한국농화학회지 Vol.24, No.4, Dec. 1981
J. Korean Agricultural Chemical Society

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

I. N.P.K. simple trials in farmers fields.

Hoon Park[2)], Young-Sun Park[3)] and Choon-Soo Lee

(Received Dec. 2, 1981)

Institute of Agricultural Sciences, Office of Rural Development
Suweon, Korea 170

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

第一報. 農家圃場에서의 NPK 單純試驗

朴 薰 · 朴英善 · 李春秀
農業技術硏究所

抄 錄

施肥窒素의 效率을 調査하기 爲하여 三要素 및 黃被尿素(SCU), 農家圃場에서 2年間 統一系(日本型, 印度型, 交雜選拔)와 一般奬勵系를 使用 試驗하였다. 統一系의 收量은 一般奬勵系에 比하여 32個地域 130個圃場에서 2回分施와 SCU를 포함한 三要素시험에서 低溫해에는 16%, 高溫多照해에는 23%의 增收를 보였다. 適定窒素水準은 統一系가 奬勵系보다 低溫해에는 3.8kg, 高溫해에는 5.5kg이 높았으며 同一系에서의 年次變異는 同年度의 系統間 變異보다 컸다. 2回分施는 1~2%의 一定치않은 收量變異를 보였다. SCU는 20%의 施肥量 節減에도 平均 2~4%의 增收를 보였으며 鹽類畓(27~39%), 新開畓(20%)과 未熟畓(10%)에서 현저한 增收效果를 보였다.

Introduction

Rice yield per unit field area in Korea is remarkably increased by introducing indica-japonica hybrid selections which are highly adaptable to high level of nitrogen fertilizer[1,10)]. The current cultivation method for high yield in which silica materials and lime are applied

1) This work was partially supported by International Atomic Energy Agency Grant RC 1807-KOR in 1976~1978.

Present address: 2) Korea Ginseng & Tobacco Research Institute, 112 Ini-Dong, Chongro-Ku, Seoul. 3) Research Institute of Agricultural Chemicals, Suweon.

with compost or rice straw seems to agravate soil fertility. Studies on fate and efficiency of fertilizer nitrogen are necessary for saving fertilizers and maintenance of soil fertility.

Fertilization efficiency increased with the decrease of dissolution rate of fertilizer when sulfur coated urea was tested[5]. Such high fertilization efficiency can save 20~40% of fertilizer nitrogen by using SCU or other equivalent dissolution controlled techniques.

However the question why 20% increase of nitrogen fertilizer as slow-releasing fertilizer above the rate at which urea showed maximum yield did not give 20% increase of yield or satisfactory economic return is not solved yet. Efficiency analysis, fate of fertilizer and interaction between soil and fertilizer nitrogen by using labelled fertilizer may answer to such questions. Recently efficiency concept of nitrogen was much developed[1,2,5,6,8].

This research was carried out as countrywide field experiments in cooperation with eight provincial offices for two years (1976 and 1977) to determine optimum fertilizer level for newly bred high yielding rice varieties in various fields using commercial fertilizers and sulfur coated urea and to investigate fertilizer efficiency using labelled nitrogen fertilizer in various application methods. A pot experiment was also carried out.

Materials and Methods

Varieties: *Tongil* varieties (japonica×indica hybrid selections) and leading local varieties (japonica) were used according to the recommendation for each region. In 1977 the local varieties were transplanted one third of the total number of fields.

Experimental sites and soils: Four locations in each province were selected according to weather pattern. Two representative soil series were selected in each location and two fields in each series were finally decided by soil fertility (high and low). Since there are 8 provinces except *Jeju* where were one or two locations for upland rice, total number of locations were 32 for low land rice.

Treatments: There were 4 nitrogen rates in 1976 and 5 in 1977. Potassium and phosphorus had three rates. No-fertilizer and no-nitrogen treatment were included. Sulfur coated urea (SCU) made by Tenessee Vally Authority (USA), and Institute of Agricultural Sciences (Korea), were used as one rate and all basal. Nitrogen as urea were applied by broadcasting in four splits at just before transplanting, active tillering, ear formation and heading. Splitting was 50-20-20-10% for one crop fields and 60-20-10-10% for two crop fields (upland crop and rice, mostly southern part). Application at ear formation stage was done 15 days before heading for *Tongil* and 24 days before for the local.

Two-split application (70-0-30-0%) was also included at one rate for the test of significance of four split application in the countrywide basis.

Field layout and management: Plot size was 12m² (3m×4m). All treatments were completely randomized and duplicated. Three (*Tongil*) and four (local) plants per hill were transplanted with conventional spacing (15cm×30cm). Other managements such as nursery, pest control followed the recommended method of Office of Rural Development. Grain and straw yields were measured by harvesting all hills except border three lines.

Analysis of soils: Soil samples were taken from each field before experiment started and analysed by standard method[9] of Institute of Agricultural Sciences (IAS).

Table 1. Varieties used and number of fields.

Tongil lines			Leading local varieties		
	1976	1977		1976	1977
Tongil	32	—	*Milyang* No. 15	95	24
Milyang No. 23	45	40	*Jinheung*	28	4
Iri No. 11*	45	—	*Shin* No. 2	4	—
Milyang No. 21	4	28	*Palgeum*	1	—
Nopung	2	20	*Akibare*	—	4
	—	60	*Nonglim* Na No. 1	—	1

**Yushin*

Table 2. Soil chemical characteristics of experimental fields.

Soils	Year	Number of fields	pH	OM (%)	Available(ppm)		Exch.(me/100g)			
					P_2O_5	SiO_2	Ca	Mg	K	CEC
Normal	1976	50	6.0	2.1	78	131	5.0	2.5	0.28	11.0
	1977	44	5.5	2.4	78	110	3.8	1.3	0.22	—
Sandy	1976	48	5.9	2.3	122	87	3.5	0.9	0.16	8.7
	1977	38	5.5	2.4	126	88	2.9	0.8	0.17	—
Poorly	1976	18	6.0	2.2	52	105	3.5	1.0	0.21	8.4
drained	1977	26	6.0	1.9	47	104	3.2	0.9	0.11	—
Unmatured	1976	11	5.9	1.8	58	159	4.6	1.3	0.17	10.6
	1977	16	5.6	2.8	66	162	4.6	1.9	0.27	—
Saline	1976	3	7.0	0.4	43	146	2.2	4.1	1.03	5.5
	1977	4	7.6	1.4	20	132	3.4	1.2	0.41	—
Virgin	1977	2	5.6	0.2	4	135	0.9	0.9	0.13	—

Results and Discussion

Varieties used were shown in Table 1. *Yushin* made an excellent yield in 1975 in most farmer's fields but in 1976 it showed unexpected sudden wilt disease (sudden death) about 10 days after heading in northern area. Thus it was not used in 1977. Damage was mild in the experimental field. New sister lines, *Nopung* and *Milyang* No. 23 were recommended instead of *Yushin* in 1977.

Milyang 15 is newly bred leading local varieties and very popular in yield and quality. *Akibare* is best in quality. *Nonglim* No. 1 is glutinous and for upland use in *Jeju*. But upland data were not included.

The chemical characteristics of top soil was shown in Table 2. It was not much different in the same management group inspite of yearly change of experimental fields. Only organic matter content in unmatured and saline soils was higher in 1977 than in 1976. Phosphorus and potassium contents were different in saline soils. It could be said that there is not significant variation in chemical characteristics in most fields but unmatured and especially saline soils have considerable variation.

Yields on various treatments were shown in Table 3 and 4 in different soil management

Table 3. Grain yield in NPK trials on various soil management groups. (kg/10a 1976)

	Tongil varieties							Leading local varieties						
	Normal	Sandy	Poorly drained	Unmatured	Saline	Mean	Index	Normal	Sandy	Poorly drained	Unmatured	Saline	Mean	Index
NPK	(50)	(44)	(18)	(8)	(3)	(123)		(50)	(44)	(18)	(8)	(3)	(123)	
000	500	479	471	441	307	66.4	480	419	413	419	386	240	410	66.0
022	525	515	528	495	279	71.1	514	465	433	467	396	237	444	71.5
122	693	666	653	639	411	92.3	667	562	550	568	525	311	550	88.6
222	735	696	699	721	454	97.9	708	623	597	608	585	345	602	96.9
222*	721	686	690	695	454	96.3	696	610	594	615	596	345	598	96.3
322	752	710	700	749	505	100	723	641	612	617	630	412	621	100
422	737	—	—	—	570	100.7	728	638	—	—	—	430	626	100.8
202	709	669	680	678	472	94.5	683	595	594	597	557	324	586	94.4
212	723	690	682	705	527	96.7	699	595	858	600	586	351	587	94.5
232	737	702	689	697	455	97.9	708	615	594	611	601	340	599	96.5
220	708	675	623	679	464	93.5	676	601	582	517	572	352	574	92.4
221	726	686	679	700	417	96.3	696	610	586	602	513	357	588	94.7
223	726	684	696	700	477	96.7	699	618	593	606	512	311	593	95.5
SCU (TVA)	728	713	725	727	598	99.4	719	641	616	620	641	480	625	100.6
SCU (IAS)	745	—	—	—	—	—		—	539	—	—	—	—	

*70% as basal 30% at ear formation. Fertilizer rates: N, 12, 16, 20, 24kg/10a for *Tongil* and 8, 12, 16 and 20 for local leading varieties respectively to each rate from 1 to 4, SCU was applied at the rate 20% less than that of 222. Number in parenthesis is number of experimental fields.

Table 4. Grain yield in NPK trials on various soil management groups (kg/10a 1977)

Fertilizer rate*	*Tongil* line								Local leading varieties					
NPK	Normal	Sandy	Wet	Unmatured	Saline	Virgin	Mean	Index	Normal	Sandy	Unmatured	Virgin	Mean	Index
Number of fields	44	38	26	16	4	2	130		16	10	4	2	32	
000	558	526	573	463	355	259	529	67	504	429	355	210	444	69
022	604	590	637	535	406	223	586	74	525	425	394	286	462	72
122	730	740	767	675	484	569	724	92	613	546	559	373	570	89
222	775	775	796	705	513	589	760	97	653	581	595	458	611	95
322	801	804	820	748	533	623	788	100	684	597	621	549	641	100
422	817	811	821	766	551	655	796	101	686	620	591	577	647	101
522	817	820	809	768	601	692	802	102	677	617	628	620	649	101
302	783	759	770	678	487	382	745	95	664	606	661	323	624	97
312	787	783	783	742	531	615	769	98	664	623	622	505	636	99
332	804	786	771	725	549	738	774	98	681	619	630	619	651	102
320	778	761	749	720	516	641	750	95	628	613	657	488	618	96
321	802	775	767	730	547	649	768	97	675	598	643	527	634	99
323	794	790	800	720	537	662	775	98	683	624	646	543	651	102

*N 12, 16, 20, 24, 28 kg/10a for *Tongil*, 8, 12, 16, 20, 24, kg/10a for local leading var. P_2O_5 and K_2O 4, 8, 12kg/10a for *Tongil*, 3, 6, 9 kg/10a for local leading var.

Table 5. Optimum fertilizer rate* (kg/10a)

Soil Management group	Year	*Tongil*				Local			
		Number of field	N	P_2O_5	K_2O	Number of field	N	P_2O_5	K_2O
Normal	1976	50	19.5	9.1	7.9	50	17.1	6.4	6.4
	1977	44	24.4	8.4	8.0	16	18.3	6.6	6.6
Sandy	1976	44	17.8	8.7	8.2	44	14.1	6.1	6.6
	1977	38	23.8	8.0	9.2	10	18.2	6.8	7.5
Wet	1976	18	16.3	9.1	10.1	18	14.6	6.5	6.2
	1977	26	23.1	8.6	9.9	—	—	—	—
Unmatured	1976	8	20.0	7.4	9.0	8	15.8	8.2	7.6
	1977	16	23.7	9.0	5.9	4	17.3	9.0	7.8
Saline	1976	3	24.0	5.9	10.4	3	18.9	5.6	5.4
	1977	4	26.4	9.1	8.5	—	—	—	—
Virgin	1977	2	26.9	11.2	12.0	2	24.0	8.1	6.9
Mean	76	128	17.8	8.4	8.1	128	15.0	6.2	6.2
	77	130	24.0	8.5	8.5	32	18.5	6.9	6.8

*Calculated by second order equation.

Table 6. Effect of two-split of urea application on grain yield (kg/10a 1977)

		Normal	Sandy	Unmatured	Virgin	Mean
Tongil line	Number of field	8	6	2	1	17
	4 split	779	732	691	740	750
	2 split	780	697	728	735	742
	2S/4S	100	95	105	99	99
Local leading varieties	Number of field	8	5	2	1	16
	4 split	694	597	657	648	656
	2 split	691	613	657	650	660
	2S/4S	100	103	100	100	101

4-split: 60-20-10-10 (barley-rice two crop field) or 50-20-20-10 (rice one crop field)
2-split: 70-0-30-0
Fertilizer rate: 20-8-8kg/10a N-P_2O_5-K_2O for *Tongil* and 16-6-6kg/10a for local varieties.

groups. The yield of *Tongil* was higher than that of leading local varieties by 16% in 1976 and 23% in 1977 in 322 plot.

The yield of 322 plot in 1977 was higher than in 1976 by 9% in *Tongil* and 3% in the leading local varieties. Solar radiation and air temperature were higher in 1977 and it was very favorable for *Tongil* line. Yield increase by 17% in wet (poor drained) soils in 1977 than in 1976 was probably due to frequent drought in growth stage resulting in lowering of underground water table.

Yield response to higher nitrogen rate was also higher in 1977 for both lines. Response to

Table 7. Relative yield(R) and frequency(F) of higher yield in comparison with 4-split application in various soil management groups (%, 1976)

	Variety	Normal	Sandy	Poorly drained	Unmatured	Saline	Total
2-split	*Tongil*-R	98.1	98.6	98.7	96.4	100	98
(70 : 30)*	*Tongil*-F	36.0	44.0	33.3	35.0	75	39.4
	Local-R	97.9	99.5	101.2	101.9	100	99
	Local-F	20	44	38.9	62.5	50	29.5
SCU**	*Tongil*-R	101	102.4	103.7	100.8	131.7	103
	Tongil-F	44	61.4	72.2	50	100	53.3
	Local-R	102.9	103.2	102	109.6	139.1	104
	Local-F	70	63.6	50	87.5	100	66.7

**Single at transplanting, *70% at transplanting and 30% at ear formation.

Table 8. Effect of SCU on yield (kg/10a, 1977)

		Normal	Sandy	Wet	Unmatured	Saline	Virgin	Mean
Tongil line	Number of fields	42	37	27	16	4	2	125
	Urea 3-split	809	783	792	726	533	623	776
	SCU basal	853	787	808	727	675	747	801
	SCU/urea	105	101	102	100	127	120	103
Leading local var.	Number of fields	15	9	—	4	—	2	30
	Urea 4 split	679	623	—	622	—	549	646
	SCU basal	681	636	—	608	—	653	656
	SCU/urea	100	102	—	98	—	119	102

Urea: 20kg N for *Tongil*, 16kg N for local. SCU: 16kg N for *Tongil*, 12.8kg N for the local, P_2O_5 and K_2O, each 8kg for *Tongil* 6kg for the local.

phosphorus and potassium was also higher in 1977 than in 1976 (Table 3 and 4). Thus the optimum fertilizer rates calculated from the second order response curve were higher in 1977 especially for nitrogen as shown in Table 5. Optimum nitrogen level was higher for *Tongil* by 3.8kg in the ccol year and 5.5kg in warm year than for the local. Yearly variation of optimum nitrogen in the same variety was greater than varietal variation in the same year.

Two-split application in 222 rate showed 98% of yield of 4-split application in *Tongil* and 99% in the local in 1976 (Table 3). In 1977 it was 99% for *Tongil* and 101 for the local at 322 plot (Table 6). This results indicate that the local seems to be better for heavy basal dressing than *Tongil* does but this varietal difference was not significant. Varietal difference seems to be greater according to soil management group as shown in Table 6 and 7 but this varietal response was not consistent in two succesive years. *Tongil* has been known as being favorable to heavy basal dressing[3,10].

Four-split application may be no more economic than two-split application when considered the yearly increase of labor cost. However there seems to be the risk of 1 to 2% yield decrease especially in normal and sandy soils (Table 7) that occupy most area of paddy fields. A decreasing tendency of yield will be a great loss in

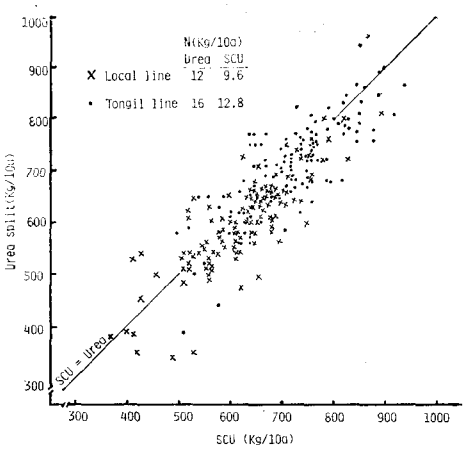

Fig. 1. Relationship between yield with urea split application and with sulfur coated urea (80% of normal urea application, 1976)

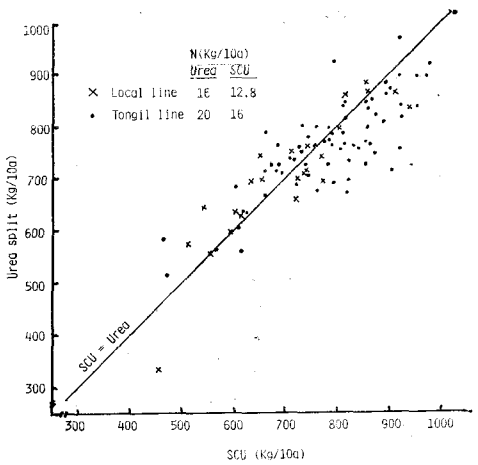

Fig. 2. Relationship between yield with urea split application and with sulfur coated urea (80% of normal urea application, 1977)

national basis even if it is 1% or less.

Sulfur coated urea (SCU) increased yield by 3% for *Tongil* in 1976 and 77 and by 4% for the local in 1976 and by 2% in 1977 (Table 7 and 8) even though nitrogen dose was decreased by 20%. Effect of sulfur coated urea was much different depending on soil characteristics. SCU increased yield by 39% for the local in saline soils and by 10% in unmatured soils in 1976 (Table 7). While it increased by 19% in virgin soils and decreased by 2% in unmatured soils in 1977 (Table 8). For *Tongil* it increased by 32% in 1976 (Table 7) and 27% on saline soils and by 20% on virgin soils in 1977 (Table 8).

Since saline, virgin and unmatured soils are problem soils especially in nitrogen it is well understood that SCU was most effective in such soils. In the saline soils the competative inhibition of sodium on nitrogen uptake may be avoided by slow release of ammonium. Lower response in 1977 might be due to higher organic matter content in saline and unmatured soils (Table 2).

Frequency of higher yield in comparison with 222 plot was 53% in *Tongil* and 67% in the local (Table 7). Frequency of maximum yield through all treatments was 39% in *Tongil* and 43% in the local. Figure 1 and 2 show well the better effect of SCU even though comparing higher levels of nitrogen.

However the consistent trend in yields between urea split and SCU as shown in these figures indicates that even SCU could not change productivity of the fields. Thus SCU opperates not in unusual way but in the simillar mode as urea.

SCU made by IAS is greater in dissolution rate than SCU made by TVA. In 1976 SCU (IAS) was more effective for *Tongil* but less effective for the local (Table 3). This facts were consistent with the varietal response trend to two-split application and SCU (TVA) as shown in Table 7. But contradictory to the decrease yield of two-split plot in both varieties (Table 7).

According to varietal response to nitrogen fertilizer in two years it could be seen that *Tongil* requires more nitrogen in the early stage under the weather of 1976 but in the later stage under the weather of 1977. That is, the better the weather is, the more nitrogen nutrition is required in that growth stage.

Acknowledgement

We thank Drs. D.A. Nethsinghe, P.M. Cate

and other staffs in IAEA for their kind help on this project. We greatly appreciate the effort of researchers in all Provincial Office of Rural Development to carry out NPK trials. Our thanks are also extended to Tennessee Valley Authority (USA) for generous supply of sulfur coated urea.

Abstract

For the investigation of efficient use of fertilizer nitrogen NPK simple trials were carried out using newly bred *Tongil* line(japonica indica hybrid selection) and the leading local varieties with sulfur coated urea in fields for two years. The yield of *Tongil* line was higher than that of leading local varieties by 16% in the cool year and 23% in warm year with high solar radiation from NPK simple trials including SCU and 2-split application which were carried in 130 fields at 32 locations. Warm year increased yield by 9% in *Tongil* but only 3% in the local than the cool year did. Optimum nitrogen level was higher in *Tongil* by 3.8kg in the cool year and 5.5kg in warm year than for the local. Yearly variation of optimum nitrogen in the same variety was greater than varietal variation in the same year.

Two-split application resulted in 1 to 2% of inconsistent yield variation. Sulfur coated urea increased yield by average 2 to 4% even at 20% reduced rate of nitrogen. It was remarkablly effective in saline (27~39%), virgin (20%) and unmatured (10%) soils.

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