Effect of Crop-Side Basal Application of Fertilizer on Growth and Yields of Rice Plants

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Introduction

The crop-side basal application of fertilizer (hereafter referred to crop-side dressing) is a newly deviced method of basal dressing of fertilizer to rice plants. By using a power-driven transplanting machine, equipped with a fertilizer application unit, basal fertilizer is applied in a line, at the depth of less than 5 cm of the plow layer of soil and 2–3 cm aside from young rice seedlings just planted.

The crop-side dressing has been studied since the middle of 1970's as a subject of fertilizer placement, and its high effectiveness on rice production or water quality conservation has been made clear[3,4,9].

In the 1980's, studies on the practical application of this new method has progressed in the Tohoku region, and with the improvement of a crop-side dressing machine mounted on the transplanting machine and that of the fertilizer to be used, the adoption of this method has rapidly spread, reaching 7.3% of the total rice-planted area in the Tohoku region in 1987. It is further spreading to other regions of the country.

Effect of crop-side dressing observed in the Tohoku region is presented in this paper.

Rice yields and yield components

In the period from the later half of 1970's to the early half of 1980's, the rice crop in the Tohoku region suffered quite frequently from cool weather damage. In some year, the rice yield in Tohoku was lower than the national average. Low temperature (about 15°C) at the transplanting time caused delayed initial growth, and unstable yields. Crop-side dressing was introduced to promote the initial growth, and also to save labor for fertilizer application.

Compiled experimental data obtained in the Tohoku region since 1975 indicates that the crop-side dressing is highly effective in cool highlands or Yamase* areas, and is more effective in cool years than in ordinary years. The result obtained in the experimental field at Yoroibata (270 m above sea level) showed, as given in Table 1, that the highest effectiveness was recognized in 1981 (cool weather damage occurred), followed by 1983 (a little low tempearture lasted until the end of July), and almost no effectiveness in 1982 (only slight influence of low temperature)[7]. The yield component analysis conducted with many experimental results indicated that the yield increase was caused by the increase in the number of panicles, while the occurrence of no yield increase or yield decrease was caused by the decrease in the number of spikelets per panicle.

On the other hand, on flat lowlands, effect of crop-side dressing was small, showing sometimes yield decrease. The data obtained in Ohmagari (Tohoku National Agricultural Experiment Station), where initial growth after

* Easterly wind of low temperature (Yamase) blowing in the rice season causes cool weather damage of rice.

Table 1. Effect of crop-side dressing on rice growth and yields in highlands

Year	Basal dressing (kg N/ha)	Date of measurement	Number of tillers (/m²)	Number of panicles (/m²)	Yield (t/ha)
1981	WLA 80	June 26	229 (100)	267 (100)	4.2 (100)
	WLA 40 + Side 40		311 (130)	339 (127)	5.0 (119)
	Side 60		308 (134)	354 (133)	5.3 (128)
1982	WLA 80 + Top 20	June 24	462 (100)	393 (100)	6.6 (100)
	WLA 60 + Side 40		512 (111)	470 (120)	6.6 (99)
	WLA 40 + Side 60		573 (124)	504 (128)	6.5 (98)
1983	WLA 80 + Top 20	June 24	373 (100)	355 (100)	4.9 (100)
	WLA 40 + Side 40		518 (139)	499 (141)	5.4 (111)
	Side 60		445 (119)	413 (116)	5.3 (110)

Location: Yoroibata, Akita Pref. Agr. Exp. Sta. Cultivar: Akihikari.
WLA: Whole layer application.
Side: Crop-side dressing, Top: Top dressing.
1981, 1983: Low temperature year, 1982: Ordinary year.

Table 2. Effect of crop-side dressing on rice growth in a plain (1983, 1984)

Treatment (B+I+P)	1983 Yield (t/ha)	Number of panicles (/m²)	Number of spikelets per panicle	Percentage of ripened grains (%)	Weight of 1000 kernels (g)	Dry weight at panicle formation stage (/m²)	1984 Yield (t/ha)
QAF-WLA (70+0+30)	6.9 (100)	508	83.9	73.2	21.9	233	6.1 (100)
QAF-Side (70+0+30)	6.7 (98)	506	73.8	85.3	21.9	272	—
QAF-Side (50+20+30)	6.8 (99)	520	74.7	85.0	21.5	319	5.3 (86)
SRF-Side (70+0+30)	7.2 (105)	525	80.4	77.2	21.4	266	6.8 (111)

Location: Ohmagari, Tohoku Nat. Agr. Exp. Sta. (Gray lowland soil: CL, CEC 20me.). Cultivar: Akihikari. B+I+P: Basal dressing+Intermediate top dressing (June 27, the 8th leaf stage)+Top dressing (Hogoe) at panicle formation stage, QAF: Quick acting fertilizer, SRF: Slow release fertilizer.
Fertillizer: Granular compound fertilizers.

transplanting is relatively vigorous, though that place is in the Tohoku region, are shown in Table 2. In 1983 (with cool weather), the crop-side dressing of quick acting fertilizer (QAF-Side plots) increased the number of panicles, but decreased the number of spikelets per panicle and resulted in the yield similar to that of the whole layer application* of the same fertilizer (QAF-WLA plot). On the other hand, in 1984 (with warm weather), crop-side dressing decreased both the panicle number and the spikelet number per panicle, and resulted in the much reduced yield. However, from the results of many experiments, it was recognized[11] that the crop-side dressing shows a tendency to give yield increase to some extent in paddy fields with high nitrogenous soil fertility, paddy fields in the first year after conversion from upland farms,

* Nitrogen fertilizer is incorporated into the whole plow layer.

paddy fields with poor drainage and rice straw application, and paddy fields with average soil fertility when crop management, such as top dressing, in the middle growth stage is appropriate. It is expected that further improvement of fertilizer application can stabilize the yield increase.

As described above, the crop-side dressing is now regarded as an yield-increasing technique in cool highlands and in Yamase areas, while it is evaluated as a labor-saving technique in cool highlands and in Yamase areas, experiments conducted in 1983–1985 showed that the yield-increasing effect of the crop-side dressing in the whole Tohoku region was about 5% (Tohoku Regional Agricultural Administration Office).

Growth progress

The crop-side dressing increased the number of tillers and plant dry weight in an early growth stage, even when the fertilizing rate was somewhat reduced, and also it promoted leaf emergence rate, and heading by 1–3 days.

However, when the crop-side dressing was practiced in plain areas, nitrogen content in rice plants rapidly declined at the 8-leaf stage (about 40–35 days before heading), resulting in remarkable decrease in the number of tillers, and in the number of panicles (reduction in percentage of productive tillers) as well as in the number of spikelets per panicle (Figs. 1, 2, Table 2). These changes were more remarkable in a warm year, 1984: nitrogen content declined to far less than 2% at the young panicle formation stage, and the number of tillers very much declined. In the QAF-Side plot, top dressing at the 8-leaf stage (before the young panicle formation stage) was practiced, though somewhat delayed, but the recovery of plant growth was

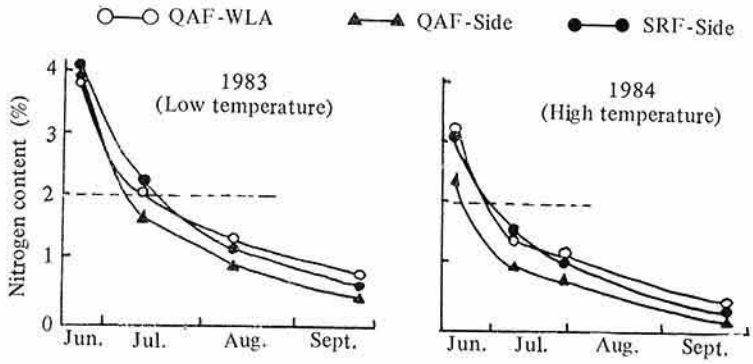

Fig. 1. Changes of nitrogen contents in rice plants

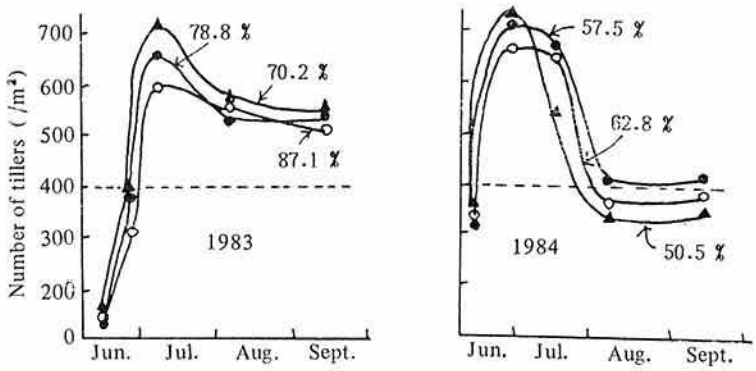

Fig. 2. Changes in the number of tillers
Percentages: % productive tillers.

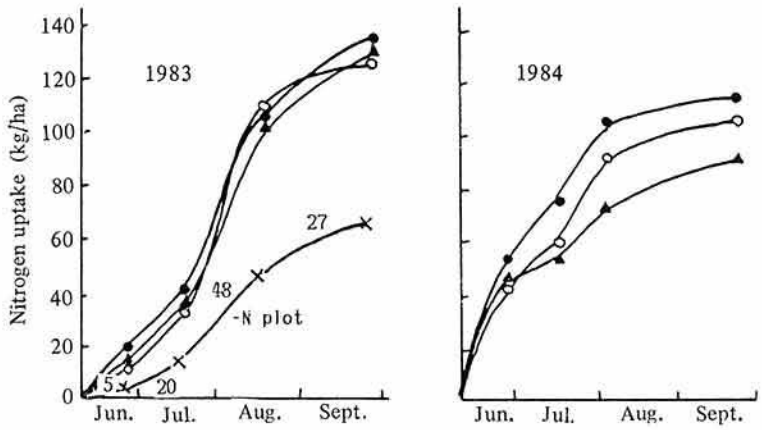

Fig. 3. Changes of nitrogen uptake by rice plants

not sufficient, and the number of tillers and percentage of productive tillers became the lowest. In the SRF-Side plot (crop-side dressing of slow-release fertilizer), nitrogen content of plants was kept higher as in the QAF-WLA plot, and the number of tillers was also similar to that of the latter, although the yearly variation in the SRF-Side plot resembled that of the QAF-Side plot.

The difference among the experimental plots in nitrogen uptake was small, and the amount uptaken continued to increase until the late growth stage in 1983 with cool weather, but in 1984 with warm weather the difference among plots appeared in late June (the 8-leaf stage), and nitrogen uptake in the QAF-Side plot did not increase in the later half of the growth period (Fig. 3). As shown later, it was conjectured that the distribution of roots was inclined toward the upper portion of the plow layer, so that nitrogen in the lower portion of the plow layer could not be absorbed enough for supporting the later half of plant growth. In this connection, in cool highlands, the amount of growth is generally small and hence the amount of nitrogen uptake is also small, so that nitrogen deficiency does not occur so rapidly as in the warm plain areas. Namely, as the nitrogen uptake tends to delay, the percentage of productive tillers becomes high.

In view of such progress of nitrogen uptake and of the number of tillers with time, the crop-side dressing of quick acting fertilizer in warm plains inevitably requires nitrogen top dressing at the 8-leaf stage. However, nitrogen top dressing at this stage is apt to elongate lower internodes (internodes IV and V) and to induce lodging. It also lowers the percentage of ripened grains (Table 3). In addition, as nitrogen deficiency occurs so rapidly, the top dressing is not in time. Thus, it is very difficult to decide the amount and timing of top dressing. However, the crop-side dressing of slow release fertilizer can omit the nitrogen top dressing and get smooth growth of plants.

As fertilizer is applied to the upper portion of the plow layer by the crop-side dressing, more roots tend to be distributed to the upper portion. Table 4 shows dry weight of top and roots. A high T/R ratio is shown in the crop-side dressing plot. It means that root growth was not proportional to the promoted top growth. This tendency continued from the initial growth stage to the maturity stage[8]. With such a pattern of root distribution, plant growth is liable to slow down in the later half period. Then, the crop-side dressing combined with the supplemental application of nitrogen to the deep portion was tested, and high yield was obtained[2]. Basically it is desirable to increase soil fertility of the plow layer for promoting the downward elongation of roots.

Table 3. Effect of timing of intermediate top dressing on rice lodging (1982)

Plot[1]	Treatment (Timing of top-dressing)	Length of internode(cm)[2]					Length of culm (cm)	Lodging[3]	Yield (t/ha)	Number of panicles (/m²)	Percentage of ripened grains (%)
		I	II	III	IV	V					
1	WLA 40(−17)	32.2	20.2	14.8	8.1	0.9	77.9	0.3	5.3	520	72.8
	Side 27(−14)	31.1	19.5	15.2	8.9	0.9	77.8	1.1	5.4	536	71.6
2	dress- 27(−25)	31.5	19.6	14.4	9.1	1.7	81.1	1.2	5.6	583	68.4
	ing 27(−40)	28.9	19.6	16.5	10.7	2.2	82.2	1.7	5.4	599	64.9
	27(−46)	30.3	19.9	15.6	10.1	1.4	80.8	1.4	5.4	562	66.7

Location: Branch of Iwate Pref. Agr. Exp. Sta. (Brown lowland soil, L.). Cultivar: Sasanishiki.

1) : In the plot 1, 40 kg N/ha was applied as basal dressing by WLA, and 20kg N/ha of top dressing was applied 17 days before heading (−17). In the plot 2, 27 kg N/ha of side dressing was made, and 20 kg N/ha was given as top dressing on indicated days (minus sign means days before heading). For side dressing paste fertilizer was used.

2) : I ～V : The lst, 2 nd,…… 5 th internodes counted from the top.

3) : Degree of lodging: 0 to 5 (severe).

Table 4. Effect of crop-side dressing on root growth

Fertilization (kg/ha)	Dry weight (g/m²)		T/R	Maximum of root length (cm)	Number of roots	
	Top	Root			/hill	/tiller
WLA 30, Top* 20	114	80	1.4	26	444	13
Side dressing 50	168	95	1.9	23	478	12

Location: Okitama Branch, Yamagata Pref. Agr. Exp. Sta. Measured at the tillering stage.

* Top dressing.

Changes in the ammonium nitrogen content in soil with time

The characteristic of the crop-side dressing is unique fertilizer placement. By customary methods of fertilizer application (incorporation to the whole plow layer, and dressing at puddling time), the basal fertilizer is placed to the depth of the plow layer. On the contrary, by the crop-side dressing, fertilizer is placed closely to seedlings. It causes a differing of nitrogen absorption by plants. As given in Fig. 4, the ammonium level in the soil between rice hills in the whole layer application plot (WLA-plot) gradually lowered with time, and almost disappeared in early July (nearly the young panicle formation stage), while in the crop-side dressing plot, it was high at the initial stage, but it rapidly lowered in mid-June, and disappeared earlier than the former case. At this time, supplemental top dressing is needed. However, as the lowering of ammonium level was slow in the plot with crop-side dressing of slow release fertilizer (SRF-Side dressing plot), this

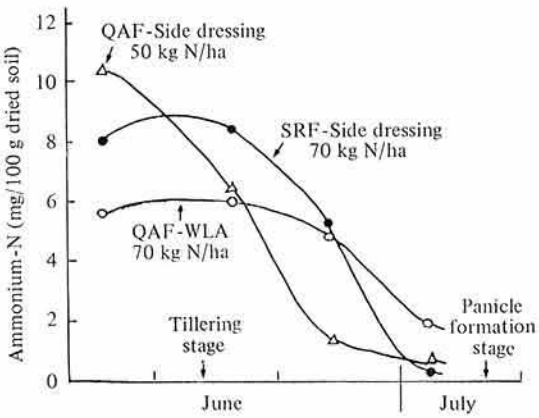

Fig. 4. Changes in ammonium level in plow soil

plot showed the pattern nearly similar to that of the WLA-plot. As the disappearance of ammonium in the crop-side dressing plot tends to occur earlier in warm years, the timing of the supplemental top dressing must be decided every year.

Crop-side dressing and intermediate top dressing

As mentioned above, the reduction of the amount of quick acting fertilizer in the crop-side dressing gave better results. When the same amount of fertilizer as used for the whole layer application was used, excessive tillering with thin stems was induced, and severe nitrogen deficiency was caused by nitrogen exhaustion in soil, as a reaction. Growth recovery was difficult, even when intermediate top dressing was done.

On the other hand, as fertilizer is placed close to seedlings, it is absorbed fast by plants, even when its amount is reduced, and also its loss due to denitrification and leaching is less, being placed inside the soil. The rate of nitrogen utilized by plants is 50% and over[10,11], which is about 20% higher than the case of the whole layer application. The rate of reduction of the amount of fertilizer depended on soil conditions and rice varieties, but was about 15–30%[11]. The crop-side dressing does not require top dressing at the rooting stage.

On the contrary, the amount of slow release fertilizer to be used for the crop-side dressing varies with degrees of slowness (strictly speaking), but as far as the fertilizers (for the crop-side dressing) on the market at present are concerned, they can be used in plain areas at the same amount as that for the whole layer application. However, it is desirable to select fertilizer for different areas and varieties. The use of slow-release fertilizer doesn't need intermediate top dressing.

For the crop-side dressing, paste fertilizer and granule fertilizer are available, and both are almost similar in fertilizer effect. As the dressing machines differ in structure each other, and fertilizer components also differ each other, it is desirable to select them for different varieties and soil fertility.

The amount of intermediate top dressing varies with areas, meteorological conditions, and nitrogenous soil fertility, but is usually 15–20 kg N/ha. When slow release fertilizer is used for intermediate top dressing, the little more amount is applied, and any later top dressing such as Hogoe is omitted. However, care is needed for the fact that mid-summer drainage causes delayed manifestation of fertilizer effects.

Crop-side dressing and nitrogenous fertility of soil

Table 3 shows the amount of nitrogen uptake by plants grown without nitrogen application, i.e., the amount of nitrogen supplied only from soil in a cool year (1983). The amount of soil nitrogen supplied by the 8-leaf stage (late June), and by the young panicle formation stage was 5% and 25% of the total soil nitrogen supply, respectively. The balance, 75%, was supplied after the young panicle formation stage. It indicates that the crop-side dressing is highly effective in promoting plant growth by supplying nitrogen during the early growth period in which the soil nitrogen supply is meager, while after the middle of the whole growth period, the plant growth depends more on the increasing soil nitrogen supply. Therefore, the crop-side dressing performs well in paddy fields where soil nitrogen supplying capacity is high, and roots can easily elongate downwards.

On the other hand, one of the reasons why the crop-side dressing does not always perform well in southwest regions of the country is that the soil nitrogen supply is plenty from the initial stage of growth due to high temperature at the rice transplanting time, and therefore there is no need to rely upon the crop-side dressing. The rapid supply of fertilizer nitrogen causes over-luxuriant growth, a minus effect. Therefore, it is known that the dressing to the middle part of every other inter-row space gives good results[6].

New development

To prevent the occurrence of nitrogen deficiency associated with the crop-side dressing and to save further the dressing labor, the development of a two-depth dressing method by a machine is in progress, aiming at the application of fertilizer with higher capacity of slow release to the portion deeper and further away from the seedlings than that of the present crop-side dressing method[12].

As the efficiency of fertilizer utilization by plants is high in the crop-side dressing, addition of agricultural chemicals to the fertilizer for crop-side dressing was attempted, aiming at both fertilization and pest control in the early stage. This method is already developed.

The crop-side dressing is a technique in the whole system of rice cultivation, so that to establish the technique of crop-side dressing, it will become necessary to look over the whole cultural technique again.

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