Analysis of the Number of Spikelets per Panicle on the Main Stems, Primary and Secondary Tillers of Different Rice Genotypes Grown under the Conventional and Nitrogen-Free Basal Dressing Accompanied with Sparse Planting Density Practices

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Abstract: The number and development of spikelets on a panicle directly affect the grain yield. In this study, we examined the differences among various rice cultivars in the number of spikelets per panicle (NSP\(^{-1}\)) on the main stems (MS), primary tillers (PT) and secondary tillers (ST), and in the numbers of spikelets on the primary and secondary rachis branches. The difference among cultivars in the responses of these characteristics to the practice of nitrogen-free basal dressing accompanied with sparse planting density (BNo) was also elucidated. The results showed that NSP\(^{-1}\) varied with the tiller position on a plant, and it was highest on MS followed by PT and ST in this order in all cultivars. NSP\(^{-1}\) on all MS, PT and ST also varied with the cultivar, and was larger in the cultivars of the panicle-weight type than in those of the panicle-number type. The difference between MS and ST in NSP\(^{-1}\) was larger in the cultivars of the panicle-weight type than in those of the panicle-number type. NSP\(^{-1}\) was larger in BNo than in the conventional cultivation (CONT) in most cultivars. The difference between BNo and CONT in NSP\(^{-1}\) varied with the tiller position on a plant and with the earliness of the cultivar, but did not clearly vary with the plant type of the cultivar. It was larger in the panicle on ST than on MS or PT, and was larger in the late-maturing cultivars than in the early- and medium-maturing ones. The larger NSP\(^{-1}\) on MS or PT compared with ST, in the cultivars of the panicle-weight type compared with those of the panicle-number type, and in BNo compared with CONT was mainly attributed to the increased number of spikelets on secondary rachis branches.

Key words: Cultivation practices, Main stems, Number of Spikelets, Primary tillers, Rice cultivars, Secondary tillers.

Rice belongs to graminaceous plants, in which the panicle (inflorescence) is composed of many spikelets on the primary and secondary rachis branches. The panicle, on the other hand, is mainly produced on the main stem (MS), primary tiller (PT) and secondary tiller (ST). The number and development of spikelets on a panicle directly affect the grain yield. Therefore, the elucidation of the number and structure of spikelets on a particular panicle can provide some substantial information on the development of stable and high yielding cultivars or cultivation practices.

The number of spikelets per panicle (NSP\(^{-1}\)) varies not only with the cultivar but also with the cultivation practice and the tiller position on which the panicle was formed. Kobayashi and Imaki (1997) indicated that the large NSP\(^{-1}\) in modern rice cultivars resulted from a large number of secondary rachis branches. The application of nitrogen fertilizer at the panicle formation period also results in the increased NSP\(^{-1}\) (Yoshida, 1981; Hoshikawa, 1989; Matsushima, 1995). Wu et al. (1998), on the other hand, stated that NSP\(^{-1}\) was often larger in the lower tiller order than in the higher tiller order. Kuroda et al. (1999), furthermore, showed that the cultivar with a larger NSP\(^{-1}\) on MS had a larger NSP\(^{-1}\) on PT and ST.

In most studies in the literature, however, NSP\(^{-1}\) among cultivars or cultivation practices was often compared using the average panicles (the panicle with an average length compared with other panicles in a hill) (Wang et al., 1996), the average NSP\(^{-1}\) (the
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The number of spikelets averaged over all panicles in a hill (Xu et al., 1997; Nagata et al., 2001), panicles on MS (Kobayashi and Imaki, 1997; Chunsheng and Yamagishi, 2001), or panicles with the longest culm in a hill (Sasahara et al., 1982). To our knowledge, information on the differences among cultivars or cultivation practices in NSP<sub>−1</sub> on MS, PT and ST is not available. We also found no studies on the effect of cultivation practice on the differences among cultivars in NSP<sub>−1</sub> on MS, PT and ST, and in the number of spikelets on primary and secondary rachis branches (NSPR and NSSR, respectively).

In previous studies (Pham et al., 2004a and b), we examined the differences among various rice cultivars in the responses of yield and yield components to the practice of nitrogen-free basal dressing accompanied with sparse planting density (BNo), an on-farm-developed cultivation practice for overcoming cool weather damage in the Tohoku region of Japan (Murata, 1994; Hirano et al., 1997; Truong et al., 1998). We showed that the grain yield averaged over cultivars and years in BNo was about 97% of that in the conventional cultivation (CONT). The grain yield of the early- and medium-maturing cultivars was often lower in BNo, but that of the late-maturing cultivars, particularly that of Ouu316 and Hitomebore, tended to be higher in BNo than in CONT. We also clarified that the number of panicles m<sup>−2</sup> was smaller, but NSP<sup>−1</sup> in BNo to that in CONT. ★ : The ratio (%) of the value in BNo to that in CONT. ▶ : The number of spikelets averaged over all panicles on a hill. 1) and 2): The average values of 4 and 12 cultivars, respectively. ANOVA: Results of analysis of variance; * and **: significant at 0.05 and 0.01 probability levels, respectively.

### Materials and Methods

#### 1. Cultivars used, experimental design and managements

Experiments were conducted in the paddy field with Wet Aldosols at the Faculty of Agriculture, Iwate University, in 1999 and 2002. Materials used, experimental design and managements were described in detail by Pham et al. (2004a, b, c and d). Briefly, twelve rice cultivars or lines were used. They were Iwate43 (I43), Hananomai (Ha), Ouu339 (339) and Fukei149 (149) of the early-maturing genotype; Akitakomachi (Ak), Hatajirushi (Hat), Fukuhibiki (Fu) and Iwanan7 (I7) of the medium-maturing genotype; and Menkoina (Me), Okiniiri (Ok), Ouu316 (316) and Hitomebore (Hi) belonging to the late-maturing one. The plant type of each cultivar is shown in Table 1. In those studies, the responses of NSPR and NSSR as well as of NSP<sub>−1</sub> on MS, PT and ST to BNo were not examined. In the present study, therefore, we elucidate the differences among various rice cultivars and between BNo and CONT in NSP<sub>−1</sub> on MS, PT and ST. Moreover, NSPR and NSSR in a panicle are also compared among cultivars, among tiller positions and between BNo and CONT.

| Cultivar name | MS | PT | ST | Average NSP<sub>−1</sub>*<sup>2</sup> |
|---------------|----|----|----|-------------------|
| CONT | BNo | B/C (%) | CONT | BNo | B/C (%) | CONT | BNo | B/C (%) | CONT | BNo | B/C (%) |
| 43(n) | 100.8 | 93.5 | 93 | 83.1 | 89.4 | 108 | 61.1 | 63.0 | 103 | 76.8 | 78.4 | 102 |
| Early | Ha (w) | 113.6 | 120.1 | 106 | 89.2 | 90.3 | 101 | 58.8 | 62.7 | 107 | 78.8 | 83.0 | 105 |
| maturing | 339 (w) | 125.4 | 103.7 | 83 | 101.8 | 89.4 | 88 | 68.8 | 63.1 | 92 | 93.3 | 80.6 | 86 |
| 149 (w) | 126.3 | 115.5 | 91 | 100.1 | 97.7 | 98 | 73.1 | 70.7 | 96 | 94.2 | 91.0 | 97 |
| Ave<sup>2</sup> | 116.5 | 108.2 | 93 | 93.0 | 91.7 | 98 | 65.5 | 64.9 | 99 | 85.8 | 83.2 | 97 |
| Ak (n) | 94.2 | 110.7 | 118 | 80.2 | 80.5 | 100 | 53.8 | 59.3 | 110 | 71.6 | 74.3 | 104 |
| Medium | Hat (n) | 104.5 | 101.8 | 97 | 82.6 | 78.5 | 95 | 55.1 | 61.7 | 112 | 73.7 | 74.3 | 101 |
| maturing | Fu (w) | 142.8 | 145.3 | 102 | 112.2 | 114.4 | 102 | 80.6 | 81.6 | 101 | 107.8 | 108.0 | 100 |
| F7 (n) | 95.9 | 108.3 | 113 | 80.9 | 80.6 | 100 | 53.5 | 62.7 | 117 | 73.3 | 76.4 | 104 |
| Ave<sup>2</sup> | 109.3 | 116.5 | 107 | 89.0 | 80.5 | 99 | 60.8 | 66.3 | 109 | 81.6 | 83.2 | 102 |

Letters in ( ) indicate the abbreviated plant type of cultivars or lines; n = the panicle-number type, i = the intermediate type, w = the panicle-weight type. ★ : The ratio (%) of the value in BNo to that in CONT. ▶ : The number of spikelets averaged over all panicles on a hill. 1) and 2): The average values of 4 and 12 cultivars, respectively. ANOVA: Results of analysis of variance; * and **: significant at 0.05 and 0.01 probability levels, respectively.
transplanted, three seedlings hill\(^{-1}\) in the middle of May. In CONT, planting density and nitrogen application regimes were the same as in the standard practice in Iwate Prefecture; the planting density was 22.2 hills m\(^{-2}\) (15×30 cm) and the total of nitrogen fertilizer was 11 g m\(^{-2}\) (6.5 g as basal dressing, 2.5 g at about 25~20 days before heading and 2.0 g at the heading stage). In BNo, the planting density was 16.7 hills m\(^{-2}\) (20×30 cm) and the amount N was 9 g m\(^{-2}\) (3.0 g at the 8th leaf-age stage, 2.0 g at the neck node initiation stage, 2.0 g at about 25~20 days before heading and 2.0 g at the heading stage). Phosphorus and potassium fertilizers at 14.0 g m\(^{-2}\) and 12.8 g m\(^{-2}\), respectively, were applied as basal dressing in both CONT and BNo.

2. Measurements

Characteristics of panicles were examined after the full heading stage. From each replication, we selected two rice hills with the average growth and the number of panicles hill\(^{-1}\). Panicles were then separated into three groups of those on MS, PT and ST. The panicles on the tertiary tiller were not found in any sample. The NSPR and NSSR of each panicle were also counted. The tertiary rachis branch was not found in any sample.

3. Statistical analysis

Data were analyzed using mean separation, variance, and regression procedures as appropriate. Testing for the homogeneity of regression coefficients was carried out for the comparison of slope coefficients between or among the regression lines (Gomez and Gomez, 1976).

Results

The obtained results were similar in 1999 and 2002. The coefficient (r), which indicate the degree of linear association, of the correlation between the average

![Graph](image)

**Fig. 1.** The correlations of the number of spikelets per panicle (NSP\(^{-1}\)) on the main stems (MS), primary tillers (PT) and secondary tillers (ST) with the average NSP\(^{-1}\) (the number of spikelets averaged over all panicles in a hill).

\(r = 0.97^{**}\)

\(r = 0.99^{**}\)

\(r = 1.21x + 11.41\)

Table 2. The ratio (%) of the number of spikelets per panicle (NSP\(^{-1}\)) on the main stems (MS), primary tillers (PT) and secondary tillers (ST), and that of the numbers of spikelets on the primary rachis branch (NSPR) and secondary rachis branch (NSSR) in BNo to those in CONT, in different cultivars.

| Cultivar groups | Cultivar name | MS NSPR | MS NSSR | PT NSPR | PT NSSR | ST NSPR | ST NSSR | Average\(^{1)}\) NSPR | Average\(^{1)}\) NSSR |
|-----------------|---------------|---------|---------|---------|---------|---------|---------|----------------|----------------|
| Early maturing  | Ak (n)        | 110     | 129     | 100     | 99      | 101     | 117     | 99              | 112            |
|                 | Hat (n)       | 97      | 107     | 98      | 97      | 98      | 104     | 96              | 97             |
|                 | Fu (w)        | 104     | 103     | 98      | 98      | 104     | 98      | 96              | 96             |
|                 | 17 (n)        | 107     | 120     | 97      | 104     | 105     | 127     | 97              | 111            |
| Average         | 102           | 115     | 100     | 98      | 103     | 127     | 100     | 99              | 111            |
| Medium maturing | Me (i)        | 97      | 132     | 96      | 124     | 97      | 136     | 96              | 129            |
|                 | Ok (i)        | 106     | 127     | 97      | 125     | 105     | 133     | 107             | 128            |
|                 | 316 (w)       | 108     | 109     | 98      | 113     | 109     | 137     | 103             | 119            |
|                 | H6 (n)        | 112     | 130     | 109     | 175     | 120     | 206     | 112             | 170            |
| Average         | 106           | 125     | 103     | 134     | 108     | 153     | 104     | 137             |                |

Letters in (   ) are as shown in Table 1. 1): Numerals in the table show the ratio (%) of values in BNo to those in CONT. 2): The value averaged over all panicles in a hill. 3) and 4): The average values of 4 and 12 cultivars, respectively.
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NSP\textsuperscript{1} (the number averaged over all panicles in a hill) in 1999 with that in 2002, for example, was high (0.92) and significant at 0.01 probability level (data not shown). Therefore, in this paper, we only present the data of 1999.

1. NSP\textsuperscript{1} on MS, PT and ST

Table 1 shows NSP\textsuperscript{1} on MS, PT and ST in various rice cultivars in CONT and BNo. Generally, NSP\textsuperscript{1} was highest on MS followed by PT and ST in this order. NSP\textsuperscript{1} on all MS, PT and ST did not clearly vary with the earliness of the cultivars in CONT. It, however, was often larger in the late-maturing cultivars than in the early-, or medium-maturing cultivars in BNo. NSP\textsuperscript{1} on all MS, PT and ST clearly varied with the plant type of the cultivar, and was always larger in the cultivars of the panicle-weight type than in those of the panicle-number type in both CONT and BNo. In comparison with CONT, NSP\textsuperscript{1} was often larger in BNo. The difference between BNo and CONT in NSP\textsuperscript{1} did not clearly relate with the plant type of the cultivars, but with the earliness of the cultivars. The difference was small in the early-maturing cultivars, but was large in the late-maturing cultivars. The difference between BNo and CONT in NSP\textsuperscript{1} was also larger on ST than on MS or PT. Overall, the NSP\textsuperscript{1} averaged over 12 cultivars in BNo was about 3%, 2% and 9% larger than that in CONT on MS, PT and ST, respectively.

2. Correlation of NSP\textsuperscript{1} on MS, PT and ST with the average NSP\textsuperscript{1}

To further clarify the differences among cultivars in NSP\textsuperscript{1} on MS, PT and ST, we examined the correlations of NSP\textsuperscript{1} on MS, PT and ST with the average NSP\textsuperscript{1} as shown in Fig. 1. The NSP\textsuperscript{1} on all MS, PT and ST significantly correlated with the average NSP\textsuperscript{1}. The correlation coefficient (r), however, was larger on PT (0.99) than on MS (0.96) or ST (0.97). The slope coefficient, which indicates the degree of the change in NSP\textsuperscript{1} on MS, PT or ST with the change in the average NSP\textsuperscript{1}, was steeper (statistically at 0.05 probability level) on MS (1.21) than on ST (0.81).

3. Difference between BNo and CONT in NSPR and NSSR

Table 2 shows the difference between BNo and CONT (the proportion of the value in BNo to that in CONT) in NSPR and NSSR. The difference was often larger in NSSR than in NSPR. The difference varied with the tiller position on a plant and with the cultivar. It was larger in ST than in MS and PT, and was also larger in the late-maturing cultivars than in the early- and medium-maturing cultivars.

Fig. 2 shows the NSPR and NSSR of a panicle in various rice cultivars in BNo and CONT. Generally, both NSPR and NSSR were larger in the cultivars of the panicle-weight type than in those of the panicle-number type in both BNo and CONT. Although cultivars with a large NSPR also possessed a large NSSR, Fukei149 had a larger NSPR and a smaller NSSR compared with other cultivars with the same NSP\textsuperscript{1}. NSPR was not clearly different between BNo and CONT, but NSSR was larger in BNo than in CONT in most cultivars, except in Ouu339 and Fukei149. The difference between BNo and CONT in NSSR did not relate with the plant type of the cultivars, but with the earliness of the cultivars. The difference was small in the early- and medium-maturing cultivars, but was significantly large in all the late-maturing cultivars.

4. Correlation of NSPR and NSSR with NSP\textsuperscript{1}

To further elucidate the differences in NSPR and in NSSR among cultivars, among tiller positions and between BNo and CONT, we analyzed the correlations of NSPR and NSSR with NSP\textsuperscript{1} as shown in Fig. 3. The regression line and correlation coefficient for each tiller position (MS, PT or ST) or cultivation practice (CONT or BNo) are not shown separately because they were nearly the same, irrespective of tiller position or cultivation practice. Both NSPR and NSSR were larger in a panicle on MS than that on PT or ST in
both BNo and CONT. The NSPR averaged over all cultivars in CONT was 60.8, 52.1 and 41.3 spikelets, and that in BNo was 61.2, 51.5 and 42.2 spikelets in a panicle on MS, PT and ST, respectively. On the other hand, the NSSR averaged over all cultivars in CONT was 50.9, 38.5 and 22.5 spikelets, and that in BNo was 54.8, 41.8 and 27.3 spikelets in a panicle on MS, PT and ST, respectively. Overall, both NSPR and NSSR significantly correlated with NSP$^{-1}$. The correlation coefficient ($r$), however, was larger for NSSR ($r = 0.98$) than for NSPR ($r = 0.95$), and the slope coefficient was also significantly steeper ($P < 0.01$) for the former (0.64) than for the latter (0.36).

**Discussion**

1. **Varietal differences in NSP$^{-1}$ on MS, PT and ST**

   In the present study, NSP$^{-1}$ on MS, PT and ST was larger in the cultivars of the panicle-weight type than in those of the panicle-number type (Table 1). The significant correlation of NSP$^{-1}$ on MS, PT and ST with the average NSP$^{-1}$ (Fig. 1) indicates that NSP$^{-1}$ is determined mainly by genetic traits. The larger correlation coefficient ($r$) for NSP$^{-1}$ on PT (0.99) compared with that on MS (0.96) or ST (0.97) suggests that the variation in the average NSP$^{-1}$ is more closely related to the variation in NSP$^{-1}$ on PT than that on MS or ST. The larger coefficient ($r$) for NSP$^{-1}$ on PT than that on MS or ST might have been caused by the larger number of spikelets on PT in a hill. In the present study, the number of spikelets hill$^{-1}$ averaged over all cultivars and cultivation practices was 339, 1776 and 672 spikelets on MS, PT and ST, respectively; and the contribution of the number of spikelets on MS, PT and ST to the total number of spikelets hill$^{-1}$ was 15.8%, 54.7% and 29.5%, respectively (data not shown). The larger slope coefficient for NSP$^{-1}$ on PT than that on MS or ST could be more appropriate for the investigation of the differences among cultivars or cultivation practices in NSP$^{-1}$. The smaller slope coefficient in the correlation line for NSP$^{-1}$ on PT (0.81) compared with that on MS (1.21), on the other hand, shows that the difference between NSP$^{-1}$ on MS and that on ST is larger in the cultivars with a large average NSP$^{-1}$ (the cultivars of the panicle-weight type) than in the cultivars with a small average NSP$^{-1}$ (the cultivars of the panicle-number type). A large difference between NSP$^{-1}$ on MS and that on ST in the cultivars of the panicle-weight type suggests that in the cultivation of these cultivars, an increased number of panicles on MS accompanied with a reduced number of panicles on ST may result in an increased number of spikelets hill$^{-1}$ or m$^{-2}$.

2. **Differences among tiller positions, among cultivars and between BNo and CONT in NSPR and NSSR**

   Yamagishi et al. (1996) and Wang et al. (1997) found that NSSR and NSP$^{-1}$ were larger in the new cultivars than in the old ones. Matsushima (1995), on the other hand, demonstrated that the application of nitrogen fertilizer at the mid-growth stage resulted in the increase in NSP$^{-1}$, especially in NSSR. In the present study, a larger NSP$^{-1}$ in the cultivars of the panicle-weight type compared with the cultivars of the panicle-number type, on MS compared with PT or ST, and in BNo compared with CONT, was also mainly caused by the increased NSSR (Table 2; Fig. 2 and 3). The correlation coefficient ($r$) of the regression lines of NSPR and NSSR against NSP$^{-1}$, for NSSR (0.98) was larger than that for NSPR (0.95) (Fig. 3) indicating that the variation in NSP$^{-1}$ among cultivars, among tiller positions and between BNo and CONT is more closely related to the variation in NSSR than in NSPR. The slope coefficient for NSSR (0.64) was about twice larger than that for NSPR (0.36) suggesting that the difference in NSSR among tiller positions, among cultivars and between cultivation practices was about twice larger than that in NSPR.

   NSP$^{-1}$ was reported to correlate closely and positively with the diameter of young panicle base (Yamagishi et al., 1992), or the thickness (sectional area mm$^2$) of the...
first elongated internode of culm in rice (Matsushima, 1972). On the other hand, Kumura (1995) indicated that a high dry matter production during the panicle formation period reduced the number of degenerated spikelets, especially on the secondary rachis branch, thereby increasing NSP\(^1\) or the number of spikelets m\(^{-2}\). Truong et al. (1998) studied on the effect of top dressing on rice grown under BNo, and stated that nitrogen top-dressing at the neck-node differentiation stage significantly increased NSP\(^1\) in BNo. In a previous study (Pham et al., 2004d), we used the same materials as in the present study, and showed that the diameter and sectional area of the basal internode IV were larger in the cultivars of the panicle-weight type than in those of the panicle-number type, and in BNo than in CONT. We also found that the dry matter production per panicle during the panicle formation period (during 4 weeks before full heading) significantly correlated with NSP\(^1\), and it was larger in the cultivars of the panicle-weight type than those of the panicle-number type and in BNo than in CONT (Pham et al., 2004c). The larger diameter and sectional area of the basal internode IV, and the higher dry matter production per panicle in the cultivars of the panicle-weight type compared with those of the panicle-number type might have brought about the larger NSP\(^2\) in the former cultivars. On the other hand, sparse planting density and the application of nitrogen fertilizer at the neck-node differentiation stage could have resulted in the thicker basal internodes (Pham et al., 2004d) and the higher dry matter production per panicle (Pham et al., 2004c), and subsequently brought about the larger NSSR and NSP\(^1\) in BNo.

3. Varietal differences in the responses of NSP\(^1\) on MS, PT and ST to BNo practice, and factors affecting the grain filling in rice plants

Truong et al. (1998) reported that NSP\(^1\) in Akitakomachi and Hitomebore, the two widely-cultivated cultivars in the Tohoku region of Japan, was larger in BNo than in CONT. The present study also showed that NSP\(^1\) was larger in BNo than in CONT in all cultivars. The increase in NSP\(^1\) in BNo, however, was greater in the late-maturing cultivars than in the early- and medium-maturing cultivars, and was mainly caused by the increase in NSP\(^1\) on ST (Table 1), and in NSSR (Table 2 and Fig. 2). The large increase in NSSR and in NSP\(^1\) on ST in the late-maturing cultivars could be the main reason for the larger number of spikelets m\(^{-2}\) and the subsequent high grain yield of these cultivars in BNo (Pham et al., 2004a and b).

Yoshida (1981) indicated that the late-maturing cultivars had a higher grain yield than the early-maturing ones under the low fertility or sparse planting conditions, but could not explain the reason. The present study suggests that the ability of the late-maturing cultivars to produce more NSSR, especially on ST, than the early-maturing ones may be the reason for the higher grain yield of the former cultivars under the condition of sparse planting density and low nitrogen fertilizer application like BNo.

The spikelets on the secondary rachis branch have been reported to be inferior in grain filling compared with those on the primary rachis branch (Arai and Kono, 1979; Nakamura and Hoshikawa, 1988; Tsukaguchi et al., 1999). Therefore, a reduced NSSR was considered to be essential for achieving the high percentage of ripened grains (PRG) and the high grain yield (Matsushima, 1995). However, Xu et al. (1997) compared the dry matter production process and yield formation of the high-yielding rice cultivar Takanari with those in a standard cultivar Nipponbare, and indicated that in spite of a larger NSP\(^1\) with more NSSR in Takanari, PRG in Takanari was almost the same as that in Nipponbare because of a higher dry matter production after heading in Takanari. Nagata et al. (2001), furthermore, demonstrated that PRG showed greatest correlation with the total amount of carbohydrate supply per spikelet during 10 to 20 days after heading. In a previous study (Pham et al., 2004c), we used the same materials as in the present study to analyze the dry matter production process related to yield and yield components of different rice cultivars grown under CONT and BNo, and found that the dry matter production after heading was often larger in BNo than in CONT because of the greater net assimilation rate, which possibly resulted from the larger and heavier 2nd and 3rd leaves as well as the better light intercepting characteristics, in BNo. We also found that the amount of carbohydrate supply per spikelet during 20 days after full heading closely and significantly correlated with PRG, and that a larger amount of carbohydrate supply per spikelet could be the main reason for the higher PRG in BNo than in CONT.

We have shown that NSP\(^1\) was larger in the cultivars of the panicle-weight type than in those of the panicle-number type, on MS than on PT or ST, and in BNo than in CONT because of the increased NSSR. Thus, increasing NSP\(^1\) without any increase in NSSR seems to be impossible, at least within the scope of this experiment. We also mentioned above that a small or big panicle was not always the cause of a high or low PRG in rice. A high PRG in the modern rice cultivars characterized by big panicles with a large NSSR (Kobayashi and Imaki, 1997) could be attained by increasing the translocation of carbohydrates stored in stems before heading to the grains and increasing the dry matter production after heading (Xu et al., 1997; Nagata et al., 2001). On the other hand, although NSP\(^1\), especially NSSR, in BNo was large, a high PRG could be achieved by the high dry matter production after heading (Pham et al., 2004c). For more understanding on the relationships among NSP\(^1\), dry
matter production and PRG, we will analyze the dry matter accumulation and partitioning in panicles on MS, PT and ST in different rice cultivars grown under CONT and BNo in future studies.

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