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Efficiency of Soil and Fertilizer Nitrogen in relation to Rice Variety and Application Time, Using ^{15}N Labeled Fertilizer[1)]

Ⅲ. Top-dressing with ^{15}N fertilizer in fields

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重窒素를 利用한 水稻品種 및 施用時期에 따른 土壤 및 施肥窒素의 效率[1)]

Ⅲ. ^{15}N 肥料의 追肥圃場試驗

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抄 錄

幼穗形成期追肥(30%)한 標識窒素의 利用率은 23~61%(5個圃場)였으며 品種間差異가 없었다. 高收畓에서 追肥窒素의 利用率이 컸으며 植物體內肥料 由來窒素의 50% 以上이 幼穗形成期以後에 吸收된 것으로 보였다.

正租에서 重窒素過剩率이 가장 컸으며 이는 追肥된 窒素가 正租로 쉽게 轉流됨을 나타낸다. 一般系보다 統一系에서 正租와 藁間의 重窒素過剩率의 差異가 커서 統一系에서 窒素의 轉流가 빠른것을 나타낸다. 地上部追肥由來窒素는 14~27%였다. 特別한 管理를 한다면 圃場條件에서 重窒素利用한 試驗은 處理當 2區에 區當 3株로 充分할 것 같다.

Introduction

Split application (usually 4 splits) on rice in Korea increases yield by around 10%. The effect of number of split on yield varies with soil, variety and year though the difference between 2 and 4 split was not much great[2)]. Top-dressing of nitrogen to rice plants is to escape overdose of nitrogen in the early stage and to eliminate nitrogen hunger in the later stage of growth. Overall effect is to keep low level of nitrogen in rhizosphere throughout the crop season. Thus a slow releasing-nitrogen fertilizer,

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sulfur coated urea (SCU) showed better yield in many cases than split application even though the rate of SCU was 20% less in a countrywide NPK trials for two years[2]. High yield with lower rate of nitrogen in SCU than in conventional 4-split application depended not only on high use efficiency of applied nitrogen but also on high efficiency for grain production of absorbed fertilizer nitrogen[3]. Yields of SCU and urea split application plots showed the same trend in various fieldse. This may indicate the similar contribution of soil nitrogen to yield in both urea and SCU application probablly due to no interaction between soil nitrogen and fertilizer nitrogen regardless of nitrogen forms. Nitrogen uptake in case of top-dressing is important in relation to soil nitrogen and fertilizer economy. Studies on nitrogen uptake using ^{15}N fertilizer in split application is very rare in Korea[7]. This experiment aims to elucidate efficiency, uptake, partition of fertilizer nitrogen and minimum number of hills for ^{15}N fertilizer experiment when top-dressed at ear formation stage in the farmer's fields.

Materials and methods

Treatment: In the plot of two-time split application(70% basal and 30% top-dressing at ear formation stage) of NPK trials[1] the labelled ammonium sulfate and urea(5 atom %) were applied. Appropriate amount of ^{15}N labelled fertilizer was disolved with irrigation water enough to cover the plot surface isolated by plastic plates and then applied to the surface. Surface soils were lightly puddled about 5cm depth with a small plastic stick. Thirty percent of 222 treatment was 4.8 Kg N/10a for Tongil and 3.6Kg/10a for the local.

Plant sampling and preparation: Number of hills was 3, 4 or per ^{15}N treated plot. All hills were harvested, and separated into grain, leaf sheath plus culm, and leaf blade. Samples were dried in a forced draft oven at 70°C for 24 hours and ground with vibrational ball mill for 3 minutes (over 100 mesh). Pooled samples were made by mixing sample powder at the weight ratio when it was necessary.

^{15}N analysis: Samples were analyzed for ^{15}N by optical method[1] using an ^{15}N analyzer(JASCONAI). Analysis was cross checked with IAEA. Total N was determined by micro Kjeldhal digestion method.

Results and discussion

Soil characteristics of ^{15}N top-dressing experiment fields were shown in Table 1. Fertility criteria are not clear yet. Fertility grade here was somewhat arbitrary because it was according to yield experience of farmer. Usually yield without fertilizer will be a good fertility criterion but this yield is changeable depending on yearly weather as mentioned previously[1] about pooly drained soils. Also highest yield with fertilizer

Table 1. Experimental site and soil characteristics.

Place	Soil series	Drainage	Soil texture	Fertility grade	Chemical characteristics					^{15}N fertilizer applied
					pH	OM	Ca	Mg	K	
					%	%	(me/100g)			
Chungnam	*Sachon*	Imper-	L	High	5.8	2.03	2.92	0.75	0.09	Urea
Daedeog		fectly		Low	6.5	1.39	3.38	0.57	0.06	Urea
Chungnam	*Yeompo*	Pooly	FSL	Low	6.8	0.28	1.90	4.28	0.96	Urea, Amm.
Boryeong										
Gyeongnam	*Yuga*	Imper-	SIL	High	5.2	1.93	4.01	1.43	0.09	Urea, Amm.
Jinyang	*Yuga*	fectly		Low	6.5	2.62	5.60	2.04	0.25	Urea, Amm.

was not always lower in the field of which yield was lowest without fertilizer.

Use efficiency (Eu) of fertilizer nitrogen which applied at ear formation stage ranged 23 to 61 for the local and 27 to 60 for Tongil(Table 2). In four of seven cases the local showed higher Eu. These data are not enough to say that the local prefers top-dressing. In high yield soil with urea there was little difference in Eu between both lines.

Uptake by 60% of top-dressed nitrogen in Daedeog seems to be a luxuary absorption of fertilizer nitrogen. Thus without any considerable increase of both yield and total nitrogen uptake amount the fertilizer nitrogen uptake increases when fertilizer is applied.

Tongil showed higher Eu than the local varieties with ammonium sulfate in two of three cases. It suggests that Tongil prefers to ammonium sulfate. Tongil easily shows chlorotic symptom under high pH in sand culture and more suseptible to high pH due to soil reduction[4].

There was also higher tendency of Eu in high fertility fields (Table 2). Abundant root distribution and less leaching of nitrogen in later stage might be an important factor for yield

Table 2. Nitrogen uptake and efficiency of fertilizer applied at ear formation stage as 30% top-dressing (1976)

Place	Fertility	Fertilizer	Milyang 23				Milyang 15				No. of replicates
			Yield (g/hill)	^{15}N uptake (kg/10a)	Cf %	Eu %	Yielc (g/hill)	^{15}N uptake (kg/10a)	Cf %	Eu %	
Jinyang	High	Amm.	28.1	1.31	20.0	27.3	27.4	1.53	24.8	42.4	3
		Urea	33.5	1.46	20.7	30.4	29.4	1.13	18.1	31.5	3
		Mean	30.8	1.39	20.4	29.0	28.4	1.33	21.5	36.9	6
〃	Low	Amm.	22.1	1.39	18.4	29.0	30.6	0.83	13.6	23.1	3
Daedeog	High	Urea	26.6	2.86	26.9	59.6	23.7	2.19	25.7	60.9	2
	Low	〃	31.5	1.81	23.0	37.7	25.4	1.38	19.5	26.1	4
Boryeong	Saline	Amm.	21.6	1.41	20.5	29.4	15.4	0.95	21.3	26.3	3
		Urea	22.3	1.34	18.2	27.9	16.7	1.32	25.3	36.6	1
		Mean	22.0	1.38	19.4	28.8	16.1	1.14	23.3	31.7	4

Amm.: Ammonium sulfate,Eu: Use efficiency (^{15}N absorbed/^{15}N applied) Cf (^{15}N taken up/total N in plant)

increase.

In saline soil the urea top-dressing appears to be better in Eu and also grain yield (Table 2 and 3). The ^{15}N excess % of Tongil was little difference between 3, 4 and 6 hills (Table 3). Thus two 3-hill plots may be better for one 6-hill plot for ^{15}N experiment.

The variation in ^{15}N excess % was considerablly higher than the variation of grain yield in saline soil for the local (Table 3) and low fertility soil for Tongil (Table 4). The variation of ^{15}N excess % between varieties tended to be greater in low yield soil (Table 5~8). It indicates that soils of low yield fields are more heterogeneous.

Among 3, 4 and 6 hill plots two plots were very close value (Table 6~8). If the plot is made and managed more carefully and precisely two 3-hill plots will give a representative value.

The distribution of fertilizer nitrogen top-dressed at ear formation stage was different among plant parts and varieties (Table 3~8). In general ^{15}N excess was in decreasing order of grain, leaf blade and leaf sheath plus culm. In some cases it was greater in leaf sheath+culm than in leaf blade. It was almost same in grain

Table 3. Yield, ^{15}N excess % of each part of rice plant grown with urea and ammonium sulfate (*Boryeong Chungnam*)

Fertilizer (ernumb of hill)	Plant part	Dry weight (gr/hill)	*Milyang* 23 (Tongil)				*Milyang* 15		
			N %	^{15}N ex.%	Cf %	Dry weight (g/hill)	N	^{15}N ex.	Cf %
Urea(6)	G	22.3	1.20	0.90	19.4	16.7	1.09	1.27	27.4
	SC	7.1	0.50	0.79	17.0	6.5	0.47	1.03	22.2
	LB	5.0	0.75	0.66	14.2	3.9	0.75	0.98	21.1
	W	34.4	0.99	0.84	18.2	27.1	0.89	1.17	25.3
Amm.(6)	G	19.0	1.27	0.99	21.4	13.2	1.11	0.79	17.0
	SC	7.1	0.50	0.75	16.2	5.6	0.51	0.66	14.2
	LB	4.2	0.84	0·86	18.6	3.3	0.60	0.99	21.4
	W	30.3	1.03	0.92	19.8	22.1	0.88	0.79	17.0
Amm.(4)	G	21.4	1.24	1.05	22.7	14.2	1.10	0.96	20.3
	SC	7.9	0.48	0.80	17.3	6.0	0.44	0.99	21.4
	LB	5.2	0.90	0.86	18.6	3.6	0.72	1.05	22.7
	W	34.5	1.01	0.96	20.8	23.8	0.88	0.98	20.2
Amm.(3)	G	21.0	1.12	1.03	22.2	15.2	1.01	1.25	27.0
	SC	5.8	0.45	0.80	17.3	7.2	0.41	1.11	24.0
	LB	4.4	0.77	0.90	19.4	4.1	0.67	1.11	24.0
	W	31.2	0.94	0.97	20.9	26.5	0.79	1.19	25.7

G: Grain, SC: Leaf sheath+culm, LB: Leaf blade, W: whole, Cf: Percent nitrogen derived from fertilizer, Amm.: Ammonium sulfate.

Table 4. Nitrogen derived from fertilizer (Cf) in various parts of two rice varieties applied with ^{15}N urea as 30% top-dressing at ear formation on low fertility field (4 hills per plot Daedeog, Chungnam 1976)

Replicate	plant part	*Milayang* 23(*Tongil* line)				*Milayang* 15			
		DW g/hill	N %	^{15}N ex.%	Cf %	DW g/hill	N %	^{15}N ex.%	Cf %
I	G	32.2	0.65	0.92	19.9	27.8	0.81	1.02	22.0
	SC	13.7	0.38	0.76	16.4	14.9	0.24	0.84	18.1
	LB	7.5	0.43	0.67	14.5	6.5	0.58	0.86	18.6
	S	21.2	0.39	0.72	15.6	21.4	0.35	0.85	18.4
	W	53.4	0.55	0.86	18.6	49.2	0.61	0.98	21.1
II	G	35.5	0.82	1.21	26.1	33.3	0.82	0.82	17.7
	SC	15.9	0.27	0.64	13.8	16.4	0.26	0.82	17.7
	LB	8.5	0.39	0.87	18.8	7.3	0.50	0.73	15.8
	S	24.4	0.30	0.74	15.9	23.7	0.34	0.78	16.8
	W	59.9	0.61	1.12	24.1	57.0	0.62	0.81	17.5
Mean	G	33.9	0.74	1.07	23.0	30.6	0.82	0.92	19.9
	SC	14.8	0.33	0.70	15.1	15.7	0.25	0.83	17.9
	LB	8.0	0.41	0.80	16.7	6.9	0.54	0.80	17.2
	S	22.8	0.35	0.73	15.8	22.6	0.35	0.82	17.6
	W	56.7	0.58	0.99	21.4	53.1	0.62	0.90	19.3

G: grain SC: sheath and culm LB: Leaf blade S: straw (SC+LB) W: whole plant (G+S).

Table 5. Yield, nitrogen content and ^{15}N excess%(6 hill plot, urea, Chungnam Daedeog)

	Plant part	*Dryweight (gr/hill)	N %	^{15}N** ex.%	Cf %	*Dryweight (g/hill)	N %	^{15}N ex.%	Cf %
High	G	26.6	1.30	1.26	27.2	23.7	1.21	1.19	25.7
Fertility	SC	14.2	0.47	1.24	26.8	11.0	0.65	1.14	24.6
field	LB	8.4	0.97	1.31	28.3	5.0	0.99	1.27	27.4
	W	49.2	1.00	1.25	26.9	38.7	1.02	1.19	25.7
Low	G	29.2	1.01	1.16	25.1	20.1	1.08	0.92	19.9
fertility	SC	13.8	0.43	1.07	23.1	13.2	0.46	0.79	17.1
field	LB	7.2	0.51	1.07	23.1	6.1	0.65	1.07	23.1
	W	50.2	0.78	1.14	24.6	39.4	0.81	0.91	19.7

*70°C for 24hr., **mean of duplicate analysis, G: grain SC: Leaf sheath+culm, Cf: Percent nitrogen derived from fertilizer, LB: Leaf blade, W: whole plant.

Table 6. Nitrogen derived from fertilizer (Cf) in various parts of two rice varieties applied with ^{15}N urea as 30% top-dressing at ear formation on high fertility field(Jinyang, Gyeongnam 1976)

Number of hill	Plant part	*Milyang* 23 (*Tongil* line) DW* g/hill	N %	^{15}N** ex.%	Cf %	*Milyang* 15 DW* g/hill	N %	^{15}N** ex.%	Cf %
	G	37.9	0.70	1.13	24.4	32.3	0.74	0.85	18.4
	SC	16.8	0.31	0.71	15.3	16.6	0.24	0.79	17.1
3	LB	7.3	0.62	0.59	12.7	6.1	0.93	0.94	20.3
	S	24.1	0.40	0.70	15.2	22.7	0.43	0.88	19.0
	W	62.0	0.58	1.02	21.9	55.0	0.61	0.86	18.5
	G	35.5	0.74	0.75	16.2	27.0	0.71	0.82	17.7
	SC	15.0	0.28	0.92	19.9	12.7	0.24	0.70	15.1
4	LB	7.9	0.60	0.62	13.4	5.6	0.81	0.53	11.4
	S	22.9	0.39	0.76	16.4	18.3	0.42	0.60	13.0
	W	58.4	0.59	0.75	16.3	45.3	0.59	0.76	16.4
	G	27.1	0.75	1.23	26.6	28.9	0.65	0.96	20.7
	SC	15.5	0.25	0.92	19.9	12.5	0.23	0.87	18.8
6	LB	6.8	0.62	0.68	14.7	5.9	0.85	0.68	14.7
	S	22.3	0.36	0.80	17.3	18.4	0.43	0.73	15.7
	W	49.4	0.57	1.11	23.9	47.3	0.56	0.89	19.3
	G	33.5	0.73	1.04	22.4	29.4	0.70	0.88	18.9
	SC	15.8	0.28	0.85	18.4	13.93	0.24	0.79	17.0
Mean	LB	7.3	0.61	0.63	13.6	5.9	0.87	0.71	15.5
	S	23.1	0.38	0.75	16.3	19.8	0.43	0.74	15.9
	W	56.6	0.58	0.96	20.7	49.2	0.59	0.84	18.1

*70°C for 24hr., **mean of duplicate analysis, G: grain, SC: Leaf sheath+culm, Cf: Percent nitrogen derived from fertilizer, LB: Leaf blade, W: Whole plant

Table 7. Nitrogen derived from fertilizer (Cf) in various parts of two rice applied with ^{15}N ammonium sulfate as 30% top-dressing at ear formation in high fertility ield (Jinyang, Gyeongnam 1976)

Number of hills	Plant part	Milyang 23 (Tongil line)				Leading local (Milyang 15)			
		DW* g/hill	N %	^{15}N** ex.%	Cf %	DW* g/hill %	N %	^{15}N** ex.%	Cf %
3	C	25.5	0.71	0.79	19.2	21.8	0.72	1.29	27.9
	SC	11.5	0.49	0.62	13.4	12.4	0.38	1.19	25.7
	LB	7.4	0.64	0.58	12.5	5.3	0.92	0.91	19.7
	S	18.9	0.55	0.60	12.9	17.7	0.54	1.06	22.8
	W	44.4	0.64	0.79	17.0	39.5	0.64	1.20	25.8
4	C	28.3	0.75	0.90	19.4	32.9	0.61	1.28	27.6
	SC	15.2	0.34	0.78	16.8	15.4	0.33	1.21	26.1
	LB	8.5	0.62	0.71	15.3	7.0	0.92	1.23	26.6
	S	23.7	0.44	0.75	16.1	22.4	0.51	1.22	26.3
	W	52.0	0.61	0.84	18.2	55.3	0.57	1.26	27.3
6	C	30.6	0.75	1.21	26.1	27.4	0.71	0.84	18.1
	SC	14.7	0.26	0.87	18.8	13.6	0.34	1.14	24.6
	LB	7.3	0.54	1.07	23.1	6.2	0.72	1.41	30.5
	S	22.0	0.35	0.97	20.9	19.8	0.46	1.27	27.5
	W	52.6	0.58	1.15	24.9	47.2	0.61	0.98	21.2
Mean	C	28.1	0.74	1.00	21.6	27.4	0.68	1.14	24.5
	SC	10.5	0.36	0.76	16.3	13.8	0.35	1.18	25.6
	LB	7.7	0.60	0.79	17.0	6.2	0.85	1.18	25.6
	S	21.5	0.45	0.77	16.6	20.0	0.50	1.18	25.5
	W	49.7	0.61	0.89	20.0	47.3	0.60	1.15	24.8

*70°C for 24hr., **mean of duplicate analysis, G: grain SC: Leaf sheath+culm, Cf: Percent nitrogen derived from fertilizer. LB: Leaf blade, W: Whole plant

and straw though there was considerable difference in two parts of straw, that is, leaf blade and others.

However the difference between grain and straw was always greater in Tongil than in the local varieties (Table 4~8). Also Tongil tend to show relatively higher ^{15}N excess value in leaf sheath plus culm than in leaf blade.

This result seems to be well accordance with greater translocation efficiency of nitrogen to grain as mentioned previously[1]. Tongil line was known as having rapid translocation rate only not of mineral nutrient but also of photosynthates from leaf to grain[5,6]. From the ^{15}N top-dressing experiment it is clear that nitrogen taken up even in the later growth stage translocates rapidly into grain in Tongil.

Percent nitrogen derived from top-dressed fertilizer (Cf) was higher in high fertility fields than in low fertility fields (Table 2) indicating that nitrogen uptake depends much more on those of later stage in higher yields. The Cf ranged 14 to 27%(Table 2) and 20% of Cf may be a criterion of high and low yield fields. By difference method Cf was 42 and 39 for Tongil and the local respectively in 1976 and 43 and 44 in 1977[3]. From this total Cf and Cf of top-dressed nitrogen one half or more of total fer-

Table 8. Nitrogen derived from fertilizer (Cf) in various parts of two rice varieties applied with ^{15}N ammonium sulfate as 30% top-dressing at ear formation in low fertility field (Jinyang, Gyeongnam 1976)

Number of hill	Plant part	Milyang 23 (Tongil line)				Milyang 15			
		DW* g/hill	N %	^{15}N** ex.%	Cf %	DW* g/hill	N %	^{15}N** ex.%	Cf %
3	G	36.6	0.74	1.01	21.8	32.4	0.70	0.55	11.9
	SC	17.4	0.30	0.48	10.4	18.8	0.18	0.38	8.2
	LB	9.1	0.74	0.49	10.6	7.8	0.66	0.51	11.0
	S	26.5	0.45	0.49	10.5	26.6	0.32	0.46	9.9
	W	63.1	0.62	0.85	18.4	59.0	0.53	0.53	11.3
4	G	29.8	0.87	0.59	12.7	31.0	0.73	0.54	11.7
	SC	16.9	0.30	0.76	16.4	14.7	0.17	0.50	10.8
	LB	7.1	0.73	0.91	19.7	8.1	0.59	0.65	14.0
	S	24.0	0.43	0.84	18.1	22.8	0.32	0.60	12.9
	W	53.8	0.67	0.66	14.3	53.8	0.56	0.55	12.0
6	G	28.1	0.80	1.12	24.2	28.5	0.63	0.83	17.9
	SC	15.4	0.25	0.64	13.8	13.0	0.17	0.70	15.1
	LB	8.4	0.58	0.57	12.3	6.5	0.69	0.79	17.1
	S	23.8	0.37	0.60	17.7	19.5	0.34	0.76	16.4
	W	51.9	0.60	1.04	22.4	48.0	0.51	0.81	17.5
Mean	G	22.1	0.80	0.91	19.6	30.6	0.69	0.64	13.8
	SC	16.6	0.28	0.63	13.5	15.5	0.17	0.53	11.4
	LB	8.2	0.68	0.66	14.2	7.5	0,65	0.65	14.0
	S	24.8	0.42	0.64	15.4	23.0	0.33	0.61	13.1
	W	56.3	0.63	0.85	18.4	43.3	0.53	0.63	13.6

*70°C for 24hr., **mean of duplicate analysis, G: grain, SC: Leaf sheath+culm,Cf: Percent nitrogen derived from fertilizer, LB: Leaf blade, W: Whole plant

tilizer nitrogen in plants is taken up after ear formation especially in higher yield fields even though fertilizer is applied 70% as basal and only 30% at ear formation.

Abstract

Use efficiency of top-dressed labelled nitrogen (30% at ear formation stage) ranged 23 to 61 %(five fields) with no clear difference between varieties. In high yield soil the use efficiency of top-dressed nitrogen was higher and more than 50% of fertilizer nitrogen in plant seemed to be taken up after ear formation, ^{15}N excess was greatest in grain indicating that top-dressed nitrogen translocates easily to grain. The difference of ^{15}N excess between grain and straw was greater in Tongil line than in the local indicating faster nitrogen translocation in Tongil. Percent nitrogen derived from top-dressed nitrogen ranged 14 to 27% in aerial part. Two 3-hill plots per treatment could be enough for ^{15}N experiment under field condition if there is specific care.

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