high-yielding cultivation of rice.

Observation of spikelet numbers for different types of tillers indicated that the spikelet number per panicle decreased linearly with the advance of tiller order (Figure 3). Spikelet number per panicle on tertiary tillers is only one-third of the spikelet number per panicle found on the main tiller. Kim (1991) found the same results in tropical rice varieties with different tillering capacity. It was seen that the percentage of productive tillers among tertiary tiller is much lower than for primary tillers. Tertiary tillers and late primary and secondary tillers make little contribution to grain yield. In high-yielding cultivation, therefore, getting more early and bigger primary and secondary tillers should be explored, while late small primary, secondary and tertiary tillers may be controlled because they are less fertile.[3]

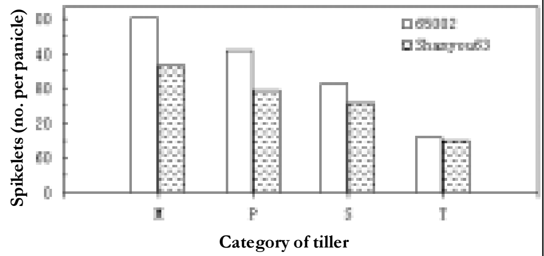
Productive tillers per hill and their distribution with sparse planting

In farmers' rice fields with hybrid rice, about 20 hill per m^2 with one plant per hill are commonly planted. In that case, the average of number of panicles per hill is 14, with panicle number per hill largely distributed between 10 to 18 with hybrid varieties (Figure 4).

However, with wider spacing of only 9 or 11 hills per m^2, planting one plant per hill of Youming 86, the average number of panicles per hill was 23.7 and 19.7, respectively. Panicle number per hill was largely distributed between 22 and 28 at 9 hills per m^2, and between 16 and 22 at 11 hills per m^2 (see Figure 5).

For variety Xieyou 9308, with the wide spacing of 9 and 11 hills per m^2 and one plant per hill, the average numbers of panicles per hill were 26.5 and 19.7, respectively. Panicle numbers per hill were largely distributed between 26 and 30 at 9 hills per m^2, and between 18 and 22 at 11 hills per m^2 (see Figure 6). Clearly, with a decrease in density, the panicle number per hill increases, though it is panicle number per square meter that is most important for yield.

Figure 3. Spikelet number per panicle on different types of tillers



Rice varieties 65002 and Shanyou 63
M = main, P = primary, S = secondary, T = tertiary

Effects of number of panicles per plant on spikelet numbers per panicle

The spikelet number per panicle and its variation seen with controlled numbers of productive tillers are shown in Figure 7. For both Shanyou 63 and Xieyou 9308, with an increase in panicle number per hill, the spikelets per panicle decrease linearly while their variation increases. Panicle number per hill increased from 3 to 15, but the spikelet number per panicle decreased by 41% in Shanyou 63 and 51 % in Xieyou 9308. The decrease in spikelet number per panicle in Shanyou 63 which has high tillering capacity is more than that in Xieyou 9308 which has lower tillering capacity. The more the number of panicles per hill is, the fewer spikelets per panicle.[4]

Relation of the percentage of productive tillers to tillering pattern

When transplanting small seedlings, the tiller number per hill increased linearly up to maximum tillering stage in both Xieyou 9308 and Youming 86 (Figures 8 and 9). The maximum number of tillers per hill reached 45 and 40 with densities of 9 and 11 hill per m^2 in Youming 86, respectively, and 50 and 43 at densities of 9 and 11 hill per m^2 in Xieyou 9308. The percentage of productive tillers was between 43 % and 67 % for Youming 86 (Figure 8) and 44% and 74% for Xieyou 9308 (Figure 9). With an increase in the maximum tiller number, the

[3] *This conclusion may, however, be conditioned by soil and water management practices. With SRI practices, which support a large and healthy root system throughout the crop cycle, the performance of secondary and tertiary is reported to be greater in terms of spikelets and filled grains, so one may not want to limit them.*

[4] *This is the general pattern reported in the literature. However, with SRI practices, one often observes a positive rather than inverse relationship between number of panicles and grains per panicle. This is what accounts for the increase in per area yield.*

Figure 4. Distribution of panicles of Xieyou 63 and Xieyou 9308 at 20 hills/m²

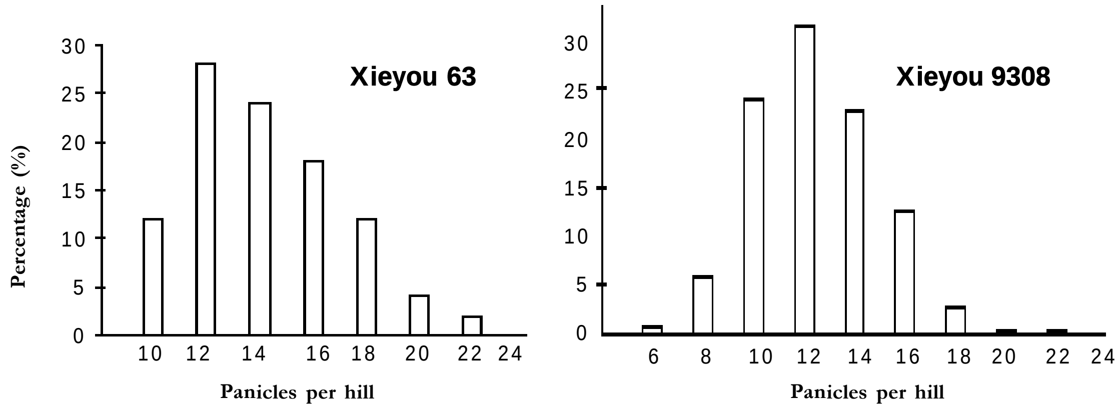


Figure 5. Distribution of panicles of Youming 86 at different densities

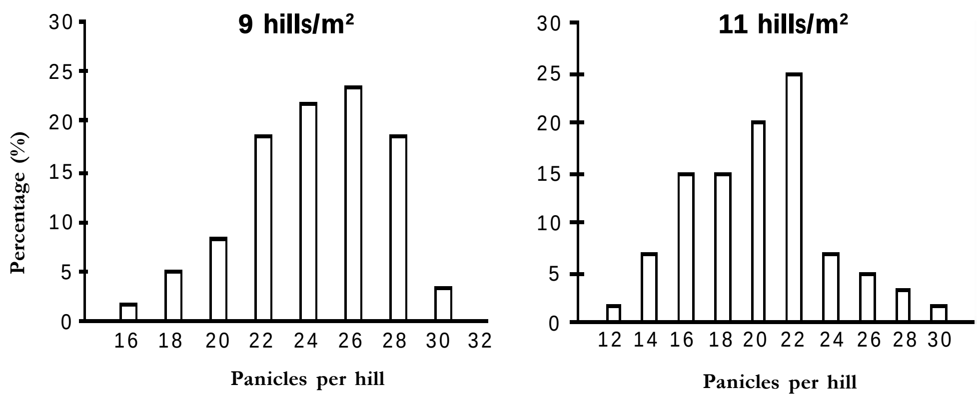
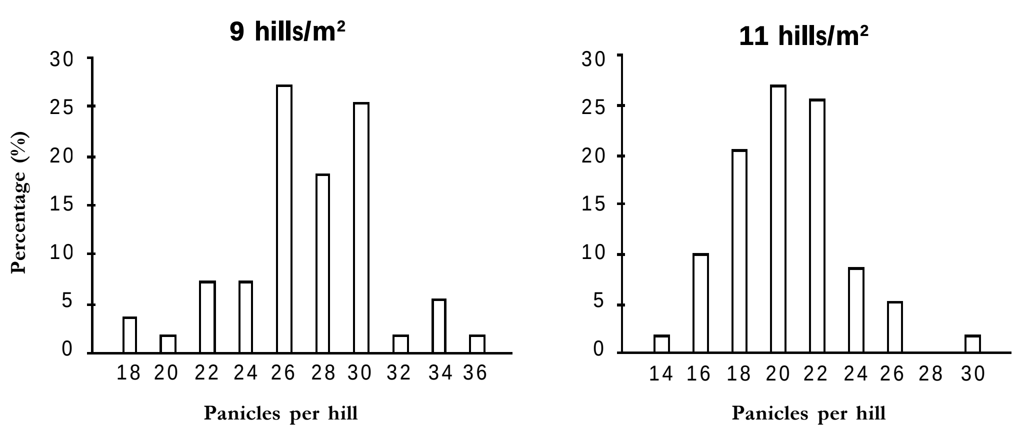


Figure 6. Distribution of panicles of Xieyou 9308 at different densities



percentage of productive tillers decreased, however. The higher the peak of the maximum tiller number, the lower was the percentage of effective tillers.

Comparison of root distribution with different plant spacing

Compared to the closer spacing of 17 hill per m^2 with Xieyou 9308, total roots per plant are higher with the wider spacing of 11 hill per m^2. However, with the wider spacing, most roots are distributed in the top layer, and roots become shallower (Figure 10). Also, roots per stem with the wider spacing decreased in different soil layers, with roots below 5 cm from the soil surface decreasing significantly (Figure 10). It seems that plant roots become shallower with the wider spacing. This may, however, reflect water management practices and the extent and depth of soil aeration.

Yield and its components with different plant spacing

Yield and its components with different spacings using Xieyou 9308 and Youming 86 are listed in Table 1. Yield was higher with closer spacing than with wider spacing. The difference in yield in different spacing was 0.7 t/ha with Xieyou 9308 and 0.5 t/ha with Youming 86. The yield with close spacing was mainly due to an increase in panicle number per unit of land and total spikelet number. The spikelets per panicle with wider spacing were higher than those with closer spacing.

Figure 7. Spikelet number and standard deviation (CV) of Shanyou 63 and Xieyou 9308 in different panicle number per hill

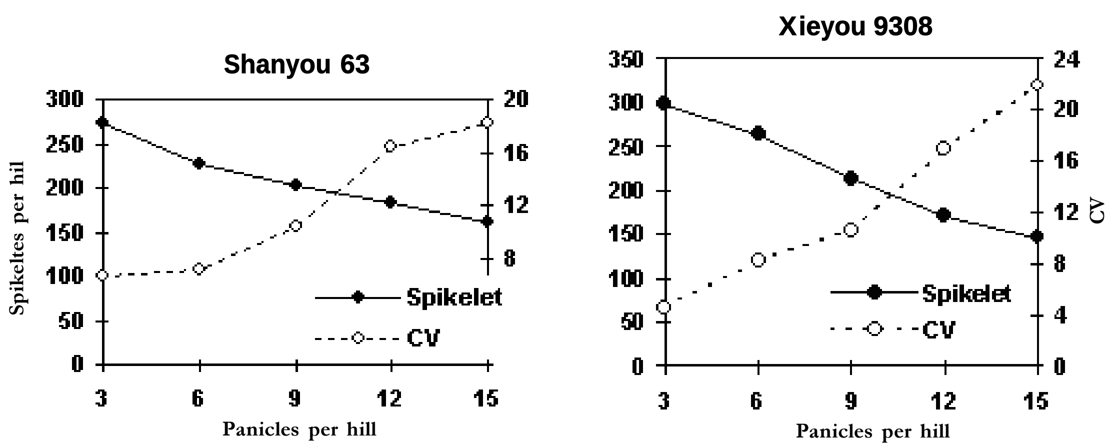


Figure 8. Tillering pattern of Youming 86 at different plant spacings with different percentages of productive tillers

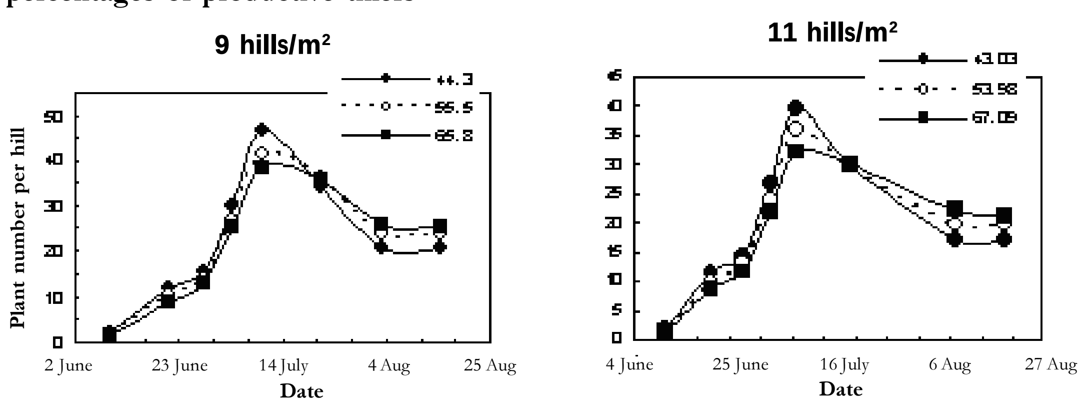


Figure 9. Tillering pattern of Xieyou 9308 at different plant spacings with different percentages of productive tillers

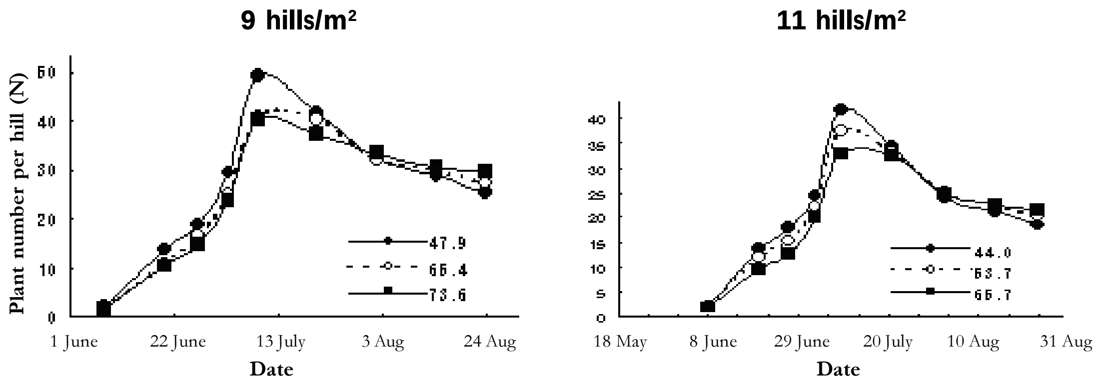


Figure 10. Distribution of root dry weight at different plant spacings in Xieyou 9308

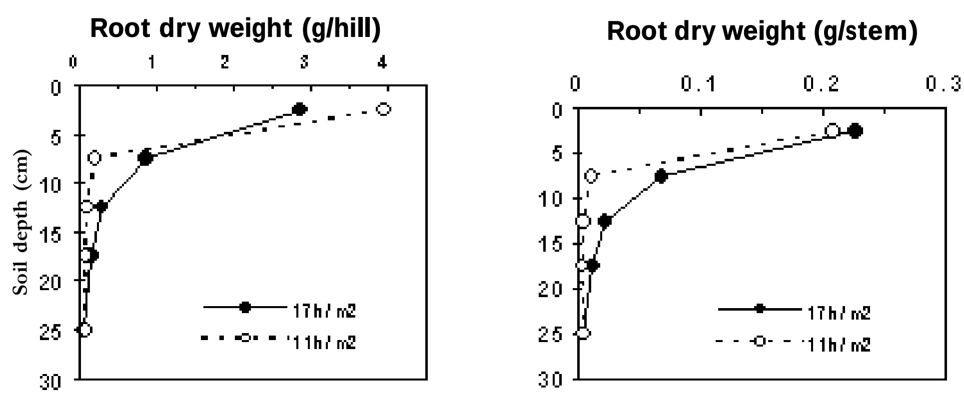


Table 1. Yield and its components with Shanyou 63 and Youming 86 at wider spacing

Hybrid variety	Density (hills/m²)	Panicles (No./m²)	Spikelets (No./panicle)	Spikelets (No./m²)	Total Fertility (%)	Grain weight (g/1000)	Yield (t/ha)
Xieyou 9308	7	185.1	161.9	29967.7	80.6	26.4	6.4
	9	203.0	159.3	32337.9	81.7	26.0	6.9
	11	201.1	157.9	31753.7	82.6	26.6	7.0
	13	219.0	153.7	33660.3	80.6	26.3	7.1
Youming 86	7	177.6	187.6	33317.8	84.8	26.7	7.5
	9	196.9	172.3	33925.9	84.3	27.0	7.7
	11	199.5	173.2	34553.4	83.9	27.3	7.9
	13	207.5	170.4	35358.0	82.2	27.4	8.0

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