STUDIES ON SOIL NUTRIENT STATUS AND ITS EFFECT ON YIELD AND QUALITY OF ESSENTIAL OIL FROM *BURSERA PENICILLATA* Engl.

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CERTIFICATE

This is to certify that the thesis entitled " STUDIES ON SOIL NUTRIENT STATUS AND ITS EFFECT ON YIELD AND QUALITY OF THE ESSENTIAL OIL FROM <u>*Bursera penicillata*</u> Engl." submitted by Mr. G. P. Dayananda for the degree of MASTER OF SCIENCE (Agriculture) in SOIL SCIENCE of the University of Agricultural Sciences, Bangalore, is a record of research work done by him during the period of his study in this University under my guidance and supervision and the thesis has not previously formed the basis for award of any degree, diploma, associateship, fellowship or other similar titles.

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CHAPTER I

INTRODUCTION

The modern civilisation can be said to have set in from the middle of the last century, and of course is used to vary from nation to nation. At different times, different yardsticks used to be employed to assess the extent of advancement of a country. Towards the beginning of the present century, the yardstick was the extent of the consumption of sulphuric acid; this used to give a fairly good account of the extent of the advancement for sulphuric acid was the basic material from which a good bit of chemical industry used to derive its sustenance. Later, roughly by about the twenties of the century the amount of soap consumed by a particular nation used to indicate the extent of its advancement. During the last 2 or 3 decades the extent of the cosmetics used was taken to indicate the advancement of the individual or the nation. At one time the use of cosmetics, used to be the privilege of the fair sex but now possibly men appear to be using as much of the cosmetics, if not more, as women. This shows the importance that cosmetics hold in the life of the people of any advanced country. In all the cosmetic preparations a good perfume is an essentiality. These perfumes may be either natural or synthetic. Amongst the natural perfumes the essential oil obtained from Bursera penicillata (Sesse and Moc, ex.DC) Engl., (formerly called Bursera delpechiana Poisson.) stands supreme.

There is a great demand for the oil from this tree both in the internal and international market. Bursera is exotic to India. It has been introduced into our country from Mexico, its place of origin, about 60 years ago. In Mexico, while the aromatic oil is produced from the wood, it is obtained from the husk of the berries in our country. It is reported that it was first in Katguni Estate, approximately 20 km from Bangalore. The land coverage in our country at present is about 1000 hectares (Rao, 1975). Still the oil produced is not able to cope up with the demand.

The optimum rainfall for the plantation of this tree is in the 80-100 cm range. Bursera comes up well in a sandy loam bordering to gravelly type of soil in preference to clays and marshes. The salient features in the cultivation of Bursera include proper choice of land and method of propagation. It can be propagated both vegetatively and by seeds. As a result of experimentation it has been observed that vegetative propagation of this plant is preferred to multiplication through seed. In an acre of land 100 to 125 trees can be accommodated. The plants bear the first crop of fruits in their third or fourth year of planting. Flowering starts by the first week of April and fruit setting starts by May. The fruit matures around July-August. With normal growth, a six year old tree is about three metres high and has a circumference of approximately 35 to 40 cm at the ground level (Fig.1). The life of the tree is around fifty years.

While the general practice is to sweep the fruits after they fall on the ground, hand picking of mature fruits from the tree is also in vogue. The husk will be separated from the seeds by mechanical threshing of the dried fruit and subsequent sieving. Later the oil will be extracted from the husk by steam distillation. Air dried husks are, by and large, used for distillation of the oil, as there is a risk of spoilage of fresh fruit by fermentation on storage. Besides husks, there is a practice of utilising heart wood of the tree for extraction of oil. The oil from the heart wood differs slightly from the oil from berries in physical and chemical composition.

Fig.1 - The Bursera tree.

Since at present, there is little information available on soil-plant relationships, a study was taken up to know the correlation that exists between the soil nutrient status and the yield and composition of essential oil of *Bursera penicillata*. The objectives were:

(1) To correlate the soil nutrient status with the yield of husk and its oil content; and

(2) To correlate the soil nutrient status with the composition and characteristics of the essential oil obtained from the husk.

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

As mentioned in Chapter I, a feasible method to increase the out turn of the Bursera oil is to determine the best sylvicultural conditions to provide the optimum crop husbandry, particularly from the nutritional angle and apply the nutrients as per the determined schedule. Although no work has been done earlier in this regard on the Bursera plant, there are a number of cases of aromatic plants wherein fertiliser application has improved the yields and in some cases even the quality of the oil. A study of these can help the projection of the present programme regarding Bursera itself. As long as the raw material was available in plenty and the demand for the finished product was not high, no need was felt for the expansion of the perfumery industry either by way of increasing the area under cultivation or by improving the yields. For increasing the area under cultivation there are limitations because most of the species are very fastidious in respect of their environmental requirements such as soil status, temperature and rainfall, etc. If they are cultivated away from their natural habitat, they may not thrive well. Even if they do so, the quality of the product may suffer. An instance of this type is the sandal tree Santalum album L., which when grown away from its natural habitat of the Karnataka and Tamil Nadu States, does not develop the sweet-scented heartwood for which the tree is famous (Rao, 1965). Hence in a number of cases, the essential oil bearing plants are grown in their natural homes and only in a few cases, as in the case of Bursera, in other regions where the climatic and other conditions are more or less similar. However, to meet the higher demand for the products, which happens with the improvement in the standards of living, the only way open is to enhance the yields by improving the sylvicultural conditions to provide the optimum crop husbandry. An effort in this direction was made in the thirtees of the present century. After studying the nutritional requirements of the concerned plants, fertilisers came to be applied with a view to improve the yields. In some cases, as for example, the lavender plant, the yields rose up as high as 50 per cent (Svab, 1970).

One of the earliest cases of this type are the studies of Lejune (1935) on certain Pelargonium spp. A little later Barmer (1938) studied the effect of fertilisers on a number of aromatic plants belonging to Labiatae and Compositae families. In 1949, Constalot showed that the yield of the bay leaf oil increased with the application of fertilizers. However, the increase in the yield of oil was not commensurate with the cost of fertilizer used. It was noticed by Virmani *et al.* (1967) that the application of fertilizers increased the oil content in palmarosa. The application of the major nutrients enhanced the oil yield in crimson red rose (Minkov *et al.*, 1970), in worm wood (Si Japtia, 1970), in *Mentha piperita* (Baslas, 1970), and in lavender (Svab, 1970).

It was shown in 1971 (Anon.) that the application of N, P and K to peppermint plants in appropriate proportions yielded highest amounts of the oil in peppermint plants. The above observations on mint were further confirmed by the work of Gretskaya and Oleinikova (1972) and Pavlenko (1972). Working on *Cymbopogon citratus*, Khan and Narayana (1972) specified the amounts of major nutrients to be used to obtain high yields of citronella oil. Similar type of work was also done by the Department of Agriculture at Sarawak (Anon., 1972). Likewise, Sherbestav *et al.* (1972) showed that the application of N, P and K raised the yields of chamomile and that of the essential oil therefrom. In the case of Java citronella (*Cymbopogon winterianus*) it was shown that fertilizers increased the output of the herbage and consequently the amount of oil per unit area although the percentage of the oil in the plant did not increase (Narayana *et al.*, 1976).

In some cases, it was shown that application of only one or two of the major nutrients was responsible for the increase in the yield of the crop; this naturally depends on the nutritional requirements of the plant, taken in conjunction with the soil status. Peppermint (both *Mentha arvensis* and *M. piperita*) is one of the species worked upon most. Although it was shown that the plant responds favourably to N, P and K application, in general, (Baslas, 1970; Anon., 1971; Gretskaya and Oleinkova, 1972; and Paulenkc, 1972), it appears that nitrogen is of primary importance in producing good yields (Baird, 1957; Datta, 1961; Skrubis, 1964; Kerekes and Hornok, 1972). As regards phosphorus, there are some contradicting reports, while significant increase in the yields was reported by the Agricultural Research Service (1954) and by Baslas (1970). Baird (1957) reported no significant increase by application of P to the above crop. Working with roses, Kamp and Shanan (1960) noticed that higher levels of P and K resulted in better yields. Similarly, it was noticed that N and P fertilization increased the yield of the leaf and the oil content in the case of geranium (Cutting, 1961). It was noticed by Mustalaea (1963) that the application of N and P produced highest flower yields in lavender. With rose geraniums Ivanova and Gogina (1967) noticed an increase of the essential oil by about 10 per cent by the application of N and K fertilizers; while phosphorus fertilizers reduced the foliage, though the oil accumulation in the leaves increased. Narayana *et al.* (1967) also observed a similar increase by the application of nitrogen alone. Working with *Matricaria chamomilla*, Virsani *et al.* (1967) reported that the application of nitrogen alone effectively improved the vegetative growth and the yield of the flowers. In the case of the vetiver grass (*Vetiveria zizanioides*) grown on peat soil to the application of K gave a good response (Anon., 1972).

In some cases, there was an adverse interaction of the nutrients in respect of the yields. In the case of rose, application of N and P increased the essential oil in the flowers, while K reduced the yield (Subina and

Manaeva, 1970). So also an increase in the peppermint oil content by nearly 35 per cent was noticed when N was applied to the crop; however, K lowered the yield by 37 per cent (Franz, 1972).

From the literature cited above, it is clear that the application of the major nutrients enhances, in general, the yields of the crop in a number of aromatic plants. The nutrients to be applied and their quantities are determined by the nutrient requirements of the concerned plants and the nutrient status of the soil. Apart from increasing the yields, it has to be known whether there is any effect of the applied nutrients on the quality of the products.

All the essential oils are invariably mixtures of the main component and a number of other compounds which are usually sweet-smelling, the main component forming usually 40 to 90 per cent. The aroma of the oil is, therefore, a combination of the aromas of all the constituent components, the main component, of course, contributing most. The constituent components comprise a variety of of volatile organic compounds like hydrocarbons, alcohols, phenols, acids, ethers, esters, aldehydes, ketones, etc. Most of these compounds contain oxygen as the extra element, but some contain N and S also. If S is present as in mustard oils, the products happen to be pungent-smelling. Depending on the nature of the constituents and their relative proportion, each essential oil has its own characteristic physical properties like density, refractive index and optical rotation, which are called physical constants. Since the composition varies with locality, season and climate, the physical constants cannot have fixed values but only a range within which they vary. In contrast to the physical constants, there are also what are called chemical constants like acid value, ester value and ester value after acetylation. The chemical constants indicate the extent of the acids, alcohols, phenols and esters present.

The term "quality" of the oil indicates the normal composition of the oil, maintaining the same physical and chemical constants. Among the constituents, acids, phenols, aldehydes and to some extent ketones impart a "raw" aroma to the oil, while alcohols and esters, more so the latter, contribute a mellow pleasant odour. By the term "improvement in the quality" it is meant a product with a higher content of the main component a higher ester content and a lower aldehyde, phenol and acid contents.

With regard to the improvement of the quality of the oil by the application of nutrients, much work has not been done in the field of essential oils. Whatever has been done is mainly confined to the past two decades. Peppermint was one of the species studied by a number of workers. Hotin (1957) showed that N and P applied during bud formation increased the menthol content of the essential oil in the leaves; however, the application of N, P and K increased the menthofuran content of the essential oil obtained from the inflorescence. Latypov (1960) noticed an improvement in the composition of the essential oil by the application of the fertilizers, while Gretskaya and Oleinkova (1972) showed that both N, P and K and N and P treatments resulted in an increase in the menthone content. From his experiments, Franz (1972) came to the conclusion that N was responsible for the increase in the menthol content, while K had the contrary effect. However, Lamlas (1970) observed that application of organic manure and sodium nitrate, increased the yield of the oil; yet they decreased the menthol content in the oil from <u>Mentha piperita</u>. Working with meadow mint, Nelson <u>et al</u>. (1969) came to the conclusion that N application resulted in an increase of menthone and a decrease of menthol in the essential oil produced. Thus, in the Mentha spp., the quality of the oil appears to have been adversely affected by the application of the fertilisers as indicated by the decrease in the menthol content and an increase in the menthone content, although the essential oil yields increased.

In pelargonium spp., an increase in the essential oil content and also in the constituent citronellol and isomenthone was found by the application of fertilisers (Korezowa, 1952).

In the caraway plant, Kazinkarte (1965) noticed an increase in the optical activity and a decrease in the refractive index by the application of N as ammonium nitrate, while the application of K as KCl lowered the optical activity and raised the refractive index and also the carvone content of the essential oil.

Working with rose geranium, Ivanova and Gogina (1967) observed that the application of fertilisers improved the quality of the essential oil by reducing the carbonyl compounds (menthone) and increasing citronellol and its esters.

In the case of Crimean red rose, the quality of the oil improved with a high content of unsaturated terpenols by the application of N, P and K (Minkov *et al.*, 1970).

The observations of Si japtis (1970) on the application of fertilizers to wormwood are noteworthy. Nitrogen, P and K application did not produce any change in the physical constants of the oil, while N in combination with P or K increased the hamazulene content. Obviously, there was an adverse interaction when N, P and K were applied together.

In geranium (*Pelargonium graveolens*) no change in the oil characteristics was noticed by the application of fertilizers (Narayana *et al.*, 1967). Similar trend was seen with lavender too (Svab, 1970).

In Java citronella, (*Cymbopogon winterianus*), N, P and K treatments resulted in an increase of the alcohols and the aldehydes (Narayana *et al.*, 1976).

The physical and chemical constants of the Bursera oil obtained from different sources have been studied by many workers.

In an experiment, it was found that a sample of the dried husks from *Bursera delpechiana* yielded 18.1 per cent of oil having the following constants: d_{15}:0.8989; $^{20.5°}_{D}$ -4°48';

$n_D^{20°}$:1.455; acid value:0.07; saponification value:216.7. The sample consisted largely of linalyl acetate, thus differing from linaloe oils of commerce, which consists principally of free linalool (Anon., 1927). In another experiment, steam distillation of linaloe wood from Mexico gave 8.1 per cent oil, having $d_{15°}$:0.8781; D:+8°15'; $n_D^{20°}$:1.46072; acid value: 1.5; ester value:47.5; the oil consisted largely of d-linalool (Anon., 1931). Simmons (1934) noticed that the oil from *Bursera penicillata* derived from two sources i.e., from wood and seed, had the following properties:

(i) *Wood oil*: $d_{15°}$:0.8867 to 0.8981; optical rotation: +1°0' to +2°30' $n_{25°}$:1.4602 to 1.4628; ester as linalyl acetate:34.4 per cent to 41.6 per cent and alcohols as linalool:73.3 per cent to 76.1 per cent.

(ii) *Oil from seeds*: $d_{15°}$:0.8878 to 0.8911; optical rotation:0°18' to −2°18'; $n_{25°}$:1.4600 to 1.4623; ester as linalyl acetate:31.5 per cent to 44.1 per cent and alcohols as linalool:71.8 per cent to 74.7 per cent.

Guenther (1941) indicated the differences that exist in the properties of the essential oil derived from the above two sources; they are as follows:

(a) *Wood oil*: Specific gravity:0.883 to 0.889;

$n_{20°}$:1.4787 to 1.4610 and optical rotation:7°10' to -12°7'.

(b) Oil from seeds Specific gravity:0.885 to 0.888; $n_{20°}$:1.4541 to 1.4650 and optical relations+2°40' to +3°10'.

Narayan and Sikhibhushan (1945) found that the oil from *Bursera penicillata* had the following characteristics: Colour: Sulphur yellow; $d_{20°}$:0.8952; $n_{20°}$:1.4658; 20°:1°50'; acid value:0, saponification value 130, saponification value after acetylation:274. The oil contained linalool to the extent of 47.7 per cent and linalyl acetate to the extent of 40.8 per cent.

Rangegowda and Ramaswamy (1965) showed that the sample obtained by them had the below mentioned properties: Colour: pale yellow; with a specific gravity:0.8943, $^{20°}_{D}$:1°50', acid value:0.99, ester value of 138.15, saponification value: 139.14, ester content:48.35 per cent as linalacetate. Rajendragupta and Ramabanerji (1966) observed that root wood of *Bursera penicillata* yielded no oil at all. Lateral roots of thirty year old tree were upto 2 cm thick, with a bark to wood ratio of about 60:40 by weight, root bark yielding 0.27 per cent oil. The root bark could not be developed into a common source of oil because of meagre root system.

It can, therefore, be seen that the essential oil *Bursera penicillata* as produced in Mexico and in India varies slightly in physico-chemical characteristics. Further the oil derived from the wood on the one hand and the seed on the other also differs slightly in the physico-chemical characteristics.

MATERIAL AND METHODS

CHAPTER III

MATERIAL AND METHODS

With the object of investigating whether there is a correlation between the yield and properties of soil and nutrient status of soil of *Bursera penicillata*, soil samples were collected from two locations (1) near forest research laboratory (FRL), Bangalore (25 years old plantation), and (2) Gottipur forest, 20 km away from Bangalore (20 years old plantation).

3.1. Collection of soil samples

Soil samples were collected from the above location during March 1974. Since the trees were in rows of ten each, 3 rows at FRL and 26 rows at Gottipur were selected at random. This was done to avoid the variation between the rows. Then, three trees in each row were selected at random and the soil samples were collected from 3 depths viz., 0 to 15 cm, 15 to 37.5 cm and 37.5 to 60 cm. Samples were collected from all the four directions of the plant from the three depths, 45 cm away from the base of plant. In this manner, samples near three trees of a row were mixed and thus three representative samples from a row were obtained. These trees were numbered.

But in FRL location samples were collected near three individual trees in a row.

3.2. Collection of leaf samples

The leaves were collected during second week of April 1974 from trees near which soil samples were selected earlier. In all, there were 15 leaf samples from Gottipur and four samples from FRL location.

3.3. Collection of berry husks

The dried husks from berries were collected four times by sweeping as detailed below:

(a) during third week of July 1974;

(b) during first week of August 1974;

(c) during fourth week of August 1974; and

(d) during third week of September 1974.

The husks were collected only at Gottipur since the trees at FRL did not bear any fruits during the year.

3.4. Preparation of soil samples

The soil samples were dried in shade, powdered well passed through 2 mm sieve and preserved in polythene bags for analytical work. For determination of organic carbon, an aliquot of 2 mm sieved soil was further powdered in an agate mortar and pestle and made to pass through 0.5 mm sieve.

3.5. Methods of soil analysis

3.5.1. pH: Soil pH was determined in 1:2.5 soil water suspension using a mains-operated pH meter with a glass electrode, as described by Jackson (1958).

3.5.2. Electrical conductivity: This was determined in the above soil-water suspension on a commercial conductivity bridge having an "electronic eye" null point indicator. The observed instrument reading was corrected by referring to the temperature coefficient table.

3.5.3. Organic carbon: Organic carbon in the soil samples was determined by following the Walkley-Black wet oxidation method as described by Jackson (1958).

3.5.4. Available nitrogen: Available nitrogen in the soil samples was determined essentially by the method described by Subbaiah and Asija (1956) as under.

Twenty grams of soil was weighed into distillation flask and 20 ml distilled water was added. To this, 100 ml of 0.32 per cent $KMnO_4$ and 100 ml of 2.5 per cent NaOH (both freshly prepared) were added. The contents of the flask were distilled and the distillate was collected in 25 ml of 4 per cent boric acid solution. The distillation was stopped when about 100 ml of distillate was collected. The boric acid containing the distillate was titrated against standard H_2SO_4. From the volume of H_2SO_4 used up, the available nitrogen content of the soils was calculated.

3.5.5. Available P_2O_5: Extractant used was Bray's No.1 solution which is 0.03 N NH_4F in 0.025 N HCl. A quantity of 5 g of soil samples was extracted with the said extractant for 5 min and was filtered. In the filtrate molybdenum blue colour was developed by using ammonium molybdate and stannous chloride reductant in HCl system. The blue colour thus developed was measured at 660 mu in "Spectronic 20" Spectrophotometer.

3.5.6. Available potassium: Available potassium was estimated in 1:5 ammonium acetate extract of the soil using "AIMIL" Flame Photometer.

3.3.7. Exchangeable calcium and magnesium: The exchangeable calcium and magnesium were determined in the ammonium acetate extract of the soil by Versenate method, using murexide and erichrome black "T" indicators respectively.

3.5.8. Available sulphur: Available sulphur in soil was extracted with ammonium acetate solution and then determined by turbidimetric method as described by Bradsley and Lancaster (1965).

3.5.9. Mechanical analysis: Mechanical analysis was carried out by the International Pippette method as outlined by Piper (1950).

3.6. Analysis of plant material

3.6.1. Nitrogen: It was analysed as per the procedure recommended by A.O.A.C. (1955).

3.6.2. Wet ashing: This was done with 0.2 g of powdered leaf sample, which was digested with 10 ml mixture of HNO_3 and $HClO_4$ (1:1). The residue was extracted with water and made upto 100 ml. The solution after mixing was passed through Whatman No.42 filter paper to remove silica. The filtrate was preserved for estimation of potassium and phosphorus.

3.6.3. Phosphorus: Phosphorus was estimated in an aliquot of the extract by the vanadomolybdate yellow colour method (Jackson, 1958) measuring the absorbance of the solution on "Spectronic-20" Spectrophotometer at 420 nm.

3.6.4. Potassium: This was estimated by using "AIMIL" Flame Photometer.

3.7. Extraction of oil

The oil was extracted from a known weight of the husk on an essential oil distillation apparatus by steam distillation for 8 hours.

3.8. Analysis of oil

3.8.1. Specific gravity: The specific gravity was found out by dividing the weight of the oil sample in air with weight of equal volume of water at the same temperature by using a specific gravity bottle. A correlation factor of 0.0064 was used to correct the temperature differences.

3.8.2. Optical rotation: Optical rotation of the oil samples was measured on a polarimeter with 2 dm long tubes against the D line of sodium vapour lamp.

3.8.3. Acid value: Accurately weighed 2.5 g of dried oil was dissolved in 20 ml of neutral ethanol and was titrated against standard potassium hydroxide solution using phenolphthalein as indicator.

3.8.4. Saponification value: Two grams of accurately weighed oil was mixed with 25 ml of 0.1 N alcoholic potassium hydroxide solution and refluxed on a water bath for one hour with intermittent rotation. After cooling, the excess alkali unutilised was determined by titrating against standard hydrochloric acid.

3.8.5. <u>Saponification value after acetylation</u>: Ten ml of oil was mixed with 10 ml of acetic anhydride and one gram of freshly fused anhydrous sodium acetate in an acetylation flask. The contents of the flask were boiled gently for 2 hours on a sand bath. After cooling, 50 ml of water was added and once again, they were heated on a boiling water bath for 15 min with frequent and thorough agitation. They were then cooled and transferred to a separatory funnel. After shaking and phase separation the lower aqueous layer was rejected. The acetylated oil was washed successfully with (a) 50 ml of brine (b) 50 ml of brine containing the equivalent of about 1 g of anhydrous sodium carbonate in solution and (c) 50 ml of brine.

At each wash, the flask was shaken vigorously and separation was allowed to take place before rejecting the lower layer. After washing the acetylated oil with brine containing the sodium carbonate, it was ensured that the wash liquor was alkaline. After giving the final wash with 20 ml of water, the acetylated oil was poured into a dish and three grams of sodium sulphate was added, and it was continuously stirred until a drop of oil produced no cloudiness when added to 10 drops of carbon disulphide in a dry test tube. The oil was filtered through a dry filter paper into a covered flask.

In this acetylated oil, saponification value was estimated as per the procedure mentioned under item 3.6.4.

3.6.6. Ester percentage (calculated as linalyl acetate):
It was calculated using the following formula:

$$\text{Ester percentage} = \frac{EM}{561}$$

where, E = refers to difference between saponification value and acid value; and

M = the molecular weight of linalyl acetate.

3.6.7. Alcohol percentage (calculated as linalool):
It was calculated using the following formula:

$$\text{Alcohol percentage} = \frac{EM}{561}$$

where, E = refers to difference between the saponification value after acetylation and saponification value; and

M = the molecular weight of linalool.

3.9. Statistical analysis

The following formula was used to find out the correlation that existed between different parameters:

$$r = \frac{N\Sigma XY - (\Sigma X)(\Sigma Y)}{\sqrt{N(\Sigma X^2) - (\Sigma X)^2 \quad N(\Sigma Y^2) - (\Sigma Y)^2}}$$

where X = one parameter
Y = another parameter
N = number of observations

The correlations were calculated between the following parameters:

(i) Yield versus pH, electrical conductivity, available nitrogen, organic carbon, available phosphorus, available potassium, exchangeable calcium, exchangeable magnesium, coarse sand + fine sand and clay per cent.

(ii) Oil percentage versus organic carbon, available nitrogen, available phosphorus, available potassium, exchangeable calcium and exchangeable magnesium.

(iii) Specific gravity of oil versus available nitrogen, organic carbon, available phosphorus, available potassium, exchangeable calcium and exchangeable magnesium.

(iv) Refractive index of oil versus available nitrogen, organic carbon, available phosphorus, available potassium, exchangeable calcium and exchangeable magnesium.

(v) Ester percentage of oil versus available nitrogen, organic carbon, available phosphorus, available potassium, exchangeable calcium and exchangeable magnesium.

(vi) Alcohol percentage of oil versus available nitrogen, organic carbon, available phosphorus, available potassium, exchangeable calcium and exchangeable magnesium.

EXPERIMENTAL RESULTS

CHAPTER IV

EXPERIMENTAL RESULTS

An investigation was carried out to know the correlations that exist between yield and composition of essential oil of *Bursera* and soil nutrient status. The results are presented below.

4.1. Mechanical composition

The results of mechanical analysis of soils of FRL and Oottipur locations are given in Table 1 and 2 respectively.

The surface soils of FRL are sandy loam in texture. But, most of the samples are sandy clay loams in intermediate depth and clay in the third depth. It is, thus, seen from these figures that clay has increased with depth, whereas sand (both coarse and fine sand fractions) has decreased with depth. The coefficients of variations for clay were 7.67, 17.97 and 5.37 for first, intermediate and third depths, respectively. The coefficients of variations for coarse sand fractions were 14.56, 11.37 and 14.23 for these depths. The corresponding figures for fine sand fractions were 5.15, 13.91 and 5.51.

Table 1: Mechanical analysis of soils of FRL location

Sl. No.	Tree No.	Depth	Gravel %	Coarse sand %	Fine sand %	Silt %	Clay %	Loss in solution	Textural class
1.	1R4T	A	3.22	42.65	32.70	2.20	19.20	0.43	Sandy loam
		B	-	26.20	32.55	11.00	29.51	0.72	Sandy clay loam
		C	-	21.40	24.05	11.03	42.14	0.45	Clay
2.	1R9T	A	3.61	42.00	32.24	2.55	19.25	0.35	Sandy loam
		B	-	5.05	32.80	10.90	30.85	0.40	Sandy clay loam
		C	0.93	21.70	24.35	11.83	40.82	0.37	Clay
3.	1R5T	A	3.22	42.80	32.82	2.49	18.70	0.36	Sandy loam
		B	-	26.20	32.85	11.00	29.57	0.36	Sandy clay loam
		C	1.01	23.31	24.06	10.75	40.78	0.19	Clay
4.	1R2T	A	4.45	41.00	32.05	3.26	19.01	0.23	Sandy loam
		B	1.20	25.04	33.51	10.80	29.25	0.20	Sandy clay loam
		C	0.05	24.15	25.35	11.56	38.58	0.10	Clay loam
5.	2R6T	A	4.00	42.01	32.01	3.98	18.30	0.10	Sandy loam
		B	1.22	25.15	33.84	10.05	29.00	0.54	Sandy clay loam
		C	-	22.05	24.80	11.80	40.75	0.60	Clay
6.	2R10T	A	3.03	41.28	31.32	2.21	21.31	0.85	Sandy loam
		B	-	25.68	31.64	10.54	32.06	0.08	Sandy clay loam
		C	-	25.31	26.28	10.62	37.40	0.39	Clay loam
7.	3R1T	A	3.81	31.15	33.30	10.45	20.80	0.48	Sandy loam
		B	1.00	16.28	23.84	11.70	45.08	0.10	Clay
		C	-	17.04	26.82	12.02	43.80	0.32	Clay

Table 1 (Contd)

Sl. No.	Tree No.	Depth	Gravel %	Coarse sand %	Fine sand %	Silt %	Clay %	Loss in solution	Textural class
8.	3R5T	A	4.52	32.33	28.40	10.31	22.68	1.76	Sandy loam
		B	-	20.68	26.96	10.74	39.20	0.42	Clay loam
		C	0.95	16.31	27.86	10.70	43.61	0.37	Clay
9.	3R6T	A	3.38	29.25	34.40	10.42	21.67	0.88	Sandy loam
		B	-	24.70	22.80	11.45	40.62	0.23	Clay loam
		C	1.01	20.17	24.08	11.72	42.90	0.10	Clay
Coefficient of variation		A	14.6836	14.5632	5.1516	73.2966	7.6058		
		B	150.8500	11.3719	13.9108	4.4119	17.9686		
		C	116.6800	14.2345	5.5094	4.9103	5.3681		

A = 0-15 cm

B = 15-37.5 cm

C = 37.5-60 cm

Table 2: Mechanical analysis of soils of Gottipur location

Sl. No.	Tree No.	Depth	Gravel %	Coarse sand %	Fine sand %	Silt %	Clay %	Loss in solution	Textural class
1.	11–20	A	4.1	31.1	22.2	12.2	30.1	0.3	Clay loam
		B	3.1	19.6	25.1	15.4	36.6	0.3	Clay loam
		C	–	19.2	20.0	16.8	43.9	0.1	Clay
2.	31–40	A	3.8	29.0	24.6	12.5	30.7	0.4	Clay loam
		B	–	21.9	24.8	13.2	39.6	0.5	Clay loam
		C	–	19.6	22.3	13.4	44.5	0.2	Clay
3.	41–50	A	3.0	28.3	24.5	12.2	30.0	1.0	Clay loam
		B	0.9	19.0	25.0	14.8	39.7	0.6	Clay loam
		C	–	17.8	23.4	14.6	43.6	0.6	Clay
4.	61–70	A	2.5	33.0	22.8	13.2	28.4	0.1	Clay loam
		B	–	22.6	25.4	13.1	38.5	0.4	Clay loam
		C	–	19.5	22.2	14.4	43.7	0.2	Clay
5.	71–80	A	3.9	31.9	23.4	10.4	30.0	0.4	Clay loam
		B	–	23.0	24.2	12.5	39.9	0.4	Clay loam
		C	0.8	23.9	19.3	13.2	42.6	0.2	Clay
6.	81–90	A	4.0	30.2	24.0	11.1	30.6	1.1	Clay loam
		B	–	22.4	25.2	11.9	39.5	1.0	Clay loam
		C	–	21.4	22.4	12.4	43.2	0.6	Clay
7.	111–120	A	4.2	32.4	22.0	12.5	28.6	0.3	Clay loam
		B	1.0	26.4	25.4	11.2	35.0	1.0	Clay loam
		C	–	22.4	20.6	12.0	44.6	0.4	Clay

Table 2 (Contd)

Sl. No.	Tree No.	Depth	Gravel %	Course sand %	Fine sand %	Silt %	Clay %	Loss in solution	Textural class
8.	121–130	A	4.1	31.0	23.1	10.5	30.8	0.4	Clay loam
		B	–	29.1	22.0	11.8	36.6	0.04	Clay loam
		C	0.4	18.7	24.0	12.4	44.3	0.2	Clay
9.	171–180	A	3.8	32.5	22.9	12.3	27.8	0.7	Clay loam
		B	1.2	2.37	25.4	11.9	37.7	0.1	Clay loam
		C	–	19.0	23.1	23.4	43.9	0.6	Clay
10.	201–210	A	3.9	30.0	24.8	10.9	30.0	0.3	Clay loam
		B	–	28.0	24.5	12.4	34.6	0.3	Clay loam
		C	0.2	20.2	21.6	13.8	44.0	0.2	Clay
11.	211–220	A	3.8	30.9	22.0	11.4	31.2	0.7	Clay loam
		B	1.2	22.0	25.6	12.4	38.4	0.4	Clay loam
		C	–	22.0	20.9	11.9	28.9	0.3	Clay
12.	231–240	A	3.5	32.0	22.5	11.9	26.9	0.8	Clay loam
		B	0.1	22.3	25.5	12.6	39.2	0.3	Clay loam
		C	–	22.8	19.8	13.6	43.6	0.2	Clay
13.	251–260	A	3.2	32.5	24.9	10.6	28.5	0.3	Clay loam
		B	–	23.1	25.3	12.9	38.4	0.3	Clay loam
		C	–	21.4	20.6	13.5	44.0	0.3	Clay loam
14.	271–280	A	3.9	31.9	22.4	10.6	28.8	1.4	Clay loam
		B	–	23.4	24.6	12.4	39.0	0.4	Clay loam
		C	0.8	22.0	19.6	13.3	44.1	0.2	Clay
15.	281–290	A	3.8	31.4	23.6	11.0	30.0	1.2	Clay loam
		B	1.0	26.5	23.1	11.1	38.0	0.3	Clay loam
		C	–	23.3	20.2	12.9	43.1	0.5	Clay

Table 2 (Contd)

Sl. No.	Tree No.	Depth	Gravel %	Coarse sand %	Fine sand %	Silt %	Clay %	Loss in solution	Textural class
16.	291-300	A	3.1	32.6	23.8	10.2	30.1	0.2	Clay loam
		B	-	23.0	25.1	12.4	39.1	0.4	Clay loam
		C	-	21.6	20.9	13.1	44.0	0.4	Clay
17.	321-330	A	4.2	30.0	22.6	11.6	30.3	1.3	Clay loam
		B	0.3	26.3	24.2	11.0	37.2	1.0	Clay loam
		C	-	21.1	21.9	13.1	43.4	0.5	Clay
18.	331-340	A	4.1	33.2	22.9	10.4	30.2	1.2	Clay loam
		B	0.1	23.9	24.8	11.9	39.0	0.3	Clay loam
		C	-	23.0	20.6	12.6	43.5	0.3	Clay
19.	361-370	A	3.9	30.2	23.8	10.0	31.6	0.3	Clay loam
		B	0.1	24.9	24.8	11.8	38.2	0.1	Clay loam
		C	0.1	21.6	21.3	12.7	44.1	0.2	Clay
20.	371-380	A	4.2	31.1	23.6	10.2	30.8	0.1	Clay loam
		B	0.1	25.9	25.9	11.8	38.2	0.1	Clay loam
		C	0.1	23.5	19.8	12.6	43.6	0.4	Clay
21.	381-390	A	3.9	33.3	23.0	10.4	28.9	0.5	Clay loam
		B	0.5	25.3	25.1	11.2	37.9	0.2	Clay loam
		C	0.2	20.8	21.9	12.9	44.1	0.1	Clay
22.	401-410	A	4.0	32.2	22.8	10.8	29.0	1.1	Clay loam
		B	0.6	27.0	22.1	11.4	38.2	0.7	Clay loam
		C	-	23.7	19.3	13.0	43.7	0.3	Clay
23.	411-420	A	4.5	30.5	22.9	10.8	30.6	0.9	Clay loam
		B	-	26.6	22.6	11.3	39.1	0.4	Clay loam
		C	-	23.9	20.1	12.8	43.0	0.2	Clay

Table 2 (Contd)

Sl. No.	Tree No.	Depth	Gravel %	Coarse sand %	Fine sand %	Silt %	Clay %	Loss in solution	Textural class
24.	431-440	A	3.8	30.0	23.8	10.4	31.0	1.0	Clay loam
		B	1.0	25.7	24.3	10.0	38.7	0.3	Clay loam
		C	0.1	23.3	20.1	12.9	43.3	0.3	Clay
25.	451-460	A	3.5	30.9	23.9	11.4	39.0	1.3	Clay loam
		B	0.1	23.4	25.2	12.3	38.7	0.3	Clay loam
		C	-	22.0	20.4	13.1	43.9	0.6	Clay
26.	471-480	A	3.2	33.0	23.8	10.6	29.1	0.3	Clay loam
		B	0.1	24.4	25.1	11.0	39.1	0.3	Clay loam
		C	-	23.0	20.6	12.9	43.6	0.3	Clay
27.	491-500	A	4.5	33.8	22.9	10.2	28.0	0.6	Clay loam
		B	-	25.5	24.6	11.4	38.2	0.3	Clay loam
		C	-	23.4	19.8	12.9	43.6	0.3	Clay
28.	511-520	A	3.8	33.3	23.3	10.6	30.0	-	Clay loam
		B	-	24.6	24.2	11.6	39.2	0.4	Clay loam
		C	-	21.5	21.3	12.8	44.0	0.4	Clay
Coefficient of variation		A	11.8120	4.4729	3.4475	7.8259	3.4952		
		B	136.7094	9.6687	4.0368	9.1907	3.2904		
		C	226.6700	8.0014	5.9926	6.7585	3.6125		

A = 0 to 15 cm B = 15 to 37.5 cm C = 37.5 to 60 cm

The soils of the other location, namely, of Gottipur are clay loam in the surface and intermediate depths, whereas in the third depth they are clayey. As noticed in FRL soils, the clay content increased, whereas sand fractions decreased as a function of depth. The coefficients of variation for clay fractions were 3.50, 3.25 and 3.61 for 0-15 cm, 15-37.5 cm and 37.5-60 cm depths, respectively. The corresponding values for coarse sand fractions were 4.27, 9.67 and 8.00 for these three depths. The fine sand fractions showed coefficient of variation values of 3.45, 4.04 and 5.99 for these depths.

It is, thus, seen that in both locations the clay has increased whereas sand fractions have decreased as a function of depth. The content of clay is more in soils of Gottipur location than those of FRL location.

4.2. Nutrient status of soils

Data pertaining to nutrient status of soils around the trees in two locations are furnished in Table 3 and 4. These include determinations such as pH, EC, organic carbon, available nitrogen, available phosphorus, available potassium, exchangeable calcium and exchangeable magnesium.

4.2.1. Soil reaction: The data show that pH of soils of

Table 3: Nutrient status of soils of FRL location

Sl. No.	Tree No.	Depth	pH	EC milli-mhos/cm at 25°C	Organic carbon %	Available P_2O_5 ppm	Available K_2O ppm	Available N mg/100 g
1.	1R4T	A	7.1	0.04	0.42	9.2	31.2	14.5
		B	7.1	0.03	0.41	7.9	27.2	14.1
		C	7.7	0.03	0.40	7.0	24.0	13.8
2.	1R5T	A	6.9	0.10	0.29	5.7	36.8	10.0
		B	6.9	0.09	0.28	5.4	32.4	9.7
		C	6.9	0.09	0.27	0.2	30.6	9.8
3.	1R9T	A	7.1	0.06	0.42	7.5	34.4	14.5
		B	7.5	0.05	0.39	6.6	34.4	13.4
		C	7.8	0.03	0.38	6.1	32.0	13.1
4.	2R2T	A	7.0	0.05	0.42	7.0	28.8	14.2
		B	7.0	0.04	0.41	7.0	30.4	14.1
		C	6.8	0.03	0.34	6.2	24.8	13.4
5.	2R6T	A	7.5	0.07	0.48	7.0	39.2	14.6
		B	6.9	0.04	0.41	5.7	35.2	14.1
		C	7.4	0.03	0.41	5.3	34.4	14.1
6.	2R10T	A	7.0	0.15	0.33	6.0	36.8	11.4
		B	7.0	0.10	0.30	6.0	33.6	10.4
		C	7.0	0.09	0.27	5.8	30.5	9.3
7.	3R1T	A	6.8	0.10	0.29	5.7	36.8	10.0
		B	7.0	0.09	0.29	4.3	34.2	10.0
		C	7.0	0.08	0.27	4.3	33.9	9.3

Table 3 (Contd)

Sl. No.	Tree No.	Depth	pH	EC milli-mhos/cm at 25°C	Organic carbon %	Available P_2O_5 ppm	Available K_2O ppm	Available N mg/100 g
8.	3R5T	A	7.0	0.08	0.33	6.6	32.8	11.4
		B	7.2	0.08	0.27	4.6	33.1	9.3
		C	7.2	0.07	0.28	4.8	29.9	9.7
9.	3R6T	A	7.6	0.07	0.32	4.7	35.2	11.4
		B	7.0	0.11	0.30	5.0	30.4	10.4
		C	7.0	0.10	0.29	4.8	29.9	10.0
Coefficient variation		A	2.8873	41.4500	18.7964	17.1304	9.4290	15.9829
		B	2.6826	42.8571	19.3195	20.1017	7.8877	18.1467
		C	4.8516	50.0736	19.3201	21.7061	11.9163	18.6639

A = 0 to 15 cm B = 15 to 37.5 cm C = 37.5 to 60 cm

Table 4: Nutrient status of soils of Gottipur location

Sl. No.	Tree No.	Depth	pH	EC milli-mhos/cm at 25°C	Organic carbon %	Available P_2O_5 ppm	Available K_2O ppm	Exch. Ca me/100 g	Exch. Mg me/100 g	Available N mg/100 g
1.	11-20	A	6.4	0.060	0.51	0.62	94.00	12.4	2.2	17.65
		B	6.2	0.080	0.36	T	65.0	12.8	2.2	14.48
		C	6.2	0.070	0.21	T	65.0	12.8	2.0	11.98
2.	31-40	A	6.5	0.060	0.73	0.66	100.0	12.0	2.2	22.75
		B	6.4	0.060	0.48	T	70.0	16.0	2.2	18.62
		C	6.3	0.135	0.32	T	70.0	13.0	2.4	12.42
3.	41-50	A	6.7	0.065	0.51	1.36	97.5	12.4	2.4	17.50
		B	6.4	0.075	0.42	T	65.0	12.8	2.4	14.48
		C	6.3	0.065	0.36	T	65.0	13.2	2.6	12.42
4.	61-70	A	6.4	0.095	0.78	1.24	107.5	12.4	2.4	23.79
		B	6.3	0.178	0.54	T	95.0	13.8	2.4	18.62
		C	6.2	0.165	0.50	T	100.0	13.8	2.6	17.24
5.	71-80	A	6.8	0.080	0.69	0.86	82.5	12.4	2.4	22.42
		B	6.4	0.160	0.54	T	70.0	13.8	2.6	18.62
		C	6.3	0.165	0.39	T	72.5	13.8	2.6	13.44
6.	81-90	A	6.6	0.100	0.36	0.80	105.0	12.4	2.4	13.32
		B	6.4	0.110	0.39	T	80.0	12.8	2.2	13.44
		C	6.3	0.110	0.30	T	82.0	13.0	2.6	10.35
7.	111-120	A	6.5	0.040	0.72	0.86	85.0	13.2	2.2	22.42
		B	6.2	0.060	0.51	T	75.0	13.4	2.4	14.48
		C	4.2	0.060	0.39	T	75.0	13.4	2.2	12.07

Table 4 (Contd)

Sl. No.	Tree No.	Depth	pH	EC milli-mhos/cm at 25°C	Organic carbon %	Available P_2O_5 ppm	Available K_2O ppm	Exch. Ca me/100 g	Exch. Mg me/100 g	Available N mg/100 g
8.	121-130	A	6.9	0.050	0.58	0.34	82.5	12.4	2.2	10.62
		B	6.5	0.065	0.43	T	85.0	12.6	2.6	14.48
		C	6.3	1.105	0.36	T	72.5	13.2	2.8	10.35
9.	171-180	A	6.6	0.075	0.79	0.86	102.0	12.6	2.4	24.[illegible]
		B	6.3	0.065	0.56	T	72.5	13.0	2.6	16.10
		C	6.2	0.065	0.42	T	72.5	12.8	2.6	12.04
10.	201-210	A	6.5	0.053	0.46	0.70	87.5	12.4	2.2	16.65
		B	6.1	0.080	0.33	T	72.5	13.0	2.4	14.14
		C	6.0	0.110	0.27	T	75.0	13.2	2.4	11.38
11.	211-220	A	6.0	0.110	0.69	0.32	95.0	13.2	2.4	21.86
		B	6.4	0.075	0.43	T	67.5	13.0	2.6	14.72
		C	6.2	0.065	0.36	T	65.0	13.4	2.6	11.70
12.	231-240	A	6.3	0.065	0.68	0.86	105.0	12.2	2.2	26.80
		B	6.1	0.410	0.52	T	70.0	12.6	2.4	16.72
		C	6.1	0.070	0.38	T	70.5	12.6	2.4	12.80
13.	251-260	A	6.8	0.065	0.74	0.86	75.0	12.4	2.2	23.80
		B	6.6	0.065	0.38	T	82.5	12.8	2.4	13.67
		C	6.4	0.075	0.33	T	75.0	13.2	2.4	11.27
14.	271-280	A	6.8	0.075	0.79	0.98	110.0	12.6	2.2	25.16
		B	6.3	0.195	0.46	T	87.5	12.4	2.4	14.48
		C	6.4	0.234	0.37	T	87.5	12.8	2.4	11.04
15.	281-290	A	6.9	0.065	0.47	1.24	110.0	12.2	2.4	16.21
		B	6.2	0.060	0.37	T	82.5	12.6	2.6	13.45
		C	6.1	0.075	0.26	T	82.5	12.8	2.6	12.25

Table 4 (Contd)

Sl. No.	Tree No.	Depth	pH	EC millimhos/cm at 25°C	Organic carbon %	Available P_2O_5 ppm	Available K_2O ppm	Exch. Ca me/100 g	Exch. Mg me/100 g	Available N mg/100 g
16.	291-300	A	6.5	0.060	0.73	0.64	97.5	12.8	2.4	16.21
		B	6.0	0.035	0.47	T	75.0	12.8	2.4	16.21
		C	5.8	0.070	0.35	T	72.5	13.2	2.6	12.07
17.	321-330	A	5.8	0.070	0.50	T	62.5	13.2	2.6	17.24
		B	6.2	0.035	0.48	T	77.5	12.8	2.6	13.10
		C	6.1	0.030	0.29	T	71.5	13.2	2.6	10.00
18.	331-340	A	6.8	0.045	0.63	0.80	88.0	12.6	2.2	20.74
		B	6.6	0.060	0.45	T	75.0	12.6	2.6	15.14
		C	6.4	0.045	0.39	T	72.5	13.0	2.6	13.45
19.	361-370	A	6.3	0.080	0.42	0.76	105.0	12.2	2.4	14.62
		B	5.6	0.140	0.35	T	67.0	12.6	2.4	15.16
		C	5.6	0.190	0.29	T	65.0	13.2	2.6	10.00
20.	371-380	A	6.4	0.055	0.51	0.80	97.5	12.4	2.2	17.85
		B	6.1	0.065	0.48	T	80.0	12.8	2.0	13.95
		C	6.0	0.065	0.35	T	80.0	13.2	2.4	11.45
21.	381-390	A	6.5	0.060	0.55	0.94	100.0	12.2	2.4	18.24
		B	6.2	0.080	0.45	T	86.0	12.6	2.6	13.52
		C	5.8	0.060	0.30	T	85.0	13.2	2.6	11.35
22.	401-410	A	6.5	0.055	0.58	0.84	97.5	12.2	2.4	18.26
		B	6.2	0.070	0.39	T	80.0	12.6	2.6	13.45
		C	6.2	0.070	0.35	T	67.5	13.2	2.6	12.07
23.	411-420	A	6.5	0.040	0.41	0.78	72.5	12.2	2.2	15.72
		B	6.3	0.060	0.36	T	62.5	12.6	2.6	12.42
		C	6.1	0.065	0.36	T	72.5	13.8	2.6	12.42

Table 4 (Contd)

Sl. No.	Tree No.	Depth	pH	EC millimhos/cm at 25°C	Organic carbon %	Available P_2O_5 ppm	Available K_2O ppm	Exch. Ca me/100 g	Exch. Mg me/100 g	Available N mg/100 g
24.	431–440	A	6.4	0.065	0.38	0.74	82.5	12.2	2.4	14.32
		B	6.1	0.070	0.32	T	72.5	12.6	2.2	11.43
		C	6.0	0.095	0.30	T	77.5	13.2	2.4	10.16
25.	451–460	A	6.3	0.095	0.57	0.96	95.0	12.4	2.6	16.21
		B	6.1	0.070	0.36	T	70.0	12.8	2.8	13.27
		C	6.1	0.065	0.30	T	70.0	13.4	2.8	10.35
26.	471–480	A	6.5	0.055	0.50	0.80	100.0	12.2	2.4	15.24
		B	6.3	0.070	0.37	T	67.5	12.6	2.6	11.76
		C	6.4	0.080	0.31	T	65.0	13.2	2.4	10.39
27.	491–500	A	6.3	0.065	0.66	0.86	100.0	12.6	2.4	18.55
		B	6.1	0.065	0.35	T	77.5	12.6	2.4	13.07
		C	6.0	0.085	0.29	T	72.5	13.4	2.6	11.00
28.	511–520	A	6.5	0.045	0.45	0.74	90.0	12.2	2.4	16.62
		B	6.2	0.075	0.38	T	67.5	12.6	2.4	12.10
		C	6.0	0.075	0.32	T	70.5	13.0	2.6	10.65
Coefficient of variation		A	3.8375	25.6102	22.0994	31.3957	12.4026	2.4934	5.2758	17.9941
		B	3.1688	75.1537	16.2431	–	10.6899	2.6640	6.9615	16.2910
		C	3.2103	50.9561	19.2799	–	10.6991	2.0841	6.5472	9.8215

A = 0 to 15 cm   B = 15 to 37.5 cm   C = 37.5 to 60 cm

T = traces

FRL location (Table 3) fall in the neutral range with values ranging from 6.8 to 7.6 in the surface layer. The range for the intermediate depth is between 6.9 and 7.5. The pH values are between 6.8 and 7.7 in the third depth. From these values, it is noticed that there is a slight increase in pH with depth. The coefficients of variations were 2.83, 2.68 and 4.80 for first, intermediate and last depths, respectively.

The soils of Gottipur, on the other hand, are acidic in nature. The pH values in the first depth vary from 5.6 to 6.9. In intermediate depth, pH values range between 5.6 and 6.6, whereas in the third depth the values are between 5.6 and 6.4. The coefficient of variation values were 3.84, 3.19 and 3.21, respectively, for first, intermediate and third depth.

Thus, it is observed that the soils of Gottipur location are acidic in nature, compared to soils of FRL location. In FRL location pH increases slightly with depth, whereas there is no such variation in pH among different depths in soil of Gottipur.

4.2.2. Electrical conductivity: From Table 3, it is seen that in soils of FRL location, salt concentration ranges from 0.04 millimhos/cm to 0.15 millimhos/cm in the first depth. In the second depth, it ranges between 0.03 millimhos/cm and 0.11 millimhos/cm, whereas in the third depth electrical conductivity varies from 0.3 millimhos/cm to 0.10 millimhos/cm. The values of coefficient of variation were 25.61, 75.15 and 50.97 for the three depths, respectively.

The values of electrical conductivity of soils of Gottipur location are furnished in Table 4. Electrical conductivity values range from 0.04 millimhos/cm to 0.11 millimhos/cm in the first depth, whereas the values vary from 0.035 millimhos/cm to 0.41 millimhos/cm in the intermediate depth. In last depth, electrical conductivity ranges between 0.065 millimhos/cm and 1.105 millimhos/cm. The coefficient of variation values were 17.99, 16.29 and 9.82 respectively for the three depths.

From the results, it is thus seen that soils of Gottipur have slightly more salt content than soils of FRL location. The salt concentration has increased with depth in soils of Gottipur, but such a variation in salt concentration is not noticed in soils of FRL location.

4.2.3. Organic carbon: The content of organic carbon is presented in Table 3 and 4 for soils of FRL and Gottipur locations, respectively.

Organic carbon content in surface soils of FRL location ranges from 0.29 per cent to 0.48 per cent, whereas in the sub-surface soils the organic carbon content varies between 0.27 per cent to 0.41 per cent. The values of coefficient of variation were 18.60, 19.32 and 19.32, respectively for three depths.

From a perusal of organic content of soils of Gottipur location, it is seen that organic carbon content ranges from 0.38 per cent to 0.82 per cent in surface soils. In sub-surface soils, the values are between 0.21 per cent and 0.52 per cent. The coefficients of variation were 22.10, 16.24 and 19.28 respectively for three depths.

The soils of Gottipur location are richer in organic carbon than soils of FRL location. Organic carbon decreased with increasing depth in soils of both locations.

4.2.4. Available nitrogen: In Table 3 and 4, the data on the content of available nitrogen in soils of FRL and Gottipur locations are presented.

The available nitrogen in surface soils of FRL location ranges between 10.0 mg to 14.6 mg/100 g, whereas in sub-surface soils it varies from 9.3 mg to 14.1 mg/100 g. The values of coefficient of variation were 15.92, 16.13 and 6.67 for three depths. In surface soils of Gottipur location, available nitrogen varies from 14.32 mg to 26.80 mg/100 g. In sub-surface soils, available nitrogen values range between 10.0 mg to 18.62 mg/100 g. The coefficient of variation values were 17.99, 16.29 and 9.62 for three depths, respectively.

Soils of Gottipur location are richer in available nitrogen than soils of FRL location. In soils of both locations, available nitrogen decreased with increasing depth.

4.2.5. Available phosphorus: Available phosphorus values are given in Table 3 and 4 for FRL and Gottipur locations, respectively.

Surface soils of FRL location have varying levels of available phosphorus ranging from 5.7 ppm to 9.2 ppm. In sub-surface soils, available phosphorus ranges from 3.2 ppm to 7.9 ppm. The values of coefficient of variation were 17.13 for first depth, 20.10 for intermediate depth and 21.70 for last depth.

Available phosphorus values in surface soils of Gottipur location range between traces and 1.36 ppm. It is present only in traces in sub-surface soils. The coefficient variation for first depth was 31.39.

Soils of FRL location are richer in available phosphorus than soils of Gottipur location. It is observed that available phosphorus has decreased with increasing depth in both the soils.

4.2.6. Available potassium: Data on available potassium status of the soils are furnished in Table 3 and 4.

The range of available potassium in surface soils of FRL location is between 28.8 ppm to 39.2 ppm whereas in sub-surface soils the range is from 24.0 ppm to 35.2 ppm. The coefficients of variation were 9.43, 7.8 and 11.92 for three depths, respectively.

In soils of Gottipur location the values of available potassium are ranging from 72.5 to 110 ppm. In sub-surface soils, the variation of available potassium is between 62.5 ppm and 100 ppm. The values of coefficient of variation were 12.40, 10.69 and 10.70 for three depths, respectively.

From a perusal of the above values, it is seen that soils of Gottipur location are richer in available potassium than the soils of FRL location. In both locations, available potassium has shown a decreasing trend with increasing depth.

4.2.7. Exchangeable calcium: The values of exchangeable calcium for Gottipur soils are presented in Table 4. From a perusal of the data, it is seen that exchangeable calcium has increased slightly with the depth. Exchangeable calcium in surface soils varied from 12.0 me/100 g to 13.2 me/100 g. In sub-surface soils, exchangeable calcium ranges between 12.4 me/100 g to 13.8 me/100 g. The values of coefficient of variation were 2.49 for first depth, 2.66 for second depth, and 2.08 for third depth.

4.2.8. Exchangeable magnesium: The data on status of exchangeable magnesium (Table 4) indicate that the surface soils of Gottipur location have varying levels of exchangeable magnesium, the values ranging from 2.2 me/100 g to 2.6 me/100 g. Exchangeable magnesium increases slightly with increasing depth and in sub-surface soils it ranges between 2.0 me/100 g to 2.8 me/100 g. The coefficient of variation values were 2.49, 2.66 and 2.08 for the three depths, respectively.

4.2.9. Available sulphur: The data on the status of available sulphur have not been presented since available sulphur is present only in traces in all the soil samples collected from Gottipur location.

Estimations of exchangeable calcium, exchangeable magnesium and available sulphur were carried out only in soils of Gottipur location, since it was thought that these can be made use of for interpreting the yield and composition of oil of husks collected from trees of this location.

Thus, the physico-chemical properties of the soils from the two locations indicate that the soils of FRL location have more sand fractions than the soils of Gottipur location. In soils of both the locations, clay increases with depth. Soils of FRL location are around neutral in reaction whereas Gottipur soils are fairly acidic. Salt content is low in the soils of FRL location compared to soils of Gottipur location. Organic carbon and available nitrogen are high in soils of Gottipur location than soils of FRL location. However, both organic carbon and available nitrogen showed a decreasing trend with increasing depth in these soils.

The status of available phosphorus is high in soils of FRL location than soils of Gottipur location. Available phosphorus content decreased with increasing depth in both soils. The content of available potassium is more in Gottipur soils than soils of FRL location.

The exchangeable bases, namely, calcium and magnesium are fairly high in soils of Gottipur location and they tended to increase with increasing depth. Available sulphur is present only in traces in soils of Gottipur location.

4.3. Leaf analysis

The results of chemical analysis of the leaf samples with respect to nitrogen, phosphorus and potassium are presented in Table 5.

4.3.1. Nitrogen: The values of nitrogen in leaf samples varies from 0.96 per cent to 0.99 per cent in FRL plantation and the highest value is recorded by "1A9T" tree and lowest by "2R2T". The mean value was 0.977 per cent. Most of the values were on higher side. The coefficient of variation was 1.3207.

The Gottipur leaf samples have varying levels of nitrogen ranging from 0.48 per cent to 0.80 per cent. The

Table 5: Leaf analysis

Region	Sl. No.	Tree number	N Per cent	P Per cent	K Per cent
FRL	1.	1R4T	0.98	0.44	1.8
	2.	1R9T	0.99	0.38	1.8
	3.	2R2T	0.96	0.37	1.7
	4.	2R6T	0.98	0.36	1.7
	Mean		0.977	0.387	1.75
	Coefficient of variation		1.3207	9.3045	3.2991
Gottipur	1.	31-40	0.78	0.30	1.6
	2.	41-50	0.80	0.28	1.4
	3.	81-90	0.68	0.25	1.4
	4.	121-130	0.55	0.28	1.5
	5.	171-180	0.80	0.42	1.7
	6.	231-240	0.60	0.28	1.4
	7.	251-260	0.65	0.35	1.6
	8.	281-290	0.60	0.30	1.5
	9.	291-300	0.70	0.38	1.7
	10.	331-340	0.70	0.40	1.8
	11.	361-370	0.48	0.32	1.5
	12.	371-380	0.57	0.28	1.4
	13.	381-390	0.58	0.28	1.5
	14.	401-410	0.56	0.26	1.3
	15.	431-440	0.56	0.27	1.4
	Mean		0.64	0.31	1.51
	Coefficient of variation		15.5305	17.0694	9.3450

highest nitrogen content is observed in 171-180 row and lowest in 361-370 row. The mean value was 0.64. Majority of values fell in lower range. The coefficient of variation was 15.53.

4.5.2. Phosphorus: Leaf samples from trees of FRL location have higher phosphorus content than those from Gottipur plants and the values range between 0.36 per cent and 0.44 per cent. The highest phosphorus content is recorded by tree "1R4T" and lowest by 2R6T". The mean value was 0.387. Most of the values were in lower range. The coefficient of variation worked out to 9.3045.

However, phosphorus content in Gottipur trees ranges from 0.25 per cent to 0.42 per cent. The highest value of 0.42 per cent is recorded in sample 171-180 and lowest value of 0.25 per cent, in sample 81-90. Mean value was 0.31 per cent and most of the samples were in lower range. The coefficient of variation was 17.0694.

4.3.3. [redacted] The range of potassium values in leaf samples from FRL location is between 1.7 per cent and 1.8 per cent. The highest potassium content is recorded in two samples namely, from 1R8T, the 1R9T. The lowest figure was also observed in two samples, namely, from 2R2T and 2R6F. The mean value was 1.75 per cent and values were evenly distributed in the range. The coefficient of variation for this parameter was 3.2991.

In leaf samples from Gottipur location, it is found that potassium varied from 1.3 per cent to 1.8 per cent. The highest value is recorded by sample 331-340 and lowest, by 401-419. The mean value was 1.51 and most of the values were in the lower range. The coefficient of variation for this parameter was 9.34.

Four leaf samples from FRL location and 15 leaf samples from Gottipur location were analysed for nitrogen. phosphorus and potassium. It is seen that leaf samples collected from FRL location had higher contents of nitrogen and phosphorus than the leaf samples collected from Gottipur location. Most of the values of these nutrients were distributed in the lower range in both locations. The values of potassium in leaf samples from FRL location were evenly distributed, whereas most of the values were distributed in lower range in leaf samples collected from Gottipur location.

4.4. Yield

Husk yields of fruits from Bursera trees of Gottipur are given in Table 6.

Table 6: Husk yield of fruits from Bursera trees of Gottipur

Sl.No.	Tree No.	Yield (kg)
1.	11-20	5.500
2.	31-40	7.015
3.	171-180	8.200
4.	201-210	5.280
5.	211-220	7.530
6.	231-240	9.075
7.	251-260	8.085
8.	271-280	9.045
9.	291-300	8.030
10.	331-340	7.150
11.	361-370	4.070
12.	371-380	5.610
13.	381-390	6.880
14.	401-410	6.050
15.	411-420	5.660
16.	431-440	4.885
17.	451-460	6.215
18.	471-480	5.480
19.	491-500	6.875
20.	511-520	5.060
Mean	6.622	
Coefficient of variation	26.5018	

4.4.1. <u>Husk yield</u>: The husk yields presented in Table 6 represent the sum of yields obtained from ten trees of the row. From the Table, it is seen that the husk yields vary from 4.07 kg to 9.84 kg per row. The highest yield is recorded from 271-280 row and the lowest from 361-370. The average yield was 6.62 kg. The values were evenly distributed in the range. The coefficient of variation was 26.30.

Since it was a lean year for FRL plantation, the trees failed to flower and hence the husks could not be collected from this plantation. Therefore, the data are not presented.

4.4.2. <u>Oil content</u>: The oil percentage and oil yield in different husk samples are presented in Table 7.

The oil percentage in the different samplesvaries from 10.25 to 13.03. The highest oil percentage is obtained from the husk sample 251-260 and lowest from 231-240. The mean oil percentage worked out to 11.53 and most of the samples were in upper range of values. The coefficient of variation among these values was 7.29.

4.5. <u>Physical constants of oil</u>

Some of the physical constants of oil like specific gravity, optical rotation and refractive index of the oil extracted from the husks are furnished in Table 7.

Table 7: Oil content and physical constants of oil

Sl. No.	Tree number	Oil %	Specific gravity	Optical rotation	Refractive index
1.	11-20	11.072	0.9404	-0°42'	1.456
2.	21-40	10.448	0.9363	-1°14'	1.455
3.	171-180	10.910	0.9427	-0°42'	1.455
4.	231-240	10.256	0.9378	-1°42'	1.454
5.	251-260	13.031	0.9363	-0°54'	1.455
6.	271-280	11.424	0.9422	-0°30'	1.456
7.	291-300	12.408	0.9418	+0°12'	1.454
8.	331-340	12.361	0.9397	-1°06'	1.455
9.	361-370	11.309	0.9419	-1°18'	1.456
10.	371-380	10.886	0.9445	-1°48'	1.454
11.	401-410	11.392	0.9439	-0°24'	1.450
12.	411-420	11.979	0.9356	-1°00'	1.456
13.	431-440	11.392	0.9356	-1°00'	1.454
14.	471-480	12.448	0.9404	-0°36'	1.455
15.	511-520	11.9371	0.9371	-1°06'	1.454
Mean		11.5300	0.9402	-0°57'	1.4539
Coefficient of variation		7.2916	0.3138	11.034	0.3148

4.5.1. Specific gravity: Specific gravity from various oil samples ranges between 0.93 and 0.94. The highest specific gravity value is noticed in 371-380 sample and lowest, in 431-440 sample. The average specific gravity was 0.94. There was not much variation between the values and coefficient of variation was 0.31.

4.5.2. Optical rotation: The optical rotation, determined in various oil samples ranges between +0°12' and -1°48'. The optical rotation of +0°12' is obtained from sample 291-300. The mean optical rotation was -0°57' and most of the values were distributed in upper range. The coefficient of variation was 11.03.

4.5.3. Refractive index: The values of refractive index (Table 7) range from 1.45 to 1.46. The highest value of refractive index is noticed in four samples namely, 11-20, 271-280, 361-370 and 411-420. The lowest value was observed in 401-410. The mean value of refractive index was 1.45. The variations were small and coefficient of variation was 0.31.

From the above, it is observed that among the various physical constants determined, values of specific gravity and refractive index do not differ much among themselves. However, there is some variation in the values of optical rotation.

4.6. Chemical constants of oil

The chemical constants are furnished in Table 8. These include acid value, saponification value, saponification value after acetylation, ester percentage and alcohol percentage.

4.6.1. Acid value: The acid value of the oil samples varies from 2.18 to 2.56. The highest acid value is obtained from the sample 31-40, whereas the lowest is from the sample 401-410. The mean acid value was 2.34 and most of the values were distributed in the upper range. The coefficient of variation between the various acid values was 4.44.

4.6.2. Saponification value: The saponification values presented in Table 8 indicate that they range between 141.83 and 156.45. The sample 401-410 has the lowest saponification value and sample 411-420, the highest saponification value. The mean saponification value was 149.02 and most of the values were distributed in the upper range. The coefficient of variation for this parameter was 3.66.

4.6.3. Saponification value after acetylation: The values of saponification avalue after acetylation (Table 8) range between 268.80 and 280.91. The highest value is

Table 8: Chemical constants of Bursera oil

Sl. No.	Tree number	Acid value	Saponification value	Saponification value after acetylation	Ester per cent	Alcohol per cent
1.	11–20	2.35	159.75	271.18	53.67	31.78
2.	31–40	2.56	139.56	274.05	47.93	36.71
3.	171–180	2.44	153.41	271.90	52.82	32.33
4.	231–240	2.36	154.78	266.80	53.33	31.23
5.	251–260	2.24	142.47	270.24	49.07	35.07
6.	271–280	2.47	151.65	275.73	52.27	33.97
7.	291–300	2.31	149.75	269.32	51.39	[illegible]
8.	331–340	2.25	152.43	280.91	52.55	35.21
9.	361–370	2.23	146.87	276.62	50.61	39.62
10.	371–380	2.34	144.46	275.16	49.72	35.88
11.	401–410	2.18	141.83	268.88	48.86	34.79
12.	411–420	2.37	156.45	276.53	53.91	32.94
13.	431–440	2.46	151.28	272.84	52.07	33.15
14.	471–480	2.36	142.12	267.45	48.90	34.25
15.	511–520	2.31	152.41	271.03	52.58	32.60
Mean		2.34	149.02	272.86	51.321	33.34
Coefficient of variation		4.4456	3.6637	3.5984	3.8459	4.5026

is recorded in sample 331-340 and lowest in sample 231-250. The average saponification value after acetylation was 272.86 and values were evenly distributed within the range. The coefficient of variation among different values was 3.69.

4.6.4. Ester percentage: The ester percentage presented in Table 6 has been reported as linalyl acetate. These values range from 47.93 per cent to 53.91 per cent in different samples, the mean being 51.32. The highest ester percentage is noticed in sample 411-420 and lowest in 31-40. Most of the values were in the upper range. The coefficient of variation among these values was 3.84.

4.6.5. Alcohol percentage: The alcohol percentage in different samples furnished in Table 6 has been calculated as linalool. These values are between 31.23 per cent and 36.71 per cent. The highest alcohol percentage is recorded by sample 31-40 and lowest by 231-240. The mean alcohol percentage was 19.48. Most of the values were in the lower range. The coefficient of variation between these values was 4.90.

The results of chemical constants, thus, indicate that most of the acid values as well as saponification values were distributed in upper range. The values of saponification after acetylation were evenly distributed. Most of the values of ester percentage in different oil samples were in the upper range, whereas most of the values of alcohol percentage were in lower range.

4.7. Correlation studies

The correlations between the various soil fertility constituents and yield and composition of essential oil of Bursera are presented in Table 9. Positive significant correlations were obtained between yield and pH, yield and electrical conductivity, yield and organic carbon, yield and available nitrogen, yield and available potassium. Positive but non-significant correlations were obtained between yield and available phosphorus, yield and exchangeable calcium, yield and exchangeable magnesium, yield and sand percentage, oil content and available phosphorus, specific gravity and all the nutrients, refractive index and all the nutrients, ester percentage and organic carbon, ester percentage and available nitrogen, ester percentage and exchangeable calcium, alcohol percentage and available phosphores and alcohol percentage and available potassium.

There were no negative significant correlations

Table 9: Relationship between the yield and composition of Bursera oil and nutrient status of the soil

X	Y (cm)	Correlation coefficient
1. Yield	pH (0–15)	0.3039
	pH (15–37.5)	0.4425*
	pH (37.5–60)	0.4359
2. Yield	EC (0–15)	0.5623**
	EC (15–37.5)	0.4141
	EC (37.5–60)	0.0957
3. Yield	OC % (0–15)	0.8887**
	OC % (15–37.5)	0.7013**
	OC % (37.5–60)	0.6100**
4. Yield	Available N (0–15)	0.9429**
	Available N (15–37.5)	0.5822**
	Available N (37.5–60)	0.0056
5. Yield	Available P_2O_5 (0–15)	0.0700
6. Yield	Available K_2O (0–15)	0.4853*
	Available K_2O (15–37.5)	0.4763*
	Available K_2O (37.5–60)	0.0311
7. Yield	Exchangeable Ca (0–15)	0.3514
	Exchangeable Ca (15–37.5)	0.4311
	Exchangeable Ca (37.5–60)	0.2036
8. Yield	Exchangeable Mg (0–15)	0.0237
9. Yield	Sand % (0–15)	0.0284
10. Yield	Clay % (0–15)	-0.2956

Table 9 (Contd)

X	Y (cm)	Correlation coefficient
11. Oil%	OC % (0–15)	−0.0010
12. Oil%	Available N (0–15)	−0.0909
13. Oil%	Available P_2O_5 (0–15)	0.0210
14. Oil%	Available K_2O (0–15)	−0.2231
15. Oil%	Exchangeable Mg (0–15)	−0.0936
16. Oil%	Exchangeable Ca (0–15)	−0.1669
17. Specific gravity	OC % (0–15)	0.0305
18. "	Available P_2O_5 (0–15)	0.0442
19. "	Available K_2O (0–15)	0.0103
20. "	Available N (0–15)	0.0871
21. "	Exchangeable Mg (0–15)	0.0133
22. "	Exchangeable Ca (0–15)	0.0210
23. Refractive index	OC % (0–15)	0.0010
24. "	Available P_2O_5 (0–15)	0.0138
25. "	Available K_2O (0–15)	0.0021
26. "	Available N (0–15)	0.0013
27. "	Exchangeable Mg (0–15)	0.0027
28. "	Exchangeable Ca (0–15)	0.0110
29. Water %	OC % (0–15)	0.0660
30. "	Available P_2O_5 (0–15)	0.0007
31. "	Available K_2O (0–15)	−0.0312
32. "	Available N (0–15)	0.1688

Table 9 (Contd)

X	Y (cm)	Correlation coefficient
33. Ester %	Exchangeable Mg (0-15)	-0.0357
34. Ester %	Exchangeable Ca (0-15)	0.0225
35. Alcohol %	OC % (0-15)	-0.1377
36. Alcohol %	Available P_2O_5 (0-15)	0.0010
37. Alcohol %	Available K_2O (0-15)	0.1136
38. Alcohol %	Exchangeable Mg (0-15)	-0.2343
39. Alcohol %	Exchangeable Ca (0-15)	-0.2397
40. Alcohol %	Available N (0-15)	-0.2058

* Significant at 5% level
**Significant at 1% level

between any parameters studied. Negative, but non-significant correlations were obtained between yield and clay percentage, oil percentage and available nitrogen, oil percentage and organic carbon, oil percentage and available potassium, oil percentage and exchangeable magnesium, oil percentage and exchangeable calcium, ester percentage and available potassium, ester percentage and exchangeable magnesium, alcohol percentage and organic carbon, alcohol percentage and available nitrogen, alcohol percentage and exchangeable calcium, and alcohol percentage and exchangeable magnesium.

DISCUSSION

CHAPTER V

DISCUSSION

Out of the foreign exchange earners for our country, the contribution of essential oils is significant. From the literature collected, it is observed that the yield and composition of many essential oil bearing plants such as citronella, mint, lavender and oil rose are influenced by soil nutrient status, apart from other agro-climatic conditions and age of the crops. The effect of soil nutrient status on yield and composition of Bursera, which is one such crop, is discussed here.

5.1. Nutrient status of soil

It may be brought out here that the Bursera plantations of FRL location and Gottipur location, taken up for study are situated in Bangalore district. The analyses of soils in these two locations included those of mechanical analysis and other physico-chemical properties. The Soil Correlation Centre unit at Bangalore has also conducted similar studies of soils in Hoskote Taluk of Bangalore District, where Gottipur is situated. The centre has also investigated the soils of Bangalore North Taluk where FRL is situated.

A critical perusal of mechanical analysis of data shows that Gottipur soils are clay loam in the surface layers tending towards clayey in sub-surfacelayers. Nagabhushan et al. (1969), while characterising soils of Hoskote Taluk, have identified seven series of soils which range from sandy loam to clay in surface soils and sandy clay to clay in sub-surface soils. The data reveal that the Gottipur soils come under the Geratagere series as described by them.

The soils of FRL location are sandy loams in surface layers and sandy clay loam to clay in sub-surface layers. It is reported that soils of Bangalore North Taluk are sandy loam to clay loam in surface layers and clay loam to clay in sub-surface layers (All India Soil and Land Use Survey Report, 1973).

From the results obtained in the present study, it is observed that the texture of the soil tends towards clayey with increase in depth at both the centres. It is a well known fact that during the chemical and biological changes taking place in soil, the finer fractions, by and large, move to the lower depths as noticed in the present investigation.

The pH values of surface soils of Gottipur location, vary from 5.8 to 6.9. In sub-surface soils, these are between 5.6 and 6.6. Nagabhusan et al. (1969) reported that pH values in surface soils of Hoskote Taluk varied between 5.4 and 6.8. In sub-surface soils these varied from 5.0 to 7.7. The surface soils of FRL have pH values ranging between 6.8 and 7.6. The range is between 6.8 and 7.7 in sub-surface soils. It is reported that the pH values of surface soils of Bangalore North Taluk vary between 6.5 and 6.7 and in sub-surface soils these range from 6.5 and 7.6 (All India Soil and Land Use Survey Report, 1973).

A critical observation of data reveals that there is little variation in pH between the surface and sub-surface soils of Gottipur location. However, in soils of FRL location, it increases sligntly with increasing depth. This may be due to leaching and accumulation of bases in the lower layers.

Salt content in surface soils of Gottipur location expressed in terms of electrical conductivity, ranges from 0.04 millimhos/cm to 0.11 millimhos/cm. The range is from 0.035 millimhos/cm to 1.135 millimhos/cm in sub-surface soils. According to Nagabhusan et al. (1969), the salt content in surface soils of Hoskote Taluk ranged between 0.1 millimhos/cm to 0.4 millimhos/cm. In sub-surface it varied from 0.1 millimhos/cm to 1.0 millimhos/cm.

Electrical conductivity values in surface soils of FRS location range between 0.04 millimhos/cm and 0.15 millimhos/cm. The variation is between 0.03 millimhos/cm and 0.11 millimhos/cm in sub-surface layer. It is reported that soils of Bangalore North Taluk have salt content ranging from 0.1 millimhos/cm to 0.3 millimhos/cm in surface soils and the range is between 0.1 millimhos/cm and 1.0 millimhos/cm in sub-surface soils.

It is seen that electrical conductivity in soils of Gottipur location has increased with depth, because generally salts move from the surface to the lower depths.

As regards Gottipur soils are concerned, the surface soils have varying levels of organic carbon ranging from 0.36 per cent to 0.82 per cent, whereas in sub-surface soils, these values range between 0.21 per cent and 0.52 per cent. However, work of Nagabhushan et al. (1969) has indicated that organic carbon in surface soils of Hoskote Taluk ranged between 0.18 per cent and 1.9 per cent. In sub-surface soils, it varied from 0.02 per cent to 0.48

per cent. It is reported that in soils of Bangalore North Taluk, organic carbon content varies from medium to high contents (All India Soil and Land Use Survey Report, 1973).

The organic carbon content in both the soils, included in the present study, decreased with depth. This is because of the addition of the leaves which get shed and the subsequent decomposition of organic matter as a result of increased microbial activity in surface soil when compared to those in sub-surface soil.

Further, the values of available phosphorus in surface soils of Gottipur range between traces and 1.24 ppm. It is present only in traces in sub-surface soils. Nagabhusan et al. (1969) showed that the available phosphorus in surface soils of Hoskote Taluk ranged from 11 ppm to 31 ppm. They also reported that the available phosphorus content in sub-surface layers of these soils varied between 7 ppm and 28 ppm. Available phosphorus in surface soils of RRL location varies from 5.7 ppm and 9.2 ppm, whereas in sub-surface soils the values are between 3.2 ppm and 7.9 ppm. The report of All India Soil and Land Use Survey Report, 1973) indicates that the soils of Bangalore North Taluk have medium content of available phosphorus.

Available potassium content in surface soils of Gottipur location ranges between 72.5 ppm and 110 ppm. In sub-surface soils, the variation is from 62.5 ppm to 100 ppm. The work of Nagabhushan et al. (1969) indicates that the soils of Hoskote Taluk have varying levels of available potassium ranging from 69 ppm to 266 ppm, whereas the variation in sub-surface layers is between 42 ppm and 265 ppm. Available potassium content in surface soils of FRL location is between 28.6 and 39.2 ppm. The values range from 24.0 ppm to 35.2 in sub-surface soils. It is reported that soils of Bangalore North Taluk have medium contents of available potassium (All India Soil and Land Use Survey Report, 1973).

Both available phosphorus and available potassium decreased with increasing depth at both the places. The periodic inadvertent incorporation of organic matter year after year to the surface layer of the soil, as a result of shedding Bursera leaves, would be a contributing factor for the higher content of these two nutrients in the said layer. Moreover, the enhanced rate of weathering, taking place in the upper surface, releases these nutrients into the soil in the available forms for plant uptake. Hence both available phosphorus and available potassium are more in the surface layer than in the sub-surface layer.

Exchangeable calcium in surface soils of Gottipur location varies between 12.0 me/100 g and 13.0 me/100 g, whereas its content in sub-surface soils is between 12.4 me/100 g and 13.8 me/100 g. The corresponding values of exchangeable magnesium in these soils are between 2.2 me/100 g and 2.6 me/100 g and 2.0 me/100 g and 2.8 me/100 g, respectively. Nagabhusan et al. (1969) noticed that cation exchange capacity of surface soils of Hoskote Taluk varies from 2.3 me/100 g to 18.0 me/100 g. However, in sub-surface soils the range is between 4.3 me/100 g and 30.1 me/100 g. They also observed that base saturation in these soils varied between 59.7 per cent and 90.0 per cent.

In the present study, exchangeable calcium as well as magnesium increased with increase in depth due to their leaching and accumulation at lower depths of soil.

Available sulphur is found to be present only in traces in soils of Gottipur location. The available sulphur in the soil might have been taken up by the plants, leaving the soil highly deficient in this nutrient. Stanford and Jordan (1966) reported that oil bearing crops possess relatively high sulphur requirement.

Information on analysis of soils where Bursera is grown is also available. Bursera is grown in Kaiguni Estates (Rangegowda and Ramaswamy, 1969) which is situated in Bangalore South Taluk. These soils are sandy loam at the surface and are gravelly loam to clay loam as sub-surface. The pH values of these soils vary from 5.3 to 6.2. The salt content ranges between 0.3 millimhos/cm and 1.0 millimhos/cm. They are low to medium in available nitrogen content and low in available phorphorus and available potassium. The exchangeable bases are low in these soils.

5.2. Leaf analysis

Nitrogen content in leaf samples collected from FRL and Gottipur locations ranges from 0.96 per cent to 0.99 per cent and from 0.46 per cent to 0.80 per cent, respectively. Phosphorus in the leaf samples from FRL location varies between 0.36 per cent and 0.44 per cent. It ranges from 0.25 per cent to 0.42 per cent in leaf samples collected from Gottipur location. However, the potassium content in leaf samples of FRL location is between 1.7 per cent and 1.8 per cent, whereas its range is from 1.3 per cent to 1.8 per cent in leaf samples collected from Gottipur location. The leaf samples from FRL have shown higher nitrogen and phosphorus contents than leaf samples from Gottipur location. This may be because the plants at FRL location are more aged than those at Gottipur.

There has been no record of work on leaf analysis of Bursera. However, the leaf analysis work in some other essential oil bearing crops has been given here. Narayana (1976) working with java citronella noticed that the leaves of this plant contained 1.16 per cent of nitrogen and 0.34 per cent of phosphorus.

5.3. Yield

During the year of investigation (1974) the plantation at FRL did not bear any fruits. The reason for the same awaits investigation. Husk yields at Gottipur varied from 4.07 kg per row to 9.85 kg per row. The variation in the yield can be attributed to various factors such as fertility status of soils, plant vigour, etc.

The oil content in the husks varied between 10.25 per cent and 13.03 per cent. The variation in oil content can be attributed to variation in vigour of plant. Rangegowda and Ramaswamy (1965) observed the recovery of oil to an extent of 13.74 per cent from Bursera husks.

5.4. Physical and chemical constants of the oil

The several physical and chemical constants of the Bursera oil like specific gravity, refractive index, optical rotation, saponification value and saponification value after acetylation, recorded during the period of investigation are discussed below.

Specific gravity of the oil ranged from 0.9356 to 0.9445. In experiments conducted by Simmons (1934), the oil from seed indicated a specific gravity of 0.8878 and 0.8911. Guenther (1941) also found such variations in specific gravity of Bursera seed oil.

However, the refractive index of the oil did not vary much, the range being between 1.450 and 1.456. This is in line with the work of Simmons (1934) wherein narrow variations were reported.

In the present study, only one oil sample is found to be dextro rotatary and the range of valuesof optical rotation is between 0°12' and -1°48'. It is reported that the optical rotation of oil sample obtained from husk was -4°48' (Anon., 1931). Guenther (1941) reported that the optical rotation of Bursera oil obtained from seed varies from +2°40' to +3°10' whereas Rangegowda and Ramaswamy (1965) observed that the optical rotation of Bursera oil was +1°50'.

Acid values in different samples ranged between 2.16 and 2.58. The variation in acid value can be attributed to the varying levels of free acids present in the oil. Rangegowda and Ramaswamy (1965) reported that acid value of a Bursera oil sample was 0.99, while Narayan and Sikhibhusan (1945) reported it as 0. Saponification value is fairly high, indicating the presence of the molecular fatty acids in the ester to a higher extent. The range of saponification values lie between 139.56 and 156.45. Narayan and Sikhibhusan (1945) indicated that the saponification value of Bursera oil was 130, while Rangegowda and Ramaswamy (1965) reported it as 139.14. Nevertheless, saponification value after acetylation ranged between 268.8 and 280.91. Narayan and Sikhibhusan (1945) reported the saponification after acetylation as 274.

5.5. Correlation studies

It may be stated here that correlation studies on the soil on one hand and yield and composition of Bursera oil on the other have not received much attention. However, an attempt has been made now in this regard.

There was a negative correlation between yield and clay percentage (-0.295) and it was not significant. Clay is known to hinder the development of roots. Tuchkov (1958) reported that root development of peppermint was greater on sandy soils compared to those grown on chernozem soils. Koresova (1962) observed that sandy loam or loamy soils produced better plant growth and higher oil contents in *Pelargonium* sp., than in heavy soils. Rangegowda and Ramaswamy (1965) reported that sandy loam soils are suited better for cultivation of Bursera.

Soil pH values for the three depths and yield of husks were found to be positively correlated. But the correlation coefficient was significant only in the intermediate depth. The mean soil pH in this depth was 6.24. This soil pH has favoured the efficient utilization of the available nutrients released due to the favourable soil reaction. It is observed that a pH range of 6.0 to 7.5 promotes the successful growth of peppermint (Anon., 1971). However, Chandra *et al.* (1968) reported that Japanese mint plants can thrive on soils having pH range of 8 to 10.

A positive and highly significant correlation was obtained between yield and electrical conductivity in the first depth. The soil is having more sand fractions and the amount of salts contained is less. This may be the optimum level of salt concentration for the plant to cause the yield increase.

Regarding the organic carbon content, there were positive and significant correlations at all the depths. The correlation coefficients were +0.8887, +0.7013 and +0.610, respectively, for the three depths. The organic carbon content is an indirect measure of organic matter in the soil, which has profound effect on various physico-chemical properties of the soil. This has resulted in higher yield and thus there were positive significant correlations at all the three depths.

Available nitrogen and yield were positively correlated. Significant correlations were obtained with first two depths, the correlation coefficients being +0.9429 and +0.5622 for the first and intermediate depths, respectively. The beneficial effect of application of nitrogen to various essential oil yielding plants has been reported by various workers. Baird (1957), Nelson *et al.* (1969) Kerekes and Hosack (1972) in peppermint, Vireani *et al.* (1967) in chamomilla, Narayana *et al.* (1967) in geranium and Miakon *et al.* (1970) in crimean red rose have shown increases in yield by the application of nitrogen.

A large concentration of available phosphorus is present in surface soils only and it is present in traces in sub-surface soils. The correlation coefficient between this nutrient and the yield was +0.0421 for the first depth which is found to be not significant. This may be because phosphorus is not present in such varying levels to cause variation in yield. However, phosphorus is known to increase the yield in essential oil bearing plants. This has been reported by Miyazaki (1969) in lemon grass, Singh and Singh (1969 and 1971) in japanese mint, Baslas (1970) and Gretskaya and Oleinikova (1972) in peppermint.

The yield and available potassium content of first two layers of soil were positively correlated with a degree of significance. The correlation coefficients were +0.4833 and +0.4763 respectively for first and intermediate depths. The available potassium content is maximum in surface layer. Rao (1975) found that the maximum distribution of lateral roots in Bursera is confined to first 60 cm of soil. So this has resulted in positive significant correlation between the available potassium and yield. Minkov et al. (1970) observed that application of potassium to the soil at a depth of 25 to 40 cm gave maximum yield in crimean red rose. Similar results of increased yield due to application of potassium was shown by Gonzalesalanso (1955) in mint plant and El japtis (1970) in vera weed.

Exchangeable calcium did not show any significant correlation with yield. There is no much variation in exchangeable calcium to bring about differences in yield. Exchangeable calcium increased with depth. The fluctuation in values of exchangeable calcium is less and this has contributed for the correlation being not significant. However, deficiency symptoms of calcium in essential oil bearing crops has been reported by Gonzalesalanso (1955) and Steward and Crane (1962). Similarly, exchangeable magnesium did not bear any significant correlation with yield.

Sufficient available sulphur was not present in quantifying amounts because of plant uptake and hence no correlation has been worked out.

It could be seen that positive and significant correlations were obtained between yield and pH, yield and electrical conductivity, yield and organic carbon, yield and available nitrogen and yield and available potassium in soils. The other nutrients did not bear any significant correlation with yield.

Oil content and available nitrogen did not bear any significant correlation. The correlation efficient was -0.0909. Eventhough nitrogen is known to influence yield of essential oil bearing crops, the oil content is not affected. Similar results were obtained by Baird (1957) and Narayana et al. (1967 and 1976), who worked with pepper-mint, geranium and Java citronella. Similarly, oil content was not influenced by available phosphorus content in the soil. The correlation coefficient was +0.021. This is in line with work of Miyazaki (1969) who has worked with lemon grass.

The correlation coefficient between oil content and available potassium was +0.2251 and it was not statistically significant. Similar trend of results were obtained by Baird (1957) on peppermint, and Narayana et al. (1976) on Java citronella.

Exchangeable calcium and magnesium did not bear any significant correlation with oil content. The relationship between exchangeable calcium and magnesium and oil content has not been reported even in other essential oil bearing perennial crops.

Correlations between physical constants of oil such as specific gravity and refractive index with soil nutrient status were also worked out. Refractive index and available nitrogen indicated meagre correlation of +0.0013 which is not significant. Such relationships between refractive index of oil and nitrogen has been obtained by Narayana et al. (1967) in geranium and Sijaptis (1970) in worm wood. Available phosphorus and available potassium did not influence refractive index as these had not significant correlations, the correlations coefficients being +0.0412 and +0.1003, respectively. This is in conformity with the work of Narayana et al. (1967) in geranium and Sijaptis (1970) in worm wood. Exchangeable calcium and magnesium did not show any significant correlation with refractive index.

Specific gravity of Bursera oil and none of the nutrients in the soil bore significant correlations. The coefficient of correlations were -0.0876, +0.0442, -0.1003, -0.0190 and +0.0228 respectively for available nitrogen, available phosphorus, available potassium, exchangeable calcium and exchangeable magnesium. Similar observations were made by Narayana et al. (1967) in geranium, and Sijaptis (1970) on worm wood.

Correlations on ester percentage and alcohol percentage of Bursera oil with various soil nutrients have

been worked out. Since ester percentage gives an idea of saponification value and alcohol percentage, an idea of saponification value after acetylation correlations with saponification value and saponification after acetylation have not been worked out. The ester content of essential oils serves as a quality index of the oil. The correlation coefficient between ester content and available nitrogen was +0.1686 but it was not statistically significant. Many workers have shown that application of nitrogen does not influence the quality indices of essential oils. This is in agreement with the work of Ivanova and Gogina (1967), Narayana et al. (1967), and Swab (1970). However, it may be stated here that with further advance in the age of plants which are only twenty years old at present, the ester content may show a significant improvement (Ivanova and Gogina, 1967). However, some workers have also shown that application of nitrogen improves the quality indices (Nelson et al., 1969; Nimken et al., 1970; and Franz, 1972). With available phosphorus, the ester content had a correlation coefficient of +0.01 which was not statistically significant. Similar reports have been made by Swab (1970) and Narayana et al. (1967). This may also be due not only to low levels of phosphorus but also its narrow variation in the soil. The correlations worked out between available potassium and ester percentage was +0.0312. This was found to be statistically not significant. It is quite possible that even by the lowest content of 65 ppm of potassium found in the soils investigated, the ester percentage in the oil might have been sufficiently influenced so that higher values of available potassium might not have caused variation in said constituents. Results of similar nature has been obtained by Svab (1970). Exchangeable calcium and magnesium did not indicate any significant correlation with either ester content or alcohol content of oil.

Alcohol percentage and the nutrients had no significant correlations. The correlation coefficients were -0.2058, 0.0210 and +0.1136 respectively with available nitrogen, available phosphorus and available potassium. This is in line with the work of Ivanova and Gogina (1967) and Narayana et al. (1967).

SUMMARY

CHAPTER VI

SUMMARY

An investigation was carried out to know the correlation that exists between soil nutrients status and yield and composition of essential oil of Bursera. Two plantations were selected for study and soils samples were collected from both the places. Soils from Gottipur had higher available nitrogen, available potassium than FRL soils. But FRL soils showed more available phosphorus contents than the soils of other location. Available sulphur was present only in traces in soils of Gottipur. The soils of both plantations were sandy loam. But in Gottipur soils clay increased with depth to a greater extent than in FRL soils.

Since it was a lean year for FRL plantation, the fruits or husks could not be collected for investigation.

Organic carbon as well as available nitrogen, soil pH, and available potassium had a favourable effect on the husk yield of Bursera, whereas available phosphorus, exchangeable calcium and exchangeable magnesium did not have any influence on yield. None of the nutrients had any effect on essential oil content of Bursera.

The physical constants of Bursera oil, such as refractive index and specific gravity were not influenced by varying contents of soil nutrients. Besides, ester content calculated as linalyl acetate and alcohol percentage calculated as linalool were not influenced by the soil nutrients. This indicates that soil fertility status has by and large little effect on composition of essential oil of Bursera.

Suggested lines for future work

1. No information on nutritional requirements of *Bursera penicillata* is available. Hence there is a need for taking up long range fertiliser trials on the crop.
2. Experiments have to be conducted to know the effect micro-nutrients on yield and composition of essential oil of Bursera.
3. There is a peculiar phenomenon of lean period when Bursera plants will not bear fruits during some years. This aspect needs intensive investigation.
4. Extraction of oil from wood and its economics have to be worked out.

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CHAPTER VII

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