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Field Crops Research 99 (2006) 59–66

Field Crops Research

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# Yield and grain uniformity in contrasting rice genotypes suitable for different growth environments

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Received 18 December 2005; received in revised form 13 March 2006; accepted 14 March 2006

## Abstract

In this study, the effect of crop season on yield and grain weight uniformity was examined in field-grown rice cultivar Tainung 67 and its sodium azide-induced mutant SA419 in 2000 and 2001. In spring, Tainung 67 had greater yield (7.2 mg ha$^{-1}$) than SA419 (6.2 mg ha$^{-1}$). Marked yield decline (averaged 27% decline) was found in Tainung 67 when it was grown in autumn. The yield decline resulting from season change was only 5.9% for SA419. The greater yield of SA419 than Tainung 67 in autumn was due to its higher net assimilation rate and better dry matter partitioning during grain filling. The distribution patterns of grain weight differed between the tested genotypes, with greater grain weight variations for Tainung 67 than SA419. Significant panicle branch effects on the distribution pattern of grain weight were also found between Tainung 67 and SA419 with greater variation for the former than the latter. SA419 has several agronomic traits, such as heavier 1000-grain weight and more uniform grain development within a panicle, that makes it a genotype with superior grain quality than Tainung 67.
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*Keywords:* Grain yield; Low amylose mutant; *Oryza sativa*; Rice; Yield components

## 1. Introduction

Rice (*Oryza sativa* L.) is the world's most important food crop. In Taiwan, two crops of rice (spring and autumn crops) are grown in a year, with an estimated area of 300–320 thousands hectare per annum. In spring crops, rice plants are transplanted between January and March, and the crops are harvested between May and July. The autumn rice crops are planted between June and August, and harvested between October and December (Chen et al., 1996). However, grain yield of spring grown rice crop is generally 10–30% greater than autumn grown rice crop, depending on growing location. Many researchers have attempted to identify factors that would explain why autumn grown rice crop is lower in grain yield in comparison with spring grown rice crop, but the results are inconclusive (Chen et al., 1996). The yield of rice is an integrated result of various processes, including canopy photosynthesis, conversion of assimilates to biomass and partitioning of assimilates to grains (harvest index) (Wu et al., 1998; Ying et al., 1998). Weng and Chen (1984) reported that the decreased biomass production and reduced harvest index (HI) were the major causes of low yield for autumn crop. The lower grain filling during ripening was also due to the decreased grain yield of autumn rice crop (Chu and Lu, 1984). However, Chen et al. (1996) indicated that the inadequate interception of solar radiation was the key factor limiting the growth and development of rice plants grown in autumn crop season.

Grain weight is an important yield component in cereal crops. It is determined by the source capacity (photosynthetic leaves) to supply assimilate during the ripening period, and by sink capacity (developing grain) to accumulate the imported assimilate (Ntanos and Koutroubas, 2002). Chen et al. (1994) reported that rice differed from most other cereals in the fact that the grain growth was

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doi:10.1016/j.fcr.2006.03.005

limited by sink capacity, as potential grain size was largely determined before anthesis. Additionally, the rigid hull would limit the expansion of grain size (Zeng and Shannon, 2000). However, cultivars with larger grain size tend to have higher grain filling rate, resulting in higher assimilate accumulation and heavier grain weight (Jones et al., 1979; Jeng et al., 2003a). Thus, it seems that developing a variety with large grain size and fast grain filling rate through breeding program may be a feasible approach to increase the yield of autumn rice crop in Taiwan, provided that the source supply is not limiting.

The Japonica rice cultivar Tainung 67 is a widely used non-glutinous variety in Taiwan (Chen et al., 1994). Recently a novel mutation pool of Tainung 67 mutated with sodium azide ($NaN_3$) was created, and a resultant mutant SA419 with larger grain size and faster grain filling rate than Tainung 67 was identified (Jeng et al., 2003a). Jeng et al. (2003b) further indicated that the developing grains of SA419 had lower granule bound starch synthase activity and accumulated less amylose (80 g $kg^{-1}$) than that of Tainung 67 (200 g $kg^{-1}$). However, the yield performance of this mutant grown in autumn crop season has not been critically examined under field-grown conditions. The primary objective of this study was to determine the yield and the yield components of cultivar Tainung 67 and its $NaN_3$-induced mutant SA419 grown in spring and autumn crop seasons. The effects of grain setting position on grain weight uniformity were also examined. Findings from this study would indicate a possible direction for rice breeding program aiming at improving the quality of rice crop.

## 2. Materials and methods

### 2.1. Agronomic practices

Rice cultivar Tainung 67 (TNG 67) and its $NaN_3$-induced mutant SA419 were grown at the experimental farm of the Taiwan Agricultural Research Institute (Wu Feng, Taichung) in the spring and autumn crop seasons of 2000 and 2001. Seeds were sown in the nursery plots, where the seedlings grew up to three-leaf stage. For spring crops, the seedlings were transplanted to experimental plots on 23 February 2000 and 9 February 2001. For the autumn crops, seedlings were transplanted to experimental plots on 1 August 2000 and 24 July 2001. Three seedlings per hill were planted at a spacing of 30 cm × 15 cm, in each experimental plot of 3 m × 6 m. Each plot received a basal application of fertilizer before transplanting (24 kg N $ha^{-1}$, 36 kg $P_2O_5$ $ha^{-1}$ and 24 kg $K_2O$ $ha^{-1}$) and 3 top-dressings of fertilizer at 20 days (6 kg N $ha^{-1}$, 9 kg $P_2O_5$ $ha^{-1}$ and 6 kg $K_2O$ $ha^{-1}$), 40 days (9 kg N $ha^{-1}$, 13.5 kg $P_2O_5$ $ha^{-1}$ and 9 kg $K_2O$ $ha^{-1}$) and 60 days (9 kg N $ha^{-1}$, 13.5 kg $P_2O_5$ $ha^{-1}$ and 9 kg $K_2O$ $ha^{-1}$) after transplanting. The experiment was designed as a randomized complete block design with four replicates.

### 2.2. Dry matter accumulations, net assimilation rate and harvest index

Plant samples, composed of two rows 1 m long, were taken at panicle initiation, heading and maturity from each plot. The plants were cut at the ground level separated into leaves, stem, vegetative parts of panicle and grains if appropriate. The samples were oven-dried at 80 °C for 72 h, and weighed for dry matter (DM) accumulation. Net assimilation rate (NAR), expressed on unit ground area base, was calculated based on dry matter accumulation over a time interval (Ying et al., 1998). Harvest index (HI) was calculated as grains weight divided by the dry matter of total above ground biomass, using the materials sampled at the stage of final harvest.

### 2.3. Grain yield and yield components

In order to estimate grain yield, the middle four rows 2 m length of each plot were hand-harvested. The grain mass was weighed and moisture content was measured. Yields were expressed at 140 g $kg^{-1}$ moisture. Additionally, 100 panicles were tagged at anthesis, among which 20 panicles were randomly chosen and hand-harvested from each plot at maturity. The panicles were oven-dried at 80 °C for 72 h for grain number and weight determinations. A sub-sample of 10 panicles was taken at random and threshed to determine the number of spikelets per panicle and 1000-grain weight. The percent of filled grains were recorded as fully matured grains, sterile florets and grain weight less than 10 mg were not included. For grain weight determinations, three 100-grain sub-samples were taken from the harvested grains to determine 1000-grain weight.

After 1000-grain weight measurements, the sampled grains were weighed on single grain level for determination of grain weight distribution. Additionally, a sub-sample of 10 panicles was selected, hand-threshed and the sampled grains were distinguished according to their positions within the panicle, i.e. the grains on distal primary branches (DPB), distal secondary branches (DSB), proximal primary branches (PPB) and proximal secondary branches (PSB) (Kato, 1986). For the grain materials of 2001, 300 grains were sampled from DPB, DSB, PPB and PSB, and weighed on the single grain level for determination of grain weight distribution. The panicle number per unit area was obtained from the samples collected for harvest index and total biomass determinations.

### 2.4. Statistics

The results were subjected to an analysis of variance (Steel and Torrie, 1980). An analysis of variance was completed first for each treatment (2 years and two crop seasons). However, the error variance of the four treatments was heterogeneous in most of the parameters (Petersen, 1994), therefore, only the sources of probability were

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