

Nitrogen and Phosphorus Fertilizer Placement Studies on Rice using N^{15} and P^{32}

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INTRODUCTION

IT is known that nitrogen fertilizer considerably increases rice yields compared to phosphorus and potassium fertilizers. But fairly heavy nitrogen losses are brought about by denitrification and leaching. Therefore, any method of fertilizer application which can minimize such losses would be of great importance in rice cultivation.

Submerged soils are believed to have at the surface a thin oxidized layer of few millimetres to a centimetre thickness followed by a reduced zone of substantial thickness. Therefore in these soils deep placement of ammonium fertilizers would be expected to be superior to surface placement. Several workers (Chandraratne, 1951; Ramiah, 1951; Mitsui, 1954) have obtained experimental evidence in support of this view. Recently a field experiment conducted in Hungary by the IAEA (International Atomic Energy Agency) has shown that placement of nitrogen as ammonium sulphate at a depth of 5 cm. and to a lesser extent at 10 cm. resulted in much higher nitrogen utilization than surface application (IAEA, 1965).

This paper describes the results of such a fertilizer placement study conducted at the Agricultural Research Station, Maha-Illuppallama during the season Maha 1965-66 under the Co-ordinated Contract Programme sponsored by the Joint FAO/IAEA Division of Atomic Energy in Agriculture. The objective of this experiment was to determine the efficiency of fertilizer nitrogen applied to lowland rice as affected by placement and the interaction with phosphorus placement, and the efficiency of fertilizer phosphorus as affected by placement and the interaction with nitrogen placement.

EXPERIMENTAL TECHNIQUE

The experiment was a randomized block design of eight treatments with six replicates. These different treatments are shown in table 1.

The experimental plots were similar to those of the earlier experiment (Nagarajah and Al-Abbas, 1965) excepting (i) treatment plots A to F had an extra plot consisting of 30 hills for total dry matter yield determination at the time of 60-day early harvest, and (ii) treatment plots G and H consisted of 110 hills. This is shown in figure 1.

The soil analysis and the profile description of the experimental site are given in tables 2 and 3 respectively.

The construction of plots, nursery preparation, transplanting, precautions taken in handling P^{32} fertilizer and cultural practices were identical to those described in the earlier experiment (Nagarajah and Al-Abbas, 1965).

All treatments received phosphorus as superphosphate at the rate of 60 Kg. P_2O_5 /ha (53.5 lb./acre) and potassium as muriate of potash at the rate of 60 Kg. K_2O /ha (53.5 lb./acre). Treatments A to F received 60 Kg. N/ha (53.5 lb./acre) while treatment G received 120 Kg. N/ha (107 lb./acre) in the form of ammonium sulphate. The radioactive sub-plots received ammonium sulphate labelled with N^{15} and superphosphate labelled with P^{32} (0.2mc P^{32} per g. P_2O_5) at the same rate as the yield sub-plots.

For treatments B, C and E, Nitrogen and Phosphorus fertilizers were applied on either side of the plant row at a distance of 7.5 cm. from the plant row and for treatments A, D and G, nitrogen and phosphorus fertilizers were mixed and applied on one side at 7.5 cm. from the plant row. When fertilizers were applied at 5 cm. depth as in treatments C, D and E, a V-shaped furrow 5 cm. in depth was first made with a special metal tool and then the fertilizers placed at the bottom of the furrow and carefully covered with soil. Sufficient care was taken to ensure that each row received equal amounts of fertilizer. In the case of treatment F, nitrogen and phosphorus fertilizers were thoroughly mixed, broadcast very evenly over the whole plot and then mixed and puddled into the top 5 cm. of the soil. The different methods of placement are indicated in figures 2 (a), 2 (b) and 2(c).

Sixty days after sowing the nursery, 54 leaves were sampled from the plants of 9 centre hills from each radioactive plot by taking the youngest fully expanded leaf from each of the two largest tillers of every plant. Since only six leaves were sampled from each hill, the subsequent growth and final yield were not significantly affected and it was possible to obtain the total dry matter and grain yields at final harvest. The 54 leaves were dried at 70° C for 24 hours, cut up into small pieces and sent to the IAEA Laboratory in Vienna for P^{32} , P^{33} , N^{14}

and N² analysis. At the same time, 12 centre hills from the 60-day early harvest yield sub-plots (figure 1) were harvested, dried at 70°C for 24 hours and total dry matter yield determined.

The average height per hill and number of tillers per hill were obtained at the following times :—

- (a) Half-way between transplanting and two weeks before primordial initiation (16 days after transplanting) ;
- (b) 60-day early harvest (34 days after transplanting) ; and
- (c) Final harvest.

After the maturation of the rice crop, the centre hills of the yield sub-plots were harvested to determine total dry matter production, grain yield, average number of panicles per hill, average panicle weight and 1,000 grain weight. The centre hills of the radioactive sub-plots were separately harvested to obtain total dry matter and grain yields.

Temperature, wind, sunshine and rainfall data were recorded from the time of sowing to final harvest and this data is presented in table 4.

RESULTS AND DISCUSSION

Plant Height Measurement

The height of the plants at the different stages of growth are presented in table 5.

Significant height differences among treatments were not observed at the initial stage. But at 60-day early harvest (34 days after transplanting) and final harvest all treatments were significantly superior to treatment H, while treatment G was superior to all the other treatments. In fact, at final harvest, plants in all G plots were heavily lodged while no appreciable lodging was observed in the other treatment plots.

Tiller Count

The number of tillers per hill at the different stages of growth is given in table 6.

At all stages of growth, the number of tillers per hill for treatments A to G were significantly higher than treatment H with treatment G recording the highest value except at the initial stage when

treatment D gave the highest number of tillers per hill. Among the treatments A to F, however, treatment D gave the highest number of tillers per hill at all stages of growth.

Dry Matter Yield, Grain Yield and Yield Components

The total dry matter yield, grain yield and the yield components are summarized in table 7.

All treatments except treatment A gave significantly higher total dry matter and grain yields than treatment H. As expected, treatment G was significantly superior to all the other treatments. For total dry matter yield treatments D and E where nitrogen was placed at 5 cm. depth were superior to treatment at 5 per cent. level of significance. In the case of grain yield treatments B to E were better than treatment A at 5 per cent. level of significance.

The total dry matter yield at 60-day early harvest presented in table 8, showed somewhat similar trends as the total dry matter yield at final harvest for treatments A to F. The difference among treatments were however, not significant, but in both cases treatment D gave the highest dry matter yield.

No significant differences among the treatments were found for panicle weight, 1000 grain weight and percentage ripened grain. The percentage of total dry matter diverted to the grain in the case of treatments A, B, C, D, E, F and H was significantly superior to treatment G.

It was observed that the total dry matter and grain yield in this experiment were considerably higher (about twice) than that obtained in the previous experiment (Nagarajah and Al-Abbas, 1965). This might be attributed to the higher panicle weight and percentage ripened grain featured in this experiment.

Figure 3 shows that the yield response of rice to nitrogen over the range 0-120 Kg. N/ha (107 lb./acre) was linear. In the earlier experiment (Nagarajah and Al-Abbas, 1965) linear response over this range was obtained only at Gannoruwa.

The total dry matter and grain yields obtained in the radioactive sub-plots are presented in table 9.

There were no significant differences among the treatments A to F but treatments C and D were slightly better than treatments A and B. The general trend however, was somewhat similar to that obtained with non-radioactive yield sub-plots.

Uptake and Utilization of Fertilizer Nitrogen and Phosphorus

Table 10 shows the percentage nitrogen and phosphorus in the plants derived from the fertilizer.

The results clearly showed that treatments C, D and E resulted in the efficient uptake of nitrogen fertilizer and were significantly superior to the treatments A, B and F. However, there were no significant differences among treatments C, D and E. As far as fertilizer phosphorus uptake was concerned treatments C, D and F were superior to treatments A, B and E.

Total nitrogen and phosphorus found in the plants for the different treatments are shown in table 11.

Though there were no significant differences among the treatments, nitrogen and phosphorus content in the plants for treatments C, D and E were slightly better than for treatments A, B and F.

Percentage utilization of fertilizer nitrogen and phosphorus by the plants presented in table 12 also emphasizes the superiority of deep placement of nitrogen fertilizer to surface placement.

These results clearly demonstrate that nitrogen fertilizer placed at 5 cm. depth in rows, result in an efficient uptake of nitrogen and was superior to surface placement. It further shows that efficiency of deep placement of nitrogen was not at all affected by either phosphorus placement or mixing with phosphorus fertilizer. (See table 10.) Phosphorus uptake from the fertilizer, on the other hand, was highest for the treatment F, where phosphorus fertilizer was applied broadcast on the surface and mixed with the top 5 cm. of soil. This treatment, however, was not significantly superior to treatments C and D. Majority of the countries which conducted this experiment obtained somewhat similar results (IAEA, 1965). A greenhouse experiment carried out at the IAEA Laboratory (IAEA, 1965) using five soils and four forms of nitrogen fertilizer also indicated that placement of nitrogen in rows at 5 cm. depth was superior to surface placement.

SUMMARY AND CONCLUSIONS

A field experiment was conducted during Maha 1965-66 at the Agricultural Research Station, Maha-Illuppallama, under the Co-ordinated Contract Programme on the application of isotopes and radiation in rice fertilization sponsored by the Joint FAO/IAEA Division of Atomic Energy in Agriculture.

The purpose of this experiment was to determine the efficiency of (i) fertilizer nitrogen applied to lowland rice as affected by placement and the interaction with phosphorus placement, and (ii) fertilizer phosphorus as affected by placement and the interaction with nitrogen placement.

Fertilizer uptake and utilization data indicated that when nitrogen was applied in rows at 5 cm. depth, then efficient uptake of both fertilizer nitrogen and phosphorus resulted. But placement of phosphorus or mixing of nitrogen and phosphorus fertilizers did not influence nitrogen uptake. Although, grain yield did not show significant differences between deep placement and surface placement, total dry matter yield to some extent agreed with this trend.

Note: 1 Kg./ha = 0.892 lb./acre
1 cm. = 0.3937 inches

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TABLE 1.—Treatments

Treatment	Placement		Fertilizers mixed or separate
	fertilizer	P-fertilizer	
A ..	applied in rows on the surface	applied in rows on the surface	fertilizer mixed before application
B ..	applied in rows on the surface	applied in rows on the surface	fertilizers are applied separately in rows without previous mixing
C ..	applied in rows at 5 cm. depth	applied in rows on the surface	fertilizers are applied separately in rows without previous mixing
D ..	applied in rows at 5 cm. depth	applied in rows at 5 cm. depth	fertilizers mixed before application
E ..	applied in rows at 5 cm. depth	applied in rows at 5 cm. depth	fertilizers are applied separately in rows without previous mixing
F ..	The nitrogen and phosphorus fertilizers are mixed, broadcast on the surface and mixed into the top 5 cm. of soil (puddled).		
G ..	This is the yield response plot and N & P are applied mixed in the row at 5 cm. depth and at a rate of 120 Kg. N/ha. and 60 Kg. P ₂ O ₅ /ha.		
H ..	This is the zero N fertilizer control plot (yield check) and no fertilizer is applied except for the basic potassium application and 60 Kg. P ₂ O ₅ /ha application in the row at 5 cm. depth.		

Note.—Treatments A–F received nitrogen at the rate of 60 Kg. N/ha.

All plots received 60 Kg. K₂O/ha as potassium chloride and 60 Kg. P₂O₅/ha as superphosphate.

60 Kg./ha = 53·52 lb./acre.

TABLE 2.—The Physical and Chemical Analysis of the Soil

Depth (cm.)	..	..	..	0–20
pH (1 : 1)	..	..	..	7·3
E. C. (1 : 5) mmhos/cm.	..	..	..	0·12
Mechanical Analysis—				
Coarse sand %	..	..	..	24·3
Fine sand %	..	..	..	52·8
Silt %	..	..	..	4·8
Clay %	..	..	..	18·3
Textural Class	..	..	..	S. L.
Organic Matter %	..	..	..	1·05
Total N %	..	..	..	0·15
Available P (Olsen) ppm.	..	..	..	4·67
Exchangeable Cations m.e./100g.—				
Ca ⁺⁺	..	..	..	5·6
Mg ⁺⁺	..	..	..	3·0
K ⁺	..	..	..	0·21
C. E. C.—m.e./100g.	..	..	..	14·8

TABLE 3.—Description of Soil Profile

Depth cm.	Thickness cm.	Boundry	Colour	Mottles	Texture	Structure	Consistency	pH.	Roots	Special Features
0-15	.. 15 ..	— ..	10YR 3/1 (very dark grey)	common .. promi- nent, small 7.5YR 4/4 (Brown- to dark brown)	Sandy clay loam	medium .. moderate sub-an- gular blocky	moist: fine wet: slight- ly sti- cky and slightly plastic	7.8 ..	common fine	—
15-40	25 ..	clear .. smooth	5YR 2/1 .. (black)	few, large diffuse 7.5YR 4/4 (brown to dark brown)	very fine .. sandy clay	medium moderate angular, blocky	moist: fine wet: sticky and plastic	7.8 ..	few fine	earth- worms present
40-60	20 ..	gradual smooth	2.5Y 4/0-5/0 (dark grey- grey)	— ..	gravelly sandy clay	medium moderate, sub- angular blocky	moist: fine wet: sticky and very plastic	8.0 ..	— ..	felspar and quartz gravel abund- ant
60+	.. — ..	abrupt wavy	2.5Yf 7/2 10YR 4/1-3/1 (light grey, dark grey- grey)	— ..	clay ..	— ..	wet: very sticky and very plastic	8.5 ..	— ..	admix- ture of white kaolin and black soil

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TABLE 4.—Mean Monthly Climatic Data from Sowing to Final Harvest

<i>Month</i>		<i>Temperature</i> (° F.) <i>Min.</i>		<i>Wind</i> (m.p.h.)		<i>Sunshine</i> (hours/day)		<i>Rainfall</i> (ins.)	
October (1965)*	..	..	72.4	..	1.01	..	5.9	..	8.37
November (1965)	..	..	72.9	..	0.28	..	6.3	..	14.17
December (1965)	..	..	71.9	..	0.58	..	4.4	..	15.70
January (1966)	..	..	69.7	..	0.39	..	7.5	..	2.28
February (1966)†	..	..	69.9	..	1.16	..	9.1	..	0.71

* average for 17 days.

† average for 26 days.

TABLE 5.—Height of Plants at different Stages of Growth (cm.)
(mean of six replicates)

<i>Treatment</i>		<i>Days after transplanting</i>		
		<i>16</i>	<i>34</i>	<i>109</i>
A	..	.. 55.5	.. 92.4†	.. 137.8†
B	..	.. 55.1	.. 91.4†	.. 139.2†
C	..	.. 53.3	.. 89.6†	.. 138.3†
D	..	.. 55.9	.. 90.8†	.. 139.8†
E	..	.. 54.0	.. 87.3†	.. 138.5†
F	..	.. 53.7	.. 88.6†	.. 135.6†
G	..	.. 54.8	.. 96.4†	.. 152.5†
H	..	.. 51.5	.. 80.2	.. 124.5
S. D. at 5% level	..	.. n.s.	.. 3.0	.. 5.2
S. D. at 1% level	..	.. —	.. 4.0	.. 7.0

TABLE 6.—Numbers of Tillers per Hill at different Stages of Growth
(mean of six replicates)

<i>Treatment</i>		<i>Days after transplanting</i>		
		<i>16</i>	<i>34</i>	<i>109</i>
A	..	.. 6.7†	.. 12.4†	.. 11.0
B	..	.. 6.5†	.. 12.5†	.. 11.4*
C	..	.. 6.4†	.. 12.3*	.. 11.1
D	..	.. 7.9†	.. 13.6†	.. 12.7†
E	..	.. 6.1*	.. 12.4†	.. 11.5*
F	..	.. 6.5†	.. 12.6†	.. 11.9†
G	..	.. 6.6†	.. 14.0†	.. 13.3†
H	..	.. 4.5	.. 10.3	.. 9.8
S. D. at 5% level	..	.. 1.3	.. 1.6	.. 1.4
S. D. at 1% level	..	.. 1.8	.. 2.1	.. 1.9

TABLE 7.—Total dry matter yield, grain yield and yield components
(mean of six replicates)

<i>Treatment</i>	<i>Total dry matter</i> (Kg./ha) %		<i>Grain</i> (Kg./ha) %		<i>Grain</i> <i>Total dry matter</i> %		<i>Panicles</i> <i>per hill</i>		<i>Panicle Weight</i> (g)		<i>1,000 grain</i> <i>weight (g)</i>	<i>Percentage</i> <i>ripened grain</i>		
A	..	11965	..	6073	..	50.9	..	10.6	..	3.76	..	28.71	..	90.7
B	..	12903**	..	6688**	..	51.8	..	10.8*	..	4.00	..	29.23	..	93.3
C	..	12163*	..	6692**	..	51.0	..	10.6	..	3.83	..	29.34	..	91.5
D	..	13516**	..	6611**	..	48.8	..	11.8**	..	3.72	..	28.86	..	91.9
E	..	13388**	..	6705**	..	50.2	..	10.9*	..	4.07	..	28.78	..	92.8
F	..	12769**	..	6542**	..	51.3	..	11.1*	..	3.87	..	28.04	..	90.2
G	..	16786**	..	7441**	..	44.3	..	12.3**	..	3.93	..	28.30	..	89.6
H	..	10756	..	5692	..	52.9	..	9.5	..	4.20	..	28.94	..	91.7
S. D. at 5% level	..	1258	..	537	..	2.5	..	1.3	..	n.s.	..	n.s.	..	n.s.
S. D. at 1% level	..	1689	..	721	..	3.4	..	1.7	..	—	..	—	..	—

1 Kg./ha=0.892 lb./acre

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TABLE 8.—Total dry matter yield at 60-day early harvest
(Kg./ha)
(mean of six replicates)

A	B	C	D	E	F	S. D. at 5% level
1427 ..	1412 ..	1383 ..	1541 ..	1313 ..	1188 ..	n. s.

1 kg./ha=0.892 lb./acre

TABLE 9.—Total dry matter and grain yield in radioactive sub-plots

<i>Treatment</i>	<i>Total dry matter</i> (Kg./ha)		<i>Grain</i> (Kg./ha)	
A	..	9982	..	5707
B	..	9111	..	6207
C	..	11757	..	6255
D	..	11943	..	6465
E	..	11028	..	5961
F	..	10891	..	5940
S. D. at 5% level	..	n. s.	..	n. s.

1 Kg./ha=0.892 lb./acre.

TABLE 10.—Percentage nitrogen and phosphorus in the plants derived from the fertilizer
(mean of six replicates)

<i>Treatment</i>	<i>Nitrogen</i>		<i>Phosphorus</i>	
A	..	18.2	..	38.9
B	..	20.6	..	37.1
C	..	31.2	..	49.7
D	..	35.9	..	50.3
E	..	31.6	..	37.7
F	..	19.4	..	50.8
S. D. at 5% level	..	6.2	..	9.9
S. D. at 1% level	..	8.4	..	13.3

TABLE 11.—Total nitrogen and phosphorus in plants
(mean of six replicates)

<i>Treatment</i>		<i>Nitrogen %</i>		<i>Phosphorus %</i>
A	..	2·59	..	0·189
B	..	2·77	..	0·185
C	..	2·81	..	0·197
D	..	2·96	..	0·215
E	..	2·76	..	0·201
F	..	2·59	..	0·198
S. D. at 5% level	..	n. s.	..	n. s.

TABLE 12.—Percentage utilization of fertilizer nitrogen and phosphorus.
(mean of six replicates)

<i>Treatment</i>		<i>Nitrogen</i>		<i>Phosphorus</i>
A	..	11·21	..	3·99
B	..	13·43	..	3·68
C	..	20·21	..	5·15
D	..	27·29	..	6·33
E	..	19·09	..	3·78
F	..	9·85	..	4·54

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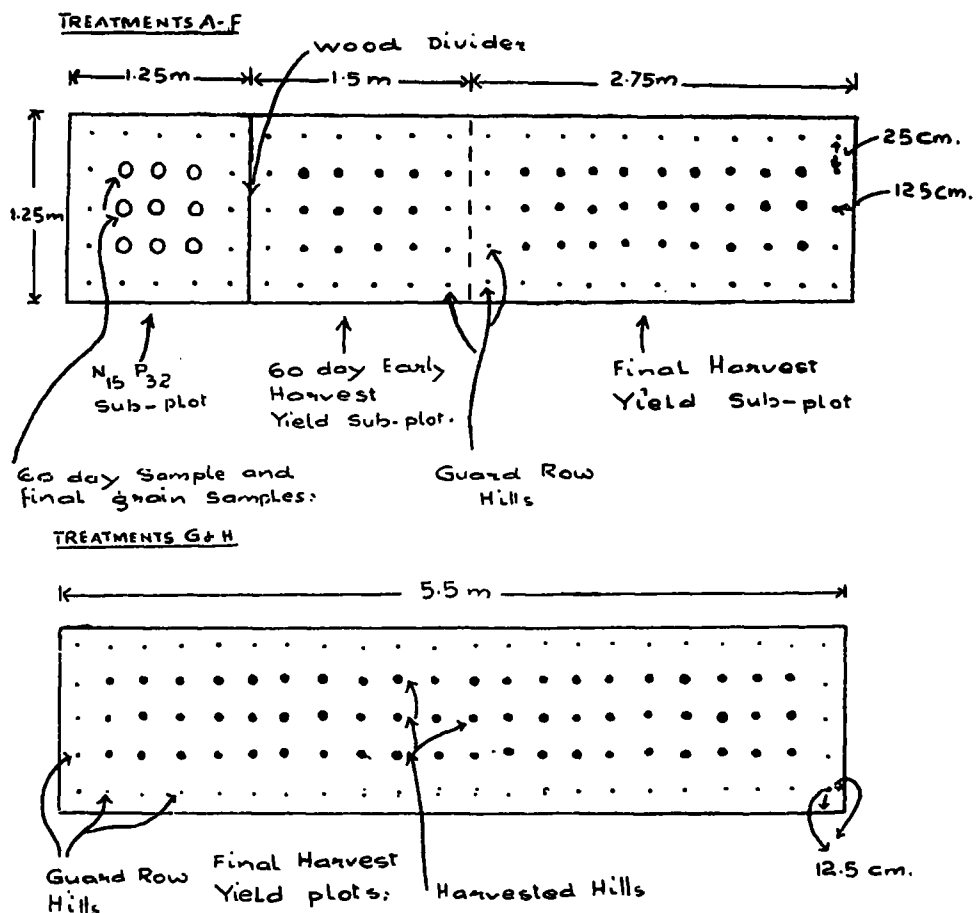


Fig. 1.—Single plot diagram showing division into sub-plots, number of hills and their time of harvest.

Figure 2.a) TREATMENTS B, C, E.

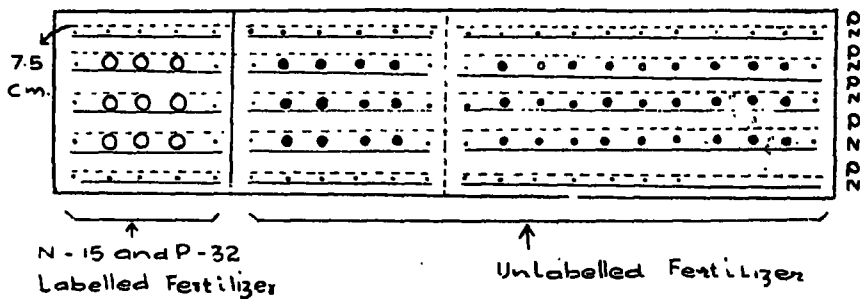


Figure 2.b) TREATMENTS A, D

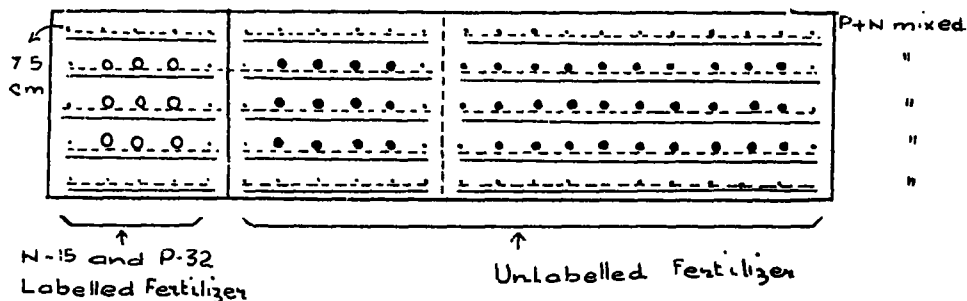
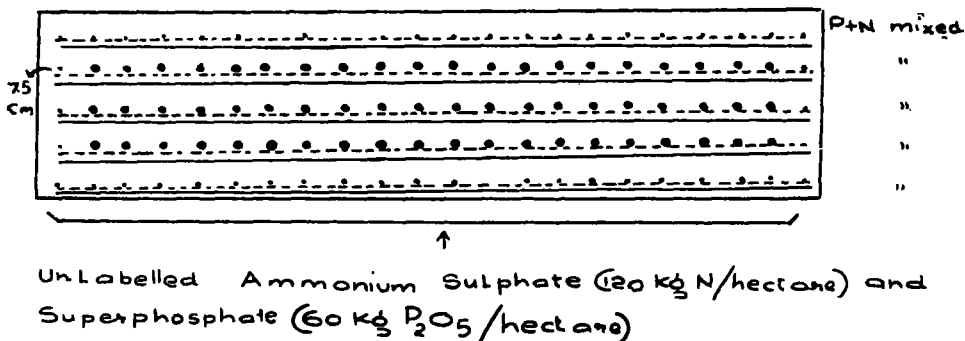


Figure 2.c) TREATMENTS



Key: Superphosphate,
 ——— Ammonium Sulphate.

Fig. 1.—Application and placement of Fertilizers.

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FIGURE 3. GRAIN YIELD RESPONSE TO INCREASING LEVELS OF NITROGEN