Analysis of High Yielding Ability in a Rice Cultivar Akisayaka

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Abstract: The yielding ability of a new rice cultivar Akisayaka was compared with that of a standard rice cultivar Yumehikari. The refined grain yield was 9% larger in Akisayaka than in Yumehikari since Akisayaka had more panicles and spikelets per unit area but had a similar percentage of ripened grain. Although the leaf area index (LAI) in Akisayaka was similar to that in Yumehikari, the leaf area of the flag leaf per unit area of Akisayaka was smaller than that of Yumehikari at the full heading stage. This indicates that Akisayaka had a larger number of smaller upper leaves than Yumehikari. The refined grain weight of Akisayaka was similar to that of Yumehikari at 30 days after heading. This implies that the plant type of Akisayaka is not so important for increasing dry matter production from early to middle ripening period although small upper leaves seems to suppress overluxuriant growth. Accordingly the most important factor for the high yield of Akisayaka was considered to exist in the late ripening stage. The refined grain weight of Akisayaka increased more rapidly than that of Yumehikari from 30 to 45 days after heading. In addition, the leaf chlorophyll content estimated with chlorophyll meter (SPAD) and top dry weight of Akisayaka exceeded those of Yumehikari at the late ripening stage. These results suggest that the large number of spikelets per unit area and the continuation of sink and source ability during the late ripening stage caused the high yielding ability of Akisayaka.

Key words: Akisayaka, Matter production, Plant type, Rice, Ripening, Yield, Yumehikari.

In Japanese rice cultivation, direct seeding is needed for reduced labor and low input cultivation for environmental preservation. It is important to use a high yield variety with good quality and taste to develop these cultivation techniques, since the use of these techniques usually results in a low yield. Recently, panicle weight types with indica type genetic background are attracting attention as high yield varieties (Takeda et al., 1984b; Jiang et al., 1988; Xu et al., 1997). However, these varieties or their progeny are not popular because of their poor quality, and it has become necessary to use a new plant type that differs from the panicle weight type to acquire both high yield and good quality and taste.

The new late variety Akisayaka, which was bred in southern Japan, possesses both high yield and good quality and taste. It is important to analyze the yielding ability of Akisayaka not only for improving cultivation techniques, but also for breeding new varieties with both the high yield and the good quality and taste. The aim of this study is to clarify the factors contributing to high yield of Akisayaka.

Materials and Methods

A standard late variety, Yumehikari, and a new late variety, Akisayaka were used. Akisayaka was bred from the progenies of the combination of Saikai 195 / Hokuriku 148 in Kyushu Okinawa Agricultural Research Center. The experiments were conducted over a four-year period (2002 to 2005) in a paddy field (gray lowland soil) at the National Agricultural Research Center for Kyushu Okinawa Region (Chikugo City, Japan; 33°11’N latitude, 130°31’E longitude). The dates of seeding and transplanting were, respectively, May 22 and June 19 in 2002, May 20 and June 17 in 2003, May 25 and June 22 in 2004, and May 18 and June 21 in 2005. The plant age in leaf number of seedlings at transplanting was from 4.0 to 5.0. Three seedlings per hill were transplanted by hand at a hill spacing of 16 cm and a row spacing of 30 cm. A compound fertilizer containing 16% N, 16% P2O5, and 16% K2O was applied; 6 g N m⁻² was applied as basal dressing, 3 g N m⁻² at 20 days before heading as the first topdressing, and 3 g N m⁻² at 10 days before heading as the second topdressing. A randomized complete block design with three replications was used. The plots were approximately 20 m².

The number of shoots or panicles, leaf area index (LAI), and top dry weight were determined by the method of Kusuda (1994). Twenty hills were harvested from each plot at the maximum tillering stage and the full heading stage. The number of shoots or panicles was counted first. About 10% of the harvested plants was then separated into leaf blade, leaf sheath with stem, and panicle. The green leaf blade area was measured with an automatic leaf area meter (LI-3000A, LI-COR, USA). At the full flowering stage, the leaf area of flag leaf was also measured. The dry weight of each sample was determined after oven drying at 80°C to a constant weight. LAI was calculated as the leaf blade area divided by the dry weight of the sub-
sample, multiplied by the dry weight of whole sample. The average SPAD value which shows the chlorophyll content of twenty flag leaves in each plot was measured every week after heading with SPAD-502 (Minolta, Tokyo, Japan).

The yield and yield components were determined by the method of Kusuda (1995). Forty hills were harvested from each plot were harvested, and the number of fresh stems of stumps was counted as the number of panicle per unit area for each plot. After threshing, the crude unhulled rice and straw were weighed. After hulling, the crude grain weight was measured. Crude grains more than 1.7 mm in width were collected as the refined grains with a grain sorter. The refined grain weight was then measured, and the grain yield was adjusted to 15% moisture content. The number of spikelets per area was calculated from the number of spikelets in approximately 7% of the sub-sample. The number of spikelets per panicle was calculated from the number of spikelets per area divided by the number of panicle per area. In 2003, 2004 and 2005, the hills were harvested at 30, 45 and 55 days after heading for analyzing the ripening pattern. T-test was used for statistical analysis.

Results

1. Growth and development before full heading stage

At the maximum tillering stage, the number of shoots per area of Akisayaka exceeded that of Yumehikari, but the LAI and top dry weight of Akisayaka were almost the same as those of Yumehikari (Table 1). The heading date was September 2 in Akisayaka and September 5 in Yumehikari. At the full heading stage, the number of panicles per area and the top dry weight of Akisayaka exceeded those of Yumehikari. Although the LAI of Akisayaka was the same as that of Yumehikari, the leaf area of the flag leaf per unit area of Akisayaka was smaller than that of Yumehikari since the flag leaf of Akisayaka was short and narrow.

2. Growth and development after the full heading stage

SPAD value of the flag leaf was higher in Akisayaka than in Yumehikari throughout the ripening period (Fig.1).

The crude grain weight of Akisayaka was similar to that of Yumehikari at 30 days after heading (Fig.2). However, the crude grain weight of Akisayaka increased more rapidly than that of Yumehikari from 30 to 45 days after heading. Subsequently, the crude grain weight was higher in Akisayaka than in Yumehikari at 45 days after heading. The crude grain weight increased slightly in both varieties from 45 to 55 days after heading. The change of the refined grain weight displayed a similar pattern to that of crude grain weight (Fig.3). However, the refined grain weight was slightly smaller in Akisayaka than in Yumehikari at 30 days after heading, although the crude grain weight was slightly higher in Akisayaka than in Yumehikari. The refined grain weight did not increase from 45 days to 55 days after heading.

The straw weight of Akisayaka was lighter than that of Yumehikari at 30 days after heading (Fig.4). The straw weight of both varieties increased gradually and similarly from 30 days to 45 days after heading. The straw weight of Akisayaka increased a little more than that of Yumehikari from 45 days to 55 days after heading. The total top dry weight (unhulled rice weight + straw weight) of Akisayaka was slightly lighter than that of Yumehikari at 30 days after heading, but increased more than that of Yumehikari from 30 days to 45 days after heading, and exceeded that of Yumehikari from 45 days to 55 days after heading (Fig 5).

3. Yield and yield components

Akisayaka had a large number of more spikelets

| Variety | Maximum tillering stage | Full heading stage |
|---------|-------------------------|--------------------|
|         | No. of shoots (m<sup>-2</sup>) | LAI (m<sup>2</sup>m<sup>-2</sup>) | Top dry weight (gm<sup>-2</sup>) | No. of panicles (m<sup>-2</sup>) | LAI (m<sup>2</sup>m<sup>-2</sup>) | Leaf area of flag leaf (m<sup>2</sup>m<sup>-2</sup>) | Top dry weight (gm<sup>-2</sup>) |
| Yumehikari | 473 | 2.66 | 249 | 341 | 4.91 | 0.95 | 1085 |
| Akisayaka | 550 | 2.56 | 245 | 399 | 4.78 | 0.81 | 1121 |

Each figure in the table is an average of 4 years. *: Significant at the 0.05 level. **: Significant at the 0.01 level. NS: Not significant.
per unit area than did Yumehikari since Akisayaka had the larger number of panicles per unit area and a similar number of spikelets per panicle compared with Yumehikari (Table 2). The thousand grain weight of Akisayaka was a little less than that of Yumehikari, and the percentage of ripened grain of Akisayaka was the same as that of Yumehikari. As a result, the refined grain yield was larger in Akisayaka than in Yumehikari.

Discussion

Takeda et al. (1984a) stated that the panicle-weight type was appropriate in southern Japan since the panicle-number type inevitably leads to overluxuriant growth. However, the LAI at the full heading stage of Akisayaka with the larger number of panicles and spikelets per unit area was the same as that of Yumehikari with a smaller number of panicles per unit area since the upper leaves of Akisayaka were smaller than those of Yumehikari (Table 1). This indicates that it is possible to breed a panicle-number type with a large number of spikelets per unit area without overluxuriant growth in southern Japan. Matsushima (1973) described the ideal type of rice for high yield: a large number of panicles per unit area, a moderate number of spikelets per panicle, and short erect upper leaves. Akisayaka seemed to be the ideal type rice produced by breeding although Matsushima tried to produce the ideal type rice by cultivation techniques.

During the ripening period, Matsushima (1973) demonstrated that many small upper leaves as in Akisayaka was superior to a few large upper leaves as in Yumehikari for dry matter production, given the same LAI. However, the differences between Akisayaka and Yumehikari in grain yield and total top dry weight at 30 days after heading were not large (Fig. 2, Fig. 3, and Fig. 5). This implies that the plant type of Akisayaka...
considered to be the ideal plant type by Matsushima is not so important for increasing dry matter production from the early to middle ripening period although small upper leaves of Akisayaka seems to suppress overluxuriant growth. Accordingly the most important factor for the high yield of Akisayaka was considered to exist in the late ripening stage. Saitoh et al. (1993) indicated that the photosynthetic rate in a single leaf of new Japanese varieties was higher than that of old Japanese varieties during the late ripening stage and that this may be one reason for the high yield of new Japanese varieties. In this study, the SPAD value and top dry weight of Akisayaka exceeded those of Yumehikari at the late ripening stage (Fig.1 and Fig.5). This suggests that Akisayaka maintains high source ability until the late ripening stage. On the other hand, Saitoh et al. (1991) indicated that low sink ability in the late ripening stage might limit the grain yield since the dry weight of the leaf sheath and stem decreases from the early ripening stage and increases again in the late ripening stage. In this study, Akisayaka seemed to have many growing grains at 30 days after heading since the refined grain weight was slightly lighter and the crude grain weight of Akisayaka was slightly heavier in Akisayaka than in Yumehikari (Fig 2 and Fig.3). These results suggest that the high sink and source ability during the late ripening stage in Akisayaka increased the refined grain weight from 30 days to 45 days after heading, although Akisayaka had a poorer source ability until 30 days before heading due to the large number of spikelets per unit area. Alternatively, since Yumehikari had superior source ability and produced much filled grain by 30 days after heading due to the small number of spikelets per unit area, the refined grain weight was not increased much at 30 days after heading. In conclusion, the high yield of Akisayaka can be attributed to the large number of panicles and spikelets per unit area and the high source and sink ability in the late ripening stage.

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* In Japanese.
** In Japanese with English summary.
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Table 2. Comparison of yield and yield components between Yumehikari and Akisayaka.

| Year | Cultivar | No. of panicles (m⁻²) | No. of spikelets per panicle | No. of spikelets (m⁻²) | Thousand grain weight (g) | Percentage of ripening (%) | Refined grain yield (gm⁻²) |
|------|----------|----------------------|-----------------------------|-----------------------|-------------------------|---------------------------|--------------------------|
| 2002 | Yumehikari | 328 | 92.6 | 30400 | 22.9 | 90.3 | 630 |
|      | Akisayaka | 384 | 90.0 | 34600 | 22.5 | 89.7 | 697 |
| 2003 | Yumehikari | 347 | 89.0 | 30800 | 22.0 | 90.4 | 613 |
|      | Akisayaka | 393 | 89.7 | 35200 | 21.3 | 89.0 | 669 |
| 2004 | Yumehikari | 370 | 88.0 | 32600 | 21.1 | 64.0 | 441 |
|      | Akisayaka | 425 | 87.1 | 37000 | 20.3 | 66.6 | 501 |
| 2005 | Yumehikari | 345 | 86.0 | 29600 | 22.5 | 81.5 | 545 |
|      | Akisayaka | 390 | 81.2 | 31600 | 21.9 | 84.2 | 582 |
| Average | Yumehikari | 347 | 88.9 | 30900 | 22.1 | 81.6 | 557 |
|      | Akisayaka | 398 | 87.0 | 34600 | 21.5 | 82.4 | 612 |

**: Significant at the 0.01 level.  NS: Not significant.