AN EXPERIMENT ON THE METHOD OF APPLICATION OF UREA ON RICE

by

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FOREWORD

The purpose of this experiment is to find the most effective method of application of ure on paddy. In this experiment the following factors i. e. 1) time of irrigation after the urea application. 2) placement of urea. 3) times of application. 4) use of ball fertilizer, are taken into consideration which we suppose to be the most essential ones in determing the method of application for rice in the present stage.

Localities and Cooperating Agencies

Locality	Cooperating agency
Taipei	Taiwan Agrcultural Research Institute.
Taipei	Taipei District Agricultural Improvement Station.
Taoyuen	Taiwan Agricultural Research Institute.
Hsinchu	Hsinchu District Agricultural Improvement Station.
Taichung	Taichung District Agricultural Improvement Station.
Pintung	Kaohsiung District Agricultural Improvement Station.
Chiayi	Chiayi Branch Station TARI.
Lotung	National Bureau of Agricultural Research.

EXPERIMENTAL DESIGN

Design I.

Experimental factors:

A. Time of irrigation after application of urea.
   - G_0 Immediately after application.
   - G_1 3 days after application.
   - G_2 6 days after application.

B. Placement of urea.
   - L_0 Surface placement.
   - L_1 Deep placement.

C. Time of application of urea.
   - T_0 All applied as basal dressing.
   - T_1 ½ applied as basal dressing, ½ applied as top-dressing 20 days after transplanting.

T_2 ⅓ applied as basal dressing, ⅓ applied as 1st top-dressing 20 days after transplantation, ⅓ applied as 2nd topdressing 40 days transplantation.

Note: 1. Double split plot design is adapted with 4 replication.

T_0 T_1 T_2 / L_0 L_1 / G_0 G_1 G_2

Field arrangement

	L_0	L_1
G_0	T_0 T_1 T_2	T_0 T_1 T_2
G_1	T_0 T_1 T_2	T_0 T_1 T_2
G_2	T_0 T_1 T_2	T_0 T_1 T_3

2. Plat size is $^1/_{1000}$ ha. The rate of $N:P_2O_5:K_2O$ is 80:80:80 kgs/ha.
3. Treatments of different placements in case of top-dressing are so handled that the deep placement can improve the mixing of urea with soil, and the surface placemout by applying the urea after weeding.
4. Treatments of different times of irrigation are effected only in case of basal dressing.

Design II.

Experimental factors:

A. Nitrogen source
- U Urea
- Ub Urea ball
- S Ammonium sulphate.

B. Time of application
- T_0 All applied as basal dressing.
- T_1 ½ applied as basal dressing, ½ applied as to top-dressing 30 days (20 days in 2nd crop). after transplanation.
- T_2 ⅓ applied as basal dressing, ⅓ applied as 1st top-dressing 20 days (10 days 2nd crop) after traasplantation, ⅓ applied as 2nd top-dressing 40 days (30 days in 2nd crop) after transplantation.

C. Amount of nitrogen:
- A_0 No nitrogen
- A_1 Nitrogen 40 kgs/ha
- A_2 Nitrogen 80 kgs/ha

Treatment:

1. A_0	6. Ub T_0 A_1	11. S T_1 A_2
2. U T_0 A_1	7. Ub T_0 A_2	12. U T_2 A_1
3. U T_0 A_2	8. U T_1 A_1	13. U T_2 A_2
4. S T_0 A_1	9. U T_1 A_2	14. S T_2 A_1
5. S T_0 A_2	10. S T_1 A_1	15. S T_2 A_2

Note: Fifteen treaments with 4 replication are arranged in randomized block. Plot size is $^1/_{1000}$ ha, The rate of P_2O_5: K_2O is 80:80 kgs/ha.

Urea ball is prepared as follows. Dissolve the Urea in water and mix it with dry clay soil (Urea soil ratio is 175:1000 when 80 kgs/ba is desired). The urea-clay mixture can be made into balls. 3 cm in diameter with hands, Put into the center of every four rice hills at the depth of about 10 cm.

DISCUSSION (DESIGN I)

In the first place, the effect of different time of irrigation after the application of urea is examined. The idea of testing this factor arises from the fact that urea is hardly adsorbed by the soil colloid such that its retention in the soil may be badly attained if leaching takes place intensively as can be expected in the sandy soil under flooding, whereas the ammonia liberated by the decomposition of urea which can be finished in the ordinary condition within 3–5 days, is strongly adsorbed by the soil colloid. This consideration makes us to suppose whether it is necessary to delay the flooding of the field for a certain interval after the urea application. The results found are far from our expectation. Few of the data show significant result. Moreover, they are found to conflict each other. Therefore, a generalized conclusion seems impossible. However, it is a striking fact to note that most of the data listed in Table 1 show significant interaction between the time of irrigation after the urea application and placement of urea, provided they interact in different way.

Table 1. Effect of Different Time of Irrigation and Fertilizer Placcements on Paddy Yield (Unit kgs/h)

locaalily	Taipei (TARI)				Lo tung				Pintung		Taipei (AIS)	
Year	1955		1956		1955		1955		1955		1955	
Crop	1st		1st		1st		2nd		2nd		1st	
	L_0	L_1	L_0	L_1	L_0	L_1	L_0	L_1	L_0	L_1	L_0	L_1
G_0	1,990	2,315	2,614	2,614	3,465	3,498	2,662	2,585	3,452	3,262	2,752	2,634
G_1	2,207	2,550	2,546	2,921	3,234	3,652	2,768	3,201	3,447	3,346	2,570	2,488
G_2	2,380	2,410	2,564	2,849	3,130	3,385	2,742	3,188	3,105	3,215	1,992	2,124
L. S. D_1	251	386	244	396	230	307	355	532	181	157	306	524
L. S. D_2	176	256	142	205	163	236	230	331	283	237	125	189

Note:
- G_0: Immediate irrigation after application.
- G_1: Irrigation 3 days after application.
- G_2: Irrigation 6 days after application.
- L_0: Surface placement.
- L_1: Deep placement.
- L. S. D_1: To be used for the significant test among the different times of irrigation at the same placement.
- L. S. D_2: To be used for the significant test between two nethods of placement at the same time of irrigation.

Data showing an adverse effect of immediate flooding after the urea application are found in Taipei (TARI) 1st crop 1955, Taipei (TARI) 1st crop 1956 and Lotung 2nd

crop 1955, Though these data can be interpreted on the assumption just mentioned, in writor's opinion its justification still requires more evidence. On the ther hand, we can see a more significant fact in Lotung 1st crop 1955, Pintung 2nd crop 1955 and Taipei (AIS) 1st crop 1955 showing an adverse effect of prolonged delay of flooding after the urea application, especially in the case of surface application. This fact can be well explained by the experimental result on the volatilization of ammonia by urea application showing the ammonia loss through this action in the concentrated urea-soil solution (1). If this is the case the more outstanding effect of irriggation taken place 6 days after application in the surface placement than in the deep placement can be easily recognized.

So far as we have considered, the contribution of this experimental result to our fertilization practice may be summarized as follows. Flooding within 6 days after the urea application will have little influence on its availabilty so long as the deep placement is effected. However any further dalay, particulary in the case of surface placement seems undesirable.

Secondly, the effect of diffeent placement is to be dicussed here. In contrast with the time of irrigation, the effect of this factor shows greater consistancy in defferent experimental data. From these results, the importance of this factor in determining the method of epplication is recognized.

Here, again the interaction with the time of irrigation is taken for discussion, i. e. the effect of placement as affected by the different time of irrigation. In Taipei 1st crop 1956, Lotung 1st crop 1955, and Lotung 2nd crop 1955, the interaction found illustrates the importance of deep placement, especialy in the of case of prolonged irrigation. To a less extent this importance role played by the deep placement in the case of immediate irrigation may be interpreted as follows. If the soil is low in moisture content befor irrigation, the urea placed on the surface will be carried into the deep place by the irrigated water, due to the great solubitity and mobility of urea on one hand, and rapid penctration of water into the drier soil on the other. This situation seems to equalize the effects of the two differe methods of placement. A similer situation, however, to a greater extent is found in Pintung 2nd crop 1955 and Taipei (AIS) 1st crop 1955 in which even a higher yield results from the surface placement in the case of mimediate irrigation. Although the accentuated loss of urea by leaching in the case of deep placement may be suggested for its cause, the truth still remains obscure.

In Lotung 1st crop 1955 and Lotung 2nd crop 1956, it is found that placement of urea has interaction with time of application illustrating the more important role played by the deep placement when urea is applied at one time than when it is applied in three time. (See Table 2) This fact provides another evidence to illustrate the accentuated loss of nitrogen in concentrated urea-solution.

Table 2. Effect of Different Time of Application and Fertilizer Placements on Paddy Yield (Unit kgs/ha)

Locality	Lotung			
Year	1955		1956	
Crop	1st		2nd	
	L_0	L_1	L_0	L_1
T_0	3,245	3,662	2,796	3,243
T_1	3,317	3,536	3,004	3,181
T_2	3,267	3,337	3,241	3,392
L. S. D_1	163	219	231	351
L. S. D_2	163	236	230	331

Note:
T_0: All applied as basal dressing.
T_1: ½ applied as basal dressing, ½ applied as top-dressing 20 days after transplantation.
T_2: ⅓ applied as basal dressing, ⅓ applied as 1st top-dressing 20 days after transplantation, ⅓ applied as 2nd top-dressing 40 days after transplantion.
L_0: Surface placement.
L_1: Deep placement.
L. S. D_1: To be used for the significait test among the differen times of application at the same placement.
L. S. D_2: To be used for the significant test between two method of placement at the same time of application.

Thirdly the effect of different times of application is to be discussed here. It may be considered from two different stand-points, i. e. the physiological and external effect. Recently, a considerable stress has been laid on the effect of nitrogen top-dressing just before earing by the Japanese investigators (2). It has been reported that throughout the entire growing season, rice exhibits two peaks in the uptake of nitrogen, and the second peak corresponds to the stage just mentioned. So far as our experimental design is concerned, the period involved in the top-dressing covers only the first peak, not extending to the second one. Since less significance can be attached to the first peak along with the retention of nitrogen in the soil, the physiological significance may be more or less limited in this experiment. As to the external effect, we consider the split application to prevent the soil from being over-concentrated in nitrogen which is detrimental to its retention. As we can see from the experimental data this factor is less affected by the others. The results found are in good accordance in all localities, showing the higher yield to occur in the split application irrespective to the times of irrigation and placements.

As for the interaction between time of application and depth of placement, it seems sufficient to say that the the effect of split application is more significant in the surface placement, as we can see in Lotung 2nd Crop. 1956, (See Table 2). In Lotung 1st Crop 1955, another, situation is found where split application gives low

yields, which may be attributed to the fact that inspite of the benificial effect of deep-placement it can only be poorly effected in the case of top-dressing. A rather peculier result occurring in Pintang can not be well interpeted.

Table 3. Effect of Different Times of Application on Paddy Yield (Unit kgs/ha)

Localily	Taipei (TARI)			Lotung		Pintung		Chiayi	Taich-ung	Hsinchu
Year	1956	1957	1957	1955	1957	1955	1955	1955	1955	1955
Crop	1st	1st	2nd	2nd	2nd	1st	2nd	1st	2nd	1st
T_0	2,597	2,279	3,017	2,786	3,149	4,052	3,379	3,321	3,170	2,800
T_1	2,706	2,512	3,076	2,605	3,286	3,862	3,228	3,404	3,374	2,970
T_2	2,747	2,337	3,209	3,123	3,435	4,126	3,308	3,737	3,900	3,250
L. S. D.	105 141	124 166	155 206	133 179	126 172	193 262	97 132	169 229	182 247	138 185

Note: For T_0, T_1 & T_2 see Table 2.

DISCUSSION (DESIGN II)

Firstly, we are going to consider the difference between ammonium sulphate and urea. However, this problem is made rather complicated by the interaction with different times of application in same experimental data.

Table 3. Effect of Different Times of Application and Nitrogen Source on Paddy Yield (Unit kgs/ha)

Locality	Taipei (AIS)			Taoyuen					
Year	1957			1956			1956		
Crop	2nd			2nd			1st		
	T_0	T_1	T_2	T_0	T_1	T_2	T_0	T_1	T_2
Ub	2,581			4,324			4,944		
U	2,456	2,526	2,550	3,838	3,933	4,178	4,728	4,589	4,560
S	2,618	2,560	2,546	3,871	4,004	4,096	4,368	4,655	4,754
L. S. D.	95 124			200 268			264 352		

Locality	Chiayi						Pintung		
Year	1956			1957			1956		
Crop	2nd			1st			1st		
	T_0	T_1	T_2	T_0	T_1	T_2	T_0	T_1	T_2
Ub	3,662			5,950			4,358		
U	3,125	3,350	3,512	5,462	5,050	5,300	3,772	3,783	3,630
S	3,413	3,550	3,625	5,300	5,000	5,300	3,689	3,774	3,995
L. S. D.	222 296			353 472			232 309		

Note: Ub: Urea ball.
U.: Urea.
S.: Ammonium sulphate.
T_0: All applied as basal dressing.
T_1: ½ applied as basal dressing, ½ applied as top dressing 30 days (26 days in 2nd crop) after transplantation.
T_2: ⅓ applied as basal dressing, ⅓ applied as 1st top dressing 20 days (10 days in 2nd crop) after transplantion, ⅓ applied as 2nd top-dressing 40 days (30 days in 2nd crop) after transplantation.

Only in Taipei (AIS) 1st Crop 1956, and in Chiayi 2nd Crop 1956, there exists significant difference irrespective of the different times of application, showing the higher yield of ammonium sulphate over that of urea.

Table 5. Effect of Different Nitrogen Source on Paddy Yield (Unit kgs/ha)

Locality	Taipei (AIS)	Taoyuen			Chiayi	
Year	1956	1956	1957	1957	1956	1957
Crop	1st	2nd	1st	2nd	2nd	1st
Ub	3,200	4,324	4,569	4,042	3,662	5,950
U	3,049	3,996	4,305	3,539	3,329	5,271
S	3,199	3,990	4,246	3,337	3,529	5,200
L. S. D_1	88:117	116:155	152:203	147:176	129:171	204:273
L. S. D_1	124:165	164:219	214:287	208:248	182:241	288:386

Note: For Ub. U & S See Table 5.
L. S. D_1 To be used for the significant test between urea and ammonium sulphate.
L. S. D_2 To be used for the significant test between urea ball and others.

In Taipei (AIS) 2nd Crop 1957 and in Pintung 1st Crop 1957. it is found that the crop yield of ammonium sulphate is significantly higher than that of urea only in the case of basal dressing, and the difference is much decreased by split application. This fact suggests that the nitrogen loss is higher in urea than in ammonium sulphate under high nitrogen concentration in the soil. In Pintung 1st Crop 1956, the situation is just reversed, and we find that the Crop yield of ammonium sulphate is significantly higher than that of urea in the case of two times of top-dressing. In Taoyuen 1st Crop 1956, the Crop yield of urea is significantly higher than that of ammonium sulphate in the case of basal dressing and that difference is decreasd by split application. Reasons so far considered can not account for the latter two examples, howerer, we suppose that the poorly effected mixing of fertilizer with the soil in top-dressing seems to lower the availability to a greater extent in urea than in ammonium sulphate.

Secondly, we are going to examine the effectiveness of urea ball. Most of data given in Table 4 & 5 invariably show the highest Crop yield of urea ball in all experimental localites except in Taipei (AIS) Here, we are interested in the fact whether there exist any similerity between the effect of urea ball and that of split application. In Taipei 2nd Crop 1957, Taoyuen 2nd Crop 1956, Chiayi 2nd Crop 1956,

we find the effect of urea ball to exceed that of split application. In Taipei 1st Crop 1956, Taoyuen 1st Crop 1956, Taoyuen 1st Crop 1957, Taoyuen 2nd Crop 1957, and Pintung 1st Crop 1956, we find no significant increament of Crop yield attained by the split application, neverthless, the effect of urea ball is significant. In Chiayi 1st Crop 1957, the split application gives diverse effect, yet the effect of urea ball is significant. From these facts, we conclude that the urea ball has its specific effect distinct from that of split application. Here, it should be noted that the effect of balling the fertilizer is not limited to urea only, it is well applied in ammonium sulphate (3). Although the effect of urea ball has been so far recognized, very little information is available concerning its mechanism involved in the soil-plant relationship. However, it may be easily inferred that. 1) more Complete retention of nitrogen can be attained. 2) urea ball provides more reasonable way of supplying nitrogen to plant. For the more comprehensive interpretation it should depends on future research.

Thirdly, the effect of split application is to be dicussed here, of which the significance has been already given in the discussion of Design I. It is to be noted that the different placement is not taken into account in design II, however, the placement to be followed here, is according to the deep placement as is specified in design I. It has been fore-mentioned in the discussion of design I, that a tendency to make the effect of top-dressing insignificant by the deep placement has been observed. This situation seems to be more apparently mainifested here, thus we find only in Taipei (AIS) 1st Crop 1957, Taoyuen 2nd Crop 1956, Chiayi 2nd Crop 1956, Pintung 2nd Crop 1956, Pintung 1st Crop 1957, that the beneficial effect of split application is significant.

Table 6. Effect of Different Time of Application on Paddy Yield (Unit kgs/ha)

Locality	Taoyuen	Taichung		Chiayi		Pintung	Taipei (AIS)
Year	1956	1956	1957	1956	1957	1956	1957
Crop	2nd	1st	1st	2nd	1st	2nd	1st
T_0	3,854	4,192	4,062	3,268	5,381	3,231	2,996
T_1	3,968	3,964	3,926	3,450	5,025	3,355	3,086
T_2	4,142	3,823	3,788	3,569	5,300	3,421	3,179
L. S. D.	142:190	228:304	129:173	158:210	250:334	72:95	95:127

Note: For T_0, T_1 & T_2 see Table 4.

The significance of the interaction between differnt times of application and different nitrogen source has been suggested in the preceeding discussion. From the standpoint of times of application it may be summarized as follows. In Pintung 1st Crop 1957, Taipei (AIS) 2nd Crop 1957 there exists an evidance illustrating the more improtant role played by the split application of urea than of ammonium sulphate. In Taoyuen 1st Crop 1956 and Pintung 1st Crop 1956, however, this situation is just reversed. Some interpretation has been given above. In Taichung 1st Crop 1956,

Taichung 1st Crop 1957, and chiayi 1st Crop 1957, the split application is found not only ineffective, but even an adverse effect has resulted irrespective of different nitrogen source.

SUMMARY

1. Irrigation within 6 days after the urea application has no significant influence on its availability so long as the deep placement is concerned.
2. Deep placement is the most essential in the application of urea, particulerly when the irrigation has been delayed.
3. Part of the urea used in top-dressing once or twice 20~40 days after the transplantation may increase the paddy yield significantly, neverthless, mixing with soil is not to be overlooked.
4. Balling the urea with some clay soil (urea soil, 175:1000) is the most effective method of application which increase the paddy yield by about 9% as a general average.
5. Urea does not differ greatly from the ammonium sulphate in its availability, however, in some experimental data, ammonium sulphate is found to be more effective.

LITERATURE

(1) LEE. L. T.: An Experiment on the Method of Application of Urea on Rice. p. 64. Agricultural Resarch Vol. 6, No. 4. 1957.
(2) MITSUI SHINGO: Inorganic Natrition Fertilization and Soil Amelioration for Lowland Rice p. 35-40 1956. Yokendo Tokyo.
(3) DITTO: p. 84.

ADDITIONAL TABLE FOR FURTHER REFERENCE

Design I

Effects of Different Times of Irrigation and Fertilizer Placements on Straw Yields (Unit kgs/ha)

Locality	Taipei (TARI)		Lotung		Chiayi	
Year	1955		1955		1955	
Crop	1st		2nd		2nd	
	L_0	L_1	L_0	L_1	L_0	L_1
G_0	2,225	2,487	3,652	3,800	4,002	3,956
G_1	2,502	3,027	3,699	4,009	4,237	4,101
G_2	2,794	2,727	3,730	4,382	3,725	4,156
L. S. D_1	415	621	311	464	312	510
L. S. D_2	277	398	225	324	191	288

Note: Table 1.

Effects of Different Times of Application and Fertilizer Placements on Straw Yield (Unit kgs/ha)

Locality	Taipei (TARI)		Lotung					
Year	1956		1955		1955		1957	
Crop	1st		1st		2nd		2nd	
	L_0	L_1	L_0	L_1	L_0	L_1	L_0	L_1
T_0	2,349	2,734	3,596	4,734	3,575	4,248	3,560	4,441
T_1	2,586	2,692	3,851	4,607	3,761	3,975	4,132	4,377
T_2	2,584	2,779	4,443	4,899	3,745	3,968	3,933	4,151
L. S. D_1	139	187	195	262	265	354	373	569
L. S. D_2	134	183	248	344	252	343	370	519

Note: See Table 2.

Effect of Different Times of Application on Straw Yield (Unit kgs/ha)

Localitg	Taipei (TARI)			Taipei (AIS)	Taichung		Pintung
Year	1955	1956	1957	1955	1955	1955	1955
Crop	2nd	2nd	1st	1st	1st	2nd	1st
T_0	4,328	3,723	2,869	3,267	6,239	3,608	3,394
T_1	4,507	3,836	3,151	3,248	5,778	3,806	3,197
T_2	4,309	4,125	3,320	3,110	5,983	4,261	3,594
L. S. D	140 188	161 216	206 276	130 176	261 354	126 171	168 227

Note: See Table 3.

Design II

Effect of Different Times of Application and Nitrogen Source on Straw Yield (Unit kgs/ha)

Locality	Taipei (AIS)			Taoyuen			Taichung		
Year	1956			1957			1957		
Crop	1st			1st			1st		
	T_0	T_1	T_2	T_0	T_1	T_2	T_0	T_1	T_2
Ub	2,444			3,520			4,608		
U	2,406	2,363	2,306	3,133	3,245	3,338	4,144	4,094	4,056
S	2,350	2,400	2,578	3,173	3,265	3,438	4,381	4,194	4,125
L. S. D.	112 150			209 280			153 204		

Locality	Chiayi						Pintung		
Year	1957			1956			1957		
Crop	1st			1st			1st		
	T_0	T_1	T_2	T_0	T_1	T_2	T_0	T_1	T_2
Ub	7,575			6,675			*		
U	6,225	6,225	6,075	6,388	5,938	5,750	3,061	3,740	3,508
S	7,375	6,225	6,600	6,088	5,975	5,938	3,790	3,763	3,753
L. S. D.	268 358			388 510			353 471		

Note: See Table 4.
*Missing data.

Effect of Different Nitrogen Source on Straw Yield (Unit kgs/ha)

Locality	Taipei (AIS)	Taoyuen		Taichung	Chiayi	Pintung
Year	1957	1957	1956	1957	1956	1956
Crop	2nd	1st	1st	1st	1st	1st
Ub	2,834	3,520	4,918	4,608	6,675	3,781
U	2,505	3,238	4,425	4,098	6,025	3,423
S	2,516	3,292	4,484	4,234	6,000	3,476
L. S. D_1	166 222	121 161	219 293	88 118	224 300	186 248
L. S. D_2	234 313	209 280	310 415	153 204	388 510	262 350

Note: See Table 5.

Effect of Different Times of Application on Straw Yield (Unit kgs/ha)

Locality	Taoyuen	Taichung	Chiayi			Pintuug
Year	1957	1957	1956	1956	1957	1956
Crop	1st	1st	1st	2nd	2nd	2nd
T_0	3,153	4,263	6,238	3,406	3,563	3,394
T_1	3,255	4,144	5,956	3,669	4,050	3,439
T_2	3,388	4,091	5,844	3,681	3,738	3,665
L. S. D.	121 161	108 144	269 360	191 256	300 402	130 173

Note: See Table 6.

尿素肥料施肥法試驗成績

(第 二 報)

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國 文 摘 要

1. 只要做深部施肥，施肥後的灌溉時期在6天內不致有顯著影響。
2. 深部施肥是尿素施肥中最重要的因素，在延遲施肥後灌溉的場合尤須遵行。
3. 部份的尿素用於追肥仍有功效，但須與土壤充分混合。
4. 尿素作爲團球使用（混合比爲尿素175對土壤1000），爲尿素施肥法中最有效的辦法比通常使用法平均增產9%之效果。
5. 尿素與硫酸銨不見有顯著差異，在少數成績中，仍有硫酸銨較優之趨勢。