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Translocation and Accumulation of Assimilates after Heading under Different Fertilizer Application in Waxy and Non-Waxy Near Isogenic Lines of Rice

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ABSTRACT : This experiment was designed to assess changes in yield difference between waxy (IWR) and non-waxy (INWR) near isogenic rice by evaluating the translocation and accumulation of assimilates in different parts of the rice plants after heading stage under different fertilizer application. Nitrogen content of culm in both IWR and INWR decreased rapidly from 35 days before heading to flowering time and after then it was maintained constantly, while the nitrogen content of leaf blade was continually reduced. Sugar content of leaf blade in IWR decreased steadly by 10 days after heading, but that in INWR increased 20 days after heading. There was no difference in starch content of culm between IWR and INWR from 35 days before heading to heading, but that of culm of IWR increased again after heading. Dry weight of IWR plant was less reduced during ripening as compared with INWR. The dry weight of culm was not significantly different between two isogenic lines.

Keywords : translocation, waxy rice, isogenic lines, nitrogen content, dry weight, sugar content, heading.

It is very important to breed waxy cultivars with high grain yielding potential since most waxy rice cultivars show low yielding potential, however, there is little available evidence to clarify the reason why waxy cultivars have low yielding potential. It is envisaged that photosynthetic ability of leaf and root system are important and there will be a relationship between ripiened grain ratio and translocation of photosynthates. A particular interest is given to grow waxy rice in sustainable crop production system and to use non-waxy and waxy near isogenic lines as experimental material (Koh *et al.*, 1997).

Ripened grain ratio is affected by translocation ability of photosyatates product from source to sink (Hiromi *et al.*, 1995). Approximately 75% of the nitrogen in a leaf of C_3 crops is used in chloroplasts and in photosynthesis (Chapin lll *et al.*, 1987., Song, 1995). Park (1966) reported that flag leaf was very important source during the grain filling period.

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Takami and Kobata (1990) reported that grain yield could be predicted with the total dry matter production during the grain filling period, and the grain yield was closely related to the potential yield when the total assimilate supply was similar to, or greater than the potential yield. To increase the ripened grain ratio and to minimize the gap between the actual and potential yield, it is very important to clarify the characteristics of dry matter production and the partitioning of dry matter in high-yielding rice varieties (Miah *et al*, 1996).

Starch is the major storage carbohydrate in higher plants and espcially in the seeds of cereal crops (Stitt and Quick, 1998,. Song, 1995). Sucrose, the major form of translocation of carbohydrate, would be moved to the sink, demanding much energy (Song., 1995). Partitioning photosynthate in both cell levels and organs, from source to sink, should be done through the implicated physiological and biochemical mechanism such as degradation of storage starch, sucrose synthesis and translocation (Song, 1995).

This experiment was carried out to understand the characteristics of yield difference between waxy and non-waxy isogenic rice by evaluating the translocation and accumulation of assimilates under different fertilizer application.

MATERIALS AND METHODS

A pot experiment

Was conducted from May 1999 to October 1999. Dry matter translocation and content of sugar and starch were assessed for waxy and non-waxy iosogenic lines grown under various fertilizer application.

The rice cultivars used

Were a near isogenic waxy line, Hwacheongbyeo waxy mutant (IWR) and the non-waxy original variety, Hwacheongbyeo (INWR). The two near isogenic lines were transplanted in an 1/2000a pot with two 5-leaf seedlings per hill on June 18, 1999. Two cultivars headed the same day, August 28.

Two Nitrogen levels

Of 4 kg/10a as basal and 4 kg/10a as basal plus 4 kg/10a as top-dressing and one orgnic matter application with 100g/ pot of chinese milk vetch straw were tested. Phosphate and Potassium of the Nitrogen teratment pots were applied as basal at the rate of 7 kg/10a and 4 kg/10a with P_2O_5 and K_2O, respectively. The three kinds of fertilizer application, i.e. basal fertilizer only, basal and top dressed, and Chinese milk vetch straw returned, were randomly allocated to 15 pots per each treatment.

Three plants were sampled on August 2 and thereafter with 10-day intervals from full heading (September 4) to harvest. Each plant was partitioned into leaf blade, culm, leaf sheath and panicle. These samples were dried at 70 for 48 hours and weighed. Samples were firstly ground by a sample mill and then reground by Cyclotec with a 60-mesh screen. Nitrogen concentration was determinated by the standard macro-Kjeldhal procedure.

Analysis of sugar and starch in rice plant

Sample 100 mg put into centrifuge tube. After adding 0.9 ml of 80% (v/v) ethanol, the tube was incubated under 80°C water bath for 30 min. and centrifuged at 15000 rpm for 5 min. and the supernatant was collected. The residue was extracted with 0.9 ml of 80%(v/v) ethanol. After evaporation of the ethanol, 0.9 ml of 4.5N perchloric acid added and incubated in a room temperature and centrifuged at 15000 rpm for 5 min. and the supernatant was collected. The residue was extracted with 0.9 ml of 4.5N perchloric acid. The solution was used for the sugar and starch analysis by the anthrone procedure. The standard solution was made with pure glucose.

Grain yield analysis

Was determined based on the theory of Murata and Matsushima (1975), and Takami *et al.* (1990).(Fig. 1)

W, plant dry matter (G+S); G, grain weight; S, the mass of plant parts other than grain; e, ending point; i, initiation.

$$W = G + S \quad (1)$$
$$We - Wi = (Ge - Gi) + (Se - Si) \quad (2)$$
$$Y = (We - Wi) + (Se - Si) \quad (3)$$

Yp=potential yield, Tp=the assimilates reserves at the beginning of grain-filling period.

$$\text{if } (We - Wi)\ (Yp - Tp) \text{ then } Y = Yp \quad (4)$$
$$\text{if } (We - Wi)\ (Yp - Tp) \text{ then } Y = (We - Wi) + Tp \quad (5)$$

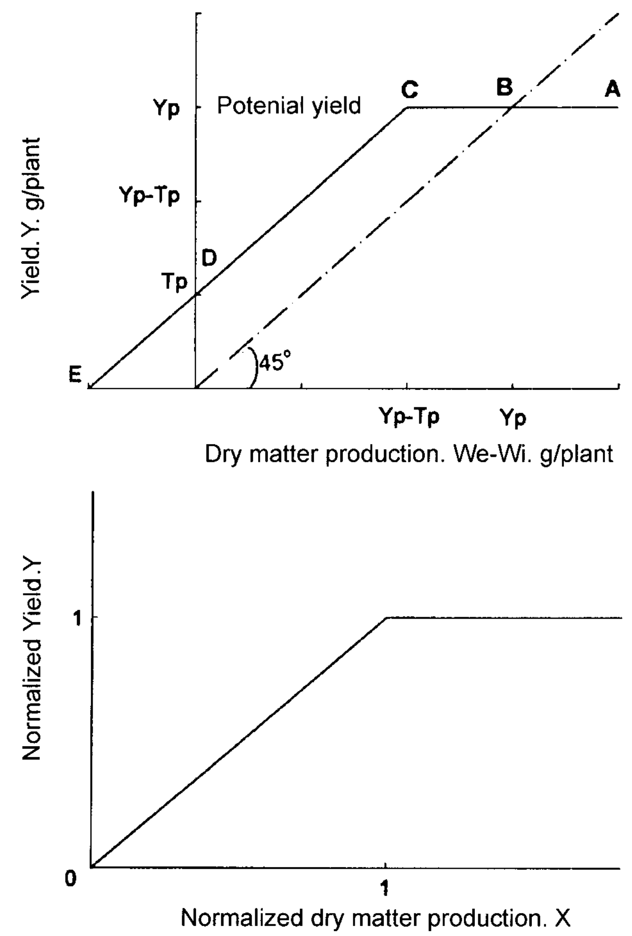

Fig. 1. (a) Relationship between the final yield (Y) and the total dry matter production in rice during the grain yield and Tp the assi milates reserves at the beginning of the period. A is the point wher (We-Wi)=(Yp-Tp), B the point where (We-Wi)=(Yp-Tp), D the point where (We-Wi)=0, and E the point where (Wi-We)=Tp. (b) The same relation in normalized form., accordiong to Eq. 6) (Modified from Takami *et al*, 1990).

$$X = (We - Wi)/(Yp - Tp),\ Y = (Y - Tp)/(Yp - Tp) \quad (6)$$

Determination of the parameters

The parameter Yp could be estimated from the final grain yield of plants in which W increased over the grain-filling period. The other parameter, Tp, can, inprinciple, be estimated as the intercept of a 1:1 line through Y, (We-Wi), whenever Y is below Yp.

RESULT AND DISCUSSION

Plant height and tiller number

Plant height and tiller number in waxy and non-waxy rice

Table 1. Plant height and tiller numbers in waxy and non-waxy rice cultivars at different growth stages under different fertilizer applications.

Treatments	Cultivars	Augst 2			September 4		October 14	
		Heading day	Plant height	Tiller no./plant	Plant height	Tiller no./plant	Culm length	Panicle no./plant
A[†]	Waxy	8.28	49.3	7.3	69.3	8.0	55.0	6.3
	Non-waxy	8.28	50.0	7.7	72.7	8.3	55.7	7.3
$LSD_{.05}$			ns	ns	ns	ns	ns	ns
B	Waxy	8.28	33.7	8.3	70.7	9.0	57.0	7.7
	Non-waxy	8.28	34.3	8.7	70.7	10.7	56.3	9.3
$LSD_{.05}$			ns	ns	ns	ns	ns	ns
C	Waxy	8.28	33.7	6.7	82.0	12.3	64.3	7.3
	Non-waxy	8.29	35.7	7.0	78.3	11.0	63.7	8.3
$LSD_{.05}$			ns	ns	ns	ns	ns	ns
Fertilizer			ns	ns	**	*	**	ns
Cultivar			ns	ns	ns	ns	ns	ns
Fertilizer × Cultivar			ns	ns	ns	ns	ns	ns

[†]A, basal application N, 4 kg/10a; B, basal and topdressed N, 8 kg/10a; C, Chinese milkvetch straw returned (100 g/ pot).

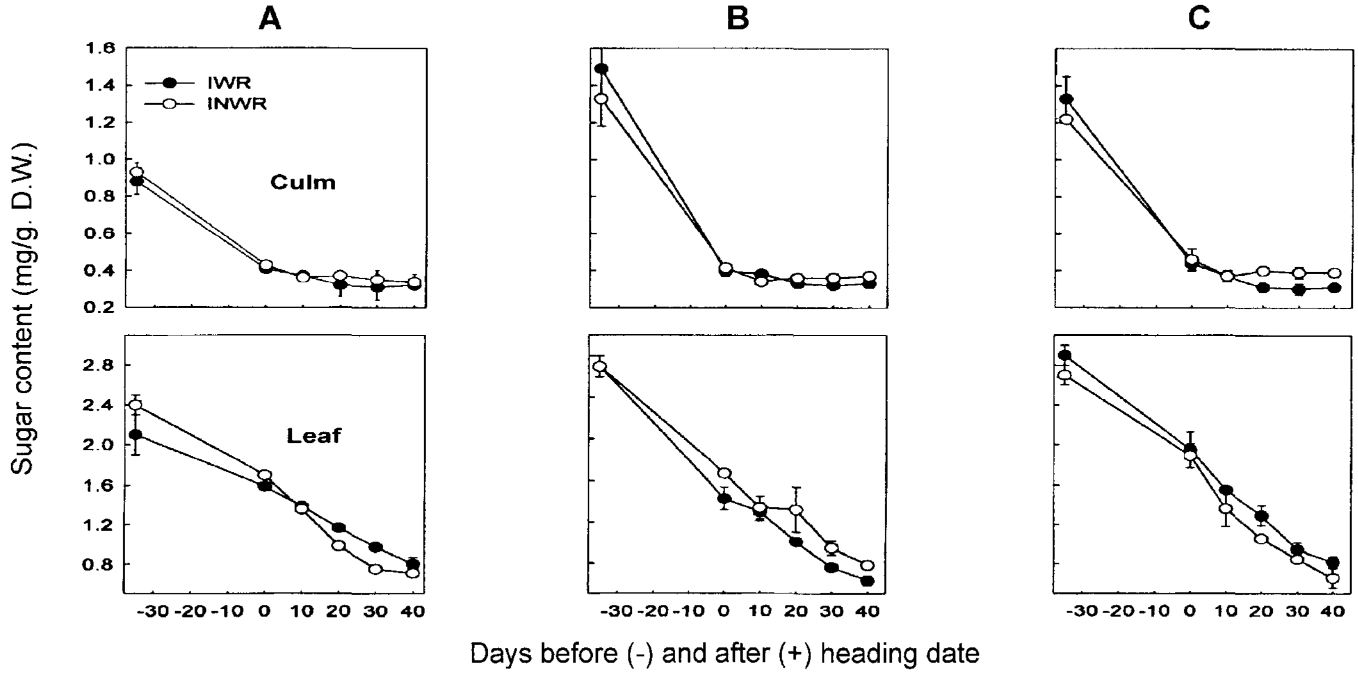

Fig. 2. Changes in nitrogen content of culm and leaf blade in non-waxy (INWR) and waxy isogenic (IWR) rice lines from 36 days befor to 40 days after heading under different fertilizer applications (Pot experiment). Vertical bars indicate means ± S.E. A, basal application N, 4 kg/10a; B, basal and topdressed N, 8 kg/10a; C, Chinese milkvetch straw returned (100 g/pot).

were shown Table 1. Plant height and tiller number in waxy and non-waxy rice were not different in the same fertilizer regime. This proves that the cultivars used in this experiment are isoginc in other agronomic characters excepter waxiness. Plant height and tiller number were significantly different in fertilizer appilcations after September 4. But there were no interactions between cultivars and fertilizer applications.

Nitrogen, sugar and starch content

Changes in nitrogen content of IWR and INWR plants were shown in Fig. 2. The nitrogen content of culm in IWR

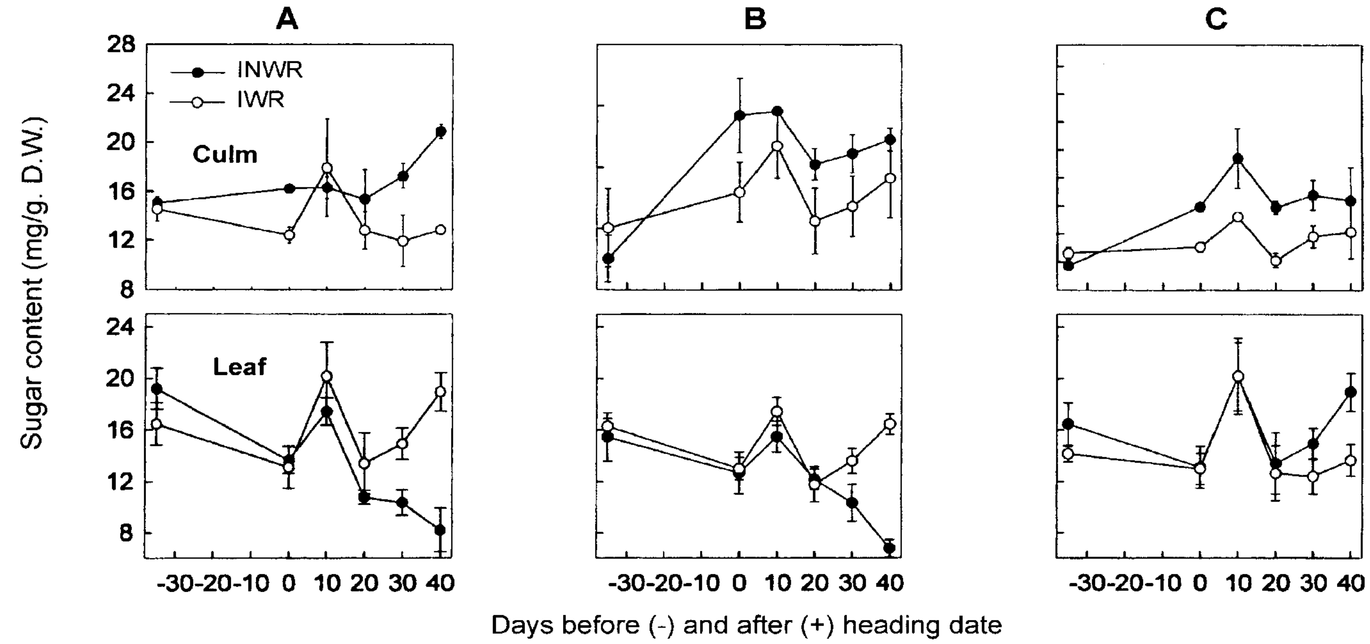

Fig. 3. Changes in sugar content of culm and leaf blade in non-waxy (INWR) and way (WR) isogenic rice lines from 35 days before to 40 days after heading under different fertilizer applications (Pot experiment). Vertical bars indicate means ± S.E. A, basal application N, 4 kg/10a; B, basal and top-dressed N, 8 kg/10a; C, Chinese milkvetch straw returned (100 g/pot).

and INWR decreased rapidly from 35 days before heading to heading (Cho *et al.*, 1999) and after then were remained constantly. The nitrogen content of leaf blade in IWR and INWR rapidly reduced from 35 days before heading to harvesting. Nitrogen content of top plant (above ground plant) parts at 35 days before heading was the lowest in basal fertilizer plot but the other two treatmenats were not significant. N assimilation occurred predominantly in the shoot at low and high external N concentration (Smirnoff and Stewart, 1985). Nitrogen content(%) of IWR and INWR was not different in same fertilizer regime.

Sugar and starch are the major form of translocation and storage, respectively, in many crops (Song, 1995). Changes in sugar and starch content of IWR and INWR along with the growth stage under different fertilizer applications were shown on Figs 3, and 4. Sugar content of culm in IWR increased at 10 days after heading. Sugar content of culm generally were maintained higher in IWR than INWR under all three fertilizer applications. The sugar content of leaf blade decreased from early growth stage to heading and then it increased once at ten days after heading. The sugar content of leaf blade decreased again during rapid grain filling period from 10 days to 20 days after heading in both IWR and INWR under any treatments of fertilizer. After rapid grain filling period, the sugar content of leaf blade increased again in IWR, while it decreased continuously in INWR under N 4 kg/10a basal application and N 8 kg/10a basal and top-dressed plots (Fig. 3).

IWR usually maintained the higer levels of sugar content in leaf blade from 20 days after heading in basal fertilizer or basal and top-dressed plots as compared with INWR, while INWR maintained the higher level of sugar content in leaf blade during late ripening stage in organic matter application plot (Fig. 3).

Starch content of culm decreased rapidly in both INWR and IWR, but IWR line maintained slightly higher starch content in culm from 20 days after heading as compared with INWR line under any fertilizer applications (Fig. 4).

The less translocation of assimilates at later ripening stage in waxy rice compared to nonwaxy one may be related to deletion of some pathway for amylose synthesis. The starch content in leaf blade rapidly decreased from early reproductive stage to 10 days after heading, thereafter it increased a little in INWR plant but not in IWR plant upto harvest time.

Song (1995) reported that the sink tissues have higher sugar and starch than those of source tissues. This tendency was also obtained in this study.

Changes in dry weight

Changes in dry weight of IWR and INWR plants during the reproductive and ripening stages under different fertilizer applications were shown in Fig. 5. Total plant dry weight increased from early growth stage to heading stage. Dry weight of panicle and top parts of plants increased after heading, but those of leaf and culm decreased. Some dry matter of leaf and culm seemed to be translocated to panicle

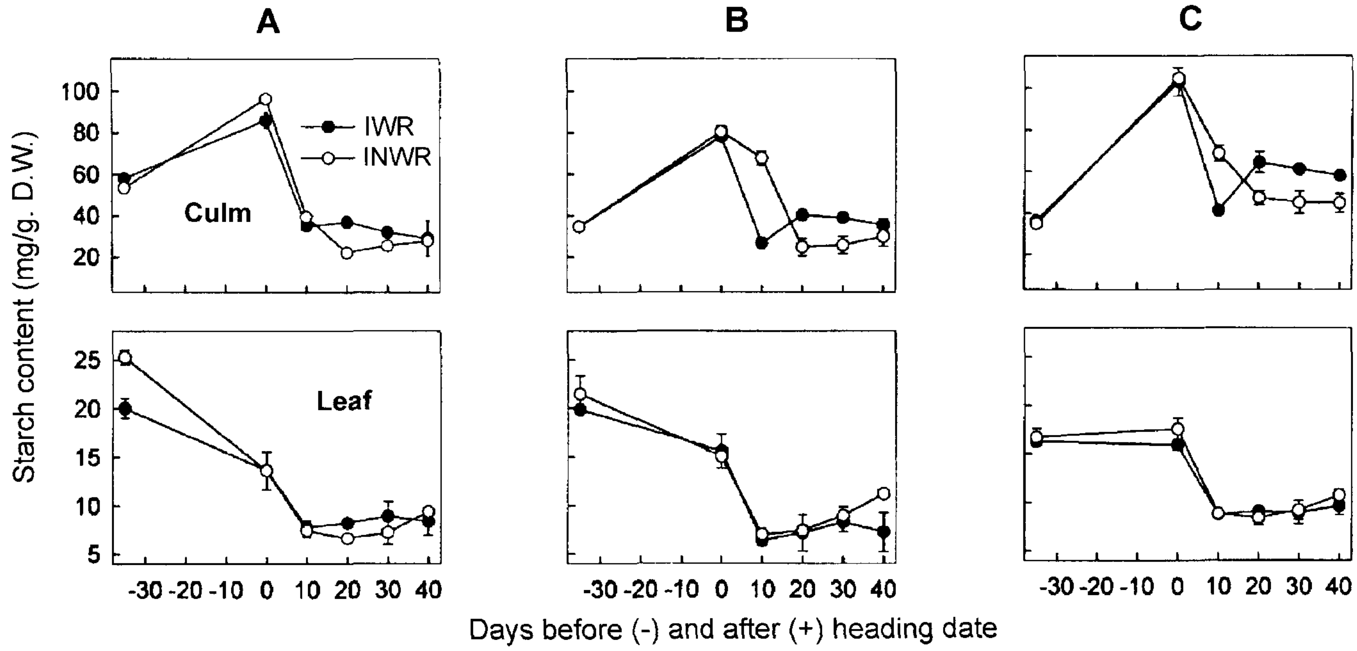

Fig. 4. Changes in starch content of culm and leaf blade in non-waxy (INWR) and waxy (IWR) isogenic rice lines form 35 days before to 40 days after heading under different fertilizer applications (Pot experiment). Vertical bars indicate means ± S.E. A, basal application N, 4 kg/10a; B, basal and top dressed N, 8 kg/10a; C, Chinese milkvetch straw returned (100 g/pot).

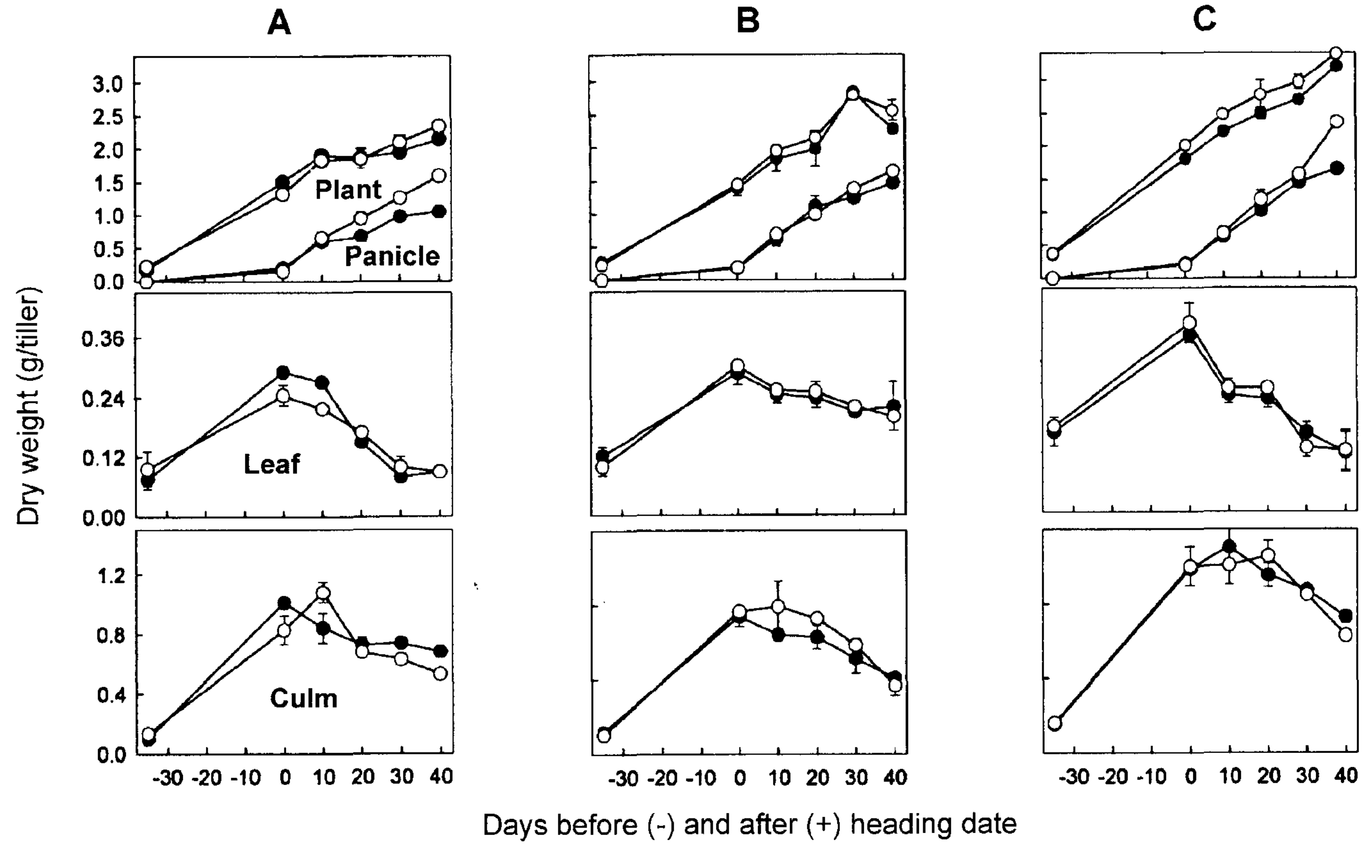

Fig. 5. Changes in dry weight of partitioned rice plant part in non-waxy (INWR) and waxy (IWR) rice lines from 36 days before to 40 days after heading under different fertilizer application (Pot experiment). Vertical bars indicate means ± S.E. A, basal and top-dressed N, 8 kg/10a; C, Chinese milkvetch straw returned (100 g/pot).

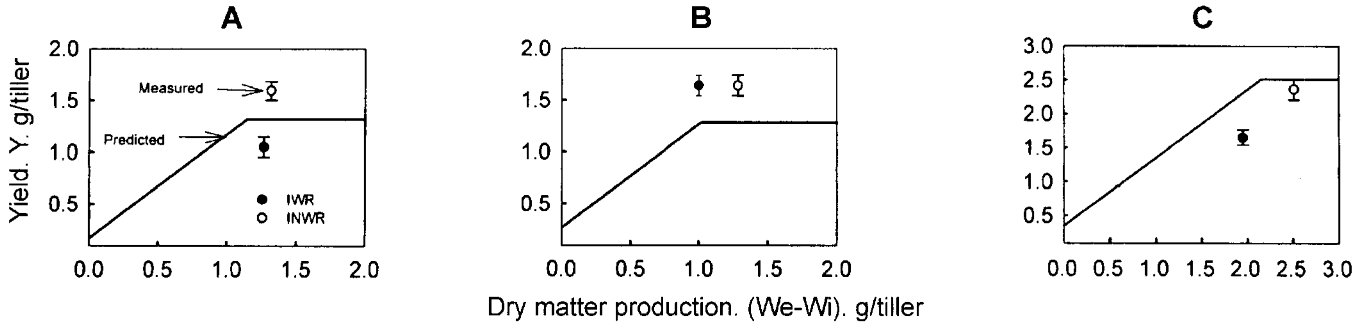

Fig. 6. Relationship between the rice yield and dry matter production during the grain-filling period in non-waxy (INWR) and waxy (IWR) rice lines under different fertilizer applications. Vertical bars indicate means ± S.E. A, basal application N, 4 kg/10a; B, basal and top-dressed N, 8 kg/10a; C, Chinese milkvetch straw returned (100 g/pot).

after heading. The panicle weight of INWR was significantly higher than that of IWR at 40 days after heading under basal fertilizer or Chinese milk vetch returned treatment, but it was not significant under the basal application. Total dry weight were highest in Chinese milk vetch straw returned plot. The changes in culm and leaf dry weight during the ripening were not significantly different between two rice cultivars under all treatments. The higher dry matter at heading stage revealed the higher proportion of dry matter translocation. Fertilizer treatment affected the yield through the dry matter production during the grain-filling period (Fig. 6). Grain yield increased with an increase of top dry matter of rice plants (Fig. 5). The top dry matter increase (We-Wi) was the highest in Chinese milk vetch straw-returned. Grain yield of IWR in N top dressed treatment was similar to that in Chinese milk vetch straw returned as compared with that in basal fertilizer application.

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