African Crop Science Journal, Vol. 21, No. 3, pp. 185 - 190
ISSN 1021-9730/2013 $4.00
Printed in Uganda.

SIGNIFICANCE OF RICE SHEATH PHOTOSYNTHESIS: YIELD DETERMINATION BY ^{14}C RADIO-AUTOGRAPHY

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(Received 7 June, 2013; accepted 8 July, 2013)

ABSTRACT

Using high-yielding hybrid rice Liangyopeijiu (LYP9), its male parent 9311 and hybrid rice Shanyou 63 (SY63) as the experimental materials, the photosynthesis of rice sheath was studied by ^{14}C radio-autography. The results showed that rice sheath could trap sunlight and produce photosynthates, and these photosynthates were transported mainly to the spikes. The ^{14}C-labeled photosynthates transported to the spikes of LYP9 and 9311 were significantly more than those of SY63 after 72 hr, which indicated that differences among genotypes existed for contribution rates of sheath photosynthesis to economical yield. Transport of the ^{14}C-labeled photosynthates to the spikes was faster in the sheaths of LYP9 than in those of 9311and SY63 at 12 and 72 hr after treatment. Hybrid rice housed the heterosis and were influenced by the inheritable characters of its parents. Since photosynthesis of rice sheath is an important supplement to rice yield, inefficient photosynthesis in rice sheaths could cause serious yield reduction.

Key Words: Hybrid rice, photosynthates, spikes

RÉSUMÉ

L'usage de l'hybride de riz à rendement élevé, le Liangyopeijiu (LYP9), son parent male 9311 et l' hybride Shanyou 63 (SY63) comme matériel expérmental, la photosynthèse du riz était étudié par radio-autographie ^{14}C. Les résultats ont montré que le "sheath" du riz pourrait piéger la lumière solaire et produire des photosynthates; ces derniers étaient principalement transportés dans les graines. Les photosynthates 14C transportés dans les graines de LYP9 et 9311 étaient significantly plus élevés que ceux dans SY63 après 72 hr, ce qui a indiqué que ces differences parmi les génotypes ont existé comme taux de contribution de la photosynthèse du sheath au rendement économique. Le transport des photosynthates du 14C aux graines était plus rapide dans les sheaths du LYP9 que dans ceux de 9311 et SY63 à 12 et 72 hr après traitement. L' hybride de riz ont accomodé l'héterosis et était influencé par les caractères héritables de ses parents. Etant donné que la photosynthèse du sheath du riz est un important supplement au rendement du riz, la photosynthèse non efficiente dans le sheath du riz pourrait causer de sérieuses réduction du rendement.

Mots Clés: Hybride du riz, photosynthates, graines

INTRODUCTION

High-yielding rice is characterised by high photosynthesis (Ou *et al*., 2003; Zhang *et al*., 2003; Wang, 2004a; Yumiko *et al*., 2006). Many researchers have studied the different aspects of photosynthesis of the high-yielding rice varieties, such as efficiency of solar energy utilisation (Xu *et al*., 2004), characters of high photosynthetic efficiency (Cao *et al*., 2000; Cheng *et al*., 2002;

Xu *et al*., 2004), leaf senescence (Ji *et al*., 2000; Ou *et al*., 2003; Yumiko *et al*., 2006), distribution of assimilates (Zhang *et al*., 2003), "Ideal Plant Type" morpha (Yuan, 2000; Sun *et al*., 2002; Lu *et al*., 2003; Yumiko *et al*., 2006), stomata (Hu *et al*., 2002), and genetic expression (Ku *et al*., 2000; Weng *et al*., 2002).

Leaves of high-yielding rice varieties usually have high chlorophyll content and higher net photosynthetic rate (Ma *et al*., 2003; Wang, 2004b), higher Rubisco content and activity (Cao *et al*., 2000; Ou *et al*., 2003), longer functional period and higher photosynthetic rate at later stage (Ji *et al*., 2000; Cheng *et al*., 2002; Ou *et al*., 2003; Wang *et al*., 2004c), and stronger expression of genes for photosynthetic enzymes (Ku *et al*., 2000; Weng *et al*., 2002). Yet very few focused on the photosynthesis of rice sheath. Further more, most studies were restricted to the leaf blades. The photosynthesis of the sheath is poorly understood. This study was aimed at exploring the features of the photosynthetic capacities of the sheath of rice.

MATERIALS AND METHODS

The experimental rice varieties included Liangyoupeijiu (LYP9), its male parent 9311 and Shanyou 63 (SY63). LYP9 is a two-line super hybrid rice, and SY63 is a three-line hybrid rice; both widely cultivated in China. It has been widely recognised that super-high yield of LYP9 is partly because of its close to "ideal plant type" morpha, its improved light transmissivity in canopy and its high photosynthetic rate (Ou *et al*., 2003; Wang, 2004b); but SY63 is not because it holds wider leaf droopy angles, weak sunlight and bad ventilation in canopy. Rice seeds were supplied by China National Hybrid Rice R & D Centre.

Experiments were conducted at the experimental centre of Changsha University of Science & Technology, China (about 28°11´N, 112°58´E). Three weeks after germination, three young seedlings were transplanted in a plastic pot. The experiment consisted of 18 cultures as treatments. Each treatment had three replications. Each plastic pot was 40 cm in diameter and 60 cm height with, 20 kg of soil. All pots were randomly permutated statistically at experimental site level. On the top soil surface of the pots, a thin layer of water, which was pumped from nearby rice field, was held during rice growth (about 2-5 cm depth). The management practices for the pots, such as pest control were carried out as per local recommendations (Zong *et al*., 2000; Liu, 2007).

The plastic pots with the rice plants of LYP9, 9311 and SY63 used for the radio-autography experiments were moved to the growth chamber at the profuse filling stage (80 to 85% of plants at grain-filling) from experimental site in order to make the rice plants grow normally in the chamber. Three days later, all the blades were covered with black plastic bags after being checked for leakage, and the bags were then sealed. Rice spikes were covered with black plastic bags, leaving only the sheaths outside.

The pots were then moved into a transparent assimilation growth chamber, with an air circulation system linked to a $^{14}CO_2$ generator. All sides of the chamber were kept under the same light intensity (450 µmol. m^{-2}. s^{-1}) during the 6-hr period of $^{14}CO_2$ assimilation. Equal quantities of $^{14}CO_2$ were pumped into the chamber using a small pump linked to both a $^{14}CO_2$ generator and the chamber by tubes for 0, 2 and 4 hr.

Intact rice plants were sampled at 12 and 72 hr, and were dried as the specimen for producing radio-autograph images. The images on films were produced under the specimen in film cassettes for 30 days; then, the radio-autographs developed. Radio-autography images of the sheaths of plants cultivated in pots were carried out for LYP9, 9311 and SY63 (Figs. 1 and 2).

RESULTS

The ^{14}C-labeled photosynthates [$^{14}CO_2$+ H_2O→($^{14}CH_2O$)+O_2)] in the sheaths still remained mainly in the sheaths and blades 12 hr later; only a small part moved to the spikes and roots (Fig. 1). However, there were more photosynthates in the spikes of LYP9 (Fig. 1-A1 and A2) than in those of its male parent 9311 (Fig. 1-B1 and B2) and SY63(Fig.1-C1 and C2). A lot of ^{14}C-labeled photosynthates were transported to the spikes of LYP9, 9311 and SY63 after 72 hr (Fig. 2), but there were more photosynthates in the spikes of LYP9 (Fig. 2-A1 and A2) and 9311(Fig. 2-B1 and B2) than in those of SY63 (Fig. 2-C1 and C2). Thus, photosynthate transport was faster in

Figure 1. Radioautography images of ^{14}C labeled photosynthates in LYP9, 9311 and SY63 12hr after being treated. A1, B1 and C1, the dry specimens of LYP9, 9311 and SY63 respectively. A2, B2 and C2, the radioautography images of A1, B1 and C1 for LYP9, 9311 and SY63, respectively.

LYP9 and 9311 than in SY63. The results also showed that the ^{14}C-labeled photosynthates in the sheaths of the three genotypes were transported mainly to the spikes and blades, while only a small portion was transported to the roots or stored in their sheaths (Fig. 2). LYP9 had the advantages of heterosis that came from its male parent, which illustrated its hybrid characters.

DISCUSSION

Autoradiography experiments effectively verified that rice sheath could trap sunlight and produce photosynthates, which was an important supplement to yield because the ^{14}C-labeled photosynthates produced by rice sheaths were transported mainly to the spikes and blades (Figs. 1 and 2).

The results also proved that during the same period of time, the contribution rates of sheath photosynthesis to economical yield was significantly different among various genotypes. For example, the ^{14}C-labeled photosynthates transported to the spikes of LYP9 (Fig. 2-A1 and A2) and 9311 (Figs. 2-B1 and B2) were significantly more than those of SY63 (Fig. 2-C1 and C2) after 72 hr, which also illustrated that hybrid rice housed the heterosis that came from its parents, i.e. its hybrid characters were influenced by the inheritable characters of its parents.

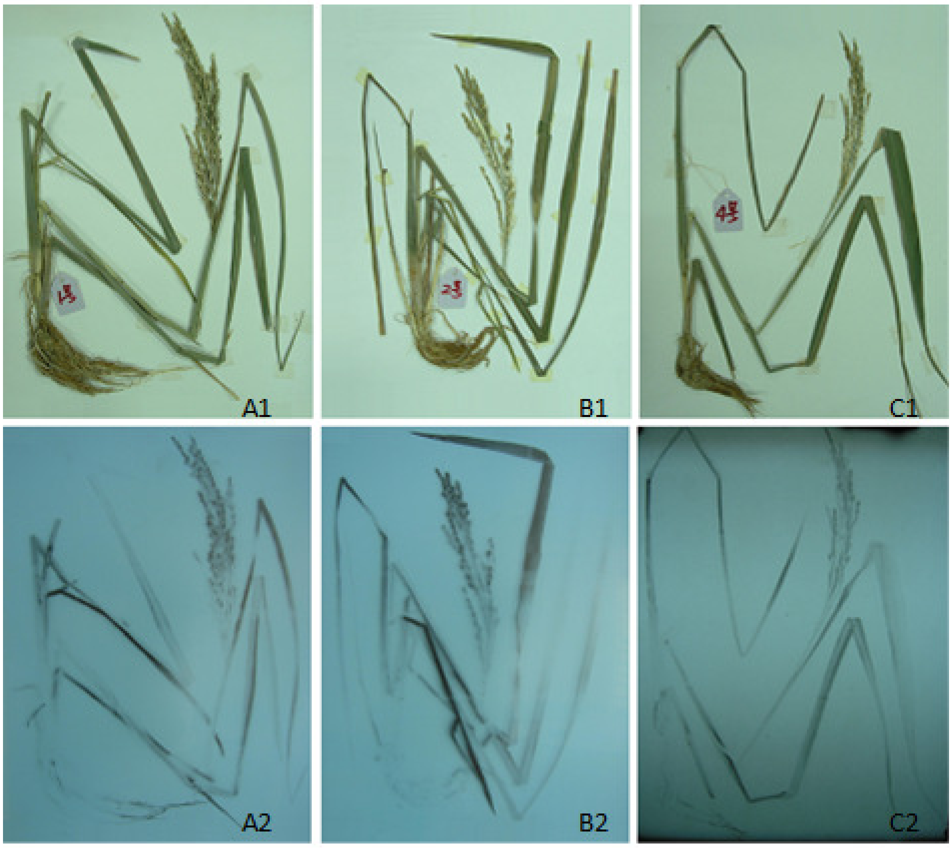

Figure 2. Radioautography images of ^{14}C labeled photosynthates in LYP9, 9311 and SY63 72hr after being treated. A1, B1 and C1, the dry specimens of LYP9, 9311 and SY63 respectively. A2, B2 and C2, the radioautography images of A1, B1 and C1 for LYP9, 9311 and SY63,

Peng *et al.* (1999) and Zong *et al.* (2000) reported that one of the important factors for high yield was the high transportation rates of photosynthates from its blade to spike. Radioautography showed that transportation of ^{14}C-labeled photosynthates to the spikes was faster in the sheaths of LYP9 (Fig. 1- A2 to Fig. 2- A2) than in those of 9311(Fig.1- B2 to Fig. 2- B2) and SY63 (Fig.1- C2 to Fig. 2- C2). This was similar to the result reported by Cheng *et al.* (2002). It was important for LYP9 to get high yield that the sheaths of the genotype were of better photic postures, could trap more sunlight in canopy, produced more photosynthates, and had higher transport rate of the photosynthates to its spikes (Fig. 1-A1 and A2, 2-A1 and A2). The photosynthesis of rice sheath was an important supplement to rice yield. Therefore, inefficient photosynthesis in the sheaths could cause serious reduction in rice yield, which is one reason why the economical yield of SY63 is lower than that of LYP9.

CONCLUSION

Rice sheath traps sunlight and produces photosynthates, which are important supplements for rice yield. Secondly, the contribution rates of sheath photosynthesis to economical yield are of significant importance among various genotypes. In addition, the photosynthetic intensity in rice sheath is related to the photic postures of its plants, i.e. the light intensity in canopy.

ACKNOWLEDGEMENT

This work was supported by the National High Technology Research and Development of China (Grant No. 2011AA10A101 and 2012AA101103). The experimental seeds of the two genotypes were provided by the China National Hybrid Rice R & D Center.

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