Studies on the placement of ammonium sulphate for lowland rice using isotopically labelled fertilizers

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INTRODUCTION

PLACEMENT of fertilizer in relation to the plant generally ensures better utilization of applied nutrients. Under conditions that exist in flooded rice culture sub-surface placement of ammonium fertilizers prior to flooding or ball placement after transplanting leads to their more efficient use, because ammonium nitrogen is not likely to be lost due to oxidation and denitrification if placed in the reduced regions of the profile (2, 3, 7, 8).

The use of isotopically labelled fertilizers enables the evaluation of the efficiency of fertilizer uptake from a source and the estimation of the percentage taken up. Earlier work in Ceylon with labelled nitrogen and phosphorus fertilizers indicated that placement of ammonium sulphate at a depth of 5 cm. from the surface resulted in better uptake of both nitrogen and phosphorus by rice (5).

This report contains the results of the fourth investigation conducted in Ceylon under the Co-ordinated Contract Programme sponsored by the Joint FAO/IAEA Division of Atomic Energy in Agriculture, Vienna, to determine the most efficient use of nitrogenous and phosphate fertilizers for rice using isotopically labelled fertilizers The findings of previous investigations in this series have already been reported (1, 4, 5).

The objects of this investigation were—

(i) to study the efficiency of utilization of ammonium sulphate by different placement methods ;

(ii) to study the interaction between nitrogen placement and the utilization of superphosphate, applied broadcast at transplanting.

EXPERIMENTAL

Five methods of nitrogen application for rice were studied at the Agricultural Research Station, Maha Illuppallama, during the wet season, Maha 1966/67. The experiment was a randomized complete block design of five treatments with six replicate on a soil, some characteristics of which are presented in Table I. The treatments were as follows :—

A .. Broadcast on the surface
B .. In rows, on the surface
C .. In rows at 5 cm. depth from the surface
D .. In rows at 10 cm. depth from the surface
E .. In rows at 15 cm. depth from the surface

Fertilizers were placed at different depths according to the procedure adopted by Nagarajah and Al-Abbas (5). Ammonium sulphate at the rate of 60 Kg. N per ha. was used for all treatments. The excess of N^{15} in sub-plots with labelled fertilizers was 0.90 atom per cent. Superphosphate at the rate of 60 Kg. P_2O_5 per ha. was broadcast on the surface in all treatments. In the sub-plots with labelled fertilizers, the superphosphate was labelled with P^{32} at approximately 0.2 to 0.4 mc. per gm. P_2O_5. All plots received muriate of potash at 60 Kg. K_2O per ha. as a basal application at planting.

The construction of plots, nursery preparation, transplanting, precautions observed in the handling of P^{32} fertilizer and other cultural practices were similar to those of earlier experiments (1, 4, 5).

Each experimental plot was divided into three sub-plots as follows :—

1. Radioactive sub-plot .. 1.56 sq. metres
2. Intermediate yield sub-plot .. 1.88 sq. metres
3. Final yield sub-lot .. 3.44 sq. metres

The 4–4½ month Indica variety of rice H_4 was used in this investigation. Mean monthly climatological data from nursery to harvest are presented in Table II.

Plants were sampled at two stages ; 40 days and 122 days from transplanting. At the earlier harvest two fully developed young leaves of each of the nine centre hills were harvested from the labelled (radioactive) sub-plots. These were bulked and dried at 70°C. From the intermediate yield sub-plots all twelve centre hills were harvested completely, dried at 70°C and dry weights recorded.

At the final harvest nine centre hills of the labelled (radio-active) sub-plots were harvested, the grain and straw separately. All twenty-seven centre hills of the final yield sub-plots were also harvested, grain and straw separately.

Leaf samples from the radioactive sub-plots at 40-day harvest were analysed for N^{15} and P^{32} at the IAEA Laboratory, Vienna ; while the material from the intermediate yield sub-plots were analysed for N^{14} and P^{31}. Details of analytical procedure were as described in the first experiment of the series (4). Grain and straw samples at the final harvest could not be analysed as intended because the samples were lost in transit from Ceylon to Vienna.

RESULTS AND DISCUSSION

Plant Growth :

Plant Height.—The mean heights of plants as affected by treatments at three stages of growth are presented in Table III. The differences in plant height were not significant at 14 and 40 days from transplanting most probably because it was too early for treatments to be effective. At final harvest, 122 days from transplanting, however the differences in plant height were highly significant. Plants in plots where nitrogen was placed in rows at 5, 10 and 15 cm. depth were significantly taller than those in plots where the fertilizer was broadcast on the surface.

The height of a rice plant is not always positively related to grain yield. Excessive height may in fact contribute to loss of yield if plants were to lodge before grain filling. In this experiment there appears to be a positive relationship between plant height and weight of filled grain (Table V).

Tiller Numbers. As in plant height the number of tillers per hill was not significantly affected by treatments at 14 and 40 days from transplanting, probably because it was too early for treatments to be effective (Table III). At harvest, however, 122 days from transplanting, the treatments showed highly significant differences. Plants in plots where nitrogenous fertilizer was broadcast on the surface or applied in rows on the surface hand significantly lesser number of tillers per hill than plants in plots where the fertilizer was placed in rows at 5, 10 and 15 cm. depth. There was a close parellelism between tiller numbers and the number of panicles per hill which is also reflected in grain yield. It will be noted later, that among the yield components the number of panicles per hill contributed most to grain yield (Table V). There appears to be a positive relationship between number of tillers and weight of straw.

Dry Matter Production. The effect of the method of fertilizer application on total dry matter production is seen in Table IV.

At the early harvest, 40 days from transplanting, the total dry matter produced by plants in plots where nitrogenous fertilizer was applied in rows at depths of 5, 10 and 15 cm. was greater than that produced by plants in plots where fertilizer was broadcast or applied in rows on the surface. At this stage the greatest dry matter production was in plots where ammonium sulphate was placed at a depth of 5 cm. As the depth of placement of fertilizer increased the dry matter production is observed to decrease. This perhaps is related to the depth of root development in the soil and most probably the fertilizer at the 5 cm. depth was more available to plants at this stage of growth, than that placed deeper. Among the surface treatments the indications are that broadcasting the fertilizer is better than concentrating it in rows, as the former method distributes it over a larger area for absorption by roots than does the latter method. Dry matter production at the early harvest is related to plant height and number of tillers per hill.

The data at the final harvest in Table IV indicates that deeper placement of ammonium sulphate (15 cm. from surface) yielded more dry matter than shallow placement (5 cm. from surface) although the opposite relationship was observed at the earlier harvest. This may be related to the extent and depth of root development during the atter half of plant growth. It is probable that plants in plots where ammonium sulphate was placed deepest had longer (and more) roots than those in plots where it was placed closer to the surface. The increased root surface would have enabled these plants to absorb other nutrients as well compared to those with shorter and less extensive root systems from other treatments. It must however be noted that increased dry matter production is of little value with rice unless accompanied by proportional increases in grain yield.

Among the surface applications, broadcasting the fertilizer uniformly produced more dry matter than when it was concentrated in rows as seen at the earlier harvest.

The data on yield in Table V shows a close parellelism between total dry matter production up to final harvest and yield of filled grain. This relationship will not be true under all conditions for excessive vegetative growth is known to depress grain yields in rice.

As expected the weight of straw at final harvest appeared to be directly related to the total dry matter produced.

Grain Yield and Yield Components

The effect of treatments on grain yield and yield components is shown in Table V.

Filled and unfilled Grain. The effect of treatments on yield of filled and unfilled grain was highly significant. Sub-surface placement of ammonium sulphate at 5, 10 or 15 cm. produced significantly higher yields than surface applications, broadcast or in rows. The highest yield was obtained when the fertilizer was placed 15 cm. below the surface and the lowest yield was obtained when the fertilizer was applied in rows on the surface.

Filled Grain. The yield of filled grain followed the same trends as that of filled plus unfilled grain, the treatments showing highly significant effects. Placement of ammonium sulphate 15 cm. below the surface produced approximately 1,900 Kg. per ha. (1695 lbs. per acre) more than when this fertilizer was applied in rows on the surface. Further, the effectiveness of fertilizer applications increased with greater depth of placement. The 15 cm. placement gave an additional yield of 1,322 Kg. per ha. over the surface broadcast application, while the yield increases from the 10 and 5 cm. placements over the surface broadcast application were 828 and 723 Kg. per ha. respectively. The lower yields in plots where ammonium sulphate was applied on the surface may most probably be due to losses of fertilizer through oxidation and denitrification as has been postulated by Pearsall (6).

Number of Panicles per Hill. Treatments had highly significant effects on the number of panicles per hill. Placement of fertilizer nitrogen at depths of 5, 10 and 15 cm. encouraged more panicles per hill than surface applications. There appears to be a positive correlation between the number of tillers and the number of panicles per hill.

Panicle Weight, Weight per 1,000 Grains and Percentage Ripened Grain. Method of nitrogen application had no significant effect on panicle weight, weight per 1,000 grains and on the percentage of ripened grains although grain yields were affected at the 1 per cent level of probability. These results are similar to those of Nagarajah and Al-Abbas (5).

Grain : Total Dry Matter Ratio. The efficiency of grain production in comparison to dry matter production as influenced by method of nitrogen placement is seen in Table V. Deeper placement of fertilizer, (10 or 15 cm. from the surface) resulted in narrower ratios than shallow placement (5 cm. from the surface). Broadcast application of fertilizer on the surface appears to result in better grain production in comparison to total dry matter, than surface application in rows.

Grain : Straw Ratio. The most efficient distribution of dry matter between grain and straw was observed when ammonium sulphate was placed at a depth of 15 cm. from the surface. This was followed by treatments where fertilizer was placed at 10 cm. from the surface, and broadcast on the surface. The narrow grain : straw ratio as a result of deeper placement (15 cm.) in spite of the significantly higher straw yield (Table IV) is a reflection of the higher grain yields in this treatment.

Utilization of Fertilizer Nitrogen and Phosphorus

The only data available on N^{15} and P^{32} analysis is of plant material from the first harvest (40 days after transplanting), because plant material harvested at maturity was lost during transport to Vienna.

The effect of treatments on the concentration of nitrogen in plant shoots and the percentage of nitrogen derived from the fertilizer were highly significant (Table VI).

The highest concentration of nitrogen was in plants from plots where ammonium sulphate was placed at a depth of 15 cm. from the surface. This was significantly different only from the broadcast application at the surface. The relatively higher concentrations of nitrogen in treatments where fertilizer was placed at depth is probably reflected in the higher grain yields in these treatments.

The highest percentage of nitrogen derived from the fertilizer was also found in plants from plots where ammonium sulphate was placed at a depth of 15 cm. from the surface. This value was different only from the treatment where fertilizer was placed in rows on the surface.

The method of nitrogen placement had no effect on either the percentage total phosphorus in plant shoots or on the percentage of this nutrient derived from fertilizer phosphorus broadcast on the surface. However it appears that placement of ammonium sulphate at 15 cm. depth resulted in the highest concentration of phosphorus in the shoots in comparison to other treatments, although the percentage of the nutrient derived from the fertilizer appeared to be the lowest.

CONCLUSIONS

The results of this investigation substantiates the findings of other investigators (2, 3, 7, 8) that sub-surface placement of ammonium sulphate gives increases in yield over surface applications of the fertilizer. This yield increase is associated with a higher concentration of nitrogen in plants. (Only data available is for plants 40 days from transplanting.) Among the yield components, the greatest contribution to yield was from the number of panicles per hill.

It is possible that losses of ammonium sulphate were responsible for the low yields and lower concentration of nitrogen in plants from plots where surface applications were made.

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TABLE I.—Characteristics of the Soil at Location of Experiment (Maha Illuppallama)

Depth (cm.)	0–20	20–40
Texture	Sandy Loam	Sandy Loam
pH (1 : 1–Soil : H_2O)	6·7	6·6
E. C. (1 : 5), (1 : 5) millimhos/cm.	0·1260	0·1121
Organic Matter %	2·39	1·94
Total Nitrogen %	0·127	0·123
Available P_2O_5 (Olsen's) (lbs P_2O_5/acre)	20·90	16·72
Cation Exchange Capacity (m.e/100g.)	15·2	14·0
Exchangeable Cations (m.e./100g.)		
Calcium	8·06	7·57
Magnesium	4·83	4·21
Potassium	0·21	0·18
Sodium	0·76	0·74
Total Exchangeable Bases (m.e./100g.)	13·88	12·74

TABLE II.—Mean Monthly Climatological Data from Nursery to Harvest

	Temperature °F		*Wind * (m.p.h.)*	*Sunshine (hrs./day)*	*Rainfall (inches)*
	Maximum	*Minimum*			
1966					
December	84·1	71·1	0·48	5·8	0·291
1967					
January	84·5	69·0	0·74	7·3	0·022
February	85·8	68·8	1·19	8·4	0·181
March	91·4	71·8	1·48	9·1	0·186
April	93·4	73·5	0·60	9·9	0·089

* Measured at 6 feet from ground.

TABLE III.—Effect of Treatments on Plant Height and Number of Tillers per Plant at Three Stages of Growth

Treatment	*Plant Height (cm.)* *No of days from transplanting* 14	40	122	*No. of Tillers Per Hill* *No. of days from transplanting* 14	40	122
A—Broadcast on the surface	41·2	71·8	117·7*a**	3·7	13·4	11·3*ab*
B—In rows, on the surface	40·7	69·3	111·4*ab*	3·6	11·2	10·2*a*
C—In rows, 5 cm. depth	43·0	74·7	121·1*b*	3·5	13·6	11·8*bc*
D—In rows, 10 cm. depth	41·0	72·6	121·4*b*	3·7	13·5	12·9*c*
E—In rows, 15 cm. depth	38·8	70·6	127·1*b*	3·4	12·9	12·8*c*
Coefficient of Variation (%)	8·14	5·33	6·07	12·77	13·27	9·08

*Duncan's Multiple Range Test at 5% level of significance.

Means not followed by the same letter within a column are significantly different from each other.

TABLE IV.—Effect of Treatments on Dry Matter Production

(Kg.[1]ha.) (Mean of six replicates)

Treatment	60 day early harvest 40 days from transplanting	Final harvest 122 days from transplanting
A—Broadcast on the surface	920*ab** ..	10178*b*
B—In rows, on the surface	821*a* ..	8881*ab*
C—In rows, 5 cm. depth	1195*b* ..	11233*bc*
D—In rows, 10 cm. depth	1033*ab* ..	11849*c*
E—In rows, 15 cm. depth	964*ab* ..	13286*d*
Coefficient of variation (%)	19·88 ..	9.35

* Duncan's Multiple Range Test at 5% level of significance.

Means not followed by the same letter within a column are significantly different from each other.

TABLE V.—Effect of Treatments on Grain Yield and Yield Components

Treatments	*Grain Yield (Filled and Unfilled) (Kg/ha)*	*Grain Yield (Filled) (Kg/ha)*	*Panicle Number per Hill*	*Panicle Weight (gm.)*	*Weight per 1,000 Grains (gm.)*	*Percentage Ripened Grain*	*Grain Total Dry Matter (%)*	*Grain Straw*
A—Broadcast on the surface	5636*a**	5233*a*	11·8*ab*	3·17	28·17	89·4	55·6*b*	1·36
B—In rows on the surface	5049*a*	4652*a*	10·8*a*	3·08	28·12	88·4	57·0*b*	1·43
C—In rows, 5 cm. depth	6385*b*	5956*b*	12·8*bc*	3·29	28·15	86·8	57·1*c*	1·44
D—In rows, 10 cm. depth	6468*b*	6061*b*	13·1*cd*	3·28	28·51	89·7	54·8*ab*	1·31
E—In rows, 15 cm. depth	6999*b*	6555*b*	14·2*d*	3·28	28·24	90·1	52·7*a*	1·21
Coefficient of variation (%)	8·29	8·67	7·74	5·38	1·37	3·94	3·34	—

* Duncan's Multiple Range Test at 5% level of significance.

Means not followed by the same letter within a column are significantly different from each other.

TABLE VI.—Effect of Treatments on the Concentration of Nitrogen and Phosphorus and Percentage of Nitrogen and Phosphorus derived from Fertilizer in Plants 40 Days from Transplanting

Treatments	*Nitrogen*		*Phosphorus*	
	% in Tissue	*% Derived from Fertilizer*	*% in Tissue*	*% Derived from Fertilizer*
A—Broadcast on the surface	2·63	54·7	·185	71·1
B—In rows, on the surface	2·77	49·0	·186	72·6
C—In rows, 5 cm. depth	3·30	54·5	·189	71·6
D—In rows, 10 cm. depth	2·98	65·0	·185	75·1
E—In rows, 15 cm. depth	3·44	67·9	·197	67·8
L. S. D. at 1%	0·68	13·8	N.S.	N.S.
Coefficient of variation	12·4%	13·0%	8·0%	7·0%