Comparison of Nitrogen Accumulation and Rate of Photosynthesis among several old and new Rice Cultivars grown in a submerged Paddy Field

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Abstract

In our previous comparison of rice cultivars (Sekitori, released in 1848, Aikoku 1882, Koshihikari 1956, Nipponbare 1963, Asanohikari 1987) grown for the past 100 years in the Kanto area of Japan, and Takanari (1990), a high yielding modern cultivar, the newer cultivars, especially Takanari, produced higher dry matter (DM) due to greater DM accumulation after heading. In this paper, we compared nitrogen (N) accumulation and the rate of photosynthesis to investigate the reasons for these differences in DM production among cultivars. Takanari accumulated most N at harvest followed by Nipponbare, Koshihikari and Asanohikari, while Sekitori and Aikoku accumulated the least. No clear differences were found in accumulated N among new and old cultivars at heading. After heading, the increase in accumulated N was greatest in Takanari, and lowest in Sekitori and Aikoku. Takanari maintained a higher rate of photosynthesis from full heading to late ripening, while photosynthesis tended to be lower in the old cultivars at mid and late ripening. These findings suggest that the high DM production in new cultivars, particularly Takanari, resulted from a higher rate of N accumulation and a higher photosynthetic rate during ripening than in the old cultivars. The physiological mechanisms underlying increased N accumulation and photosynthesis remain to be investigated.

Media summary

Higher nitrogen accumulation and maintenance of a higher photosynthetic rate during ripening resulted in higher dry matter production in new cultivars, particularly in Takanari.

Key Words

Dry matter production, photosynthesis, nitrogen accumulation, old and new cultivars, rice, root length density

Introduction

Meeting the food demands of a rapidly growing world population needs a highly productive agriculture that conserves and preserves environmental quality (Alva et al., 2005). Fertilizer application is one of the key elements for high-yielding rice cultivation, of which nitrogen (N) plays an essential role (Matsushima, 1976;

Mae, 1995). Because N is susceptible to many loss pathways, it is the most yield-limiting and most difficult nutrient to manage (Mikkelsen, 1987). To minimize environmental risk and reduce rice production costs, exploiting the potential traits contributing to N use efficiency and improving N use efficiency as well as grain yield are vital (Wada, 1986; Ladha et al., 1998; Samonte et al., 2006). Previously, we compared grain yield and dry matter (DM) production of several old and new rice cultivars as the first step in research to improve fertilizer N use efficiency of rice. We found that the newer cultivars, especially Takanari, had higher DM (Taylaran et al., 2007). In this study, we investigated the reasons for these differences in DM production by comparing N accumulation and the rate of photosynthesis of these cultivars.

Materials and methods

The same rice (*Oryza sativa* L.) cultivars were studied as before: Sekitori (released in 1848), Aikoku (1882), Koshihikari (1956), Nipponbare (1963), Asanohikari (1987) and Takanari (1990). They were grown in 2005 and 2006 in a paddy field of the University Farm (35^{o}41'N latitude, 139^{o}29'E longitude) with an alluvial soil (clay loam) derived from the Tama River. The experiment was laid out in a randomized complete block design with 3 replicates. Seedlings at the 4th leaf expanding stage were transplanted on May 26 at a density of 22.2 (30 cm x 15 cm) hills m^{-2} with 3 plants per hill. Fertilizer was applied at rates of 5.0, 5.0 and 5.0 g m^{-2} of N, P_2O_5 and K_2O as a basal dressing, and 1.0 and 1.0 g m^{-2} of N and K_2O as topdressing at panicle formation stage, respectively. N concentration of plants was determined using a CN analyzer (MT-600, Yanako Inc., Kyoto, Japan). For root samples, at early ripening a soil core 50 mm in diameter and 750 mm in length was taken between hills with a cylinder tube (FV-493-1MB; Fujiwara Factory, Tokyo, Japan). Root length density was measured using an image analysis system (WinRHIZO; Regent Instruments Inc., Quebec, Canada). Rate of photosynthesis was measured on the attached flag leaf with a portable photosynthesis system (LI-6200; LI-COR Inc.) under solar radiation higher than 1200 μmol m^{-2} s^{-1}. Measurement started at an air CO_2 concentration of about 370 μmol mol^{-1} in the assimilation chamber.

Results

Takanari accumulated the largest amount of N at harvest and Sekitori and Aikoku the smallest (Fig. 1). However, N accumulation at heading was not larger in the newer cultivars (data not shown). There was a close correlation between the increased in dry weight and increased in accumulated N after heading (Fig. 2). These results indicate that the higher N accumulation after heading is important for higher DM production. Root length density of Takanari in the 0-12.5 cm and 12.5-25 cm soil layers was significantly higher than that of Nipponbare and Aikoku (Table 1). Takanari also had the highest total root length, followed by Nipponbare, while Aikoku had the lowest. These results suggest that the new cultivars, especially Takanari, might have a characteristically better developed root system than the old ones. Photosynthetic rate of the flag leaf of Takanari was significantly higher from full heading to 38 days after heading (Fig. 3), followed by Asanohikari and Nipponbare, although photosynthetic rate tended to be lower in Nipponbare than in the other cultivars at heading. Sekitori and Aikoku tended to have the lowest photosynthetic rate at mid ripening. These results indicate that the newer cultivars had superior photosynthetic characteristics than the old ones.

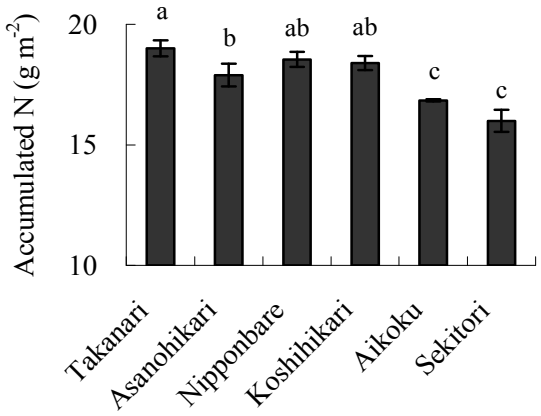

Fig. 1. Total accumulated N at harvest in 2005. Bars with the same letters are not significantly different at 5% level by Tukey's test (n=3).

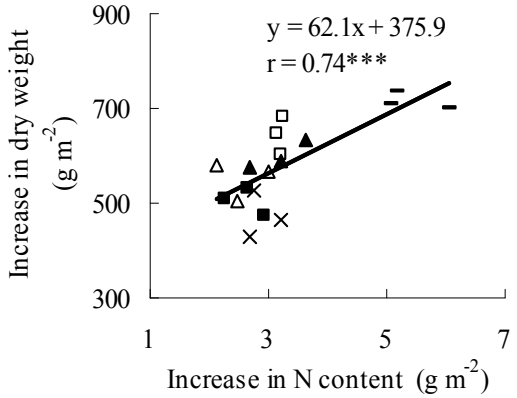

Fig. 2. Relationship between increase in dry weight and increase in accumulated N after heading in 2005. ▬ : Takanari; ▲ : Asanohikari; × : Nipponbare; □ : Koshihikari; △ : Aikoku; ■: Sekitori. * Significant at 0.001 level.**

Table 1. Root length density (cm cm^{-3}) for each 12.5-cm soil layer and total root length at ripening in 2006.

	Depth (cm)					Total root length (cm)
	0-12.5	12.5-25	25-37.5	37.5-50	50-62.5	
Takanari	10.91a (0.79)	4.78a (0.45)	1.27b (0.23)	0.38b (0.08)	0.18ab (0.01)	200.35a (17.23)
Nipponbare	7.97b (0.61)	3.02b (0.27)	2.35a (0.35)	1.03a (0.07)	0.21a (0.04)	164.48b (9.86)
Aikoku	6.95b (0.45)	2.88b (0.80)	0.86b (0.47)	0.26b (0.07)	0.12b (0.05)	131.55c (19.72)

Means in each soil layer with the same letters are not significantly different at 5% level by LSD. Standard deviations are given in parentheses (n = 3).

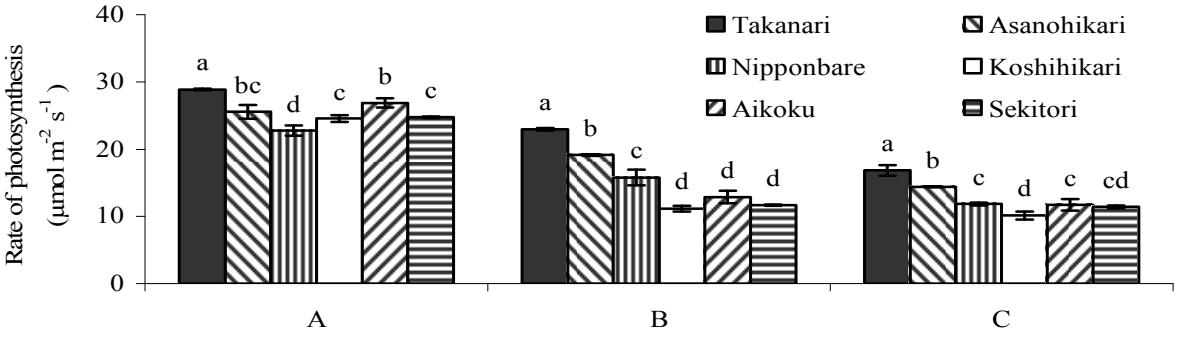

Fig. 3. Rate of photosynthesis at full heading (A), 28 days after heading (B) and at 38 days after heading (C) on the attached flag leaf in 2005. Bars within each growth stage with the same letters are not significantly different at 5% level by Tukey's test (n=3).

Conclusion

The newly released cultivar Takanari accumulated the largest amount of N, probably due to a better

developed root system, followed by Nipponbare, Koshihikari and Asanohikari; the oldest cultivars, Aikoku and Sekitori, accumulated the least N. Photosynthetic rate of Takanari was higher from full heading to 38 days after heading than that of the old cultivars. These results suggest that the higher N accumulation and photosynthetic rate during ripening resulted in greater DM production in the new cultivars, particularly in Takanari. The physiological mechanisms underlying higher N accumulation and photosynthetic rate remain to be investigated.

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