Effects of New Foliar-Application Fertilizer Containing 5-Aminolevlinic Acid on Yield Increase of Direct-Sowing Rice Plants

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Abstract

In Japan, the cultivation methods for rice plants (*Oryza sativa* L.) in paddy field can be mainly classified into two types, i.e. mechanical transplanting cultivation and direct-sowing. However, in the case of direct-sowing cultivation the grain number per m^2 becomes often an excess of 30,000 grains. As the result, the decrease of percentage of ripened grains takes places in inferior grains than in superior ones and, as a consequence, the grain yield decreases. In the present experiment, effects of foliar application fertilizer containing 5-aminolevulinic acid (5-ALA fertilizer: commercial name; Penta-keep) on the percentage of ripened grains in direct-sowing rice plants were examined. This 5-ALA fertilizer was sprayed at the heading stage of cvs. Koshihikari and Tenkomori, the promotive effect on the yield increase of grains was found in both the cultivars tested. It should be noted that the high yielding effects were at least in part supported by the increasing of grain filling in inferior grains and superior, especially in inferior grains. On the other hand, the excellent effect of 5-ALA fertilizer was found in the aerial spray by small automated helicopter. From all results, we emphasize that the application of foliar application fertilizer containing 5-ALA are very useful to achievehigh yield of direct-sowing rice plants.

Keywords: 5-aminolevulinic acid (5-ALA), direct-sowing of rice plants, new foliar-application fertilizer (-ALA fertilizer; Penta-keep), yield-increase

Introduction

In Japan, the cultivation methods for rice plants (*Oryza sativa* L.) in paddy field can be mainly classified into two types, i.e. mechanical transplanting cultivation and direct-sowing. In recent year, the growing area using the latter cultivation type progressively tends to the extension because of the establishment of labor-saving cultivation for rice. However, the grain number per m^2 of rice plants cultivated by direct-sowing becomes often an excess of 30,000 grains. As the result, the decrease of percentage of ripened grains take places in inferior grains than in superior ones and, as a consequence, the grain yield decreases.

Yoshida *et al*. (1996) reviewed that 5-aminolevulinic acid (5-ALA) has often promoting effects on yield increase of crops. Hotta *et al*. (1997) reported that ALA has plant growth regutating properties at low concentration (<30ppm) and the foliar application of this compound enhanced the growth and yield of kidney beans, barley, potato and garlic. However, there is insufficient information about the promotive effect of ALA on the grain filling of rice plants. The supply of large amount for 5-ALA having high-quality and inexpensive price has already been successfully achieved by Tanaka (1995). A new foliar-application fertilizer containing 5-aminolevlic acid using the extension in agriculture field was also developed by Cosmo Oil Research Group (Tanaka *et al*. 2006). Commercial name for this fertilizer is PENTAKEEP® super or 5-ALA fertilizer.

This experiment, therefore, was carried out to clarify whether the foliar application of 5-ALA fertilizer was able to alter the percentage of ripened grains, especially in direct-sowing rice plants. The utility for achieving high yielding grains of direct-sowing rice cultivation was discussed.

Materials and Methods

Experiment I (2009)

Rice cultivation. Rice cultivars used were Koshihikari (medium maturing variety) and Tenkomori (late maturing variety) in Toyama, Japan. The coating pregerminated seeds with calcium peroxide (CaO_2 of 2-fold) were sown in paddy soil by using direct-shooting seeder. The sowing rate of both the cultivars was 2.5～2.8 kg per 0.1ha.The controlled availability fertilizer (LPs, N:P:K=18:12:12) was basally dressed at rate of 30～35kg per 0.1ha. When the growth of rice plants reached the full heading time, 5-ALA fertilizer was sprayed to the whole plant.

Spray of 5-ALA fertilizer. Fertilizer 5-ALA was composed of N at 8.0%, P_2O_5 at 5.0%, K_2O at 3.0%, MgO at 3.0%, Fe at 0.29%, Mn at 0.12% and other micro-elements, but the concentration of 5-ALA was not only open. At the full heading time, 5-ALA fertilizer was sprayed weekly twice to whole plants. The concentration and application volume of 5-ALA fertilizer were 2000-fold solution and 200 liter per 0.1ha, respectively. The percentage of ripened grains, such as superior and inferior gains of panicle, was determined at the harvesting time. Yield component of rice plants and quality of grains was also observed.

Experiment II (2010)

Cv. Koshihikari was grown in paddy field. The rates of basal-dressing fertilizer were the same as those used in Experiment I. The application of 5-ALA fertilizer was sprayed by small automated helicopter. In this case of aerial application, the concentration and application volume of 5-ALA fertilizer were 8-fold solution and 0.8 liter per 0.1ha, respectively. The effects of spraying 5-ALA fertilizer on the percentage of ripened grains and yield component were evaluated at the harvesting stage.

Results and Discussion

In Japan, the yield decrease of direct-sowing rice plants is attributed to the excess of grain number per m^2 (more than 30,000 grains). This excess of unfulled grains per m^2 takes place the increase of sterile and imperfect grains in panicle. In practical producing field of direct sowing cultivation, the percentage of ripened grains in cv. Koshihikari was well known to vary the range of 65～74%. For achieving high-yielding grains in direct-sowing rice cultivation, therefore, understanding the effects of 5-ALA fertilizer was particularly important. In this experiment, the unfulled grains of panicle were divided into superior and inferior grains (Figure.1).

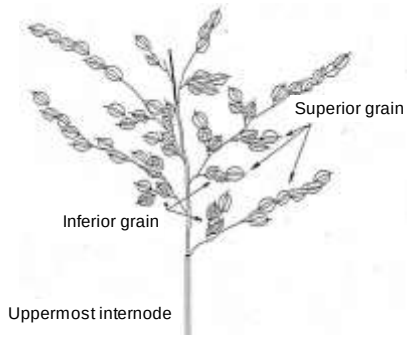

Figure 1. Classification of superior and inferior grains in panicle.

All grains attached directly to primary branches and the terminal grains of secondary branches were defined as superior grains and the grains on secondary branches, excepting the terminal one, were defined as inferior grains. The following data (Tables 1, 2, 3) were obtained from Experiment I. Table 1 shows the effects of spraying 5-ALA fertilizer on yield component. In the case of cv. Koshihikari, the rate of grain-straw was 1.1 in both the control plants (untreated-treated with 5-ALA fertilizer) and the plants treated with 5-ALA fertilizer. The unfulled grain number per m^2 was about 33,000 in both the plants. In the case of cv.Tenkomori, the grain-straw ratio and unfulled grain number were 0.9 and 30,000～33,000, respectively. The yield components in both the cultivars did not vary with the spraying 5-ALA fertilizer.

Table 1. Effects of 5-ALA fertilizer on yield component

Cultivar	Treatment 5-ALA fertilizer	Unfulled grain weight (g/hill)	Straw weight (g/hill)	Unhulled grain - straw ratio	Panical number per hill	Unhulled grain number per hill	Unhulled grain number per m^2
Koshihikari	Untreated (control)	51	48	1.1	22.9	1.839	33.470
	Treated	52	49	1.1	23.0	1.806	32.860
Tenkomori	Untreated (control)	45	48	0.9	21.2	1.654	30.103
	Treated	46	51	0.9	21.7	1.786	32.504

1. The density of direct-sowing rice plants is 21~24 per m^2
2. The value show the means of 3 replications. The number of hills tested is 240.

The percentage of ripened grain in rice plant treated with 5-ALA fertilizer is shown in Tables 2. As was expected, the 5-ALA fertilizer enhanced the percentage of ripened grains. This increase was much more marked in the inferior grains than in the superior ones. The extent of the increase in both the cultivars brought about by the spraying treatment amounted from 13.6 to 29.9% (cf. control) in the inferior grains. Thus, the spraying treatment of 5-ALAfertilizer significantly affected the grain filling of inferior grains ($p < 0.05$).

Table 2. Effect of 5-ALA fertilizer on percentage of ripened gains

Cultivar	Treatment 5-ALA fertilizer	Unhulled grain number per panicle	Ratio of grains per panicle (%)		Percentage of ripened grain (%)	
			Superior grains	Inferior grain	Superior grains	Inferior grain
Koshihikari	Untreated (control)	80.3±45	77.9±0.7	22.1±0.7	$82.7±3.0_a$	$54.9±2.1_b$
	Treated	78.5±5.5	82.8±2.3	17.2±2.3	$88.8±2.8_a$	$84.8±4.6_a$
Tenkomori	Untreated (control)	78.0±7.0	71.8±2.6	28.2±2.6	$94.0±3.3_a$	$79.8±4.4_b$
	Treated	82.3±2.8	72.7±3.0	27.4±3.0	$95.7±1.4_a$	$93.4±1.5_a$

1.Date are means±SE of 150 panicles.
2.Different letters within columus in each cultivar indicate significant differences by Tukey's multiple range test ($p<0.05$)

As for the 1,000 grain weight, the cv. Tenkomori showed higher value in inferior grains than that in superior ones (Table 3). In the case of cv. Koshihikari, the fulled grain yield of the plants treated with 5-ALA fertilizer was 627.5kg per 0.1ha, this value was higher than that of control plants (Table 4). The effect of spraying 5-ALA fertilizer also was much more marked in the case of cv. Tenkomori. The degree of yield increased was 145.5kg per 0.1ha. These findings showed that 5-ALA fertilizer acts as a regulator for yield increase of rice plants through a steady increase of grain filling, especially in inferior grains. Regarding the physiological function of 5-ALA, Tanaka (1995)

has been reported in radish plants that 5-ALA enhanced the activity of photosynthesis and suppressed the rate of respiratory activity. Yoshida (1996) showed that the accumulation fractan in rakkayo and shallot plants was increased by 5-ALA application. From the results obtained here and these findings, the steady increase of the percentage of ripened grains by the application of 5-ALA fertilizer seemed to be dependent on the activity of photosynthesis during the grain filling period. However, the physiological functions of this fertilizer during maturation of rice grains are still almost unknown at the present.

Table 3. Effect of 5-ALA fertilizer on yield and quality of gains (hulled grains)

Cultivar	Treatment 5-ALA fertilizer	1000 grain weight (g)	Grain yield (kg/0.1ha)	Quality of grain (%)		
				Protein content (%)	Amilose content (%)	Index of paratability
Koshihikari	Untreated (control)	22.2.0±0.5	506.6	6.1	18.7	73
	Treated	22.0±0.5	627.5	5.9	18.7	74
Tenkomori	Untreated (control)	22.3±0.3	583.3	6.0	18.9	74
	Treated	23.7±0.5	728.8	6.0	19.0	75

1.means±SE
2.quality of grains is determined by Satake rice*grain paratability tester

Table 4. Effects of 5-ALA fertilizer sprayed by the helicopter on the percentage of ripened grains in cv. Koshihikari

Treatment 5-ALA fertilizer	1000 grains weight (g)	Percentage of ripened grains (%)		Grain yield (kg/0.1ha)
		Superior grains	inferior grams	
Untreated (control)	$21.2\pm0.3_a$	$83.5\pm3.9_a$	$68.7\pm5.1_b$	670.0
Treated	$20.8\pm0.2_a$	$86.2\pm5.0_a$	$79.2\pm4.3_a$	696.2

1.Data are means±SE of 150 panicles
2. Different letters within columns indicate significant differences by Tukey's multiple range test (p=0.05)

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