

Varietal differences in response to nitrogen fertilizer in rice

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INTRODUCTION

Plants differ in yield and yield potentials depending on varieties and strains. These differences can be attributed to differences in physiological traits, among which mineral nutrition, viz. ion absorption, translocation and utilization plays an important role. Because absorption of nutrients is mostly through the roots, differences in root characteristics also account for differences in nutrient absorption.

Of the soil-derived nutrient elements plants in general require nitrogen in the greatest amount, and varietal differences in nitrogen nutrition of plants have been reported by several investigators (3, 4, 5, 6, 7, 8, 9). In rice many nutritional variants are known and this in part accounts for its wide range of edaphic adaptations. In general, japonica varieties of rice respond more to nitrogen than indica varieties (2, 10, 15, 16).

Yamada (15, 16) reported differences in response to nitrogen between the indica varieties H-4 and Murungakayan 302. While H-4 responded well to increased nitrogen fertilization by increased grain production at all levels, Murungakayan 302 failed to respond at the higher levels of nitrogen. The increase in yield in H-4 was brought about mainly by an increase in the number of panicles and it was therefore classified as a panicle number type. Murungakayan 302, on the other hand behaved like a panicle weight type showing increase in grain number per panicle.

MATERIALS AND METHODS

This paper reports the findings of a field experiment conducted at Gannoruwa, Peradeniya during the season Maha 1959/60 to study differences in response to nitrogen of three varieties of rice, which was presented elsewhere (14).

The characteristics of the soil on which this investigation was conducted were as follows:—

Texture	..	..	sandy clay loam
pH	..	..	5.2
Cation exchange capacity	..	..	15.0 m.e. per 100g.
Organic matter	..	..	2.0 per cent.
Total nitrogen	..	..	0.15 per cent.
Available phosphorus	..	..	32.0 lbs P_2O_5 per acre
Exchangeable potassium	..	..	0.10 m.e. per 100g.

The treatments consisted of three levels of nitrogen at the rates of 0, 30 and 60 lbs. of element per acre supplied as ammonium sulphate. A third of the nitrogen was supplied at planting and the remainder at the time of primordia initiation. Phosphorus and potassium were applied at 100 lbs. P_2O_5 and 50 lbs. K_2O per acre as concentrated superphosphate and muriate of potash respectively. The varieties of rice used were H-4, Murungakayan 302 and Murungan Samba 3081. Twenty-six day old seedlings were transplanted in plots of size 10×19.5 ft., which were separated from one another by 1 foot wide ridges. The seedlings were transplanted in rows at a spacing of 12 inches between rows and 6 inches within rows with three seedlings per hill. Growth records were maintained beginning two weeks from transplanting. Sixteen plants from each treatment were used for recording the number of tillers per plant and the height per plant.

Nitrogen in plant tissue was determined by the Kjeldhal method on a semi-micro scale. The total content of nitrogen in the tissues was estimated from the concentration of nitrogen and the dry weight in each case.

RESULTS AND DISCUSSION

The response to fertilizer is usually assessed in terms of increase in yield of harvested produce, as for instance an increase in grain yield in the case of rice. This may not however take into account a response in vegetative growth manifested by the plant with added fertilizer. If the addition of nitrogenous fertilizer brings about an increase in any growth attribute, as for instance the total dry weight then it would be reasonable to conclude that in this respect there has been a response to added fertilizer. If however, this response is not accompanied by an increase in grain yield it would be necessary to explain

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factors which contribute to vegetative growth but not to grain yields. For this purpose, the response to fertilizer nitrogen is analyzed in terms of growth of both vegetative and reproductive organs.

VEGETATIVE GROWTH

Tillering

Varietal differences in response to nitrogen fertilization were seen in respect of tiller production (Table I). Responses to increased nitrogen fertilization were seen initially (40 days) and up to maturity (124 days) with all varieties. H-4 consistently had more tillers per plant for any treatment than Murungakayan 302. Thus at maturity H-4 had approximately 30 per cent more tillers per plant at the no nitrogen level and approximately 10 per cent more at the 60 lbs. level of nitrogen than Murungakayan 302. Murungan Samba 3081 also showed a response to nitrogen fertilization which was closer to H-4 than that shown by Murungakayan 302 at 40 days, but at maturity the number of productive tillers were reduced considerably in plants receiving nitrogen at the rate of 60 lbs. per acre.

At maturity the increase in tiller number between 30 and 60 lbs. nitrogen per acre was 63 per cent for H-4 and 72 per cent for Murungakayan 302 (Table I). In Murungan Samba 3081 there was a reduction of approximately 9 per cent in the number of tillers between 30 and 60 lbs. nitrogen per acre. It should however be noted that although both varieties H-4 and Murungakayan 302 showed increased tillering due to increased nitrogen fertilization, the number of panicles per hill was increased only in the former variety (with the consequent increase in grain yield), while in the latter there was a reduction in both the number of panicles per hill and in grain yield (Table 3). In Murungan Samba 3081 also there was an increase in panicle number per hill and in grain yield with increased nitrogen fertilization. Although the number of tillers per hill decreased at maturity at the higher level of nitrogen in comparison to that at the lower level.

Plant Height

The variety H-4 was generally the shortest and Murungan Samba 3081 the tallest at any level of nitrogen fertilization (Table 2). The variety Murungakayan 302 was intermediate in plant height. At high levels of nitrogen fertilization short varieties of rice perform better because they are less prone to lodging than tall varieties. Lodging of a crop generally results in yield reduction

Under the conditions of this experiment the greatest response in plant height to added nitrogen was in H-4 between 0 and 30 lbs. N per acre. The next increment of nitrogen had much less effect on plant height in this variety although there were relatively larger increases in plant height between 30 and 60 lbs. nitrogen per acre in the other two varieties.

Weight of Straw

The dry weight of straw increased with increasing levels of nitrogen fertilization in H-4 and Murungan Samba 3081, but in Murungakaya 302 there was a reduction in weight at 60 lbs. nitrogen per acre (table 3).

YIELD AND YIELD COMPONENTS

Number of Panicles Per hills

There were differences among the three varieties of rice in the effects of nitrogen fertilization on the number of panicles per hill (Table 3). With increasing levels of nitrogen there was a steady increase in the number of panicles per hill in H-4, whereas in Murungakayan 302 there was a reduction in the number of panicles (Table 3). The behaviour of Murungan Samba 3081 was intermediate. Here too, like with H-4, there was an increase in the number of panicles per hill at 60 lbs. nitrogen per acre, but this increase was not as high as with H-4. The behaviour of H-4 and Murungakayan 302 to increasing levels of nitrogen fertilization was similar to the observations of Yamada (15, 16).

Weight per Panicle

In all three varieties the weight per panicle increased as the level of nitrogen increased from 0 to 30 lbs. per acre, and decreased at the higher level of fertilization (Table 3).

Grain Yields

In H-4 and Murungan Samba 3081 grain yields showed steady increase with increased application of fertilizer nitrogen from 0 to 60 lbs. per acre but Murungakayan 302 showed an increase from 0 to 30 lbs. nitrogen per acre and a reduction in grain yield at 60 lbs. nitrogen per acre (Table 3).

Excess nitrogen in some varieties can lead to exhaustion of carbohydrates as a result of excessive vegetative growth and this may eventually result in high sterility in the panicles. In Murungakayan

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302 there was imperfect grain filling and high sterility. However, the decrease in grain yield was also accompanied by a decrease in weight of straw.

The response in grain yield to the addition of nitrogen in H-4 and Murungakayan 302 confirm the findings of Yamada (15, 16). As stated by Yamada (15, 16) this investigation confirms that Murungakayan 302 is best suited for soils of relatively low fertility in contrast to the variety H-4 which has the potentiality for high yields on fertile soils or at high rates of fertilizer application. The other yield components such as spikelets per panicle, percentage ripened grain, and 1,000 grain weight have not been considered in this experiment.

NITROGEN IN PLANTS

The concentration and content of nitrogen in plant leaves of the three varieties at three stages of growth viz:—vigorous tillering; heading and harvest are presented in Table 4. The concentration of nitrogen in the leaves was generally highest at the stage of vigorous tillering and lowest at harvest in H-4 and Murungakayan 302 with intermediate values at heading indicating that these varieties are somewhat similar in their abilities to absorb this element. This may be attributed to their genetic relationship (Murungakayan 302 being a parent of H-4). In contrast the concentration of nitrogen in the leaves of Murungan Samba 3081 was highest at heading (among the stages selected for tissues analysis in this investigation). Among these varieties Murungan Samba 3081 was further different in generally having the lowest concentration of leaf nitrogen at tillering and the highest at maturity at any level of fertilization.

The production of dry matter and the accumulation of storage products such as starch in plants is related to the balance between photosynthesis and respiration in which processes carbohydrates are produced and utilized respectively. Some investigators have studied the manner in which varieties respond to heavy fertilization.

In an investigation with three varieties of rice Takahashi, Iwata and Baba (12) found that a low response variety absorbed more nitrogen and exhibited vigorous growth but accumulated less carbohydrates in leaf sheaths and culms during the early stages of growth as compared with a high-response variety.

According to Baba (1) the number of spikelets produced per hill generally increases with increasing nitrogen supply, but the percentage of ripened grains tends to decrease beyond a certain level of

nitrogen supplied, this tendency being more pronounced in low response varieties than in high response varieties. Increased supplies of nitrogen caused greater decreases in starch contents in leaf sheaths plus culms in low response varieties, indicating a greater reduction in starch accumulation under heavy application of nitrogen. According to Baba this may be due to the fact that low response varieties, during the early stages of growth, absorb nitrogen and increase vegetative tissue and leaf area at the cost of photosynthetic product with the result that only a small proportion of the synthesized carbohydrates are utilized as starch. Thus the contents of lignin and cellulose increase with increase of nitrogen supply in these low response varieties. Similar results were obtained by Osada and Murata (10,11) who in a series of experiments on the relationship between photosynthesis and adaptability of varieties for heavy fertilization found that low response varieties of rice were less efficient in accumulating starch than high response varieties.

From these results it appears that nitrogen nutrition is intimately connected with the carbohydrate status of the rice plant. Those varieties that maintain an adequate carbohydrate supply particularly at the critical stages of growth such as primordia initiation and heading are able to utilize nitrogen continuously. Varieties that fail to respond to high levels of nitrogenous fertilizer do so mainly because of the exhaustion of carbohydrates in the plants.

SUMMARY

Three varieties of rice, H-4, Murungakayan 302 and Murungan Samba 3,081 were each grown at 0,30 and 60 lb. nitrogen per acre. Grain yields of the varieties H4 and Murungan Samba 3081 increased with each increment of nitrogen but that of Murungakayan 302 increased only up to 30 lb. nitrogen per acre and decreased at the higher level. The variety H4 showed an increase in panicle number with increasing levels of nitrogen whereas Murungakayan 302 showed a decrease at the higher level of fertilization. Straw weight increased with increasing nitrogen fertilization in H-4 and Murungan Samba 3,081 while in Murungakayan 302 there was a reduction in weight at the higher level.

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REFERENCES

1. BABA, I. 1961 Mechanism of response to heavy manuring in rice varieties. International Rice Commission, News letter 10 (4) : 9-16.
2. BEACHELL, H. and EVATT, N. S. (1961). Yield performance of an introduced japonica rice variety in the Texas Gulf Coast. I. R. C. News-letter 19 (4) : 1-14.
3. CHANDRARATNE, M. F. (1961). Variety-Nitrogen interactions in rice I. R. C. News letter 10 (4) : 17-19.
4. FREY, K. J. (1959). Yield components in oats II. Effect of nitrogen fertilization. *Agron. Jour.* 51 : 605-608.
5. GOKHALE, N. G. and BHATTACHARYA N. G. (1960). Mineral composition of clonal tea from north-east India *J. Sci. Food Agr.*, 11 : 526-528.
6. GRIFFITH G (ap) (1958). Nitrate content of some grass species and strains. *Nature* 182 : 1099-1100.
7. GRIFFITH G. ap., and JOHNSTON, T. D. (1960) Nitrate : Nitrogen content of herbage I. Observations on some herbage species *Jour. Sci. Food Agr.*, 11 : 622-626.
8. HARVEY P. H. (1939) Hereditary variation in plant nutrition. *Genetics*, 24 : 437-461.
9. LINEBERRY, R. A. and BURKHART, L. (1943) Nutrient deficiencies in the strawberry leaf and fruit. *Plant Physical*. 18 : 324-333.
10. OSADA, A. and MURATA, Y. 1962 a Studies on the relationship between photosynthesis and varietal adaptability for heavy manuring in rice plants. *Proc. Crop. Sci. Soc., Japan*, 30 (3) : 220-223. 1. The relationship in the case of medicine-subsidiary varieties.
11. OSADA, A and MURATA, Y. 1962 b. Studies on the relationship between photosynthesis and varietal adaptability for heavy manuring in rice plants. II The relationship in the case of early-maturing varieties. *Proc. Crop. Sci. Soc., Japan*, 30 (3) : 224-227.
12. TAKAHASHI, Y., IWATA, I. and BABA I. (1959). Studies on the varietal adaptability for heavy manuring in rice I. Varietal differences in nitrogen and carbohydrate metabolism affected by different supply of nitrogen. *Proc. Crop. Sci. Soc. Japan* 28 (1) : 22-24.
13. TANAKA, A., PATNAIK, S. and ABICKANDKI, C. T. (1958). Studies on the nitrogen nutrition of rice plant (*O. sativa L.*) Part II. A comparative nitrogen requirement of indica and japonica varieties of rice. *Proc. Indian Acad. Sci. Sect. B.* 48 (1) : 14-27.
14. THENABADU, M. W. (1960). Studies on the response to nitrogenous fertilizers in rice. *Proc. 16th Annual Sessions, Ceylon Ass. for Adv. of Sci.*
15. YAMADA, N. (1959). The nature of fertilizer response in japonica and indica rice varieties. I. R. C. News letter 3 (4) 14-19.
16. YAMADA, N. (1959). The nature of fertilizer response in japonica and indica rice varieties. *Tropical Agriculturist* 55 : 163-172.

Table 1.—Effect of Nitrogen Fertilization on Tillering

(Average number of tillers per plant)

Variety	Level of Fertilizer (lbs. N. per acre)	Age of Plants (Days)						
		40	61	68	75	90	114	124
H-4	0	4.1	5.4	5.4	5.8	5.5	5.5	7.0
	30	5.6	7.3	7.1	7.5	7.6	8.0	7.1
	60	7.5	9.2	9.1	9.3	11.5	11.8	11.6
Murungakayan 302	0	3.8	4.7	4.7	3.9	4.9	4.5	4.8
	30	4.0	5.1	5.1	5.1	5.4	5.6	6.1
	60	4.7	7.1	7.6	7.7	10.4	10.9	10.5
Murungan Samba 3081	0	3.6	5.3	5.6	5.8	5.5	6.3	4.5
	30	5.5	7.0	7.0	7.1	7.0	7.8	8.5
	60	6.5	9.6	9.6	8.9	9.5	10.4	7.8

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TABLE 2.—Effect of Nitrogen Fertilization on Plant Height (cm)

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Variety	Levels of Fertilizer (Lbs. N. per acre)			Age of Plants (Days)						
				40	61	68	75	90	114	
H-4	0	..	..	48.9	53.0	59.2	64.3	74.4	90.3	
	30	..	..	49.9	59.8	63.8	69.9	93.0	108.8	
	60	..	..	49.3	62.8	67.8	75.3	95.0	115.8	
Murungakayan 302	0	..	..	55.0	63.1	68.7	73.2	92.2	106.6	
	30	..	..	50.6	64.9	67.1	73.7	89.8	110.1	
	60	..	..	54.2	68.6	75.3	82.3	105.4	130.2	
Murungan Samba 308	0	..	..	50.3	60.3	62.8	71.1	88.5	108.9	
	30	..	..	47.0	60.8	66.7	74.7	99.9	121.0	
	60	..	..	51.0	67.2	70.4	77.8	103.0	135.4	

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TABLE 3.—Effect of Nitrogen Fertilization on Yield and Yield Components of Varieties

<i>Variety</i>	<i>Level of Fertilizer (lbs. N. per acre)</i>			<i>Grain yield per hill (gm.)</i>		<i>No. of panicles per hill</i>		<i>Weight per panicle (gm.)</i>		<i>Weight of straw per hill (gm.)</i>		<i>Grain : Straw ratio</i>	
H 4	..	0	..	15.42	..	5.8	..	2.66	..	28.62	..	0.54	
		30	..	18.72	..	7.0	..	2.67	..	37.14	..	0.50	
		60	..	24.90	..	9.6	..	2.59	..	47.83	..	0.52	
M. 302	..	0	..	13.27	..	4.2	..	3.14	..	25.19	..	0.53	
		30	..	21.52	..	5.8	..	3.17	..	38.13	..	0.56	
		60	..	8.77	..	3.4	..	2.51	..	28.07	..	0.31	
M. S. 3081	..	0	..	15.50	..	6.0	..	2.58	..	23.72	..	0.65	
		30	..	17.52	..	5.6	..	3.14	..	33.94	..	0.52	
		60	..	22.22	..	7.3	..	2.12	..	44.38	..	0.50	

TABLE 4.—Effect of Nitrogen Fertilization on Concentration and Content of Nitrogen in Leaves at three stages of Growth
(per hill of 3 plants)

Variety		STAGES OF GROWTH												VARIETAL DIFFERENCES IN RESPONSE TO NITR	
		Levels of Fertilizer (Lbs. N per acre)	Concentration of N (%)		Content of N (gm.)		Concentration of N (%)		Content of N (gm.)		Concentration of N (%)		Content of N (gm.)		
			Vigorous		Tillering		Heading		Harvest		Harvest		Harvest		
H-4	..	0	..	2.4	..	0.010	..	2.3	..	0.109	..	0.8	..	0.027	
		30	..	3.0	..	0.019	..	2.1	..	0.139	..	0.8	..	0.025	
		60	..	2.2	..	0.017	..	2.6	..	0.197	..	0.9	..	0.037	
Murungakayan 302	..	0	..	3.3	..	0.012	..	2.1	..	0.016	..	0.6	..	0.011	
		30	..	3.7	..	0.015	..	2.4	..	0.176	..	0.9	..	0.022	
		60	..	3.4	..	0.017	..	2.6	..	0.182	..	0.9	..	0.033	
Murungan Samba 3081	..	0	..	1.6	..	0.005	..	1.9	..	0.093	..	2.2	..	0.038	
		30	..	2.5	..	0.012	..	2.8	..	0.177	..	1.1	..	0.025	
		60	..	2.7	..	0.021	..	3.4	..	0.294	..	1.2	..	0.055	

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