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Study of Soil and Crop Parameters of Coconut Orchard for Design of Tractor Operated Coconut Basin Lister Cum Fertilizer Applicator

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To study the soil and crop parameters of coconut orchard for the design of tractor operated coconut basin lister cum fertilizer applicator.
Place and Duration of Study: The study was conducted in Instructional Farm, KCAET in the Year 2021.
Methodology: Soil parameters such as moisture content, bulk density, cone index and shear strength; crop parameters such as trunk diameter and root zone depth of coconut palm were studied using standard procedures to design tractor operated coconut basin lister cum fertilizer applicator.
Results: The soil moisture content varied from 13.2 to 15.6% with mean of 14.66%. The soil bulk density ranged from 1615 to 1865 kg m^{-3} with mean of 1696.6 kg m^{-3}. The soil cone index varied

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from 0.428 to 1.506 N mm^{-2} with mean of 1.041 N mm^{-2}. The soil shear strength varied from 1.47×10^{-3} to 3.13×10^{-3} N mm^{-2} with mean of 2.31×10^{-3} N mm^{-2}. The trunk diameter of coconut palm varied from 32.3 to 38.1 cm with mean of 34.74 cm. The root zone depth of coconut palm varied from 13.4 to 15.2 cm with mean of 14.3 cm.

Conclusion: Soil moisture content, bulk density, cone index and shear strength helped in the design of power requirement, rotor shaft, cutting blades, main shaft etc. of the machine. The trunk diameter of the coconut palm aided in deciding the working width of the machine while the root zone depth assisted in finalizing the operational depth of the machine.

Keywords: Basin lister; coconut; cone index; shear strength; soil bulk density.

1. INTRODUCTION

Agriculture plays an integral role in the economy of India and the total workforce involved in agriculture and allied sector in the country is 54.6%. In India, the total geographical area and the net sown area is 328.7 million hectares and 139.4 million hectares respectively in 2016-17. India is favourable for growing horticultural crops such as vegetables, fruits, tuber crops, mushroom, ornamental crops, medicinal and aromatic plants, spices and plantation crops like coconut, cocoa, tea, coffee, etc. The horticultural crops production in the country was 319.56 million tonnes in an area of 26.21 million hectares and horticultural crops production in Kerala was 9.16 million tonnes in an area of 1.55 million hectares for the year 2019-20 [1]. Coconut palm comes under plantation crops in the category of horticulture crops. The plantation crops production in the country was 16.03 million tonnes in an area of 4.07 million hectares for the year 2019-20 and the plantation crops production in Kerala was 5.5 million tonnes in an area of 0.97 million hectares for the year 2019-20 [1].

India's share in coconut production in the global arena is 34.73%. Around 12 million people of the country depend on coconut cultivation, processing and related activities. The area and production of coconut in the country was 2.17 million hectares and 20,308.70 million nuts respectively for the year 2019-20 [1]. The south Indian states have a share of 89.66% in the area and 88.97% in production of coconut in the country. Kerala leads in coconut production with 34.37% share of production in the country and it produced 6980.30 million nuts in an area of 0.76 million hectares for the year 2019-20 [1]. The basin listing operation is performed in about a 1.8 m radius around the coconut palm for irrigation requirements aiding in the growth of plants. The fertilizer application is performed by digging a ditch to a depth of 10 cm at a radius of 1.8 m from the base of the coconut palm. For the good management of coconut palm; 0.50 kg of N, 0.32 kg of P_2O_5 and 1.20 kg of K_2O fertilizer rates need to be applied [2]. Drudgery prone, expensive, time consuming, less ease of operation, plant damage, accident prone, lower operational depth, lower precision and fertilizer losses occur with manual operation of basin listing and fertilizer application. The availability of machines and research works were not reported for basin listing and fertilizer application operations of the coconut palm. Therefore, a research work was attempted to design and develop a tractor operated coconut basin lister cum fertilizer applicator. In this regard, soil and crop parameters were studied to assist in the design of various parts of tractor operated coconut basin lister cum fertilizer applicator.

Adeniran and Babatunde [3] investigated soil properties affecting optimum soil cultivation and the study revealed that the cone index increased with depth and decreased with an increase in moisture content as high moisture content reduced the soil cohesion. Kumar et al. [4] conducted a study to assess soil cone index for no-tillage and conventional tillage and the results indicated that higher bulk density and greater soil depth resulted in higher cone index while higher moisture content reduced cone index. Thorat et al. (2014) studied soil properties such as soil moisture content, soil bulk density and cone index for the design of ridge profile weeder and they found that draft increased with cone index but showed a reverse trend with soil moisture content and soil bulk density exhibited linear relationship between with soil moisture content. Srinivas and Meena [5] studied the cone index in sandy loam soils with cone penetrometer and it varied from 11.7 to 15 N/cm^2 up to a depth of 5 cm. Further, it was concluded that the cone index increased with depth and affected the operational speed and power requirement of the machine.

2. METHODOLOGY

The study was conducted in Instructional Farm, KCAET in the Year 2021. The procedure for measuring soil and crop parameters influencing the design and development of a tractor operated coconut basin lister cum fertilizer applicator are elucidated below. These parameters were taken just before the operations of basin listing and fertilizer application for the coconut palm.

2.1 Soil Parameters

Soil parameters such as moisture content, bulk density, cone index and shear strength were determined as they would be helpful in the design of tractor operated coconut basin lister cum fertilizer applicator.

2.1.1 Moisture content

Moisture content is the ratio of the weight of water to the weight of the solids. It is expressed in percentage and is found out by oven dry method as shown in Fig. 1. Soil samples of different locations were collected from the fields at depth upto12.5 cm. The soil samples of 50 g each were collected in different containers and placed in a hot electric oven under a controlled temperature of 105°C for 24 hours [6]. The weight before and after drying was found out using an electronic weighing balance having a sensitivity of 0.01 g. The moisture content of soil affects the draft of the implement and slip. Soil moisture content helps in the optimum design of the machine for lowering energy input.

$$\mathrm{MC} = \frac{\mathrm{W_1} - \mathrm{W_2}}{\mathrm{W1}} \times 100$$

Where,

MC	=	Soil moisture content, %
W_1	=	Initial weight of soil sample, g
W_2	=	Final weight of dry soil sample, g

Fig. 1. Soil moisture content measurement by oven drying method

2.1.2 Bulk density

The compactness of the soil is determined by the bulk density and is measured by core cutter as shown in Fig. 2. Initially, the cylinder volume was determined by measuring the internal diameter (10 cm) and height of the core cutter (12.5 cm). Then empty core cutter was weighed and noted. A small area of the soil to be tested in the experimental field was exposed and the surface was levelled. A cylindrical core cutter was pressed into the soil mass using the rammer with a dolley placed over the top of the core cutter. Pressing was stopped when the dolley protrudes about 15 mm above the surface. Surrounding soil of core cutter was removed and it was taken out. The core cutter filled with soil was removed and weighed. The bulk density was calculated using the equation mentioned [7].

$$\rho = \frac{\mathrm{M}}{\mathrm{V}}$$

Where,

ρ	=	Bulk density of soil, kg m^{-3}
M	=	Mass of the oven dried soil, kg
V	=	Volume of core sampler, m^3

Fig. 2. Soil bulk density measurement by core cutter method

2.1.3 Cone index

A Cone penetrometer was used to measure the penetration resistance of the soil by positioning it near the coconut palm. The cone index indicates soil resistance and it is expressed as force per square centimetre required for a cone of standard base area to penetrate into soil to different depths. The cone index for the same soil varies with the cone apex angle, area of cone base and depth of penetration [8]. A uniform force was placed on the handle and the deflection of dial gauge was noted for different depths. The cone index was measured from 2.5 to 12.5 cm depth and recorded manually.

2.1.4 Shear strength

The shear strength of a soil is the maximum resistance offered by the soil to shear stress [9]. The in-situ measurement of shear strength of soil was carried out using a Triaxial shear test apparatus. A bore hole at depth of 12.5 cm was dug out. Casing was extended up to these depths and hence the entire unit was fixed at the location during the test. Vane was connected to the rod having the same female thread and it was pushed downward with a moderate steady force up to a depth of 50 mm below the bottom of the bore hole and allowed to move further. The initial dial gauge reading was set to zero and the gear handle was turned so that the vane was rotated at the rate of 0.1 deg. per second, this in turn helps to get a uniform rate of 12 turns per minute. The torque indicator dial gauge reading was noted and the rotation of vane was continued until the reading drops appreciably from the maximum.

$$S = \frac{T}{\pi\left(\frac{D^2 H}{2} + \frac{D^3}{6}\right)}$$

Where,

S = Shear strength, kgf cm^{-2}
T = Torque, kgf cm
D = Overall diameter of vane, cm
H = Height of the vane, cm

2.2 Crop Parameters

The major crop parameters such as trunk diameter of coconut palm and root zone depth were considered. These parameters were studied at the time of basin listing and fertilizer application for coconut palm. These parameters influence the design of a tractor operated coconut basin lister cum fertilizer applicator.

2.2.1 Trunk diameter of coconut palm

About 25 coconut palms were selected randomly in the experimental plot to measure the trunk diameter of coconut palm. The trunk diameter of coconut palm was recorded by using the measuring tape and the average of these readings was noted. It helps in deciding the working width of machine and in turn the filed capacity of machine.

2.2.2 Root zone depth

To measure the root zone depth, 25 coconut palms were chosen at random in the coconut plantation area. An area of 1.5 m radius around the coconut palm was marked and the soil was dug randomly until the roots appear. Then measuring tape was used to measure the root zone depth of coconut palm against the flat top layer of soil and the average of these readings was considered. Root zone depth helps in deciding the depth of operation of machine and design of parts such as rotor shaft, cutting blades, main shaft etc. that determine the machine power requirement.

3. RESULTS AND DISCUSSION

3.1 Soil Parameters

The data of soil parameters obtained from experiments was statistically analysed in MS Excel 2019 version [10]. The obtained results of soil parameters are rationalized in the following sections [11].

3.1.1 Moisture content

The moisture content of the soil was determined and statistically analysed. The soil moisture content varied from 13.2 to 15.6% with a mean of 14.66%, coefficient of variance of 6.77% and standard deviation of 0.993 as mentioned in Table 1. The machine needs to be designed considering the obtained moisture content of soil as it affects the energy demand for basin listing operation.

3.1.2 Bulk density

The soil bulk density was measured randomly in the experimental plot of coconut plantation. Soil samples were collected within the radius of 1.8 m of coconut palm as the basins and fertilizer application is done in this zone. The bulk density of soil was determined and statistically analysed. The bulk density of the soil ranged from 1615 to 1865 kg m^{-3} with a mean of 1696.6 kg m^{-3}, coefficient of variation of 5.94% and standard deviation of 100.842 as shown in Table 1. Generally, the bulk density of soil varies with soil moisture. It was observed that bulk density of soil increased with increase in soil moisture content and had a linear relationship. Soil bulk density is a crucial parameter in the ease of movement of machine in basin listing and fertilizer application operations.

Table 1. Soil and crop parameters

	Soil parameters				Crop parameters	
S. No.	**Moisture content (%)**	**Bulk density (kg m^{-3})**	**Cone index (N mm^{-2})**	**Shear strength (10^{-3}×N mm^{-2})**	**Trunk diameter (cm)**	**Root zone depth (cm)**
1	14.8	1865	0.428	1.47	32.3	14.5
2	15.5	1705	0.837	1.86	38.1	13.4
3	13.2	1672	1.113	2.45	35.8	15.2
4	14.2	1615	1.325	2.64	34.2	14.8
5	15.6	1626	1.506	3.13	33.3	13.8
Range	2.4	250	1.078	1.66	5.8	1.8
Mean	14.66	1696.6	1.041	2.31	34.74	14.34
S.D	0.993	100.842	0.424	0.653	2.276	0.733
C.V(%)	6.77	5.94	40.73	28.26	6.55	5.11

3.1.3 Cone index

The cone index of soil was determined and statistically analysed. The cone index varied from 0.428 to 1.506 N mm^{-2} with a mean of 1.041 N mm^{-2}, coefficient of variation of 40.73% and standard deviation of 0.424 as given in Table 1. The cone penetration resistance values increased with depth as the bulk density increased. As the depth increased from surface, the soil resistance was also increased. The cone index is an important consideration in the design of power requirement of the machine. The coefficient of determination (R^2) value was estimated as 97.17% indicating the high accountancy of cone index with depth and it is depicted in Fig. 3. The model was highly significant ($p \leq 0.05$) which means that there is a linear relationship between cone index and depth and it is reported in Table 2.

3.1.4 Shear strength

The shear strength of soil was determined and analysed statistically. The shear strength of soil varied from 1.47×10^{-3} to 3.13×10^{-3} N mm^{-2} with mean of 2.31×10^{-3} N mm^{-2}. The coefficient of variation was found out as 28.26% while the standard deviation was 0.653. Shear strength is a vital parameter in soil-tool interaction design of basin lister for coconut palm. The coefficient of determination(R^2) for the regression model was 98.36% as shown in Fig. 4 revealing the linear relationship between shear strength and depth. The model was significant as $p \leq 0.05$ and it is given in Table 3.

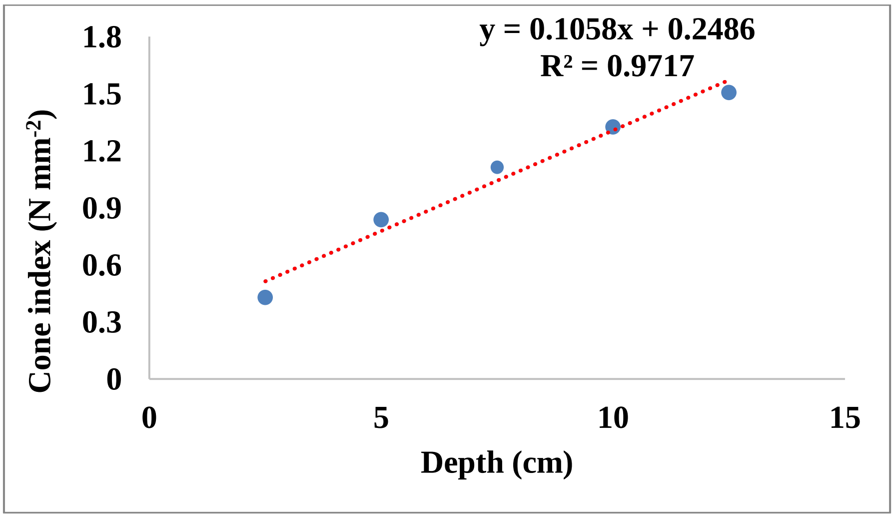

Fig. 3. Relation between cone index and depth

Table 2. ANOVA for cone index

	df	SS	MS	F	Significance F
Regression	1	0.699074	0.699074	102.9402	0.002039906
Residual	3	0.020373	0.006791	-	-
Total	4	0.719447	-	-	-

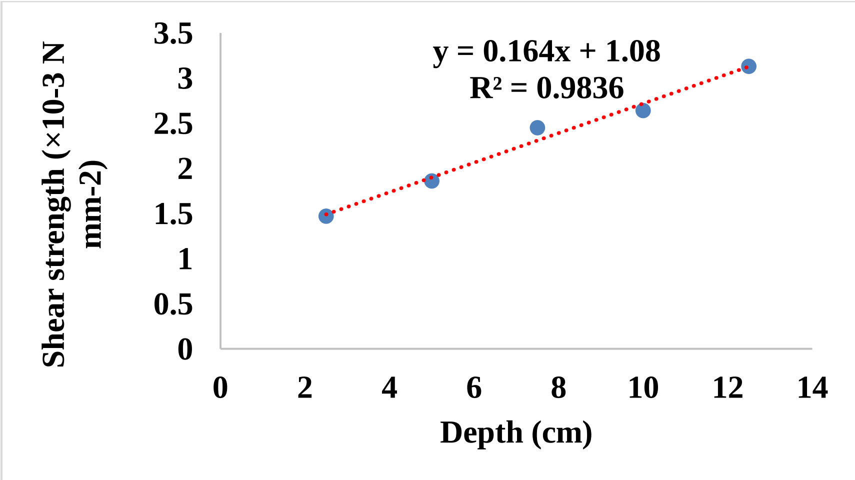

Fig. 4. Relation between shear strength and depth

Table 3. ANOVA for shear strength

	df	SS	MS	F	Significance F
Regression	1	0.000176	0.000176	189	0.000833
Residual	3	2.8E-06	9.33E-07	-	-
Total	4	0.000179	-	-	-

3.2 Crop Parameters

The data obtained from experiments was statistically analysed and the results are explained below that aid in the design of machine.

3.2.1 Trunk diameter of coconut palm

The trunk diameter of coconut palm was measured and statistically analysed. The trunk diameter of coconut palm varied from 32.3 to 38.1 cm with a mean of 34.74 cm. The coefficient of variation and standard deviation were 6.55% and 2.276 respectively as given in Table 1. The trunk diameter varies with variety and age of coconut palms. The trunk diameter of coconut palm is an important consideration in deciding the working width of machine and in turn effects the power requirement of machine.

3.2.2 Root zone depth

The root zone depth of coconut palm varied from 13.4 to 15.2 cm at a radius of 1.5 m from the trunk of the palm. The mean and standard deviation were 14.34 and 0.733 respectively while the coefficient of variance was 5.11% as given in Table 1. This parameter needs to be considered as the basin lister operation must not cause damage to roots of coconut palm. It also helps in deciding the depth of operation of machine and power requirement of machine.

4. CONCLUSION

The soil parameters such as moisture content, bulk density, cone index and shear strength and crop parameters such as trunk diameter and root zone depth of coconut plantation were studied and results were obtained. Soil moisture content, bulk density, cone index and shear strength helped in the design of power requirement, rotor shaft, cutting blades, main shaft etc. The trunk diameter of coconut palm aided in deciding the working width of machine while the root zone depth assisted in finalizing the operational depth of machine. The soil and crop parameters were taken into consideration to design the tractor operated coconut basin lister cum fertilizer applicator for optimum field performance.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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