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INFLUENCE OF SOIL TYPE AND SELECTED SOIL MORPHOLOGICAL PROPERTIES ON YIELD OF COCONUT (*COCOS NUCIFERA*) I. BANDIRIPPUWA ESTATE, LUNUWILA

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ABSTRACT

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A study on the effect of soil type on coconut yield was conducted at Bandirippuwa Estate, Lunuwila which is located in the border of the Wet and Intermediate rainfall zones of Sri Lanka. A 2 hectare block of coconut land consisting of 300 adult palms was selected for this study.

A detailed soil survey carried out on this land showed that there are four soil types which are some of the major soil types of the coconut growing areas in Sri Lanka. The four soil types are: (1) Sudu series, which is poorly to imperfectly drained, very deep loamy sand, (ii) Boralu series, deep phase, which is well drained, deep, sandy clay loam with gravels (iii) Pallama series, which is imperfectly drained, very deep, sandy loam and (iv) Boralu series, shallow phase, which is well drained, shallow, sandy clay loam with gravels. The corresponding average yields (kg copra/palm/year) for the period 1943 - 1952 were: (1) 16.9 (ii) 13.7 (iii) 11.0 and (iv) 9.4.

The effects of soil depth, gravel depth (depth at which gravels appear), soil texture and drainage and their interactions on coconut yield are discussed. Yield depended on soil or gravel depth only in light textured and better drained soils. Gravel depth influenced yield only in shallow soils (< 120 cm). Texture affected yield when the depth of soil or gravel was shallow or the drainage was good. Yield was dependent on drainage only in heavy textured soils.

INTRODUCTION

In Sri Lanka, coconut is cultivated under a variety of soil and climatic conditions. Coconut grows on coastal sands (sandy Regosols or Entisols) in the Northern and Eastern Provinces; on acid soil with lateritic gravels or laterite (Red Yellow Podzolic soils with laterite or Ultisols) in the Southern and Western Provinces; and in the North Western Province on acid sandy clay loams with strong mottling in the subsoil (Red Yellow Podzolic soils with mottled subsoil or Ultisols) and sandy clay loams with gravels (Non Calcic Brown soils and Reddish Brown Earths or Alfisols) as well as the lateritic gravels with laterites and sands mentioned earlier (De Alwis and Panabokke, 1972 - 73). The Northern and Eastern Provinces are in the Dry zone (mean annual rainfall < 1300 mm) and experience rainfall mostly during the North East monsoon and suffer drought during the rest of the year. Southern and Western Provinces are in the Wet zone (rainfall > 1900 mm) and North Western Province in the Intermediate zone (rainfall 1300 - 1900 mm) receiving rainfall both in the South West and North East monsoons and therefore are not subject to extensive periods of drought except perhaps the Northern Section of Puttalam District in the North Western Province.

As there are a wide range of soils and rainfall zones, considerable variation in productivity and yield is expected. Although there are vague ideas about good or poor soils for coconut (Salgado, 1950), no quantitative information is so far available, on the yield of each of the different soil types.

The performance of coconut depends on many factors such as soil characteristics, climate, management practices, genetic character of the planting material, age etc. A study on the effect of soil type[1] on coconut yield is feasible only when the other factors are nearly the same among the soil types to be compared. As these factors are seldom the same from estate to estate it is rather difficult to relate the yields to the differences in soils alone. Further, estate owners very rarely keep records of the yield, palm by palm, for a sufficiently long period of time to permit reliable analysis of the data.

This paper presents the results of a study on the effect of soil type and some selected soil morphological properties such as texture, soil depth, gravel depth (depth where gravels begin to appear), drainage and their interactions on coconut yield in a block of 2 ha located in the border of the Wet and Intermediate zones, where desirable environmental conditions suitable for this study prevail.

MATERIALS AND METHODS

Experimental Site

A block of 2 ha at Bandirippuwa Estate, Lunuwila, which receives a mean annual rainfall of about 1900 mm was selected for this study. The block consists of 300 adult palms (variety, *typica*) of uniform age, each of which received the same management from 1933 to 1952. Cultural practices such as manuring, harrowing and ploughing were carried out regularly according to the recommendations of Coconut Research Institute of Sri Lanka.

Yield data

The yield record (nuts and copra) of each palm for each pick has been maintained by the Botany Division of the Coconut Research Institute of Sri Lanka from 1942 onwards (when the palms were 45 years). The average yield of each palm for the period 1943 - 1952 was used in this study.

Soil data

A detailed soil survey of the site was carried out and measurements on soil depth, gravel depth, texture and drainage were made from borings at the centre of each square formed by 4 palms. The soil characteristic corresponding to a palm was obtained by averaging the values obtained from the 4 borings lying at the apices of the square with the test palm at the centre. The average of only 2 or 3 borings was used for palms lying along the boundaries of the block. In order to study quantitatively the effects of these soil characteristics on the yield of coconut, numerial values were assigned to each soil characteristic as follows:–

Soil depth – actual value within the range 0 to 125 cm
Gravel depth – actual value within the range 0 to 125 cm
Drainage – Score
80 – well drained
60 – moderately well drained
40 – imperfectly drained
20 – poorely drained.

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1 The word "type" is not used to convey the meaning as in the Soil Classification but to designate soils with different characteristics.

Average texture – **Score**

100 – sand
80 – loamy sand
60 – sandy loam
40 – sandy clay loam
20 – sandy clay

Average texture denotes the weighted average of the different textures in the soil profile.

RESULTS AND DISCUSSION

Effect of soil type on yield

The detailed soil survey of the site revealed that there are four soil types. A sketch of the experimental site, with the soil boundaries is shown in Fig. 1. Description of these soils and the average yield of the palms corresponding to each of these soils are presented in Table 1.

Soil 1 is shallow, well drained, sandy clay loam, and lateritic gravels appear almost from the surface. Laterite is observed above a depth of 50 cm. These properties are typical of the most extensive soil type of the coconut growing areas of Sri Lanka - the shallow phase of the lateritic soils. Soil 2 has almost the same properties as Soil 1, except that it is deep and gravels appear deeper in the profile. Mottles were observed in the subsoil. This soil is similar to the deep phase of the lateritic soils of the coconut growing areas. At series level, both these soils could be classified as Boralu series (Anon., 1963).

Soil 3 is very deep, imperfectly drained, sandy loam at the surface to sandy clay loam at depth. Unlike the first two, no gravels appear upto 125 cm, the deepest level tested. Prominent mottles appear at depths below 75 cm. This soil has properties similar to the deep loamy soils of the coconut growing regions, and could be classified as Pallama Series (Anon.,1963)

Soil 4 is very deep, poor to imperfectly drained and loamy sand to sand in texture and no gravels appear down to 125 cm, the deepest layer tested. This soil has properties similar to the cinnamon sands of the coconut growing regions and at series level is classified as Sudu series (Anon., 1963).

From the above descriptions it could be seen that the four soils observed in the experimental area roughly represent a major part of the soils in the coconut growing areas of Sri Lanka. Table 1 shows that the yield of coconut varied widely among these soils. Soil 1 had the lowest yield probably due to its shallow depth. The higher yield of palms in Soil 2 over Soil 3 shows that coconut prefers well drained soils to imperfectly drained ones. However, this does not appear to apply in the case of Soil 4. Palms in Soil 4, under poor to imperfectly drained conditions, had the highest yield among the four soil types. A likely explanation is that in areas like this where the rainfall is low or unevenly distributed, and the texture is light (low moisture holding capacity) palms may have to depend on the ground water during periods of drought. Under such conditions imperfect drainage may be advantageous. Palms in Soil 4 being in light textured soils and in the border of the Wet and Intermediate rainfall zones had therefore beneficial effects from imperfect drainage. But if the texture is heavy as in Soil 2 and 3, soil aeration would become limiting and therefore good drainage is necessary for better performance of the palms.

Effect of soil morphological properties on yield

The mean soil characteristics corresponding to palms of various yield groups did not show any distinct relationship between yield and any single soil characteristic (Table 2). This is to be expected as these individual characteristics interact among themselves and the yield is mostly governed by such interactions. In this section the effects of these interactions on yield are discussed.

Soil depth and texture : Table 3 shows the interacting effects of depth and texture on yield. A score of 45 was used to distinguish the light textured soils from the heavy textured soils and a depth of 120 cm was used to distinguish deep soils from the shallow soils (unless otherwise stated a depth of 120 cm was always taken as the demarcation of shallow and deep soil depths or gravel depths in the rest of the paper). These scores were selected arbitrarily to have sufficient number of palms above and below these scores for the data to be statistically analysed.

The data show that in light textured soils there was a significantly higher proportion of high yielding palms in the deeper soils (x^2 = 7.54**). In the heavy textured soils, high and low yielding palms were equally distributed between the shallow and deep soils, indicating that in heavy textured soils the yield was not significantly influenced by depth of soil— 120 cm being taken as the depth of demarcation between shallow and deep soils (x^2 = 0.42 N.S.). This suggests that in heavy textured soils 120 cm is adequate for coconut, but in light textured soils a depth more than 120 cm is preferred. For the heavy textured soils, soil depth may have some influence on yield at depths of demarcation less than 120 cm, but the data is not sufficient to permit any analysis at such depths of demarcation.

The data also show that a significantly high proportion of high yielding palms is associated with a heavy texture when the soils are shallow (x^2= 5.33**). But the yield was not significantly affected by texture when the soils are deep (x^2 = 0.10 N. S.). This is probably due to the unfavourable conditions of the necessarily limited soil volume and the less fertile light textured fraction where the soils are shallow.

Gravel depth and texture : The effects of gravel depth and texture are similar to the effects of soil depth and texture discussed earlier - where texture is light, gravel depth has influence in light textured soils but not in heavy textured soils and texture has influence in soils having shallow gravel depths but not in soils having deep gravel depths (Table 4).

In the heavy textured soils, gravel depth appears to have no significant bearing on yield when the arbitrarily chosen depth of demarcation was 120 cm. Therefore similar tests were carried out for varying depths of demarcation namely 90, 60 and 30 cm. The corresponding x^2 values are shown in Table 5. The results show that the x^2 values increase progressively as the level of demarcation of gravel depth is reduced and become significant at a depth of 30 cm. This indicates that in heavy textured soils a depth of demarcation of around 30 cm for gravel can be considered reasonable for coconut. Below this gravel depth, there was a predominance of high yielding palms even in heavy textured soils. This suggests that for a good yield, there should be a minimum gravel depth of 30 cm in heavy textured soils.

Therefore in heavy textured soils the limiting gravel depth influencing coconut yield was very much lower than in the case of light textured soils (30 vs 120 cm). This is expected as a greater soil volume is required in light textured soils in order to have the same amount of surface area, charges etc., for the retention of nutrients and moisture as in heavy textured soils.

Soil depth and drainage : Table 6 shows the interaction of soil depth and drainage on yield. A score of 70 was used to distinguish good from impeded drainage. The data shows that where the drainage is good there was a significantly higher proportion of high yielding palms in deep soils (x^2 = 5.21*) indicating that performance of coconut is better at soil depths $\geq$ 120 cm. In soils with impeded drainage, depth of soil appears to have no bearing on yield (x^2 = 0.23, N. S.). This suggests that deep roots do not make significant contribution towards the yield under conditions of impeded drainage. This may be due to insufficient root aeration at depths.

No significant influence of drainage on yield was observed within the range of shallow or deep soils.

Gravel depth and drainage : Whether the drainage is good or impeded, gravel depth appears to have no significant bearing on yield (Table 7). Chi-square tests were repeated for other gravel depths and the results are shown in Table 8. When the gravel depth of demarcation is reduced, x^2 values became significant indicating that a gravel depth of demarcation of 90 cm can be considered reasonable. However, this feature appears to be associated with soils having good drainage. Therefore both soil depth and gravel depth have some influence on yield only in soils, with good drainage.

Drainage exerted no significant influence on yield within the range of shallow or deep gravel depths.

Drainage and texture : Drainage and texture had varying interactions (Table 9). Good drainage in association with heavy texture gave significantly higher yield. Under good drainage, texture had significant effect on yield (x^2 = 6.18**), while in heavy textured soils, drainage had significant effect (x^2= 5.20*).

Although the heavy textured soils have the disadvantages of poor aeration, impeded root penetration, poor infiltration (saturated), they have the advantage of a high capacity for retention of water and plant nutrients. The set backs or disadvantages, mentioned above could be overcome by better drainage and therefore the palms on heavy textured soils are observed to perform better than the palms on light textured soils under better drainage.

It was suggested earlier in the paper that under impeded drainage, light texture may be of advantage at places where there is insufficient rainfall. But the data in Table 9 shows that under impeded drainage there was no significant effect of soil texture on yield. Due to lack of sufficient data analysis could not be made at other levels of demarcation of heavy and light textured soils.

Soil depth and gravel depth: Table 10 shows the interaction of soil depth and gravel depth on yield. The x^2 values showed that these interactions are not significant. The data for shallow soils were regrouped and tested for gravel depths of demarcation of 60 and 30 cm. The results are shown in Table 11. It could be seen from this table, that when the gravel depth of demarcation is lowered to 30 cm, a significantly higher proportion of high yielding palms occurred at deeper gravel depths. This is probably because in shallow soils, the soil volume is limited and if this too is largely occupied by gravels, the fine soil fraction is still reduced thus affecting the yield considerably. The data for deep soils was not sufficient to test for other gravel depths of demarcation.

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Table 1. *Mean yield of coconut on different soil types*

Soil	Depth	Texture	Drainage	Gravel	Copra weight kg/palm/year	Nuts/palm/year
1	Shallow	Sandy clay loam	Well	Present	9.4	48.2
2	Deep	Sandy clay loam	Well	Present	13.7	69.3
3	Very Deep	Sandy loam	Imperfect	Absent	11.0	66.3
4	Very Deep	Loamy sand	Poor to imperfect	Absent	16.9	77.7

Table 2. *Mean soil characteristics of palms of various yield groups*

Yield group nuts/palm/year	Soil depth cm	Gravel depth cm	Drainage score	Texture score	Number of palms
≥ 90	109	94	64.5	47.1	32
80–89	108	91	65.5	45.4	52
70–79	105	88	67.3	45.4	54
60–69	113	97	59.0	47.9	59
50–59	107	94	63.0	46.2	44
40–49	97	75	66.8	45.9	36
< 40	102	79	66.4	46.1	21

Table 3. *Soil depth* x *texture interaction*

Yield nuts/palm/year	Light texture score ≥ 45			Heavy texture score < 45		
	Number of palms in soil depth (cm)			Number of palms in soil depth (cm)		
	< 120	≥ 120	total	< 120	≥ 120	total
High yielding ≥ 50	29	92	121	82	38	120
Low yielding < 50	16	17	33	18	6	24

Table 4. *Gravel depth* x *texture interaction*

Yield nuts/palm/year	Light texture score ≥ 45			Heavy texture score < 45		
	Number of palms in gravel depth (cm)			Number of palms in gravel depth (cm)		
	< 120	≥ 120	total	< 120	≥ 120	total
High yielding ≥ 50	57	64	121	105	15	120
Low yielding < 50	22	11	33	22	2	24

Table 5. *Chi - squared values for different gravel depths of demarcation for heavy textured soils*

Gravel depth of demarcation (cm)	Chi - squared value
120	0.33
90	0.39
60	0.31
30	3.49*

* Significant at 5 % level.

Table 6. *Soil depth* x *drainage interaction.*

Yield nuts/palm/year	Drainage good score ≥ 70			Drainage impeded score < 70		
	Number of palms in soil depth (cm)			Number of palms in soil depth (cm)		
	< 120	≥ 120	total	< 120	≥ 120	total
High yielding ≥ 50	93	20	113	17	111	128
Low yielding < 50	31	1	32	3	22	25

Table 7. *Gravel depth* x *drainage interaction*

Yield nuts/palm/year	Drainage good score ≥ 70			Drainage impeded score < 70		
	Number of palms in gravel depth (cm)			Number of palms in gravel depth (cm)		
	< 120	≥ 120	total	< 120	≥ 120	total
High yielding ≥ 50	105	8	113	57	71	128
Low yielding < 50	31	1	32	13	12	25

Table 8. *Chi - squared values for different gravel depths of demarcation*

Gravel depth of demarcation (cm)	Chi-squared value	
	Drainage ≥ 70	Drainage < 70
120	0.67	0.47
90	4.15*	0.01
60	4.38*	- †

* Significant at 5% level
† no data available.

Table 9. *Texture* x *drainage interaction*

Yield nuts/palm/year	Drainage good score ≥ 70			Drainage impeded score < 70		
	Number of palms in texture			Number of palms in texture		
	< 45	≥ 45	total	< 45	≥ 45	total
High yielding ≥ 50	91	32	123	24	71	95
Low yielding < 50	17	16	33	12	35	47

Table 10. *Gravel depth* x *soil depth interaction*

Yield nuts/palm/year	Deep soil ≥ 120 cm			Shallow soil < 120 cm		
	Number of palms in gravel depth (cm)			Number of palms in gravel depth (cm)		
	< 90	≥ 90	total	< 90	≥ 90	total
High yielding ≥ 50	8	123	131	91	19	110
Low yielding < 50	1	22	23	31	3	34

Table 11. *Chi-squared values for different gravel depths of demarcation for shallow soils* (< 120 *cm*).

Gravel depth of demarcation "A" cm	Percentage of high yielding palms		Chi-squared value
	< A	≥ A	
90	74.6	86.4	1.44
60	70.1	81.8	2.73
30	56.7	81.6	8.11**

** Significant at 1% level.

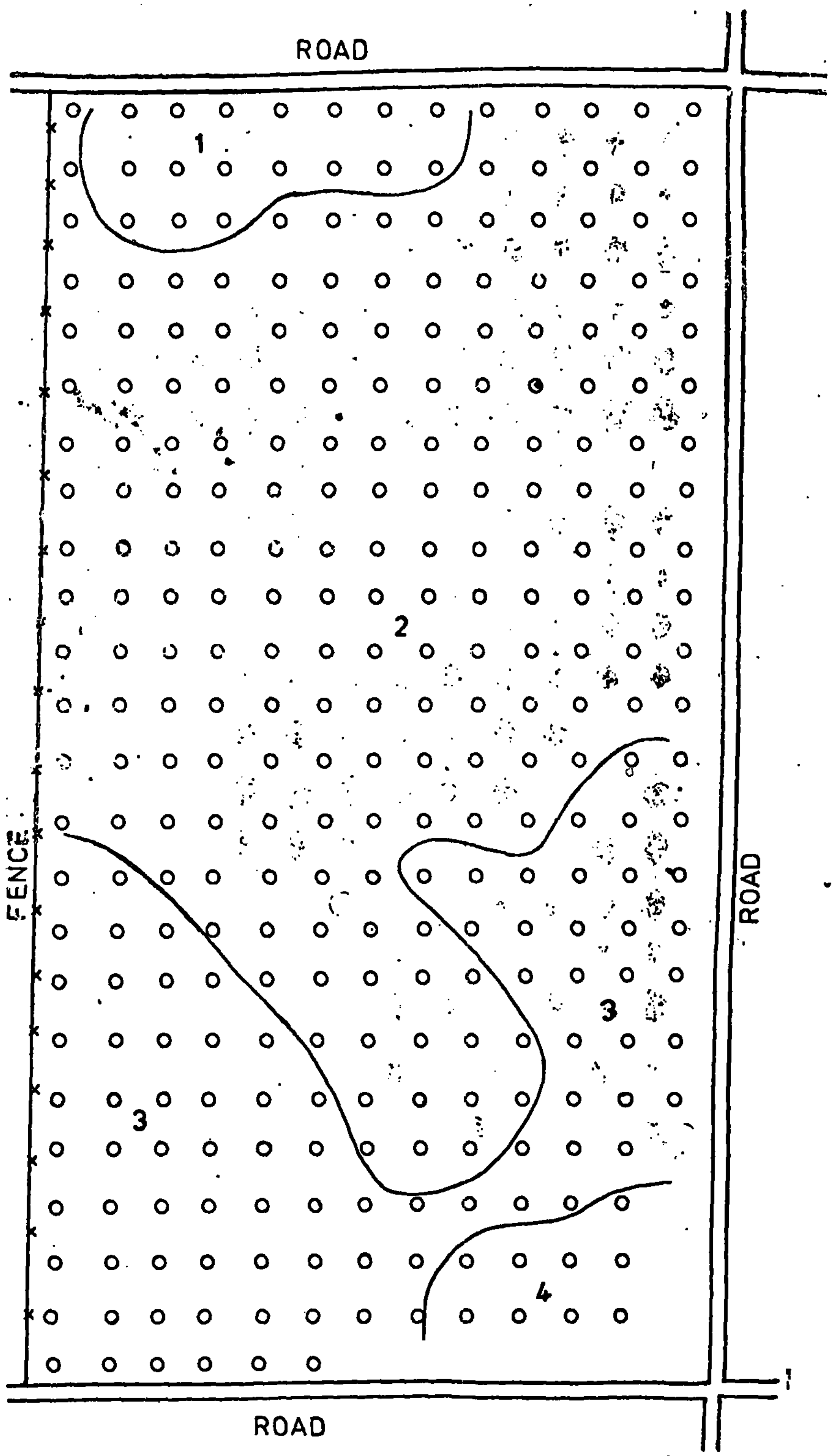

Fig. 1. Soil map of the 300 palm block (o-coconut palms,)