稲の多収性育種の現状と戦略

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Breeding of High-Yielding Rice Cultivars in Japan

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Introduction

The yield ability of each major crop is considered to be an index of the level of development of agriculture in a country. In Japan, the average yield of brown rice, which had been 1.78 t/ha in 1883, reached 5.32 t/ha in 2005 through improvements in both cultivars and cultivation technology. This increase means that the accumulation of long-term studies is necessary to improve yield ability.

Breeding of rice cultivars with high yielding ability in Japan

High yield is the most important breeding objective in crop research, but it is difficult to improve yield dramatically without using various genetic resources. The introgression of yield-related characteristics of indica cultivars, such as total grain number and grain filling ability, is expected to improve the yield potential of domestic rice cultivars (KATO 2008). However, tropical indica cultivars tend to have insufficient tolerance to cold temperature and blast. The combination of the high yield potential of indica cultivars and the yield stability of domestic japonica cultivars is a basic strategy by which to establish high-yielding, stable cultivars suitable for cultivation in Japan.

Established rice cultivars with high yielding ability

1. Rice cultivars with high grain yields

We carried out several research projects to develop high-yielding cultivars suitable for utilization as animal feed or processing materials (SAKAI et al. 2003). By 2009, we had released a series of high-yielding cultivars adapted for each part of the country.

Brown rice yields of more than 8 t/ha have been achieved by several high-yielding cultivars such as 'Takanari' (IMBE et al. 2004), 'Hokuriku 193' (GOTO et al. 2009), and 'Momiroman' (HIRABAYASHI et al. 2010). The yields of these cultivars are up to 38% higher than those of ordinary cultivars. Their eating quality is moderate compared with that of more widely grown cultivars; however, their superior yielding ability is expected to expand the utilization of rice or other purposes. The high yielding ability of these cultivars is based on their large panicle, solid culm, and superior grain-filling ability. For example, the average brown rice yield of early-maturing 'Bekoaoba', which is suitable for the Tohoku area, was 9.2 t/ha in performance tests from 2001 to 2008 in Akita prefecture. In addition, 'Hokuriku 193', which had been utilized for bioethanol production, had brown rice yields of 7 to 9 t/ha in three years of performance tests in farmers' fields in Niigata prefecture (Fig. 1). However, cultivars derived from indica cultivars tend to be susceptible to cold and blast. The improvement of these shortcomings is needed to stabilize the yields of high-yielding rice cultivars.

Fig. 1. 'Hokuriku 193'

2. Rice cultivars with high whole-plant yields

For whole-crop silage use, the entire aerial part of the plant (consisting of grains, leaves, and stems) is harvested at the yellow-ripe stage. The total digestible nutrient (TDN) yields of high-yielding rice cultivars are around 1.2 t/ha, which are 3% to 27% higher than those of ordinary cultivars, and similar to those of forage maize. There are two types of rice cultivars with high

whole-plant yield: grain-type and leafy-type. The grain-type cultivars have a high proportion of grain that contributes to high whole-plant yield: examples include 'Hoshiaoba' and 'Yumeaoba'. The leafy-type cultivars have a high proportion of leaves and stems: examples include 'Tachisuzuka' and 'Leaf Star'. The leafy-type cultivars are also expected to serve as unique materials for cellulose production because of their high content of nonstructural carbohydrate in the stem and leaf sheath.

Established high-yielding rice cultivars

1. 'Momiroman', a cultivar with high grain yield

'Saikai 203' ('Mizuhochikara') is a cultivar with large panicles that has the potential to produce a large number of grains; however, its grain filling is insufficient to produce superior grain yield. 'Momiroman' was selected to improve the grain filling of 'Saikai 203' by the introduction of New Plant Type. The high yield of 'Momiroman' was confirmed in multi-location performance tests, and this cultivar has been released for use as feed rice and for the production of flour for rice noodles.

'Momiroman' has a superior growth volume and a solid culm (Fig. 2). However, its grain filling is still too low under low levels of solar radiation; thus, future improvement is needed to stabilize the yield of 'Momiroman' (HIRABAYASHI et al. 2010).

2. 'Leaf Star', a cultivar with high whole-plant yield

'Leaf Star' shows superior leaf and stem growth, but its grain yield is less than that of ordinary cultivars. Its parental cultivar 'Chugoku 117' was selected from a cross of a US cultivar with a strong stem and a Taiwanese cultivar with superior plant growth characteristics. 'Leaf Star' has shorter panicles and lower grain yield than ordinary cultivars. However, its whole-crop yield and TDN yield of the aerial parts are higher than those of ordinary cultivars. It is grown for high-quality whole-crop silage (KATO et al. 2010).

Fig. 2. 'Momiroman'

Future research strategies for high yield

Future improvement of yield will require both increases in plant grain number and improvement of grain-filling ability. In order to improve grain filling, new yield-related characteristics should be considered for study (for example, elongation of the ripening period) to complement basic studies of photosynthesis and translocation of photosynthate. One problem that must be urgently addressed is stabilization of blast resistance. Many high-yielding cultivars have inherited true resistance to blast, along with their high yielding ability, from indica cultivars. The risk of resistance breakdown is increasing because the cultivation areas of these cultivars are expanding. Thus, high-yielding cultivars with stable field resistance to blast should be developed as soon as possible.

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単収はその国の作物の開発水準を示す指標の一つと言え、収量性の向上には長期間の成果の積み重ねが必要である。

多収性は最も重要な育種目標であるが、既存の日本品種などの狭い遺伝資源だけで品種改良を進める限り、収量を飛躍的に向上させることは難しいと言わざるを得ない。積極的に熱帯のインド型品種等を育種素材として利用し、優れた籾着生数や登熟性などの収量関連形質を日本品種に導入する事によって収量性の向上が期待できる。

育成された多収水稲品種

1）玄米多収品種

農研機構では飼料用や加工用に向けて米飯食味や玄米外観品質は劣るが、700～1000kg/10aの高い収量性を示す多収性品種の開発を進め、2009年までにほぼ全国の稲作地域で栽培可能な多収性品種シリーズを育成した。こうした品種は穂重型の草型をもち、大きな穂を支える強い稈と、優れた登熟力により高い収量性を実現している。なかでも東北地方向けの「べこあおば」は2001年から08年に秋田県大仙市で行った極多肥栽培で、平均して920kg/10aの高い粗玄米重を示した。また、新潟県でのバイオエタノール原料稲栽培実証事業で利用されている「北陸193号」は新潟県三条市における3ヵ年の現地実証試験で700～900kg/10ａの粗玄米重を示した。しかし、インド型品種の多収性を導入した多収性品種は耐冷性やいもち病抵抗性が劣る傾向があり、今後のさらなる改良が必要である。

2）茎葉多収品種

茎葉と籾を一緒に収穫し、稲発酵粗飼料として家畜に給与するために、株全体の収量が高い品種が開発されている。全重が多収の品種には「べこあおば」、「夢あおば」のように子実の割合が多い品種と、「たちすがた」や「リーフスター」のように子実よりも茎葉の生育が全重多収に貢献している品種がある。茎葉が多収な品種は“茎葉型”と呼ばれ、成熟期に通常の品種ではコメに蓄積される炭水化物が稈などにも多く蓄積し、消化性の良い稲発酵粗飼料の原料となる。

今後の多収戦略

さらに収量性を向上させるためには、籾数と増加と登熟力の向上が求められる。一穂籾数の増加は耐倒伏性を維持するために稈質の強化も不可欠となり、玄米の収量増加に直結しない可能性が考えられる。そのため、穂数の増加による単位面積当たり籾数の増加を考える必要がある。さらに、登熟力を向上させるためには、光合成能力などの基礎的な研究に加えて、登熟期間の延長などの新しい収量形質の導入なども検討される必要がある。