

THE INFLUENCE OF TOPOGRAPHY ON RICE LAND PRODUCTIVITY AND ITS EFFECTS ON NITROGEN AND PHOSPHORUS FERTILIZATION

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ABSTRACT

Recent studies have shown considerable differences in yielding ability within the same rice tracts in relation to their topographic position. Field experiments were conducted during maha 80/81 and yala 81 to study the land productivity of three topographically different land elements and their response to two levels of nitrogen and four levels of phosphorus application in a selected rice tract in the Kegalle district.

Inherent nutrient status varied with the land element. While *medhakumbura* had a stable environment for grain production the yielding ability of *godakumbura* and *madakumbura* varied with season and hydrological condition of the soil.

Response to N & P varied with land element and season. Response to increased N was evident in the *godakumbura* during both seasons whereas *medhakumbura* responded only to N in yala season. Response to high N application was not significant in both seasons in *madakumbura*. All three land elements responded upto 60 kg P_2O_5 /ha in both seasons. Comparatively very high yield response to 60 kg P_2O_5 /ha in the *madakumbura* emphasises the importance of P application for this land element. However, application of 90 kg P_2O_5 /ha did not increase yields even in this land element which could be attributed to the other stress factors brought about by the continuous water logging conditions.

INTRODUCTION

Influence of topography on hydrological properties of rice lands has been neglected until recently. Recent studies carried out by the Land and Water Use Division of the Department of Agriculture, Sri Lanka have shown

that considerable differences exist within the same rice tracts at different topographic positions (Somasiri *et al*, 1978). The differential performance of new improved rice varieties at different locations of the same rice tract in the mid - country region is a good example to show this variability.

In the early studies, rice soils in the mid-country region were generalized as homogeneous local alluvium or colluvium (De Alwis and Panabokke, 1972). In 1978, Somasiri *et al* introduced a four-tiered scheme of rice land classification with increasing specificity for successive categories. In this new rice land classification system, rice lands were categorised into "rice land systems" "rice land complexes" and "rice land elements" with increasing specificity in descending order.

A rice land complex is a contiguous tract of rice lands within a rice land sub-system. It is generally lower order valleys or tracts of terraced slopes. A rice land element is a sub-division of rice land complex with more or less constant land qualities for uniform management over the entire element. These land elements are areas of different hydrological conditions, and separate areas of natural moisture enrichment from areas of relative moisture depletion (Somasiri *et al* 1978). According to this classification the 'goda' land element or *godakumbura* is found in valley heads and sides of valleys where fields are subjected to water stress during some part of the growing season. The 'mada' land element or *madakumbura* is mainly found in valley bottoms where two or more rice tracts intercept, and ground water table is on or closer to the surface. These fields are inundated during most part of the year, and upwelling conditions are very common which are usually accompanied by severe stress problems for rice plant growth. The *medhakumbura* is an intermediate land element between *goda* and *mada*. Adequate moisture is available throughout the year and drainage is good. No upwelling or stress conditions for plant growth are found in these fields. Thus, in sloping terrains, topographic position can greatly influence both physical and chemical properties of rice soils (Somasiri *et al* 1978). Little attention has been paid in the past to understand these variabilities and their effects on rice production.

This study was undertaken to investigate the variation in major nutrients content (N, P & K), productive capacity, and response to nitrogen and phosphorus fertilizer in a typical rice land complex in the mid - country.

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MATERIALS AND METHODS

Three land elements namely, *goda*, *medha* and *mada* were selected in the Hingula land complex in the Mawanella rice land system.

Field experiments were carried out for two seasons in the selected land elements during maha 80/81 and yala 1981. Rice variety Bg 94—1 (3½ months) was tested using 2 levels of N (40 and 80 kg N/ha) and 4 levels of phosphorus (0, 30, 60 and 90 kg P_2O_5 /ha) in a 2×4 factorial experiment in a randomized complete block design with 3 replicates. A plot size of $4m \times 3m$ was used. A control plot with no N and P fertilizers was also included. All treatments received 60 kg K_2O /ha. The forms of fertilizer were urea (46%N) conc. super phosphate (42% P_2O_5) and muriate of potash (60% K_2O). All phosphorous fertilizers, and half of the potassium fertilizer were applied as basal. The balance potassium was applied as 2nd top dressing (TDM) 6 weeks after transplanting. Percentage N applied as basal, 1st top dressing and (TDM) were 8%, 50% and 42% of the total nitrogen respectively. Twenty one day old seedlings were transplanted at a spacing of $20cm \times 20cm$.

Soil samples were taken from each land element prior to planting and were analysed for pH, N, P, K, and organic matter content. Department of Agriculture recommendations were followed for pest control. Plots were hand-weeded at 2, 4 and 6 weeks after transplanting. No irrigation water was supplied to treatment plots and the crop depended totally on rainfall.

All plots were harvested discarding two border rows around each plot. Grain weight was recorded at 14% moisture content. Grain yield for the two seasons was subjected to combined analysis of variances considering all variables as fixed.

RESULTS AND DISCUSSION

Nutritional Status of the Soil

Soil analysis data for the 3 land elements are presented in Table 1. A considerable variability exists between different land elements with regard to their chemical properties in the upper soil layers. The available P (Olsen P) decreased with the downslope, and comparatively low levels of P was found in *madakumbura* and *medhabumbura*. In the mid-country wet zone where the parent material consists mainly of acid crystalline rocks and where the intensity of weathering is high, the phosphorus content in many rice fields is low (Nagarajah *et al*, 1979).

There is sufficient evidence to show that under submerged conditions the concentration of water-soluble and available P is high (Ponnamperuma, 1972). However, according to Patrick and Khalid (1974) even though more P is

released to the solution under reduced conditions, yet when soils are brought in contact with a solution high in P, a reduced soil will remove more P from the solution than an oxidized soil. On the other hand when the P content in the solution is high, the possibility of losing large portions of P due to runoff is also high. Under *madakumbura* conditions, the soil is inundated throughout the year and due to runoff during times of high precipitation, a large portion of P in the solution would be removed. This also could have resulted in low levels of P in *madakumbura*.

Results indicated that under *godakumbura* conditions the availability of P is comparatively higher than *madakumbura*. This agrees with Moormann and van Breeman (1978) who reported that rice grown in ill-drained fields suffers more P deficiency than rice in the adjacent better drained fields. Goswami and Banerjee (1977) summarizing the work of others on availability of P, reported that prolonged alternate wetting and drying increased the availability of phosphorus. *Godakumbura*, because of its topographic position is subjected to alternate wetting and drying more frequently than the other two land elements and this could be one reason for higher level of P in *godakumbura*.

In contrast to P levels, the percentage of total N and organic matter increased with down slope, with *madakumbura* recording the highest percentage of total N and organic matter (OM). Increase in organic matter content with down slope, is partly due to the downward movement of organic matter both as particle and soluble forms. Because of the low topographic position and poor drainage OM accumulation is high in *madakumbura*. Moormann and van Breeman (1978) reported that within a given toposequence, soils in the lower topographic positions with poor drainage have a higher OM content than the soils in the better drained positions. Variation of total N with downslope may be related to OM content of the soil. Another reason that could be attributed to low N levels at *godakumbura* is its alternate wetting and drying process which leads to loss of N by nitrification and denitrification.

Productivity of different Land Elements

Grain yields for different land elements for maha 80/81 and yala 81 are presented in Table 2. Average yields for the three land elements varied with the season, and season $\times$ land element interaction (L $\times$ S) was significant (Table 3). During the maha season *godakumbura* gave the highest yield

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and yields decreased downslope with *madakumbura* giving the lowest yield (Table 2 & Fig. 1a). Yield decrease in *madakumbura* was about 34% compared to *godakumbura*. However, during the yala season an opposite trend was observed with *godakumbura* giving the lowest yield. The yield difference between *medhakumbura* and *madakumbura* was small and non-significant. When yields of both the seasons were compared *medhakumbura* had a more stable environment than *godaknnbura* and *madakumbura*. Vivekanandan (1984) reported that moderately drained fields (*medhakumbura*) have suitable soil and hydrological conditions for crop growth during both the wet and dry seasons.

These seasonal variations in land element productivity can be explained by taking into account the rainfall pattern and its effects on hydrology. Rainfall (Fig. 2) during the yala season was low and the rice crop was subjected to water stress during some periods of crop growth. Frequency of water stress and its intensity at a particular land element is dependent not only on the amount of rainfall received and its distribution, but also of the water feeding capacity of the adjacent uplands. *Godakumbura* is subjected to more moisture stress than the other two land elements due to loss of water by sub-surface flow as well as runoff. Since all three land elements were within the same rice tract it is reasonable to assume that they received the same amount of precipitation. However, due to its topographic position, large amount of water is lost from *godaknmbura* as runoff and sub-surface flow. Therefore, *godakunbura* is subjected to water stress more frequently than the other two land elements even during short dry spells. On the other hand, due to water gain from upper topographic positions, *medhakumbura* and *madakumbura* had adequate water for crop growth throughout the season.

Low rainfall during the yala season acted favourably on *madakumbura* by reducing the ill drained conditions normally found in this land element during the maha season. No upwelling was found about two weeks after transplanting and, in fact, there were periods of drying during the season. These unusually dry conditions created an aerobic condition in *madakumbura* during some periods and this could have reduced the stress conditions such as high concentration of organic acids, high Fe^{++} content and Zn deficiency which usually affect plant growth. This may be the reason for high yields obtained in *madakumbura* during the yala season compared to the maha

season. This indicates that if the drainage conditions of the *madakumbura* could be improved in maha, the yield potential of this land element could also be increased.

High total rainfall and its good distribution during maha increased both the direct water availability and the amount of feeding from the adjacent uplands to *goda* land element. This provided adequate moisture throughout the season for *goda* land element and was the main reason for very high yields recorded in this land element. Contrary to this, excess water and increased upwelling conditions in *madakumbura* created a condition unfavourable for plant growth and thus yields were very low during the maha season in this land element. Poor plant growth in this type of soils could be attributed to poor root development (Vivekanandan, 1984).

Response to Nitrogen Fertilizer

The overall increase in yield at 80 kg N/ha over 40 kg N/ha for the mean of the experiments was only 7%. This overall yield increase at the N level was mainly due to the significant yield increases observed during both seasons in *godakumbura* and during the yala season in *medhakumbura*. No significant response to increased N level was observed in *madakumbura* during either yala or maha seasons. The N & P interaction was not significant in any of the seasons or locations.

Results clearly indicated that under *madakumbura* conditions there is very low response to increasing N levels from 40 to 80 kg N/ha. One reason for this very low response could be the high level of N and OM present in this type of soil (Table 1.) On the other hand, under dry conditions (*godakumbura*), there were responses to increased level of N during both seasons. Compared to *madakumbura*, the inherent OM and nitrogen contents in *godakumbura* are low (Table 1). Furthermore, cycles of alternate wetting and drying that take place in *godakumbura* will lead to heavy nitrogen losses due to denitrification, whereas this may not occur in *madakumbura*. Therefore, incorporation of N fertilizer into the *godakumbura* is more important than to *madakumbura*. In *medhakumbura*, a good response to increased N level was observed during the yala season but this was not observed during the maha season. A similar response have been observed in *medakumbura* in the Kandy district (Vivekanandan, 1984).

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Response to Phosphorus Fertilizer

Yield response to different levels of P for the two seasons is presented in Table 2. Response to different levels of P fertilizer was observed in all land elements during both seasons.

Level of P response varied both with the land element as well as with the season. During the yala season in *godakumbura* a significant yield increase was observed upto 90 kg P_2O_5 /ha, whereas in the other two land elements the response was upto 60 kg P_2O_5 /ha.

Due to water stress in *godakumbura* during the yala season this soil behaved more like an upland soil. Crop growth was poor during this season and the plant uptake of phosphorus fertilizer could have been low at low P levels. At higher P levels the availability of P was comparatively higher and yield response was observed at 90 kg P_2O_5 /ha. On the other hand during the yala season in *madakumbura* the soil factors were favourable (due to low water stagnation) for plant growth and nutrient uptake, and this resulted in very high yield increases both at 30 and 60 kg P_2O_5 /ha levels but not at 90 kg P_2O_5 /ha level.

During the maha season in *godakumbura* and *medhakumbura* no significant yield increase was observed at 30 kg P_2O_5 /ha over zero P level, but at 60 kg P_2O_5 /ha level yields increased significantly. In *madakumbura* significant yield increases were observed at both 30 and 60 kg P_2O_5 /ha levels. However, the yield levels in this land element was lower than the other two land elements for this season. Therefore, it is evident that inspite of good response to added P very high yields could not be obtained in *madakumbura* during the maha season due to other stress factors that inhibit plant growth as a result of continuous inundation of fields.

Interactions between phosphorus (P) $\times$ land element (L), phosphorus (P) $\times$ season (S) and phosphorus $\times$ land element (L) $\times$ seasons (S) were significant. Thus it is clear that even within a single rice tract the response to phosphorus fertilizer can vary with the topographic position and as well as with the season. The P response level was upto 60 kg P_2O_5 /ha at all land elements but the percentage yield increase in *madakumbura* for each P level was comparatively higher (Fig. 1b).

Level of P fertilizer recommended by the Department of Agriculture is 59 kg P_2O_5 / ha. Therefore, results clearly demonstrate that the application of the full basal fertilizer recommendation will fulfil the P requirement for all three land elements. Increasing the P levels beyond the recommendation (59 kg P_2O_5 / ha) would not increase yields even in *madakumbura* where the P availability is low. Investigations by Nagarajah *et al* (1979) and Vivekanandan (1984) also indicated that phosphorus deficiency in poorly drained soils can be corrected by the addition of about 40 — 60 kg P_2O_5 / ha.

Comparison of yields between seasons for *madakumbura* indicates that yields were higher during yala than maha at each of the P levels. It is therefore clear that high yield levels cannot be attained by application of phosphorus alone, but there are other seasonal factors which govern yields that have to be taken into account. Higher yields obtained during the yala season were due to low water stagnation in these fields which would have eliminated some of the stress factors that limit plant growth. Since the P levels used during both seasons were the same, the main factor that would have made the yield differences is the level of water stagnation in *madakumbura*. Continuous inundation and water logging in *madakumbura* give rise to development of other stress factors other than P deficiency. In most of these soils there can be more than one stress factor that limits plant growth (Gunawardena, 1982) and a good understanding of these factors is required to improve the yield potential of *madakumbura*.

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Table 1. Soil analysis data of surface samples (0–15 cm) for the three land elements.

<i>Land element</i>	<i>pH</i>	<i>Total N%</i>	<i>P ppm (Olsen)</i>	<i>Exch. K me / 100g</i>	<i>Organic matter%</i>
Goda	4.4	0.09	22	0.17	1.94
Medha	4.8	0.12	6	0.14	2.38
Mada	4.5	0.14	4	0.14	4.58

Table 2. Effect of different levels of nitrogen and phosphorus on grain yield of rice variety Bg 94–1 (3½ months) at different land elements—Maha 80/81 and Yala 81 seasons.

<i>Treatment</i>	<i>Yield — (t / ha)</i>					
	<i>Goda</i>		<i>Medha</i>		<i>Mada</i>	
	<i>Maha 80 / 81</i>	<i>Yala 81</i>	<i>Maha 80 / 81</i>	<i>Yala 81</i>	<i>Maha 80 / 81</i>	<i>Yala 81</i>
1. N0 P0 (control)	4.45	2.40	3.24	3.71	2.87	3.75
2. N40 P0	4.98	2.68	4.07	4.06	3.07	3.75
3. N40 P30	5.10	2.96	4.12	4.39	3.58	4.74
4. N40 P60	5.85	3.06	4.99	4.75	3.99	5.56
5. N40 P90	5.46	3.29	4.90	4.75	3.73	5.22
6. N80 P0	5.39	3.21	4.32	4.47	3.15	2.98
7. N80 P30	5.59	3.33	4.39	4.97	3.78	5.18
8. N80 P60	6.01	3.49	5.29	5.38	4.15	5.76
9. N80 P90	5.85	3.64	4.84	5.33	4.07	5.54
Location Mean	5.41	3.12	4.46	4.65	3.60	4.72
<i>Main effects of N&P</i>						
N40	5.34	3.00	4.52	4.49	3.59	4.82
N80	5.71	3.42	4.71	5.04	3.79	4.86
P0	5.18	2.94	4.19	4.27	3.11	3.36
P30	5.35	3.15	4.25	4.68	3.68	4.96
P60	5.93	3.28	5.14	5.07	4.07	5.67
P90	5.66	3.47	4.87	5.04	3.90	5.38
LSD (0.05, 16)						
Nitrogen	0.38	0.17	ns	0.32	ns	ns
Phosphorus	0.58	0.25	0.56	0.45	0.35	0.62
N × P	ns	ns	ns	ns	ns	ns
CV%	8.1	6.3	9.9	7.9	7.7	10.4

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Table 3. Combined analysis data to compare nitrogen, phosphorus, land element and season effects and their interactions: (Yield t / ha).

		Season		Land element			Phosphorus				Mean
		Maha 80 / 81	Yala 81	Goda	Medha	Mada	P ₀	P ₂₀	P ₄₀	P ₆₀	
Nitrogen	N ₄₀	4.49	4.10	4.17	4.50	4.21	3.77	4.15	4.70	4.56	4.30
	N ₈₀	4.73	4.44	4.56	4.87	4.33	3.92	4.54	5.01	4.88	4.59
Phosphorus	P ₀	4.16	3.52	4.06	4.23	3.24					3.84
	P ₃₀	4.43	4.26	4.25	4.47	4.32					4.35
	P ₆₀	5.05	4.67	4.61	5.10	4.87		—			4.86
	P ₉₀	4.81	4.63	4.56	4.96	4.64					4.72
Land element	Goda	5.53	3.21								4.37
	Medha	4.61	4.76		—			—			4.69
	Mada	3.69	4.84								4.27
	Mean	4.62	4.27	4.37	4.69	4.27	3.84	4.35	4.86	4.72	

LSD (0,05,12)

1. Land elements = 0.33
2. Seasons = 0.28
3. Land elements × Season = 0.48

LSD (0,05,84)

4. Nitrogen = 0.13
5. Phosphorus = 0.18
6. Land elements × Nitrogen = 0.22
7. Land elements × Phosphorus = 0.31
8. Season × Nitrogen = 0.18
9. Season × Phosphorus = 0.26
10. Nitrogen × Phosphorus = 0.26

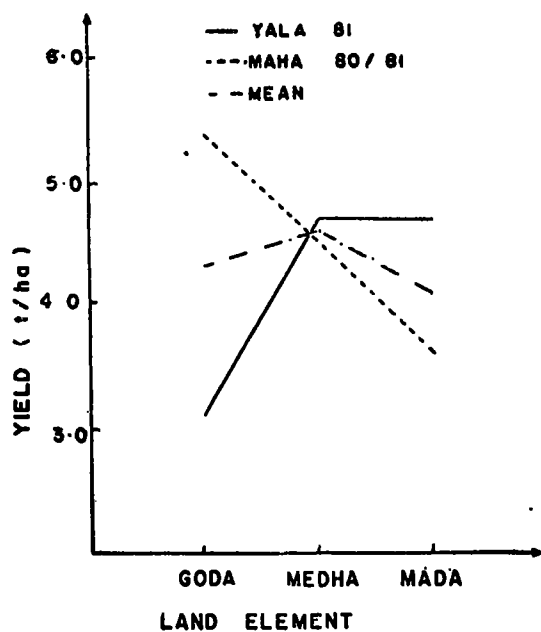


Fig. 1a Effect of season and land element on grain yield

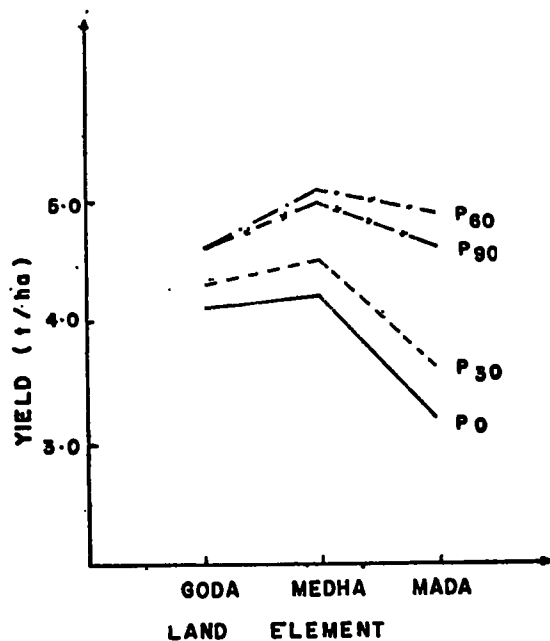


Fig. 1b Effect of land element and P fertilizer on grain yield

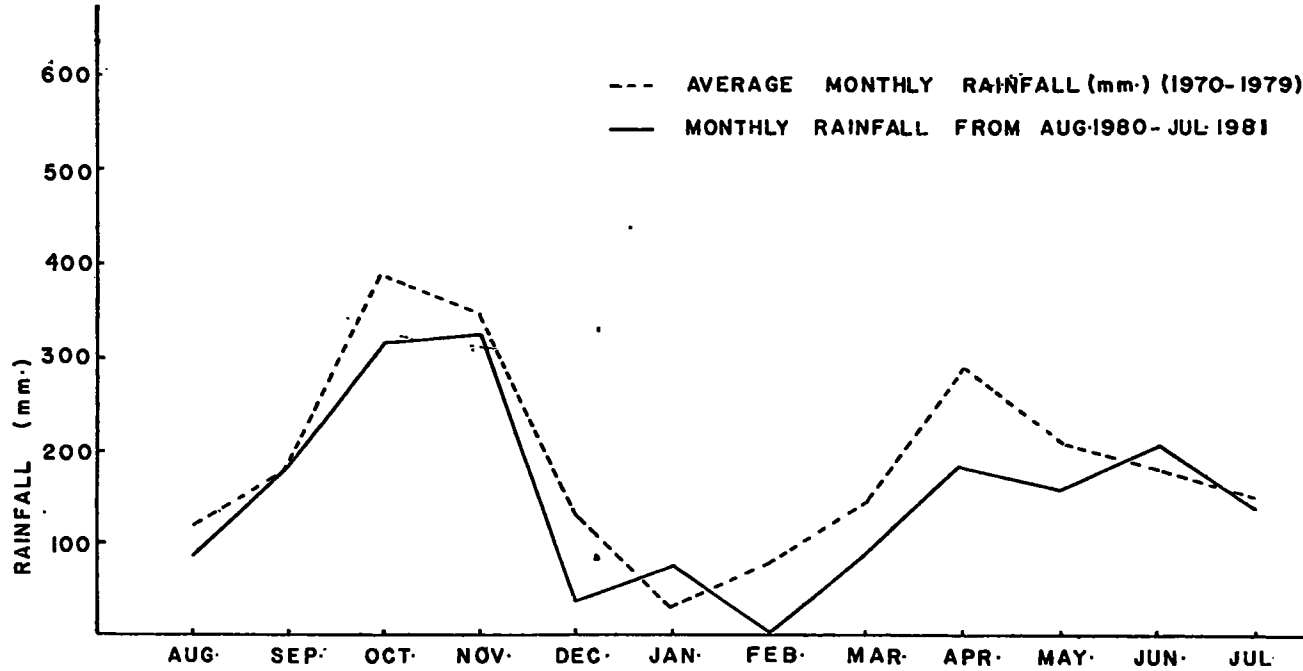


Fig. 2. Monthly rainfall (Aug. 1980 — July 1981) and average monthly rainfall (1970 — 1979) in Kegalle District