EVALUATION OF *Ocimum* LINES FOR HERBAGE YIELD, OIL CONTENT AND EUGENOL

By

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THESIS

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Department of Plantation Crops & Spices
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1988

DECLARATION

I hereby declare that this thesis entitled "Evaluation of *Ocimum* lines for herbage yield, oil content and eugenol" is a bonafide record of research work done by me during the course of research work and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

Vellanikkara,
9--9--1988.

MAYA.S.NAIR

CERTIFICATE

Certified that this thesis entitled "Evaluation of *Ocimum* lines for herbage yield, oil content and eugenol" is a record of research work done independently by Smt.Maya.S.Nair, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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MAYA.S.NAIR

To my parents

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Introduction

INTRODUCTION

Essential oils are odoriferous bodies of oily nature obtained mainly from plant kingdom. They are formed in special cells, glands or ducts in the whole or part of a plant such as flower, leaf, bark, wood, root, rhizome, fruit and seed, imparting to them natural perfume. Aromatic plants have long been exploited for the production of essential oils, which form indispensable ingredients of the necessities in many spheres of human activity. India is a veritable emporium of medicinal and aromatic plants, where about 2,500 species of the former and about 100 species of the latter are known to grow in her tropical plains, temperate and alpine hills. Foreign trade in essential oils amounts to about six crores of rupees annually, of which exports account for four and half crores and the balance being imports.

The name 'Thulsi' evokes venerable responses in the minds of millions of Hindus. From time immemorial thulsi occupies a special position in the Hindu household. It is grown in a raised place in front of the house called 'Thulsithara' and the devout Hindus offer water to thulsi

Plate I. Thulsithara

Enlargement size: 3
Photograph size : 12x8

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every morning. Though considered to be holy and secred in nature, its unique medicinal properties have not escaped the keen observation of the Hindus. Generally purple coloured O. sanctum lines are preferred by the people for the homestead planting as well as for other uses.

The genus Ocimum is a fascinating group of aromatic plants belonging to the family Labitae, yielding various essential oils and aromatic chemicals which have a unique place for use in home medicines, perfumery, flavour and food adjuncts. The juice of the leaves of Ocimum possesses antiseptic, diaphoretic, antiperiodic, stomachic and expectorant properties and is useful for treating diseases of heart and blood, leucoderma, asthma, bronchitis, lumbago, vomiting, painful eye and discharge of ear. The seeds are used for treatment of disorders of genito-urinary system. The root is given in decoction as a diaphoretic to treat malaria fever. Every part of the plant finds its application in the treatment of snake bites.

From commercial point of view, Ocimum spp. are rich in camphor, citral, geraniol, linalool, linalyl acetate, methyl chavicol, eugenol and thymol. Among the various chemicals mentioned, eugenol has been relatively more important because of its demand and value. The source oils (clove and cinnamon oils) for extracting eugenol are mostly imported. Eugenol is one of the most important natural

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isolates having warm, powerful spicy odour and taste and this is widely used in pharmaceutical preparations, in perfumes, for soaps and cosmetics and as a flavouring agent in all kinds of foods. Apart from all these uses, eugenol is the starting material for the preparation of synthetic vanillin.

Clove is the principal source of eugenol. Eventhough there is scope for extending its cultivation in the lower elevations of Western and Eastern ghats, its long pre-bearing age, extreme variability, slow growth, difficulty in harvesting the produce due to inaccessable heights and requirement of heavy rainfall stand as impediments. Ocimum spp. like O. sanctum and O. gratissimum containing good percentage of eugenol can serve as new potential sources of eugenol. There is ample scope for cultivation of Ocimum plants under a wide range of soil and ecological conditions in India bestowed with one of the greatest emporia of different geographical regions and diversity of altitudes from sea level to mountains.

In view of the importance of ocimum, Regional Research Laboratory, Jammu started a programme of exploration, introduction and improvement. O. gratissimum was found to

contain good gene pools and as a result of screening and breeding a new strain was evolved by hybridisation of selected chemotypes of O. gratissimum. This strain was appropriately named as 'CLOCIMUM' meaning 'clove scented ocimum'. It is anticipated that the establishment of Clocimum on a large scale, will not only augument the present production of eugenol but may also bring down its price drastically. Hindustan Lever Company, Bombay recently purchased a lot of 500 kg of Clocimum oil from Regional Research Laboratory, Jammu. The purchase by such a well known large company gives an indication that Clocimum oil has been accepted by the perfumery industry as a substitute for clove oil. In Regional Research Laboratory, Jammu, Sobti et al. (1980) got a net profit of Rs. 1,200 per hectare in the first year and Rs. 7000 per hectare in the second and third year each by the cultivation of Clocimum.

Clocimum was introduced to Aromatic and Medicinal Plant Research Station, Odakkali during 1981-82 and studies revealed that it could be successfully cultivated as an irrigated crop under prevailing conditions of Kerala. It was also found that Clocimum can definitely be an alternative source of eugenol due to its relatively easy cultivation and distillation and comperable yield.

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Considering the high cost of production of clove, if a strain of Ocimum spp. rich in eugenol is identified under Kerala homestead conditions, this probably can be used as an alternative source of eugenol. Further, the cultivar Clocimum is identified as an important item in the Research Project Bank for the Plant Introduction Experiments of Kerala Agricultural University. So far, no systematic approach seems to have been made in Kerala to test the adaptability of the various Ocimum lines and to assess their corresponding essential oil and eugenol yields.

Hence, the present study was taken up with the following objectives:

1) To select better types based on leaf colour, aroma and flavour;
2) To study the growth and flushing behaviour of each type and to isolate superior ones having better flushing characters;
3) To select a purple coloured O. sanctum line for the Kerala homesteads;
4) To select eugenol rich strain to undertake large scale cultivation of Ocimum for essential oil production;
5) To explore the possibility of growing Clocimum under Vellanikkara conditions.

Review of Literature

REVIEW OF LITERATURE

The genus Ocimum has been recently identified as one of the important aromatic groups of herbaceous plants with commercial value. Research work done on this crop is meagre as compared to the work on other commercially important aromatic and medicinal plants. The literature available on this crop is reviewed below:

2.1 Origin and distribution

Kirtikar and Basu (1918) suggested that Ocimum is cultivated throughout India, but doubtfully indigenous to Malay Archipelago, Australia, West Asia and Arabia. According to the reports of CSIR, Ocimum is a genus of aromatic herbs, undershrubs or shrubs distributed in the tropical and warm temperate regions of the world (Anon., 1966). Sobti et al. (1976) studied the geographical distribution of 160 reported species of the genus Ocimum and found that the genus is well distributed in the warmer parts of both hemispheres from sea level to 6000 feet. Considering Valvilov's view, they reported that Central and West Africa are the primary regions of origin of Ocimum

species. Their study on distribution of various species in India revealed that O. *genum* is confined mostly to southern parts, O. *basilicum* occur throughout India, O. *americanum* spread in North Western regions of India, O. *gratissimum* and O. *adscendens* have distributional ranges within Southern and South eastern regions of the Indian subcontinent, O. *sanctum* is cultivated in almost every part of India and O. *kilmandscharicum* introduced to India does not have a natural distribution.

2.2 Taxonomy

From the studies conducted on classification of genus *Ocimum*, CSIR stated that *Ocimum* should be classified on the basis of chemical composition of oil rather than their botanical origin (Anon., 1966). Because of the propensity of chemotypes in *Ocimum* spp., Guenther (1974) suggested that it is appropriate to classify various oil types according to their chemical composition and geographical source. Accordingly O. *basilicum* was classified into European type, Reunion type, Methyl cinnamate type and Eugenol type; O. *gratissimum* to Thymol, Eugenol and citral type; O. *sanctum* containing eugenol as the major constituent; O. *kilmandscharicum* a rich source of camphor and O. *viride*

having thymol as the major constituent. The study of dermatotypes of ten species of Ocimum by Gupta and Bambie (1978a) revealed that the sixteen types of trichomes observed, fall under four categories, such as capitate glenduler, non-glenduler, uniseriate filiform, non-glendular biseriate filiform and non-glandular capitate. They also suggested that on the basis of trichome types, different species of Ocimum can be identified. Another investigation on venation pattern of ten species of Ocimum by Gupta and Bambie (1978b) supported the preposition that venation pattern did not have much significance in the delimitation of species in the genus Ocimum. Philip and Damodaran (1985) classified O.sanctum into chemotypes based upon the chemical composition of their essential oils, like eugenol, methyl eugenol and caryophyllene contents. They identified and classified types having purple leaves and green leaves in the local cultivars of O. sanctum having methyl eugenol as the major constituent and another green type having eugenol as the major constituent.

2.3 Crop improvement

Many of the Ocimum spp. cross freely amongst themselves and so it is possible to improve Ocimum spp. for

more yield of volatile oils and aroma chemicals by planned hybridisation and selection programme, coupled with systematic analysis of oil at various steges of improvement (Krishnamoorthy, 1985).

Sobti et al. (1978b) studied the essential oil analyses from a selection of Ocimum basilicum var. thyrsiflora two forms of O. canum, two forms of O. basilicum var. glabratum, several interspecific hybrids, a new O. spp. and allopolyploids derived from F_1 sterile hybrids of O. canum and O. basilicum. They found that the hybrids and allopolyploids generally yielded more herbage and oil. Investigations of Pushpangadan et al. (1979) indicated that a high genetic variability existed in O. americanum and using this natural variation, by planned hybridisation programme a variety was evolved having high herbage and oil yield and 70 to 90 per cent citral. Khosla and Khurana (1980) in their cytological investigations with 24 taxa belonging to 11 species of Ocimum found out that hybridity and polyploidy leads to higher percentage of essential oil and yield. Eugenol obtained from cloves (Eugenia caryophyllata) is highly priced and Sobti et al. (1980) had undertaken a programme of development of an alternative and cheap source of eugenol at Regional Research Laboratory, Jammu. They

found that the different races collected from USA, West Africa and different parts of India are cytotypes of O. gratissimum and together would provide a rich genetic pool for many desirable characters. They produced a new strain by hybridisation and recurrent selection of selected chemotypes of O. gratissimum which had been named as Clocimum with 75 to 80 per cent eugenol in oil. Krishnan (1981) detected natural crossing at varietal level of O. basilicum to the extent of 66.7 per cent using seedling pigmentation as gene marker. Extensive hybridisations were carried out by Sobti and Pushpangadan (1982) in all possible combinations among O. gratissimum, O. sanctum, O. canum, O. americanum and O. kilmandscharicum. They observed that the hybrids produced were promising with high herbage and oil yield and offered great scope for use in the industry and some of the amphidiploids produced were important from the essential oil point of view. Khosla and Sobti (1984) produced F_1 hybrids involving different geographical races of O. gratissimum (collected from Jammu, USA, and Kerala respectively) and found that Jammu and USA races crossed freely with each other and produced fertile and vigorous hybrids, whereas the hybrids involving Jammu/USA races and Kerala races were strikingly dwarf and completely sterile.

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Chemical and genetic investigations were conducted by Khosla *et al.* (1985) on *O. gratissimum*, *O. suave* and *O. viride* and reported that the F_1 hybrids and allopolyploids produced by these species had an average higher herbage and oil yield. Khosla and Sobti (1986) produced highly sterile F_1 hybrids by crossing *O. gratissimum* and *O. viride* and fertility was induced by treating young shoots with colchicine. They were of opinion that the synthesised fertile amphidiploids unlike F_1 hybrids showed regular meosis and 68 to 75 per cent seed set compared to 1.4 to 1.9 per cent in F_1 hybrids.

Some investigations were carried out on the inheritance of certain constituents and pigmentation. Studies of Sobti *et al.* (1976) revealed that citral, linalool, geraniol which are monoterpenes are inherited independently of eugenol and methyl chavicol which are phenolic in nature. Naregund *et al.* (1979) reported about inheritance of pigmentation based on intervarietal hybridisation between French basil variety of *O. basilicum* with a local variety, 'Kamakasturi'.

2.4 In vitro techniques

Getsadze (1978) reported that the resultant mutants of *O. gratissimum* developed by irradiation of seeds with

10-11 KR of gamma rays exhibited a higher essential oil content as well as greater degree of resistance to Fusarium oxysporum. Singh et al. (1980) found that when O. canum seeds and seedlings treated with different doses of X-rays, the plants from seeds did not produce any appreciable morphological changes, whereas the plants from seedlings showed irregular branching with 6 and 9 KR, however it did not increase herbage yield or oil content.

Investigations conducted by Ahuja et al. (1982) on O. viride, O. gratissimum, O. viride x O. gratissimum (Sterile hybrid) and O. basilicum x O. kilmandscharicum (fertile hybrid) indicated that the first apical nodal segments responded well when cultured in Murashige and Skoog revised tobacco medium supplemented with cytokinins and auxins or in combination. They observed uniform increase in shoot number from a single explant during subculturing under optimum conditions in 40 to 45 days with an initial lag of 15 to 20 days after which the shoot number remained unchanged. Plantlets developed were successfully transferred to the field with only 10-25 per cent mortality. Dalton (1983) was of the opinion that in O. basilicum continuous culture, on Murashige and Skoog medium could be used to establish, a steady state in fructose excess. Phosphate was

shown to be limiting growth, when its concentration in the medium was doubled (from 16.5 to 39 µg/ml) the concentration of drymass and all biomass elements increased. Fructose became limiting after doubling phosphate concentration and the cells responded by becoming greener and more photosynthetic. Banthrope *et al.* (1986) studied callus cultures derived from seven oil producing plants like *Jasminum officinale*, *Rosmarinus officinalis*, *Lavandula angustifolia*, *Anethum graveolens*, *O. basilicum*, *Pinus radiata* and *Tanacetum vulgare* and assayed their ability to synthesise and accumulate mono and sesquiterpenes. They found that callus cultures might be a convenient source of biomass for studies on the enzymes of terpenoid biosynthesis.

2.5 Spacing and nutrition

Cikalov (1957) studied the methods of planting of *O. gratissimum* and recommended a spacing of 60 x 60 cm. Balyan *et al.* (1982) recommended a spacing of 40 x 40 cm and 50 x 50 cm for Ciocimum. A study on nutrition with P and K combinations and fixed dose of N/ha (80 kg) showed that a combination of 80 kg P_2O_5 with 30 kg K_2O per ha gave a maximum yield. Experiments by Choudhari and Bordoloi (1984) revealed that *O. gratissimum* could be grown successfully

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as a perennial crop and gave maximum yield of herb and oil from a spacing of 45 x 45 cm (49,000 plants/ha). They also found that the interaction between plant density and cuttings were significant in herb yield, oil content, oil yield and eugenol percentage.

According to Gulati et al. (1978) there was an increase in the herb and oil yield of O.basilicum with the increased rate of nitrogen application. By pooling the yield data of both harvests a maximum yield of 284.06 q herb per ha corresponding to 39.56 kg oil per ha was obtained in plots applied with 120 kg N per ha, whereas control plot (0 kg N/ha) gave 280.75 q/ha herb corresponding to 26.99 kg oil per ha. Investigations of Pareek et al. (1980) revealed that the herbage yield of O.sanctum increased in response to an application of 40 and 80 kg N per ha by 21.1 per cent and 63.04 per cent over control respectively. However in terms of increase in oil content, this trend was limited up to a level of 40 kg N per ha and the eugenol content remained more or less unaffected by application of nitrogenous and phosphatic fertilizers. Pareek et al. (1982b) reported that a mixed nitrogenous and phosphatic fertilizer at the rate of 40 kg N and 20 kg P_2O_5 per ha improved the herbage yield and oil yield significantly. Investigations were

conducted by Asthana and Gupta (1984) on the effect of N and P level on physiological parameters at three growth stages in sacred basil (O. sanctum L.). They suggested a fertilizer level of N_{20} P_{60} kg/ha to be optimum for securing highest oil and eugenol productivity. Investigations were conducted by Dey and Choudhari (1984b) to study the fertilizer requirement of O.sanctum with two levels of N (50 and 100 kg/ha) P (25 and 50 kg/ha) and K (30 and 60 kg/ha) with single, double and triple combinations. The results revealed that all fertilizer treatments were more or less ineffective in increasing the content of essential oil and eugenol. The application of nitrogen either singly or in combination with P and K or both favoured plant growth and increased yield of essential oil and eugenol per plant. Sreesly (1986) reported that a double application of N was most effective, 90 kg N per ha at 30-35 days and 90 kg N per ha 60 days after germination was recommended. Ingle et al. (1985) carried out investigations to study the effect of fertilizer doses with spacing on the yield of Ocimum during 1983-84. They observed that wider spacing (75 x 75 cm) was significantly superior to narrow spacing (50 x 50 cm) in both cuttings and also in total yield of dry foliage. A fertilizer dose of 90 kg N per ha was found to be significantly superior to 60 and 30 kg N per ha.

2.6 Growth regulators

Choudhari (1979) studied the effect of growth regulators such as NAA, 2,4-D, GA_3, Maleic hydrazide, benzimidazole and Chloro chloride on essential oil content of Ocimum sanctum Maleic hydrazide (200 ppm) significantly increased the yield of oil in leaves and inflorescence. Dey and Choudhari (1984c) reported that the essential oil and eugenol content increased in Ocimum sanctum plants (45-50 days old) after foliar spraying with gibberellic acid and kinetin (50 and 100 ppm). They also observed that maximum increase in essential oil and eugenol content was obtained after treatment with GA_3 (100 ppm) at mid-reproduction stage and GA_3 treatment was significantly superior than kinetin in increasing plant height and total herb, while chlorophyll, protein and carbohydrates were increased more by kinetin. El Sahhar et al. (1984) treated O. basilicum plants with GA_3 at 30-150 ppm in June, August, October and one month after transplanting, one month after first harvest and one month after second harvest respectively. They found that herbage fresh weight and essential oil yield increased in all cases with GA_3 rates up to a maximum of 90 ppm and then declined. Mousa and El Emary (1984) in their investigations with O. basilicum, sprayed GA_3

(50, 100 and 200 ppm) or MH (100 and 200 ppm) four times (one for each cut) and observed that GA_3 considerably reduced plant height, number of branches per plant and herbage yield. Whereas MH especially at 200 ppm reduced height of the plant but increased the herbage yield and MH at 100 ppm greatly increased the number of branches per plant. Oil content was increased significantly by GA_3 at 50 ppm and MH at 100 and 200 ppm. Pouchs (1964) sprayed young plants of Hibiscus abelmoschus, Pelargonium roseum and O. gratissimum with 0.02 per cent gibberellic acid. He found that Hibiscus abelmoschus grew to a height of 108 cm compared to 74 cm in controls and produced about twice as many buds. Green matter production was not increased in Pelargonium roseum and O. gratissimum but essential oil content of O. gratissimum was 0.518 per cent compared to 0.229 per cent in controls.

2.7 Seasonal variation

From very early times itself seasonal variation of the active principles in essential oil bearing plants was recorded. Variation in concentration of active principles may be to a considerable extent, due to climatic conditions of the area from which the materials are collected (Chakravarthi, 1970).

Greysnyh (1956) showed O. gratissimum to be a short-day plant and raising seedlings under short day conditions (15 days) in frames, covered from 4 p.m. to 8 p.m. was found to hasten early development and increased the yield of green matter and seed. Ghosh and Chatterjee (1975) reported that Palmarosa possessed the characteristics of long day plants and reported promotive effects of light on biogenesis of essential oil formation. Long day conditions was accompanied by increased foliar growth and accumulation of dry matter. Investigations of Pareek et al (1980) from experiments conducted during 1978 and 1979 crop years in Delhi conditions indicated that O. sanctum could be grown as a short duration (115 days) kharif crop. Selyan et al. (1982) reported that in Clocimum long days and high temperature were favourable for plant growth and higher oil production. Investigations of Putiefsky (1983) on influence of temperature and day length on growth and germination of Ocimum basilicum and Origanum vulgare indicated that only temperature had a positive influence on plant height. He also observed that fresh yield was significantly influenced by day length and temperature in all the three harvests of both the species.

Bradu *et al*. (1977) reported that ratio of linalool to linalyl acetate in oil of *Mentha citrata* was somewhat affected by maturity of the plant, the time of harvest and environmental and seasonal variations. Investigations by Adams (1979) on diurnal variations in terpenoids of *Juniperus scopularum* revealed that there were significant differences in the samples taken during winter and summer. Dey and Choudhari (1980) determined the total essential oil and eugenol content of *O. sanctum* in different months starting from October to March. They found that the total oil content was lowest in the month of October, which gradually increased and reached a peak in December (0.679 per cent) and declining thereafter. A similar trend in eugenol content was observed as that of total oil. According to Fleisher (1981) in *Ocimum basilicum* at the same phenological stage, the content of essential oil in the plant increase towards autumn. Kurian *et al*. (1984) were of opinion that the high yield obtained for Clocimum during October was due to favourable season prevailed, which resulted in increased plant height and number of branches.

Investigations of Hotin (1968) revealed that atmospheric temperature had the greatest effect on essential oil accumulation. He observed that in Menthol mint and

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East Indian basil leaves and clary sage and Lavander inflorescences, a rise in temperature to 23-25°C increased the essential oil content but reduced the menthol content of mint essential oil. Sinha and Jaa (1984) reported that both spread of germination and its percentages in O. canum, O. sanctum and O. basilicum were very much related to the characteristics of temperature between the range employed and scarification.

2.8 Growth characters

Sobti et al. (1978a) observed that O. gratissimum, O. viride and O.suave had heights of 240, 178 and 125 cm and leaf blade sizes of 9.8 x 4.4, 8.7 x 4.42 and 3.97 x 3.11 cm respectively. According to Pareek et al. (1980) O.sanctum had a mean height of 66.6 cm and 78.1 cm at 50 per cent flowering stage and early seeding stage respectively. They also found out the mean number of branches as 24.1 and 24.3 respectively. Balyan (1981) suggested a quick and non-destructive formula, L x W x 0.612 for finding out the leaf area of Mentha and Ocimum. Accordingly the calculated leaf area of Clocimum was 18.781 cm^2. Kurian et al. (1984) recorded the plant height and total number of branches of Clocimum during first, second and third

harvest periods. According to them, Clocimum had 17.5, 18.6 and 16.7 branches during the three harvest seasons respectively and the corresponding heights were 82 cm, 119.4 cm and 94.7 cm

2.9 Relationship between growth parameters and economic yield

Leaves are the principal organs of production of photosynthates and hence, higher the leaf area, more is the interception of light, leading to higher net canopy photosynthesis and higher dry matter production (Nichiporovich, 1954). He opined that, to obtain high yields, leaves must photosynthesise as much as possible and eventually transfer material to economically important parts of the plant. But increase in leaf area beyond optimum, only resulted in a decreased net assimulation rate due to self shading. He was of the opinion that leaf area variation is mainly responsible for the yield variation in plants. Watson (1952, 1956) suggested that variation in yield due to varietal, fertilizer and seasonal effects manifested mainly through variation in leaf area. The yield depended on the size, efficiency and duration of photosynthetic system. He concluded that leaf area contributed more to biological yield. In other words, the leaf surfece which intercepts solar radiation was more important than photosynthetic efficiency per unit area.

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Thorne (1971) observed that growth and yield of crops were frequently correlated with leaf area index. Yoshida (1972) concluded that leaf area index and photosynthetic rate appeared to be the major determinants of crop growth rate and total dry matter production in rice. Nath and Bharadwaj (1975) observed that total dry matter production is positively correlated with leaf area, leaf area duration and photosynthetic efficiency. Emphasising the importance of leaf area, Watson and French (1962) opined that varieties differed from one another in leaf area production and in net assimulation rate. Muramoto et al. (1965) observed that differences in the rate of leaf area development were associated with dry matter production in cotton. Heath and Gregory (1938) found that dry matter production could be determined by leaf area and net assimulation rate and hence, the variation in dry matter production was mainly attributable to variation in leaf area among the genotypes.

Stern and Donald (1961) reported that crop growth rate was influenced by leaf area index, dry matter production increased with increase in leaf area index.

Loomis and Williams (1963) were of the opinion that leaf photosynthetic rate was a powerful factor in determining

crop growth rate. The total dry matter production of crop community was influenced by crop growth rate which in turn was affected by leaf area index, leaf photosynthetic rate and leaf angle. Wallace and Munnger (1965) noted in bean varieties that high leaf area and leaf area ratio lead to higher yields. Kalpan and Koller (1977) observed that leaf area growth rate was positively correlated with plant growth rate in soyabean.

2.10 Harvesting and yield

According to Pravdoljubova (1958) in Jubilee basil the maximum total green mass and oil yield per plant was reached during seed ripening, when bracts in the lower half of the central inflorescence were turning brown. Investigations conducted by Sobti *et al.* (1978a) at experimental and medicinal garden of Regional Research Laboratory, Jammu, on *O. gratissimum*, *O. suave* and *O. viride* indicated that harvesting time was 10-15 days after flowering and the herbage yields per plant in one cutting was 575, 450 and 495 g respectively. Studies by Sobti *et al.* (1979) revealed that transplanted crops of RRL-07, *O. sanctum*, *O. gratissimum* (strain No.1), *O. gratissimum* (strain No.2) and *O. gratissimum* (improved strain by polycross technique)

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produced herbage yields of 77.5, 42.5, 39.75, 60 and 74 tonnes per ha and oil yields of 57.5, 37.5, 50.25, 62.5 and 98.75 kg per ha respectively. Pareek *et al*. (1980) reported that yields of herbage and oil were highest in *O. sanctum* when the crop was harvested between the early (age 100 days) and late seeding (age 115 days) stages of growth, whereas the eugenol content was highest at late seeding stage. He also suggested a harvesting height of 15 cm above ground level. Fleisher (1981) studied the essential oils from two varieties of *O. basilicum* in Israel and found that the oil content increased as the plant developed and reached its maximum in the full bloom stage. Trivedi *et al*. (1981) observed that, of the fourteen selections of *Ocimum* species tried at Indore station of All India Co-ordinated Improvement Project for Medicinal and Aromatic Plants, the following gave best herbage and oil yields, *O. gratissimum* EC 111091 (1025 g per plant; 63.47 l/ha) and *O. citriodorum* EC 110586 (753 per plant; 57.99 l/ha).

According to Bulyan *et al*. (1982) in Clocimum, oil content as well as eugenol content were maximum at flower initiation and seed setting stages and the content went down at full flowering stages. They were of opinion that

in the first year 2-3 harvests could be taken and thereafter four harvests (May, July, September and December). A harvesting height of 15-20 cm above ground level was recommended in the first year, 20-30 cm in the second year and 35-45 cm in the third year. They reported a total herb yield of 554 g/ha and oil yield of 166.2 kg/ha for Clocimum at a spacing of 40 x 40 cm. Investigations of Pareek et al. (1982) showed that the crop O. sanctum should be harvested at full bloom period (90 days) when it possessed optimum oil and maximum eugenol in oil. They found out that the increase in the herbage yield was in the ratio 1:7 between vegetative (12.9 g/ha) and seed maturity stages (91.01 g/ha). The oil yields between vegetative and seed maturity stages were 22.96 and 56.76 l per ha and eugenol yields were 11.23 and 20.5 l per ha respectively. The harvesting height recommended was 10-15 cm over ground level. Sobti and Pushpangadan (1982) reported a fresh herb yield of 40 tonnes/ha and oil yield of 160 kg/ha for improved strain of O. gratissimum (RR1-08). They observed that a crop of ocimum sown in February could be harvested by the middle of April, July and middle or end of September and suggested a cutting height of 20-25 cm above ground level. Asthana and Gupta (1984) reported

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that optimum oil and eugenol yields were observed in O. sanctum when the foliage was handpicked at 50 per cent flowering stage compared to pre-flowering and complete flowering stages. Choudhari and Bordoloi (1984) observed maximum pooled yield (two years) of herb (84.48 tonnes/ha) and oil yield of (44.28 kg/ha) in O. gratissimum under a spacing of 45 x 45 cm. Kurian et al. (1984) reported that Clocimum crop under Odakkali conditions could give herbage yields of 1.3, 7.3 and 3.2 tonnes per ha and oil yields of 9.1, 40.5 and 15.9 kg per ha respectively in the first, second and third harvests. They observed full flowering stage to be the optimum time of harvesting. Sethi (1985) reported that full bloom stage (90 days) is the best stage for harvesting O.sanctum and at that time it contained maximum eugenol in oil. According to Choudhari and Bordoloi (1986) four cuttings could be taken in O.gratissimum and among this the second cutting yielded maximum oil. They also observed that O. gratissimum produced highest pooled (two years) yields of herb (71.1 tonnes/ha) and oil (387.2 kg/ha) when sown in May followed by April (69.1 tonnes/ha and 376.1 kg/ha). Choudhari et al. (1986) reported maximum herb yields of 35.88 and 40.05 tonnes per ha and oil yields of 190.7 and 268.9 kg per ha in the first and

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second year respectively for O. gratissimum under doses of N_{200} P_{100} K_{100} kg/ha. They also observed a positive correlation (r values 0.99) between herb and oil yield, where regression equation was found to be Y = 5.28 x - 1.72.

2.11 Oil and eugenol content

Nadkarni and Patwardhan (1952) observed that the seed of O. sanctum yielded 17.62 per cent fatty oil with good drying properties. Pravdoljubova (1958) reported that the highest oil yield from Jubilee basil (0.91 per cent) was obtained when the seed started to ripen in the lower whorls of the central inflorescence. According to CSIR reports, the leaves of O. sanctum on steam distillation yielded a bright yellow oil possessing pleasant odour characteristic of the plant with appreciable note of cloves (Anon., 1966). It was also noted that O. sanctum grown in Ghazipur (Krishna Tulasi) possessed 45-76 per cent phenols, Sri Tulasi yielded 50-76 per cent phenols and another sample of O.sanctum from Allahabad contained 71 per cent eugenol in oil. Guenther (1974) observed that the leaves of O.sanctum on steam distillation yielded 0.7 per cent essential oil having strong odour of cloves. Vaidya (1977) reported that O. sanctum yielded an oil with herbal spicy odour containing

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65-70 per cent eugenol and stressed the importance of cultivation of this plant. Investigations of Sobti *et al.* (1977) on *O. viride* indicated that young shoots in both flowering and post flowering plants gave high oil yield of 0.68 per cent (FWB) and 0.85 per cent (FWB) respectively. Lal *et al.* (1978) observed that water distillation of *O. sanctum* yielded 0.7 per cent oil and eugenol content by Gas Liquid Chromatography (GLC) was 70.5 per cent by weight. Sobti *et al.* (1978a) employed hydro-distillation method for extraction of oil from *O. gratissimum*, *O. suave* and *O. viride* and the oil yields in percentage were 1.8-2.0, 1.8-2.3 and 0.3-0.7 respectively. They also found out the major constituents of essential oils using GLC and Thin Layer Chromatography (TLC). Accordingly *O. gratissimum* contained 70 per cent eugenol, *O. viride* contained 78 per cent thymol and *O. suave* possessed 44.7 per cent sesquiterpene alcohols. Choudhari (1979) extracted the essential oil of *O. sanctum* by hydro-distillation and reported that maximum oil content on dry weight basis (DWB) was in the leaves (1.3 per cent) followed by inflorescence (0.45 per cent). He also observed that defloration caused considerable decreases in oil content. According to Sobti *et al.* (1979) the oil contents in RRL-07 (New species

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synthesised) O. sanctum, O. gratissimum (strain No.1), O. gratissimum (strain No.2) and O. gratissimum (improved strain by polycross technique) ranged from 0.06-0.1, 0.07-0.1, 0.12-0.15, 0.17-0.25 and 0.35-0.5 per cent respectively on fresh whole herb basis. Dey and Choudhari (1980) employed TLC method for determining eugenol content in essential oil of O.sanctum. They were of opinion that the result of colorimetric method was sufficiently reproducible and it can be used for routine work for eugenol estimation. Investigations of Pareek et al. (1980) showed that the average oil content on fresh weight basis in the whole herb (at maturity) of O.sanctum was 1.4 per cent, stem-1.7 per cent, leaves-2.15 per cent, inflorescence 0.38 per cent and seed-0.263 per cent. It was also noted that young growing leaves borne at the top of branches possessed less oil content than full grown mature leaves. A maximum eugenol content of 52.2 per cent in oil was also reported during the late seeding stage. Sobti et al.(1980) observed that the two parental strains of Clocimum, namely O. gratissimum (Race No.1). O. gratissimum (Race No.2) and Clocimum yielded 0.15, 0.08 and 0.5 per cent essential oil respectively. They used the techniques of TLC and GLC to identify and estimate various major chemical constituents

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of essential oil and found that Race No.1, Race No.2 and Clocimum contained 45-85, 50-80 and 70-80 per cent eugenol in the essential oil respectively.

Balyan et al. (1982) were of opinion that the harvesting of Clocimum should be done without including the woody stem portion which contain only negligible oil, almost all oil is stored in the leaves. They also observed that distillation of oil should be carried out within 6-8 hours of harvest, further delay caused considerable loss in yield and quality of oil. Chatterjee et al. (1982) identified eugenol and linalool of O. sanctum and O.basilicum oils respectively using TLC, GLC and IR spectrometry and found that these two compounds possessed nematicidal activity. Dey and Choudhari (1982) characterised leaves of different ages of O.sanctum such as young, premature, mature and senescing on the basis of level of chlorophyll and protein and activity of catalase and the changes in essential oil and its major components. It was observed that the free phenol and essential oil content decreased but polyphenol oxidase and peroxidase increased with leaf age. Pareek et al. (1982a) conducted experiments in O. sanctum during 1980 and 1981 crop seasons and using hydro-distillation method, the fresh herbage was distilled.

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They found out that oil content in the herbage was maximum at vegetative stage (1.73 per cent, DWB) because of the predominance of leaves over stem part in the produce. A constant decline in oil content from 41 per cent at seed maturity stage over vegetative stage was observed with increase in age of the crop and suggested that it might be due to the shedding of lower leaves and leaf senescence at maturity causing decline in oil content of the foliage and gain in weight of stem in the produce at maturity. The eugenol content estimated using gas chromatography (GC) at full bloom stage was 53.5 per cent. Puri (1982) reported that a strain of O. gratissimum namely Clocimum contained 65 per cent eugenol. According to Dey and Choudhari (1983), of the three major components of O.sanctum oil, eugenol and methyl eugenol decreased with progress of leaf age but caryophyllene increased. Nair and Kurian (1983) reported that the oil of Clocimum contained 70 per cent eugenol. According to Dey and Choudhari (1984a) hydro-distillation method of Von-Rechenberg could be used to determine essential oil content in O. sanctum and they found out that the leaf contained highest percentage of essential oil (0.97 per cent) followed by the inflorescence (0.28 per cent) and stem (0.09 per cent) and roots are devoid of essential oils.

Using GLC method of analysis, they identified ten components, of which the three major components namely eugenol, methyl eugenol and caryophyllene contributed about 85.42 per cent of total oil. Philip and Damodaran (1985) employed hydro-distillation method to extract volatile oil from different varieties of O. sanctum. They also estimated eugenol, methyl eugenol and hydrocarbons using TLC method and were of opinion that TLC method can serve as a finger print for G.C. They identified and characterised two chemotypes in the local O. sanctum population, a purple variety and a greenish variety both containing methyl eugenol and a green coloured variety containing eugenol as the predominent constituent of the oils.

Materials and Methods

MATERIALS AND METHODS

The present investigations on the evaluation of Ocimum lines for herbage yield, oil content and eugenol were carried out at College of Horticulture, Vellanikkara during 1985-'86.

3.1 Materials

Twenty five Ocimum lines collected from different geographical regions were used for the study (Table 1). The experiment was laid out in simple lattice design with four replications.

The soil at the experimental site is sandy loam with moderate fertility and good drainage. The meterological data during the cropping season are presented (Fig.6, Appendix I).

Methods

3.2 Preparation of nursery

Seeds of Ocimum lines were tested for their viability and those having more than 70 per cent germination were used for the experiment. Nursery beds of 0.5 m width,

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Table 1. Characteristics of different Ocimum lines

	Lines	Source	Colour of leaf
1	Clocimum	U.A.S., Bangalore	Green
2	Ocimum sanctium	Mannuthy, Trichur	Purple
3	Ocimum sanctum	Vellanikkara, Trichur	Greenish purple
4	Ocimum sanctum	Vithura, Trivandrum	Green
5	Ocimum gratissimum	Pala, Kottayam	Green
6	Ocimum sanctum	Puthur, Trichur	Greenish purple
7	Ocimum sanctum	Kattakkada, Trivendrum	Greenish purple
8	Ocimum sanctum	Ottappalam, Palghat	Greenish purple
9	Ocimum sanctum	Kolazhy, Trichur	Green
10	Ocimum gratissimum	Pala, Kottayam	Green
11	Ocimum sanctum	Cherpu, Trichur	Purple
12	Ocimum sanctum	Neyyardam, Trivendrum	Purple
13	Ocimum sanctum	Nellankara, Trichur	Purple
14	Ocimum sanctum	Vellanikkara, Trichur	Green
15	Ocimum gratissimum	Vellanikkara, Trichur	Green
16	Ocimum sanctum	Nettissery, Trichur	Purple
17	Ocimum sanctum	Perumbavoor, Ernakulam	Greenish purple
18	Ocimum sanctum	Thiruvambadi, Trichur	Green
19	Ocimum gratissimum	CIMAP, Lucknow	Green
20	Ocimum gratissimum	UAS, Bangalore	Green
21	Ocimum sanctum	Ollukkara, Trichur	Purple
22	Ocimum sanctum	Viyyur, Trichur	Greenish purple
23	Ocimum sanctum	CIMAP, Lucknow	Light green
24	Ocimum sanctum	Viyyur, Trichur	Green
25	Ocimum gratissimum	U.A.S., Bangalore	Green

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0.1 m height and 2 m length were taken and well manured with well rotten cattle manure. Since seeds are tiny, they were mixed with equal quantity of sand and sown uniformly on nursery beds. After sowing the seeds, a mixture of cattle manure and soil was thinly spread over the seeds and irrigated with a rose can. BHC-10 per cent was also sprinkled around nursery beds to prevent the attack of ants and termites. The beds were irrigated twice daily.

The seeds of Ocimum gratissimum and Clocimum germinated within 8-12 days of sowing, while both purple and green types of Ocimum sanctum took 10-14 days for germination.

3.3 Experimental plots

3.3.1 Preparation of land

The land was well prepared with three ploughings so as to obtain a medium fine tilth. Cattle manure was applied before the third ploughing. Plots of 2 m x 2 m size were prepared and in each plot four furrows were taken at a distance of 0.5 m in between them.

3.3.2 Application of manures and fertilizers

Cattle manure at a rate of 10 tonnes/ha was incorporated into the soil before the third ploughing.

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The fertilizer dose of 80:80:30 kg/ha was also followed. Half nitrogen, full quantity of phosphorus and potash were applied as basal dose in the form of urea, superphosphate and muriate of potash respectively. Remaining half portion of nitrogen was applied after one month of planting.

3.3.3 Transplanting

The seedlings were transplanted to the mainfield at 4-6 leaf stage during the month of January. The spacing between plants within a furrow was 0.5 m, accommodating 16 plants in a plot. Temporary shades were provided to protect the young seedlings from direct sunlight till they established in the field. Gap filling was carried out within seven days of transplanting.

3.3.4 After cultivation operations

The plants were irrigated daily for 15 days till they were established and afterwards they were irrigated at an interval of four days according to the requirement. Weeding was carried out three times. During rainy season earthing up was done, as a result of which the furrows were turned up into ridges to avoid water stagnation. No serious pest or disease was observed except for a mild attack of

white grub which was effectively controlled by incorporating BHC-10 per cent.

3.3.5 Harvesting

Three harvests were made in an year when the plants flowered uniformly. First harvest was taken during the second week of April, second during the last week of July and final during the second week of November. The crop was cut at a height of 20 cm above ground level and the field was irrigated thoroughly for the rejuvenation of plants.

Observations recorded

3.4 Growth parameters

From the centre of each plot, five plants were marked out for taking morphological observations, after leaving border plants. Five other plants in the plot were utilized for taking observations on yield at each harvest and for recording data on essential oil yield.

Observations on growth characters namely height, spread and number of branches of a plant were taken at monthly intervals from January 1986 to November 1986.

3.4.1 Plant height

Height of the plant from ground level to the tip of the longest branch was measured (cm).

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3.4.2 Spread of plants

Maximum horizontal extention of branches in the north-south and east-west directions were measured and multiplied to get actual spread of the plant (cm^2).

3.4.3 Height at first branching

Height of the plant from ground level to the branching point was measured (cm).

3.4.4 Total number of branches

The total number of branches in the observation plants were counted and expressed in numbers.

3.4.5 Number of days to blooming

Number of days taken for first blooming after transplanting and number of days taken for blooming after first and second harvests were recorded.

3.4.6 Intervals of flushing

Number of days taken for flushing after each harvest was recorded.

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3.4.7 Leaf area

From each Ocimum line 10 leaves were selected and using the relationship between length and width and mean area of leaf a correction factor was worked out using the formulae $\frac{EA}{LXW}$

Where

EA is the area of leaf from graph

L is the maximum length of leaf

W is the maximum width of leaf.

Then leaf area was calculated by multiplying the maximum length and width of leaves with the correction factor.

3.5 Yield parameters at each harvest

3.5.1 Herbage yield per plant

The herbage yield from five plants in each plot was recorded and the average herbage yield per plant on fresh weight basis was calculated. Dry weight of the herbage was also estimated after drying the herbage to constant weight in an oven at 80°C.

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3.5.2 Herbage yield per hectare

From the average herbage yield per plant, the herbage yield per hectare was calculated on fresh as well as dry weight basis.

3.6 Chemical analysis

3.6.1 Essential oil content

The essential oil content was estimated by extracting the herbage in clevenger trap apparatus after each harvest. Since the density of oil is less than water, the trap specified for lighter oils (than water) was used. One hundred grams of the chopped plant material was taken in a one litre flask and 500 ml water was added. This was heated and the oil was collected for 2½ hours and expressed in percentage.

3.6.2 Oil yield per hectare

The yield of oil per hectare was calculated by multiplying the yield of fresh herbage per hectare, with the percentage recovery of oil.

3.6.3 Eugenol content and eugenol yield per hectare

The percentage of eugenol in the oil was estimated

by thin layer chromatography (TLC) technique using Folin-ciocalteu reagent (Dey and Choudhari, 1980). Thin layers of 0.25 cm thickness were made on TLC plates using silica gel. These were dried in chromatographic oven at 110°C for 30 minutes. After cooling the plates to room temperature, oil was spotted on this layer using a microsyringe. The chromatographic plates were then kept inside a chamber saturated with benzene. When benzene had ascended to the desired height, the plates were taken out and dried in room temperature for 15 minutes. It was again dried in a chromatographic oven at 110°C for 15 minutes and kept outside at room temperature for 10 minutes. Then chromatographic plates were kept inside a chamber saturated with iodine vapours for developing spots.

The spots were scraped off and eugenol was eluted from them in 3 ml of 80 per cent ethanol. The colorimetric estimation of eugenol is based on principle of reaction of phenolic compounds with alkaline Folin-ciocalteu reagent. From the supernatant alcoholic extract, 0.5 ml portion of elute was transferred to a clean test tube and 3 ml of 35 per cent aqueous sodium carbonate and 1 ml of Folin-ciocalteu reagent (1:10 with distilled water) were added. After 15 minutes, the intensity of colour was measured at 660 nm in spectronic-20. Eugenol being a

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phenolic compound gave a blue colour with Folin-ciocalteu reagent and the intensity of colour was found to be directly proportional with concentration of eugenol.

Eugenol yield per hectare was calculated by multiplying eugenol percentage with oil yield per hectare.

3.7 Selection of better types based on colour, aroma and flavour

The Ocimum lines were scored for leaf colour and aroma using the following scores.

Leaf colour	Scores	Leaf aroma	Scores
Green	1	Highly aromatic	1
Light green	2	Moderately aromatic	2
Greenish purple	3	Slightly aromatic	3
Purple	4		

3.8 Statistical analysis

The data collected on yield and quality attributes were analysed in a microcomputer using standard statistical methods specified for simple lattice design (Panse and Sukhatme, 1985) and the superior lines were compared.

Results

RESULTS

The results of the different aspects of investigations are presented under the following sections. The analysis of variance tables for the different characters are appended (Appendices II to XII).

4.1 Growth parameters

4.1.1 Plant height

The data pertaining to the plant height are presented in Table 1, which was taken at monthly intervals from January 1986 to November 1986 and the analysis of variance, in Appendix II.

The data on plant height revealed that generally the height of the plant increased progressively from January to November. In June, July and August the relative increases in height for all lines were greater compared to other months.

It may be seen that during January the plant height varied from 10.94 cm to 38.41 cm. The six different lines which recorded maximum heights during this month include lines 8, 2, 3, 9, 5 and 13 and Line 8 differed

Table 1. Plant height of Ocimum lines (cm) from January 1986 to November 1986

Ocimum lines	January	February	March	April	May	June	July	August	September	October	November
1	15.59	43.76	44.92	49.24	56.65	86.33	121.06	143.85	149.39	151.33	165.91
2	31.29	43.87	46.04	49.27	58.41	72.88	91.22	101.05	106.56	122.67	130.31
3	30.42	37.55	47.83	50.55	67.69	75.84	99.47	102.75	116.54	120.83	126.35
4	26.75	40.94	43.75	45.00	50.97	56.69	77.02	88.28	93.78	97.50	103.18
5	27.55	48.27	49.49	50.45	58.80	68.80	101.78	127.96	137.12	139.73	162.29
6	26.21	42.89	47.79	52.14	60.17	67.34	90.84	106.39	114.01	117.58	130.90
7	10.94	31.45	35.58	46.34	51.72	64.49	84.58	89.12	107.11	110.90	121.62
8	38.41	47.86	49.43	53.65	67.15	74.66	94.34	103.60	110.98	119.87	128.08
9	28.66	37.19	40.69	41.39	47.20	58.89	76.34	87.22	95.25	99.88	104.12
10	19.93	42.86	52.12	59.63	60.27	72.88	110.30	136.76	138.46	153.78	169.36
11	21.93	35.01	42.73	47.11	51.76	61.45	88.39	95.24	109.29	112.67	128.71
12	15.51	31.02	39.01	40.89	54.83	61.77	83.34	95.34	102.17	119.67	138.43
13	27.33	38.54	41.58	43.81	59.22	64.88	88.78	101.04	104.34	115.38	131.70
14	24.45	35.62	38.18	38.94	45.82	57.99	74.76	83.67	92.55	96.38	103.85
15	13.41	31.78	42.81	39.87	45.07	77.28	102.86	120.30	135.93	139.00	158.96
16	26.52	38.91	41.54	48.20	55.58	65.79	86.35	95.46	104.95	113.87	130.59
17	26.22	39.33	41.71	46.03	51.92	65.18	80.12	93.64	104.28	115.87	131.31
18	25.05	38.96	39.93	41.11	43.75	53.26	74.40	79.92	85.80	99.18	92.15
19	16.81	45.06	49.92	44.88	50.03	67.88	103.90	126.12	137.04	149.00	162.19
20	13.02	30.44	42.21	44.36	49.35	69.23	94.49	120.19	131.92	141.13	158.80
21	24.35	33.63	35.52	40.63	49.33	58.63	76.28	84.03	89.68	110.00	125.39
22	25.65	42.37	42.71	43.83	58.79	66.97	89.26	99.88	105.24	127.68	139.78
23	26.30	43.52	44.24	46.90	49.75	56.47	63.38	69.84	75.75	81.55	82.27
24	26.10	37.03	38.87	39.76	42.27	56.38	68.19	76.19	98.98	110.50	94.86
25	12.66	30.82	37.41	42.03	47.04	65.23	105.18	121.32	123.86	143.25	159.29
CD 0.05	3.542	3.778	3.420	4.005	3.910	4.583	4.707	5.544	6.180	5.756	6.554

significantly from others. The height of Ocimum lines in February ranged from 30.44 to 48.27 cm. Lines 5, 8, 19, 2, 1 and 23 recorded maximum heights respectively and among these lines 5 and 8 differed significantly from others. During March the plant height differed from 35.52 to 52.12 cm. Lines 10, 19, 6, 5, 8 and 3 having maximum heights during this month did not differ significantly. In April the maximum plant height observed was 59.63 cm and minimum 38.94 cm. In this month lines 10, 8, 6, 3, 5 and 2 recorded top heights and of these line-10 differed significantly from others. During the month of May the maximum and minimum heights observed were 67.69 cm and 42.27 cm respectively. Lines 3, 8, 10, 6, 13 and 5 showed maximum heights and among these lines 3 and 8 differed significantly from other four lines. The plant height during June ranged from 53.26 to 86.23 cm. The six different lines which recorded maximum heights were lines 1, 15, 3, 8, 2 and 10 of these line-1 differed significantly from others. While in July the plant height ranged from 63.38 to 121.06 cm. Lines 1, 10, 25, 19, 15 and 5 showed top heights in this month and lines 1 and 10 differed significantly from others. During August, the plant height varied from 69.84 cm to 143.85 cm. Lines 1, 10, 5, 19, 25 and 15 recorded top heights and of these

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lines 1 and 10 showed significant difference from others. In September the plant height varied from 75.75 to 149.39 cm. Lines 1, 25, 10, 5, 19 and 15 showed maximum heights and lines 1 and 25 differed significantly from the other four lines. Whereas in October the range of plant height was from 81.55 to 153.78 cm. The six different lines having maximum heights during this month were 10, 1, 19, 25, 20 and 5, of these line-10 differed significantly from others. During November the maximum height recorded was 169.36 cm and minimum 82.27 cm. Lines 10, 1, 5, 19, 25 and 15 which recorded maximum heights showed no significant difference.

4.1.2 Spread

Data on spread of 25 different Ocimum lines are presented in Table 2. The analysis of variance is given in Appendix III. In general most of the lines exhibited maximum spread during July. Among the 25 lines studied line-1 showed maximum spread.

In January the spread differed from 64 cm^2 to 565 cm^2. Lines 3, 10, 1, 18, 5 and 17 showed maximum spread during this month and line-3 differed significantly from others. In February the minimum and maximum spreads

Table 2. Spread of Ocimum lines (cm^2) from January 1986 to November 1986

Ocimum lines	January	February	March	April	May	June	July	August	September	October	November
1	492.00	1069.00	1562.21	2067.25	2576.02	4548.75	6363.97	13038.00	8493.54	7384.25	8070.50
2	337.25	1990.25	2483.03	2848.50	5890.00	7077.95	7354.59	5030.00	5959.75	6840.75	6817.50
3	656.00	1997.75	2701.67	2856.25	4674.80	5513.45	6829.24	4397.25	6809.19	5679.00	5797.90
4	129.75	1439.50	2060.96	2318.50	4042.24	5844.06	6035.96	4018.50	7056.91	6437.50	6098.75
5	379.75	1358.00	1812.89	2192.50	4541.27	6579.42	5654.51	7264.75	6443.65	6390.00	6933.25
6	233.75	1130.75	1962.99	2389.25	4870.01	7118.07	7452.66	5245.25	6492.22	6853.00	6532.25
7	64.00	348.25	1549.06	2839.00	3134.74	4560.03	5051.04	4364.25	6777.19	6620.00	5062.00
8	237.75	2457.75	3056.95	4578.00	4958.54	6573.28	6753.68	3961.25	6999.87	5266.00	5655.50
9	331.00	1331.00	1795.50	3918.00	4499.98	4814.88	5388.40	4104.25	5598.84	5653.25	5084.50
10	518.00	2556.00	4104.42	4743.00	5011.26	8550.00	8617.20	5844.25	8301.33	8326.00	8628.00
11	244.00	847.25	1006.33	3638.00	5412.01	6350.67	7275.51	7450.00	7463.02	7484.75	5768.50
12	67.00	408.00	1297.90	1837.75	4549.00	5258.13	5372.63	4206.25	4508.49	5249.00	4841.50
13	330.50	1434.00	2186.79	2572.25	4068.05	4595.37	6312.03	5853.00	6631.17	6574.25	7445.50
14	190.75	1216.25	1547.58	1775.25	3192.24	4847.23	5835.75	4266.50	5585.14	5959.00	5428.50
15	236.50	551.25	1063.26	1722.50	2899.27	5323.85	6171.05	5482.00	6241.63	7058.25	9001.00
16	258.25	1053.25	2784.13	3458.25	4023.00	5514.40	6476.88	5840.25	6920.10	6993.75	6655.00
17	379.25	1946.25	2749.70	2841.25	3873.74	4656.36	6993.16	4699.25	7234.81	6684.25	6985.00
18	483.75	1881.50	2026.84	2229.25	3075.29	3764.35	4749.80	4134.50	5865.25	7552.50	4928.25
19	369.50	1460.00	2353.64	2428.25	3850.25	7570.21	7577.27	7047.25	8051.47	9917.00	7843.00
20	203.75	612.25	1538.06	2628.25	4040.76	7344.08	6546.82	7856.25	6935.46	8655.00	7755.75
21	263.75	1408.00	2369.38	2606.00	3359.96	5346.71	5669.91	6528.00	7075.78	7601.00	7777.25
22	167.00	1697.75	2534.20	2879.00	5037.45	6445.42	6544.79	4720.00	6369.99	7032.50	5655.25
23	184.25	1143.00	1746.84	2075 25	2750.25	3666.42	3906.68	2952.50	2996.43	2949.00	3351.50
24	184.25	922.00	1515.63	1837.75	2555.44	4752.78	5126.65	3776.25	5306.65	5807.50	4994.00
25	206.50	1076.50	1428.56	2245.00	4894.72	7204.89	6919.45	9860.00	8603.89	9751.00	8756.50
CD = 0.05	30.291	89.399	56.480	223.848	145.753	164.646	52.027	45.018	51.632	51.528	318.946

observed were 348.25 cm^2 and 2556.00 cm^2 respectively. Lines 10, 8, 3, 2, 17 and 16 showed maximum spread and of these 10 and 8 differed significantly from others. The range of spread in March was between 1006.33 cm^2 and 4104.42 cm^2. Line 10 differed significantly from the other five lines 8, 16, 17, 3 and 22, which recorded maximum spread during this month. In April the spread of different Ocimum lines veried from 1722.50 cm^2 to 4743.00 cm^2. Lines 10, 8, 9, 11, 16 and 22 showed maximum values for spread and lines 9 and 22 differed significantly from others. Whereas in May the maximum and minimum values of spread were 5890.00 cm^2 and 2555.44 cm^2 respectively. Lines 2, 11, 22, 10, 8 and 25 which had maximum spread during this month showed no significant difference. During the month of June almost all lines showed a substantial increase in spread and ranged from 3666.42 cm^2 to 8550.00 cm^2. No significant difference was observed among the lines 10, 19, 20, 25, 6 and 2 which recorded maximum spreads. During July most of the lines attained maximum spread values and minimum and maximum spreads recorded were 3906.60 cm^2 and 8617.20 cm^2 respectively. Lines such as 10, 19, 6, 2, 11 and 17 recorded top spread values and line 10 differed significantly. During August barring lines 1, 5, 11, 20, 21 and 25 all others showed a decline in spread and range of variation was from

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2952.50 cm^2 to 13,038.00 cm^2. All the different lines which recorded maximum spreads like 1, 25, 20, 11, 5 and 19 differed significantly. In September the spread varied from 2949.00 cm^2 to 8603.89 cm^2. Lines 25, 1, 10, 19, 11 and 17 which had maximum spread values in this month did not differ significantly. In October the maximum spread was 9917.00 cm^2 and minimum 2949.00 cm^2. Different lines having maximum spread values were 19, 25, 20, 10,21 and 18. No significant difference was observed between lines 21 and 18, while all others differed significantly. During November, the minimum and maximum values of spread recorded were 3351.50 cm^2 and 9001.00 cm^2 respectively. Lines 15, 25, 10, 1, 19 and 21 exhibited maximum spreads. No significant difference was observed among lines 15, 25 and 10 as well as among lines 1, 19 and 21.

4.1.3 Height at first branching

Data on height at first branching of 25 different lines are presented in Table 3. The analysis of variance is given in Appendix IV. Minimum branching height recorded was 7.26 cm (line-1) and maximum 22.74 cm (line-6). In general the Ocimum gratissimum and Clocimum lines had a tendency to branch at lower heights. This is visible from

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Table 3. Height at first branching of *Ocimum* lines (cm)

Ocimum lines	Height (cm) at first branching
1	7.26
2	17.82
3	17.16
4	14.96
5	9.51
6	22.74
7	19.77
8	19.95
9	10.45
10	10.61
11	21.58
12	19.71
13	18.25
14	15.80
15	12.67
16	18.78
17	20.16
18	13.93
19	9.07
20	15.03
21	18.37
22	15.44
23	14.13
24	11.15
25	10.83
CD = 0.05	2.729

the Table. Only exception to this is line 20 which branched comparatively at a higher height of 15.03 cm.

4.1.4 Number of branches per plant

Data presented in Table 4 represent the total number of branches per plant from January to November. The analysis of variance is presented in Appendix V. An increase in number of branches per plant was observed from January onwards which reached maximum value in July.

During January, the number of branches varied from 2 to 12.75. Lines which possessed maximum number of branches during this month were 9, 11, 8, 14, 3 and 21 and they were on par. It may be seen that during February the branch number varied from 6.30 to 25.50. Lines 9, 3, 23, 10, 13 and 17 having maximum number branches did not differ significantly. During March maximum and minimum branches observed were 55.62 and 10.83 respectively. Line-8 differed significantly from other lines like 3, 9 10, 14 and 16 which had maximum number of branches during this month. In April number of branches per plant differed from 19.07 to 170.81. Lines 3, 8, 2, 9, 23 and 10 had maximum branches during this month and lines 3 and 8 differed significantly from others. While in May, maximum and minimum number of

Table 4. Number of branches of Ocimum lines from January 1986 to November 1986

Ocimum lines	January	February	March	April	May	June	July	August	September	October	November
1	4.14	8.54	21.75	26.67	64.05	178.05	331.39	186.72	175.00	132.89	133.13
2	6.19	20.00	39.20	71.06	118.48	198.73	431.60	283.78	240.00	221.74	205.25
3	9.50	23.80	47.10	170.81	334.70	486.70	538.31	437.60	331.58	220.77	215.50
4	3.25	13.94	30.50	48.27	60.60	224.55	365.88	192.40	246.55	256.07	175.88
5	4.04	11.50	24.85	54.13	77.15	122.15	283.72	173.50	118.20	120.91	170.69
6	5.16	14.29	27.25	50.11	84.72	132.80	344.22	259.67	236.43	183.15	202.68
7	2.15	6.68	10.83	19.07	33.35	117.65	305.20	194.22	153.10	160.15	134.33
8	10.35	18.73	55.62	95.19	186.08	323.60	396.47	242.23	279.10	216.41	200.25
9	12.75	25.50	44.15	66.17	174.75	311.10	535.25	331.80	291.75	202.18	204.38
10	8.35	20.35	43.85	64.12	95.80	185.40	259.48	359.00	280.33	131.90	151.63
11	11.25	18.30	29.00	45.45	72.35	171.05	382.28	213.09	183.15	130.64	166.33
12	2.00	9.50	19.70	33.01	69.35	164.25	211.45	151.70	179.32	117.51	100.25
13	8.47	20.20	35.40	62.23	107.30	225.18	374.10	151.90	110.23	120.06	180.33
14	9.75	18.50	43.50	52.20	138.40	318.48	350.38	236.10	204.13	183.01	179.50
15	3.59	6.30	16.90	21.81	37.50	106.80	218.00	189.14	147.33	96.71	144.68
16	6.28	13.58	42.13	47.38	74.65	135.40	248.16	187.88	217.10	203.48	210.83
17	6.30	20.15	35.60	65.49	78.93	194.45	339.35	196.16	184.90	167.65	200.38
18	6.70	12.60	26.45	54.99	105.05	257.60	489.48	284.34	250.32	288.18	280.33
19	6.90	11.05	22.45	32.58	65.80	136.25	257.78	177.20	227.98	187.93	254.38
20	5.75	12.65	28.15	39.89	71.00	133.13	323.67	158.35	133.93	152.50	133.88
21	8.90	9.68	26.55	38.79	73.28	194.00	322.19	178.69	248.33	122.64	170.63
22	4.21	13.40	23.55	33.00	53.05	165.10	299.18	237.63	183.88	107.34	120.50
23	6.80	20.90	33.20	65.92	85.95	156.25	239.76	186.09	154.08	150.89	72.00
24	8.35	15.56	26.13	35.54	83.05	185.30	289.28	196.70	148.10	134.52	190.50
25	4.18	10.80	17.60	25.00	64.05	181.15	232.24	197.82	162.33	159.88	180.68
CD = 0.05	2.549	3.431	4.722	5.975	6.487	10.236	10.079	9.295	7.658	7.853	10.204

branches produced by the plants were 334.70 and 33.35 respectively. Significant difference was observed among all the six lines which produced maximum number of branches (lines 3, 8, 9, 14, 2 and 13). In June there was a considerable increase in branch number and the maximum and minimum values recorded were 486.70 and 106.80 respectively. Lines 3, 8, 14, 9, 18 and 13 had maximum number of branches during this month and lines 3, 18 and 13 differed significantly. All the 25 lines produced maximum number of branches during July and maximum and minimum values recorded were 538.31 and 211.45 respectively. Maximum number of branches were produced by lines 3, 9, 18, 2, 8 and 11 and of these lines 2 and 18 differed significantly. From August onwards number of branches started declining and the range during this month was from 151.7 to 437.6. Lines 3, 10, 9, 18, 2 and 6 had maximum number of branches during this month and except 18 and 2 all others showed significant difference. While in September maximum number of branches produced was 331.00 and minimum 110.23. Among those lines which had top branch numbers lines 3 and 9 differed significantly from others like 10, 8, 18 and 21. In October maximum and minimum values recorded for branch number were 288.18 and 96.71 respectively. Lines 18, 4, 2, 3, 8 and 16 produced maximum branches during this month and of these lines

18 and 4 showed significant difference. In November branch number varied from 72.00 to 280.33. The six different lines having maximum number of branches during this month were 18, 19, 3, 16, 2 and 9. Of these lines 18 and 19 differed significantly.

4.1.5 Number of days to blooming

The data on number of days to blooming after transplanting and after first and second harvest are presented in Table 5 and analysis of variance in Appendix VI.

All the Ocimum lines required more number days for flowering after transplanting than after first or second harvest. The days taken by the Ocimum lines for flowering after the first and second harvest were almost on par. It may be seen that the number of days to blooming after transplanting varied from 68.41 to 116.52 days. The lines which flowered quickly were 22, 24, 23, 6, 21 and 18 and they were on par. The days taken for flowering after first harvest varied from 62.2 to 102.2. No significant difference was observed among the six different lines which flowered quickly after first harvest like lines 4, 9, 21, 6, 11 and 18. The number of days taken for blooming after second harvest

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Table 5. Number of days taken for blooming after transplanting first and second harvest by *Ocimum* lines

Ocimum lines	Number of days taken for blooming		
	After transplanting	After first harvest	After second harvest
1	116.52	89.25	88.67
2	90.45	76.98	76.25
3	92.01	76.58	76.10
4	81.16	72.55	72.30
5	112.54	88.30	86.30
6	77.30	69.83	68.23
7	88.27	79.93	78.88
8	92.96	88.35	87.88
9	82.41	71.80	70.55
10	114.67	99.15	98.15
11	78.79	68.80	67.70
12	89.24	80.63	80.58
13	96.71	89.05	90.17
14	94.98	90.70	88.22
15	101.34	96.15	96.73
16	79.10	72.95	73.65
17	91.35	88.22	88.87
18	68.41	66.20	67.98
19	95.27	89.10	90.95
20	101.20	94.33	92.82
21	75.29	71.10	71.38
22	78.59	72.75	70.05
23	77.80	75.78	76.10
24	77.91	73.08	78.38
25	108.51	102.20	102.35
CD = 0.05	5.349	4.404	3.743

ranged from 67.7 to 102.35. Lines 21, 9, 22, 6, 18 and 11 flowered easily after second harvest and did not differ significantly.

4.1.6 Intervals of flushing

Data presented in Table 6 represent the intervals of flushing in different Ocimum lines after each harvest. The analysis of variance is given in Appendix VII.

Generally most of the lines flushed quickly after the second harvest. The flushing interval after the first harvest ranged from 8.50 to 13.10 days. Lines 5, 8, 10, 24, 21 and 25 took minimum number of days for flushing after first harvest and were almost on par. While, after second cutting the flushing interval ranged from 8.23 to 10.52 days. Six different lines which flushed quickly after the second harvest were 5, 11, 20, 25, 15 and 5 and of these line 22 differed significantly. The interval of flushing after third harvest ranged from 8.54 to 12.30 days. Lines 20, 25, 5, 10, 15 and 1 flushed quickly after third harvest and except lines 20 and 25 all others differed significantly.

4.1.7 Leaf area

The leaf area corresponding to 25 different Ocimum lines and the correction factors worked out for these lines

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Table 6. Intervals of flushing of Ocimum lines after each harvest (days)

Ocimum lines	Intervals of flushing (days)		
	After first harvest	After second harvest	After third harvest
1	9.03	8.86	8.54
2	11.35	9.63	10.02
3	9.25	9.69	10.00
4	13.10	9.60	10.16
5	8.80	8.23	9.05
6	9.10	9.73	9.72
7	9.80	9.14	9.57
8	8.80	10.41	10.18
9	11.15	10.17	10.78
10	8.80	8.80	8.83
11	10.50	8.52	9.40
12	10.72	9.38	9.99
13	9.30	10.10	10.15
14	11.15	10.41	10.76
15	8.53	8.34	8.70
16	9.60	9.80	9.97
17	9.05	9.57	9.62
18	10.80	8.99	9.58
19	9.10	8.84	9.23
20	8.93	8.43	9.13
21	8.68	9.78	9.85
22	10.92	8.69	10.14
23	8.50	10.46	12.30
24	8.80	10.52	10.46
25	8.60	8.40	9.11
CD @ 0.05	0.971	0.774	0.446

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Table 7. Leaf area (cm^2) of *Ocimum* lines

Ocimum lines	Leaf Area	Correction factor
1	24.75	0.58
2	5.67	0.76
3	7.03	0.76
4	4.75	0.72
5	27.22	0.60
6	5.89	0.70
7	4.64	0.75
8	5.88	0.74
9	4.34	0.72
10	21.85	0.55
11	5.66	0.73
12	5.69	0.77
13	4.59	0.75
14	5.35	0.74
15	16.91	0.57
16	4.63	0.76
17	4.86	0.77
18	5.17	0.67
19	36.37	0.65
20	13.16	0.58
21	4.62	0.75
22	5.63	0.79
23	5.13	0.75
24	3.89	0.75
25	20.40	0.58

are presented in Table 7. The table shows that line 19 (36.37 cm^2) exhibited maximum leaf area, followed by lines 5 (27.72 cm^2), 1 (24, 75 cm^2), 10 (21.85 cm^2), 25 (20.40 cm^2), 15 (16.91 cm^2), and 20 (13.16 cm^2). All the other lines had leaf areas in the range of 3-6 cm^2. The correction factors for O. gratissimum were between 0.55 to 0.67, on the other hand the correction factors for O. sanctum were in the range of 0.7 to 0.8.

4.2 Yield parameters at each harvest

4.2.1 Herbage yield per plant

Data on the herbage yield of 25 different Ocimum lines are furnished in Table 8. Analysis of variance is given in Appendix VIII.

Total herbage yield from a plant in an year varied from 231.15 g (57.45 g/plant, Dry Weight Basis - DWB) to 1494.11 g on fresh weight basis (362 g/plant, DWB). Second cutting contributed more towards yearly plant yield followed by the third and first cuttings. The herbage yield produced from a plant varied from 12.30 g (4.14 g/plant, DWB) to 119.25 g (42.03 g/plant, DWB) on fresh weight basis, during first harvest, lines 1, 8, 3, 10, 19 and 6 produced

Table 8. Herbage yield per plant of Ocimum lines (g)

Ocimum lines	Herbage yield (g/plant)									
	First harvest		Second harvest		Third harvest		Mean		Total yield per plant per year	
	FWB	DWB	FWB	DWB	FWB	DWB	FWB	DWB	FWB	DWB
1	119.25	42.03	977.99	193.05	386.87	126.92	494.70	120.67	1484.11	362.00
2	37.08	13.91	427.54	88.56	76.02	26.41	180.57	42.96	541.70	128.88
3	96.30	36.15	449.53	103.78	77.08	27.12	207.64	55.68	622.91	167.05
4	24.62	8.29	233.25	53.50	59.90	18.26	105.92	26.68	317.77	80.05
5	44.90	17.06	643.59	143.96	473.02	128.89	387.17	96.64	1161.51	269.91
6	71.07	25.03	380.36	94.26	121.98	42.46	191.14	53.92	573.41	161.75
7	12.50	4.41	288.42	64.16	54.82	18.94	118.58	29.17	355.74	87.51
8	99.40	33.67	375.16	83.06	82.38	28.06	185.65	48.26	556.94	144.79
9	38.50	13.69	392.88	83.32	46.40	14.57	159.26	37.19	477.78	111.58
10	90.80	36.36	558.46	144.20	346.03	107.03	331.76	95.90	995.29	287.69
11	25.50	9.43	258.16	69.03	56.15	17.43	113.27	31.96	339.81	95.89
12	12.30	4.14	256.71	57.16	61.13	22.03	110.05	27.78	330.14	83.33
13	31.60	10.85	354.96	69.51	57.64	19.97	148.07	33.44	444.20	100.32
14	27.15	10.81	287.42	63.32	27.03	8.55	113.87	27.56	341.60	82.68
15	31.50	11.39	518.26	114.39	300.45	86.12	283.40	70.61	850.21	211.90
16	33.75	11.14	248.39	62.79	59.35	19.54	113.83	31.16	341.49	93.47
17	27.65	10.55	252.94	53.48	76.95	28.59	119.18	30.87	357.54	92.62
18	38.75	14.83	279.68	68.82	51.41	19.34	123.28	34.33	369.84	102.99
19	71.80	25.99	718.15	182.42	319.88	96.72	369.94	101.72	1109.83	305.17
20	52.15	18.22	674.49	143.19	264.50	77.73	330.38	79.71	991.14	239.14
21	19.00	6.23	177.39	41.30	34.76	9.92	77.05	19.15	231.15	57.45
22	28.00	10.61	199.94	43.69	41.56	15.07	89.83	23.12	269.50	69.37
23	19.75	7.62	244.18	69.75	14.24	4.85	100.94	27.41	302.82	82.22
24	24.65	9.46	373.65	85.16	34.84	11.11	144.38	35.24	433.14	105.73
25	42.88	14.74	721.49	146.64	220.21	68.63	328.19	76.67	984.58	230.01
CD = 0.05	8.091	3.405	41.547	12.946	14.734	4.150				

Plate II. Clocimum: Ready for first harvest

Plate III. Ocimum gratissimum: Ready for first harvest

Plate IV. Ocimum sanctum (purple): Ready for first harvest

Plate V. Ocimum sanctum (green): Ready for first harvest.

Plate VI. Clocimum: Reflushing after second harvest

Plate VII. Ocimum gratissimum: Reflushing after second harvest.

Plate VIII. Ocimum sanctum (purple): Reflushing after second harvest.

Plate IX. Ocimum sanctum (green): Reflushing after second harvest.

Enlargement size: 3

Plate X. Clocimum: Ready for third harvest

Plate XII. Ocimum sanctum (purple): Ready for third harvest.

Enlargement size : 3
Photograph size : 12x8

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maximum herbage yields during this harvest and of these line 1 differed significantly. During second harvest, the fresh herbage yield varied from 177.39 g (41.30 g/plant, DWB) to 977.99 g (193.05 g/plant, DWB). Lines 1, 25, 19, 20, 5 and 10 had maximum yields during this period and among these lines 1 and 10 differed significantly. The maximum and minimum fresh herbage yields recorded during the third harvest period were 473.02 g (128.89 g/plant, DWB) and 14.24 g/plant (4.85 g/plant, DWB) respectively. During this time lines 1, 5, 10, 15, 19 and 20 recorded maximum herbage yields per plant and all these differed significantly.

4.2.2 Herbage yield per hectare

Data on the herbage yield on fresh and dry weight basis from the three different harvests of Ocimum lines are presented in Table 9 and analysis of variance is given in Appendix IX.

Total yield of herbage in a year ranged from 9.25 (2.3 tonnes/ha, DWB) to 59.36 tonnes per ha on fresh weight basis (14.37 tonnes/ha, DWB). A perusal of data indicated that maximum herbage yield was contributed by the second harvest followed by the third and first harvest. In all the three harvests line-1 produced high herbage yields.

Table 9. Herbage yield per hectare of Ocimum lines (tonnes)

Ocimum lines	Herbage yield (tonns/ha)							
	First harvest		Second harvest		Third harvest		Total yield per hectare per year	
	FWB	DWB	FWB	DWB	FWB	DWB	FWB	DWB
1	4.77	1.57	39.12	7.72	15.47	5.08	59.36	14.37
2	1.48	0.55	17.10	3.64	3.04	1.06	21.62	5.15
3	3.85	1.44	17.98	4.16	3.08	1.09	24.91	6.69
4	0.99	0.32	9.33	2.14	2.40	0.78	12.72	3.24
5	1.80	0.67	25.74	5.76	18.92	5.17	46.46	11.60
6	2.84	1.00	15.21	3.77	4.88	1.70	22.93	6.47
7	0.50	0.17	11.54	2.57	2.19	0.76	14.23	3.50
8	3.98	1.35	15.01	3.32	3.30	1.11	22.29	5.78
9	1.54	0.55	15.72	3.33	1.86	0.58	19.12	4.46
10	3.63	1.45	22.34	5.77	13.84	4.29	39.81	11.51
11	1.02	0.39	10.33	2.76	2.25	0.70	13.60	3.85
12	0.49	0.17	10.27	2.28	2.45	0.88	13.21	3.33
13	1.26	0.44	14.20	2.78	2.30	0.80	17.76	4.02
14	1.09	0.44	11.50	2.53	1.08	0.34	13.67	3.31
15	1.26	0.46	20.73	4.58	12.02	3.45	34.01	8.49
16	1.35	0.45	9.94	2.51	2.37	0.78	13.66	3.74
17	1.09	0.42	10.12	2.14	3.09	1.14	14.30	3.70
18	1.53	0.59	11.19	2.75	2.06	0.77	13.25	4.11
19	2.87	1.01	28.73	7.30	12.79	3.86	44.39	12.17
20	2.10	0.72	26.99	5.73	10.58	3.11	39.66	9.56
21	0.76	0.26	7.10	1.65	1.39	0.39	9.25	2.30
22	1.12	0.42	8.00	1.75	1.66	0.61	10.78	2.78
23	0.79	0.31	9.77	2.79	0.57	0.20	11.13	3.33
24	0.98	0.38	14.95	3.39	1.39	0.44	17.32	4.21
25	1.71	0.59	28.86	5.87	8.81	2.74	39.38	9.20
CD = 0.05	0.320	0.148	1.662	0.518	0.589	0.167		

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During the first harvest, fresh herbage yield varied from 0.49 (0.17 tonnes/ha, DWB) to 4.77 tonnes per ha (1.57 tonnes/ha, DWB). No significant difference was observed among those lines which recorded maximum herbage yields during this period like 1, 8, 3, 10, 19 and 6. While in second harvest the maximum and minimum fresh herbage yields recorded were 39.12 tonnes/ha (7.72 tonnes/ha, DWB) and 7.10 tonnes/ha (1.65 tonnes/ha, DWB) respectively. Lines 1, 25, 19, 20, 5 and 10 showed top yields during this harvest and except lines 25 and 19 all others showed significant difference. During third harvest the fresh herbage yield varied from 0.57 (0.20 tonnes/ha, DWB) to 18.92 tonnes per ha (5.17 tonnes/ha, DWB). All the six different lines like 5, 1, 10, 19, 15 and 20 which produced maximum herbage yields during this harvest differed significantly.

4.3 Chemical analysis

4.3.1 Oil content

The oil content of Ocimum lines are presented in Table 10 and analysis of variance is given in Appendix X.

The oil content in Ocimum lines differed significantly in all the three harvests and in general,

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Table 10. Oil content in different Ocimum lines as influenced by harvests (per cent)

Ocimum lines	Oil content (per cent)							
	First harvest		Second harvest		Third harvest		Mean	
	FWB	DWB	FWB	DWB	FWB	DWB	FWB	DWB
1	0.85	2.45	1.18	5.98	2.15	6.52	1.39	5.45
2	0.55	0.83	0.43	2.10	0.75	2.17	0.57	1.70
3	0.40	1.05	0.40	1.85	0.68	1.95	0.49	1.62
4	0.40	1.20	0.48	2.18	0.73	2.38	0.54	1.92
5	0.50	1.35	0.83	3.55	1.30	4.76	0.88	3.22
6	0.40	1.13	0.52	1.98	0.77	2.24	0.56	1.78
7	0.37	1.08	0.47	2.23	0.70	2.07	0.65	1.79
8	0.40	1.18	0.35	1.63	0.62	1.87	0.46	1.56
9	0.37	1.05	0.33	1.52	0.70	2.30	0.47	1.62
10	0.60	1.45	1.00	3.82	1.13	3.55	0.91	2.94
11	0.45	1.08	0.55	1.98	0.70	2.27	0.57	1.78
12	0.27	0.83	0.45	1.98	0.80	2.22	0.51	1.68
13	0.43	1.20	0.50	2.50	0.82	2.37	0.58	2.02
14	0.43	1.05	0.60	2.73	0.80	2.53	0.58	2.10
15	0.60	1.67	0.82	3.55	1.15	3.95	0.86	3.06
16	0.40	1.23	0.48	1.90	0.80	2.50	0.56	1.88
17	0.38	1.00	0.40	1.90	0.80	2.17	0.53	1.80
18	0.45	1.30	0.55	2.23	0.60	1.60	0.53	1.71
19	0.58	1.63	0.70	2.75	1.20	4.01	0.83	2.80
20	0.65	1.95	0.70	3.35	1.23	4.11	0.86	3.14
21	0.40	1.23	0.50	2.10	0.70	2.62	0.53	1.98
22	0.43	1.15	0.45	2.05	0.80	2.20	0.56	1.80
23	1.05	2.65	1.00	3.55	2.00	5.82	1.35	4.01
24	0.45	1.15	0.47	2.32	0.80	2.51	0.57	1.99
25	0.60	1.73	0.70	3.43	1.30	4.06	0.87	3.07
CD = 0.05	0.105	0.174	0.055	0.181	0.047	0.172		

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the range was between 0.46 per cent to 1.39 per cent on fresh weight basis. Maximum oil content was recorded by the third harvest followed by the second and first harvests. Maximum percentage of oil was recorded in lines 1 and 23 in all the three harvests. During first harvest the oil content on fresh weight basis ranged from 0.27 per cent (0.83 per cent, DWB) to 1.05 per cent (2.65 per cent, DWB) Lines 23, 1, 20, 10, 15 and 25 showed maximum oil contents during this harvest and among these lines 23 and 1 differed significantly. The range of variation in oil recovery during second harvest was from 0.33 per cent on fresh weight basis (1.52 per cent DWB) to 1.18 per cent (5.98 per cent,DWB). Lines, 1, 23, 10, 5, 15 and 19 showed maximum oil contents during this harvest period and lines 1, 5 and 15 differed significantly. While in third harvest the range of oil content was from 0.6 per cent (1.6 per cent, DWB) to 2.15 per cent on fresh weight basis (6.52 per cent, DWB). Lines 1, 23, 5, 25, 20 and 19 recorded maximum oil contents and except lines 5 and 25 all other lines differed significantly.

4.3.2 Oil yield per hectare

Data relating to the oil yield from different lines during each harvest are presented in Table 11 and

Table 11. Oil yield of Ocimum lines from different harvests (l/ha)

Ocimum lines	Oil yield (l/ha)				
	First harvest	Second harvest	Third harvest	Mean	Total yield/ ha/year
1	40.16	461.64	332.54	278.11	834.34
2	4.86	73.18	22.82	33.62	100.86
3	15.41	73.81	20.90	36.71	110.12
4	3.94	46.15	17.36	22.48	67.45
5	8.99	214.52	184.97	136.16	408.48
6	11.37	78.90	37.66	42.64	127.93
7	1.72	54.05	15.24	23.67	71.01
8	15.90	52.30	20.52	29.73	88.72
9	5.73	50.93	12.88	23.18	69.54
10	21.80	222.20	156.00	133.33	400.00
11	4.54	54.82	15.64	25.03	75.10
12	1.32	44.48	19.46	21.75	65.26
13	5.30	70.18	18.92	31.47	94.40
14	4.56	68.64	8.54	27.25	81.74
15	7.56	168.96	138.22	104.91	314.74
16	5.40	45.96	18.72	23.36	70.08
17	4.00	39.96	24.42	22.79	68.38
18	6.79	61.54	12.20	26.84	80.53
19	16.45	202.68	153.12	124.08	372.25
20	13.68	188.48	129.36	110.51	331.52
21	3.04	34.60	9.71	15.78	47.35
22	4.74	35.36	13.26	18.45	53.36
23	7.98	98.00	11.50	39.13	117.38
24	4.35	70.71	11.12	28.73	86.18
25	10.29	201.18	115.18	108.88	326.65
CD = 0.05	1.430	9.595	34.270		

analysis of variance in Appendix XI. The total oil yield per hectare in an year varied from 47.35 to 834.34 l. Maximum contribution was made by the second harvest towards total yield of oil. In all the three harvests maximum quantity of oil was contributed by line-1.

During first harvest it may be seen that the oil yield ranged from 1.32 to 40.16 l per ha. Lines, 1, 10, 19, 8, 3 and 20 produced maximum oil yields and of these lines 1, 10 and 20 differed significantly. While in second harvest period the oil yield ranged from 34.6 to 461.64 l per ha. During this period lines 1, 10, 15, 19, 25 and 20 showed maximum oil yields and of these lines 1 and 20 differed significantly. The maximum and minimum oil yields during third harvest period were 332.54 and 8.54 l per ha respectively. Line 1 differed significantly from all other lines which topped in oil yields like lines 5, 10, 19, 15 and 20.

4.3.3 Eugenol content and eugenol yield per hectare

Data relating to the eugenol content of Ocimum lines are presented in Table 12. Line-1 possessed maximum eugenol in the essential oil (71.82 per cent) followed by lines 13 (59.05 per cent), 9 (52.82 per cent), 15 (48.65 per cent), 18 (46.11 per cent) and 17 (45.34 per cent).

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Table 12. Eugenol content (per cent) and eugenol yield (l/ha) of Ocimum lines

Ocimum lines	Eugenol content (per cent)	Average eugenol yield l/ha/harvest	Total eugenol yield l/ha/year
1	71.82	199.74	599.22
2	22.40	7.53	22.59
3	40.16	14.74	44.22
4	37.83	8.51	25.52
5	34.55	47.04	141.13
6	34.38	14.66	43.98
7	11.73	2.78	8.33
8	33.78	9.99	29.97
9	52.82	12.24	36.73
10	18.25	24.33	73.00
11	15.13	3.79	11.36
12	12.42	2.70	8.11
13	59.05	18.58	55.74
14	7.95	2.16	6.50
15	48.65	51.04	153.12
16	37.35	8.73	26.18
17	45.34	10.33	31.00
18	46.11	12.38	37.13
19	38.27	47.49	142.46
20	38.90	42.99	128.96
21	7.61	1.20	3.60
22	13.11	2.33	6.99
23	15.86	6.21	18.62
24	6.85	2.00	5.90
25	17.59	19.15	57.46

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Minimum percentage of eugenol was observed in line-24.

It may be seen that the eugenol yield in an year varied from 3.6 to 599.22 l per ha. Maximum eugenol was produced by line 1 (599.22 l/ha) followed by lines 15, 19, 5 and 20 which produced 153.12, 142.46, 141.13 and 128.96 l per ha eugenol respectively.

4.4 Selection of better types based on leaf colour, aroma and flavour

The 25 different Ocimum lines were scored based on their leaf colour and aroma with respect to eugenol content. The results are presented in Table 13.

The scoring on leaf colour and aroma showed that lines 1, 4, 5, 9, 15, 18, 19 and 20 possessed green coloured leaves with high aroma. On the other hand, line 23 had highly aromatic light green coloured leaves and lines 3 and 17 possessed greenish purple leaves with high aroma. Line-13 which was purple pigmented possessed maximum eugenol among the O. sanctum lines. With respect to the eugenol content and leaf colour, aroma and flavour line 1 is most superior followed by lines 13 and 9. The purple leaf colour was found to be inferior compared to the green, light green or greenish purple colour.

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Table 13. Scoring of Ocimum lines based on leaf colour aroma and flavour

Ocimum lines	Leaf colour	Leaf aroma	Eugenol content (per cent)
1	1	1	71.82
2	4	2	22.40
3	3	1	40.16
4	1	1	37.83
5	1	1	34.55
6	3	2	34.38
7	3	3	11.73
8	3	2	33.78
9	1	1	52.82
10	1	2	18.25
11	4	3	15.13
12	4	3	12.42
13	4	1	59.05
14	1	3	7.95
15	1	1	48.65
16	4	2	37.35
17	3	1	45.34
18	1	1	46.11
19	1	1	38.27
20	1	1	38.90
21	4	3	7.61
22	3	3	13.11
23	2	1	15.86
24	1	3	6.85
25	1	2	17.59

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4.5 Correlation studies

Correlation between growth parameters like height of plant, spread of plant, number of branches per plant, number of days to blooming and leaf area of plant and yield parameter like oil content on one hand and the yield of fresh herbage per plant during the second harvest period on the other hand were worked out. The correlation coefficients for different characters are furnished in Table 14.

The oil content and leaf area of plant showed highly significant correlation with yield of the plant during second harvest. No significant correlations were observed between the characters such as spread of plant, number of branches per plant, number of days to blooming and yield of the plant during second harvest, while the height of the plant showed a non-significant negative correlation with yield of the plant during second harvest.

4.6 Economics of cultivation

Economics of cultivation and the net profit of Clocimum and O. sanctum (line-6) and O. gratissimum (line-5) which produced maximum oil yields per hectare were computed (Table 15, Appendix-XII). The price of oil was taken as

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Table 14. Correlation coefficients for different variables

Y	x	Correlation coefficients (r)
Yield of fresh herbage per plant (second harvest)	Height of plant	-0.0594^{NS}
"	Spread of plant	+0.1226^{NS}
"	Number of branches per plant	+0.0216^{NS}
"	Number of days for flowering	+0.1555^{NS}
"	● Leaf area of plant	+0.8368**
"	Oil content(%)	+0.6033**

n = 100 df = 98

● Correlation coefficient for leaf area worked out taking 25 observations,

n = 25 df = 23

NS Not significant

** Significant at one per cent level

Table 15. Economics of Ocimum cultivation and distillation of oil from one hectare

Items	Clocimum	O.gratissimum (line-5)	O.sanctum (line-6)
1. Oil yield (lit)	834	408	128
2. Income @ Rs.100/lit cost of oil	83,400/=	40,800/=	12,800/=
3. Expenditure for harvesting and distillation (Rs.)	14,495/=	13,865/=	12,691.50
4. Net profit/loss	65,935/=	25,005/=	10,850/=

Rs. 100/= per litre (Balyen et al., 1982) for the calculation of the net profit. It was seen that a net profit of Rs. 65,935/= and Rs.25,005/= could be obtained from Clocimum and O. gratissimum (line-5) crops, respectively. The O.sanctum (line-6) crop gave a net profit of only Rs.108.50.

Discussion

DISCUSSION

The genus Ocimum is one of the important aromatic herbaceous plants of the family Labiatae. Many of the species are grown in the homesteads and are also seen wild in the different agroclimatic zones of the country of which Ocimum sanctum, O. gratissimum and O. basilicum need special reference. O. basilicum has been exploited as a rich source of eugenol in countries like France. O. sanctum is considered to be very sacred from the religious point of view by the Hindus from time immemorial. The leaves and inflorescence are used in the worship of God. Its cultivation is mainly confined to the homesteads. It is part and parcel of the Hindu households. One cannot imagine a Hindu household without a thulsi plant and a Thulsithara, a specially designed place in front of a house. Here, in Kerala the purple coloured Krishna thulsi is preferred by the people than the green coloured plants. Though O. gratissimum is seen here and there, it is not much preferred as O. sanctum.

In O. sanctum though only the purple coloured and green coloured types are common if closely observed much

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variability in the leaf and inflorescence colouration, serration of leaves and leaftips etc. can be noticed. Some of them also differ in their aroma.

Eventhough much variability exists only very little work has been done to exploit this plant. The existence of geographical races and chemotypes were reported by Philip and Damodaran (1985). Some attempts were also made elsewhere to evaluate the races collected from the different parts of the country including that from Kerala (Sobti et al., 1980).

Recently works were undertaken to identify the constituents of oil in the various species of Ocimum especially O. sanctum and O. gratissimum. A rich pool of genetic variability is built up in various institutions like RRL, Jammu and various studies were undertaken which resulted in identifying types having different aroma chemicals like eugenol, isoeugenol, thymol caryophyllene etc. In many cases O. sanctum and O. gratissimum were classified as species containing high eugenol.

Eugenol is an important chemical required by the pharmaceutical industry and also by the perfumery industry. Hence attempts were made to isolate races/types which are

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rich in eugenol and which resulted in the release of a eugenol rich strain 'Clocimum' by the RRL Jammu having eugenol content of about 70 per cent. Some other studies revealed that even in O. sanctum races are available which are rich in eugenol.

A number of investigations also revealed that the oil content and eugenol are highly influenced by the season. That is, these plants exhibit seasonal variation in the above characters. Some other workers pointed out the variation in oil content in the different plant parts like stem, leaves and inflorescences. They all agree in one point that the oil content and aroma chemicals are maximum when the plants are at blooming stage than at any other stage of growth of plants. These studies also revealed that the plants can be harvested 3 or 4 times in anyear.

Some of the workers even suggested for large scale commercial cultivation of Ocimum plants as an alternate source of eugenol whose present source is clove oil. The release of the strain Clocimum and its exploitation as a commercial crop is a breakthrough in the expleitation of the Ocimum spp.

Eventhough some sporadic works have been reported, not much extensive studies were undertaken to exploit the available variability in O. sanctum or O. gratissimum under Kerala conditions.

Hence, an attempt was made to exploit available variability in O. sanctum and O. gratissimum along with the only released strain Clocimum. An extensive study was undertaken for the first time in Kerala collecting eighteen lines of O. sanctum, six lines of O. gratissimum and the only released strain Clocimum.

The prime objective of the evaluation is to identify lines having high herbage yield, oil content and eugenol. It also aimed at identifying a line having good purple colour coupled with high oil content and eugenol for the homesteads of Kerala. The other objective was to see if Clocimum can be groomed for commercial cultivation under Kerala conditions.

For the above purpose the different lines were evaluated for various characters. The main morphological characters such as plant height, spread and number of branches were studied for one year at monthly intervals. The height at first branching, time taken for initial

blooming, intervals of flushing and blooming after each harvests also were studied. Three harvests were done during one year i.e. in April, July and November. The herbage yield, the oil content and the eugenol content were estimated.

The results of these investigations are presented and their inter relationships are discussed here.

5.1 Growth parameters

5.1.1 Plant height

There was progressive increase in height from January to November for all the Ocimum lines included in the study. But the relative increase was greater during June, July and August. This was because of the congenial climatic factors such as rainfall, relative humidity and temperature and also the lines were in their prime period of growth. The positive influence of temperature on plant height was reported by Putiefsky (1985). The progressive increment in height was also reported by Pareek et al.(1980) for Ocimum sanctum. Though the height of different lines did not show any particular pattern during the early periods of growth O. gratissimum lines such as 1, 5, 10, 15, 19, 20 and 25 (158.80 - 169.36 cm) were definitely superior than O.sanctum lines (82.27 cm - 139.78 cm) in their quantum

expression of height. Thus the species difference was expressed here. Sobti et al. (1978) while evaluating O. gratissimum found that the height varied from 150 to 300 cm and the height recorded in this study was within the above range.

The present study showed that there is no correlation between plant height and herbage yield.

5.1.2 Spread

The lines included in the study did not exhibit a consistent behaviour. But in general there was progressive increase in spread with the age of the plant except towards the later periods. Maximum spread were expressed during July-August period (3906.68 - 13,038.00 cm^2). Majority of the lines showed maximum spread during July and then revived in September. While lines 1, 5, 11, 20, 21 and 25 had maximum spread during August and they also exhibited further revival signs in the later periods. The absence of definite pattern in spread can be attributed to the differences in height of initial branching and orientation of branches. The flowering and branching behaviour of the Ocimum spp. is peculiar (Fig.2, Fig.3). Early branching lines will definitely increase the further spread of the plants.

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The apparent decrease in spread expressed by certain lines may be due to the destruction of unharvested inflorescence flower heads after they dried up. The later revival tendency of the lines may be due to the reflushing and reflowering taking place. This can be further explained by the harvesting time adapted. The plants should be harvested at full boom stage and thereby the reflushing is induced and thus further spread is also increased. The maximum spread was during July-August in all the lines. And the second (major) harvesting was done at that time, which is also the prime period of growth.

The present study revealed that the influence of spread of the plants on the herbage yield is not pronounced.

5.1.3 Height at first branching

The lines having lower heights at first branching were 1, 25, 10, 9, 5 and 19 (Table 3, Fig.1, Appendix IV). That is in majority of cases the O. gratissimum lines exhibited a tendency to branch at lower heights except line 20 which had branched at a higher height of 15.03 cm. While the lowest branching line was line-1 which branched at 7.26 cm. The line-6 of O. sanctum had the highest height of branching (22.74 cm).

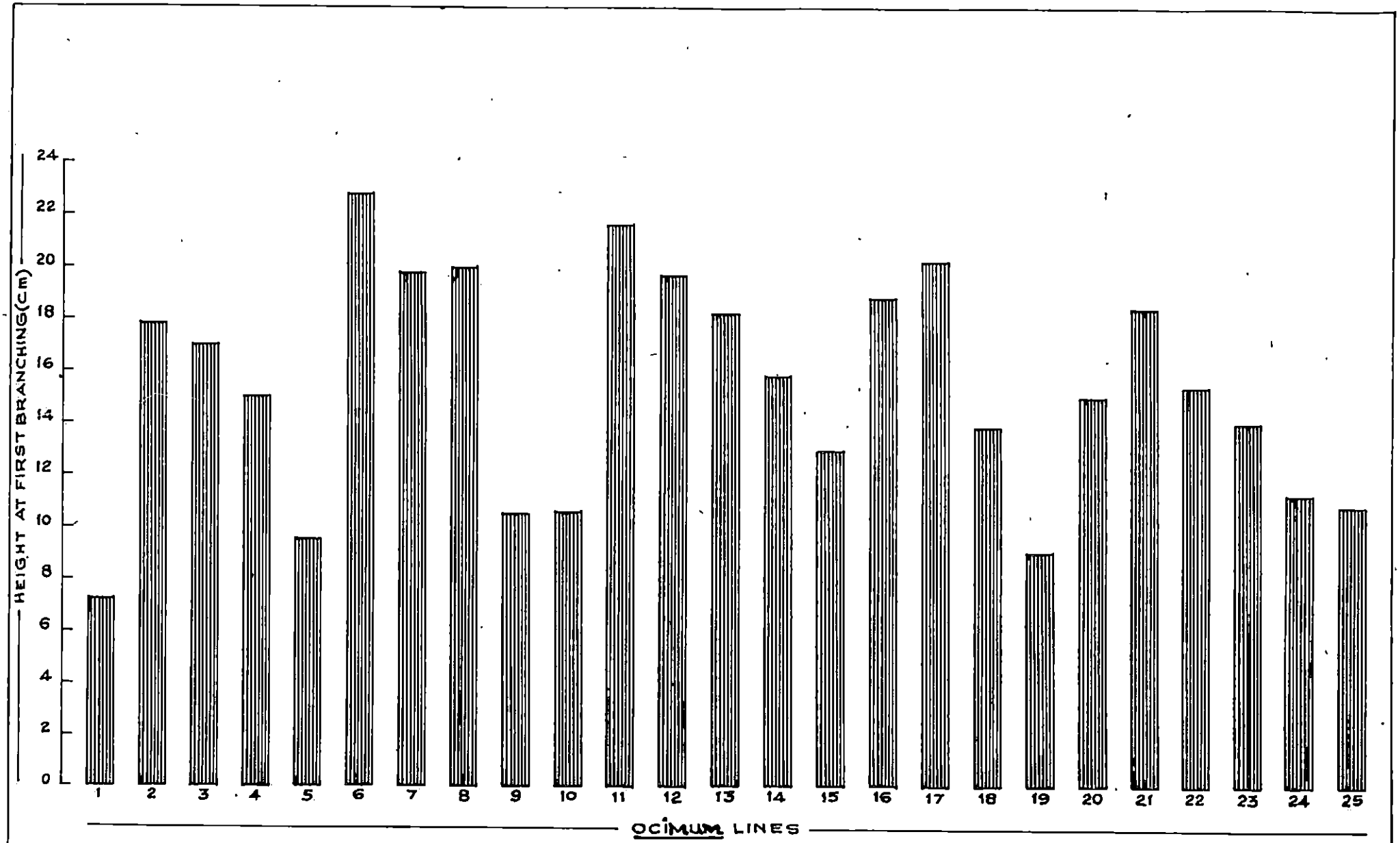

FIG. 1. HEIGHT AT FIRST BRANCHING OF OCIMUM LINES.

In this experiment the harvesting height adapted was 20 cm above ground level, so that the plants are harvested above their branching heights. Thus the harvesting induces better flushing and development of new branches inducing the spread of the plants.

Here also almost all the O. gratissimum lines branched at lower heights than the majority of the O. sanctum lines, thus the species difference is exhibited.

5.1.4 Number of branches

From January to July there was increase in the number of branches for all the 25 lines studied. There after the number of branches produced did not show any definite pattern. This may be due to the fact that withering of the flower heads and induction of flushing was not uniform. Thus for better flushing behaviour, the plants should be pruned, so that they may be stimulated for better flushing which immediately produces more branches and in turn reaches the full bloom stage (Fig.2, Fig.3). This is also the best stage of harvesting for better herbage and oil yield. This can be further related with the indefinite pattern of spreading behaviour of the various lines. Kurian et al. (1982) explained that there was progressive increase of branches with age of plants in case of Clocimum when three harvests

FIG. 2. *Ocimum sanctum*: TWIG

FIG.3. CLOCIMUM : TWIG

were undertaken. This was also supported by the mean number of branches reported by Pareek et al. (1980). He opined that plant height and number of branches had a positive effect on the total herbage yield produced. But such a relationship could not be noticed and stressed here as there is no correlation between the number of branches and herbage yield/plant.

In the present study the number of branches recorded were higher (211.45 - 538.31) than that reported by the previous workers (Pareek et al., 1980; Kurian et al., 1982). They might have recorded only the main branches whereas, here, all the branches were counted and recorded. This might be the reason for higher values in the present study.

5.1.5 Number of days to blooming

All the lines took more duration for initial flowering after transplanting. It ranged from 68.41 days for line 18 and 116.52 days for line 1. In this respect all the Ocimum gratissimum lines took more than 100 days to initial flowering after transplanting with one exception (line 19 with 95.27 days). This clearly indicated that the O. gratissimum lines are having longer vegetative growth

period and thereby indicate that they are long duration crops than the O. sanctum lines, thus expressing the species difference. The value recorded by Pareek et al. (1980) for flowering in O. sanctum was 75 days. But in the present study all the lines took more time for flowering and it may be due to the influence of congenial climatic factors which influenced the early vegetative growth thus making the vegetative phase longer.

The time taken for the blooming after the first and second harvest also followed a similar tendency explained earlier. But, here, it has to be emphasised that the number of days taken for blooming after the first harvest and second harvest were less than that required for blooming after transplanting. This may be due to the influence of age and physiological maturity of plants.

But this character is also not correlated with the herbage yield per plant.

5.1.6 Intervals of flushing

In general, intervals for flushing after harvesting is less in the case of most of the O. gratissimum (8.23 - 9.23 days) lines than most of the O. sanctum lines

(8.52 - 13.10 days). Early and quicker flushing is advantageous and express the regeneration capacity of the lines.

Here it is stressed that the O. gratissimum lines are quicker in flushing behaviour but they took longer time for blooming after each harvest than the O. sanctum lines. These two characters are interlinked to the fact that with quicker flushing (regeneration) and slower flowering the lines will get more time to be in the vegetative phase thereby the crop growth rate etc. will be more and this in turn will result in higher herbage yield. This again can be supported by the correlation studies carried out. Good relationships existed between the herbage yield and leaf area. Quicker regeneration is actually a sign of health and vigour so that it can be generalised that O. gratissimum lines had comperatively good vigour and better growth than that of O. sanctum lines. This can be attributed to the species difference. This can further be linked with the good regeneration capacity of Clocimum reported by Kurian et al. (1982).

5.1.7 Leaf area

The leaf area at the second harvesting stage was computed (Table 7, Fig.4). It is seen that the Ocimum gratissimum lines 5, 10, 15, 19, 20 and 25 and Clocimum

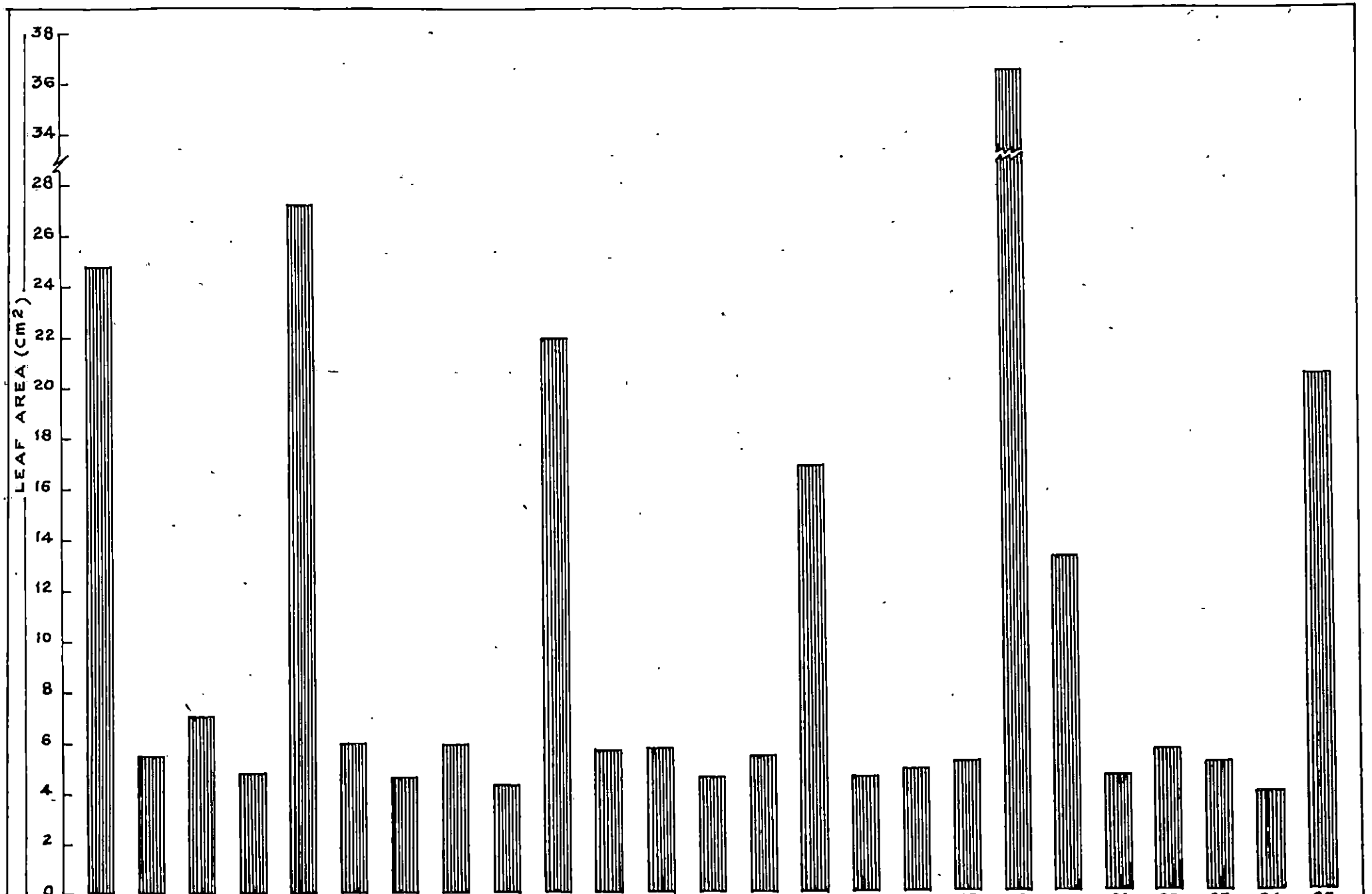

FIG. 4. LEAF AREA OF OCIMUM LINES

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have higher leaf areas as compared to O. sanctum lines. The leaf area ranged from 3.89 (line 24) to 36.37 cm^2 (line 19). Among the O. gratissimum lines leaf area range was between 13.16 (line 20) to 36.37 cm^2 (line 19). In the case of O. sanctum lines it was to the tune of 3.89 (line 24) to 7.03 cm^2 (line 3).

The leaf areas reported by the previous workers like Sobti et al. (1978) were higher than that of the present study for O. gratissimum (43.12 cm^2). Balyan (1981) reported the leaf area of Clocimum as 18.781 cm^2 and the value corresponding to Clocimum in the present study was 24.75 cm^2. For Clocimum the range reported were between 21.25 cm^2 to 134.64 cm^2, for O. gratissimum was between 28.09 cm^2 to 45.05 cm^2 and for O. sanctum (green type) was between 3.5 cm^2 to 14.85 cm^2 and for purple type it was between 6.12 cm^2 to 9.24 cm^2 (Nair, G.S.(1980) unpublished).

The size of the leaf blade is important to the fact that it has positive correlation with oil content and herbage yield (Sobti et al., 1978). The higher leaf areas also resulted in higher herbage yield in this study also. The correlation studies revealed highly significant positive correlation between these characters. The influence of

this character on herbage yield is discussed elsewhere in this chapter. Here also the O. gratissimum and Glocimum has revealed their superiority over O. sanctum lines. Thus the species difference were clearly brought out.

5.2 Yield parameters at each harvest

5.2.1 Herbage yield per plant

The herbage yield per plant in an year showed that maximum yield was recorded by line 1 with 1494.11 g followed by the O. gratissimum lines in the order of 19, 10, 25, 20, 15 and 5 (850.21 - 1161.51 g). The O. sanctum lines have lower yields (231.15 - 622.91 g). Sobti et al. (1978) got an yield of 575 g/cutting for O. gratissimum in an experiment conducted at Regional Research Laboratory, Jammu. In 1979 they reported herbage yields of 315 g, 450 g and 655 g, for O. gratissimum types from Kerala, Jammu and USA respectively. The reported value for O. sanctum type was only 125 g whereas a synthetic variety had 720 g herbage yield. Trivedi et al. (1981) reported an herbage yield of 1025 g/plant for O. gratissimum. Sobti et al. (1982) reported herbage yields of 200-800 g, 150-200 g and 150-450 g for the O. gratissimum types from Jammu, U.S.A. and Kerala respectively.

Thus it is seen that in the present study the yield reported were higher than that reported by the previous workers. This may be due to the higher number of branches and higher leaf area reported. In this character also the O. gratissimum lines showed their superiority over O. sanctum lines. The progressive increase in yield with age of the plant is expressed by Sethi (1985). As the age increases the number of branches and the leaf area increase and thereby the yield increases.

Highly significant positive correlation between herbage yield per plant and the leaf area during the peak harvesting time indicated their relationship. The higher is the leaf area the higher is the herbage yield. This relationship is discussed elsewhere in this chapter.

5.2.2 Herbage yield per hectare

The herbage yield was compared on fresh weight basis as the oil was extracted from fresh herbage. Two aspects were evaluated under this. Average herbage yield per harvest and the total herbage yield per hectare (Table 9, Fig.5).

The average yields during the three harvests revealed that second harvest recorded maximum herbage yield

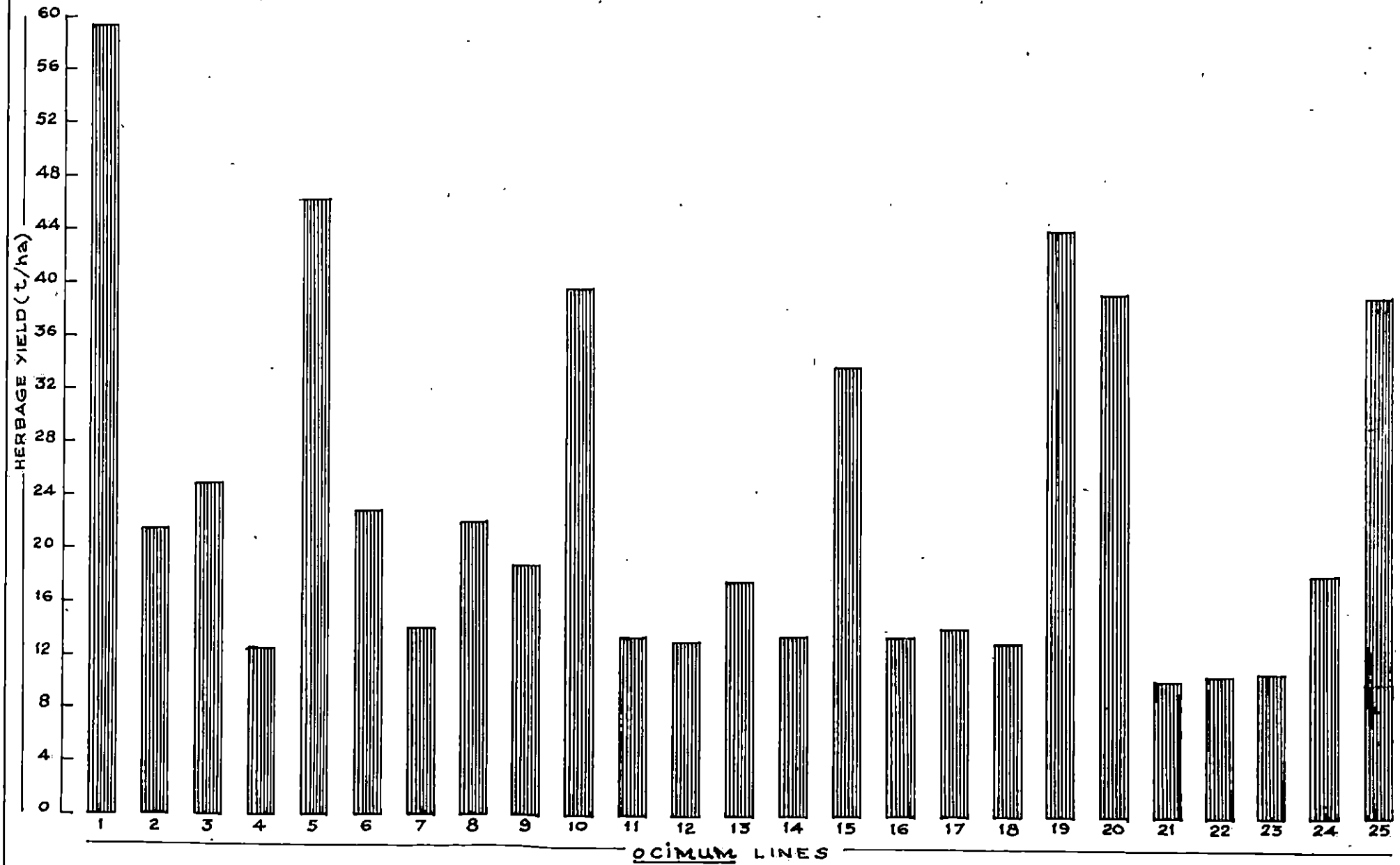

FIG.5. TOTAL HERBAGE YIELD OF OCIMUM LINES IN AN YEAR.

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followed by the third and first harvests. The three exceptions to this effect were lines 3, 8 and 23 which produced more herbage yield during the initial harvest than the third.

In general, Clocimum and other O. gratissimum lines produced higher herbage yield than the O. sanctum lines, but this was clearly evident only at the second and third harvests. The highest yielder during the main harvest (second harvest) was Clocimum and poorest was line 21 of O. sanctum.

This part of study is important to the fact that this reflects the regeneration capacity of the various lines. Here it is proved beyond doubt that the Clocimum and other O. gratissimum lines have better capacity of regeneration after harvests than the O. sanctum lines. Some of the O. sanctum lines even recorded poorer yield in the third harvest than in the initial harvest. In this connection it is seen that the line 23, from Lucknow was having the lowest yield in first and third harvests. This may be due to the aclimatisation problem. The regeneration capacity of this line may be poor.

The contribution of the second harvest was also expressed by previous workers like Choudhari and Bordoloi(1986).

Among the four cuttings taken in an year the second cutting recorded maximum yield. This may be because of the higher rate of growth at this period and higher regeneration capacity of the lines because of their prime age of growth. Kurian *et al.* (1984) recorded maximum yield of 7.3 tonnes/ha in the second harvest followed by the third with 3.2 tonnes and the least value was recorded at the first harvest with 1.3 tonnes per ha in case of Clocimum. This can be related with the leaf area. The positive relationship of leaf area can be the main reason why the lines have a higher yield during the peak period of growth.

The second factor studied here was the total yield per hectare per year. This also showed a similar tendency as that of the yield per plant. The *O. gratissimum* lines recorded the maximum yields of which Clocimum (line 1) had the highest yield (59.36 tonnes/ha/year). The *O. sanctum* lines were comparatively poor yielders (9.25 - 24.91 tonnes per ha) than *O. gratissimum* lines (34.01 - 46.46 tonnes/ha). The total yield is a function of the three harvests and as such it can also be reasoned as discussed before. Sebti *et al.* (1979) while evaluating RRL-07, *O. sanctum*, *O. gratissimum* (strain-1 and 2) and an improved strain of *O. gratissimum* found that the herbage yields were 77.5,

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42.5, 39.75, 60 and 74 tonnes per ha respectively and the herbage yield recorded in the present study was comparable to these reports. The reported yield of Clocimum by Balyan et al. (1982) (554 q/ha) was also in agreement with the results obtained. Other workers Pareek et al.(1982), Choudhari and Bordoloi (1984), Kurian et al. (1984) and Choudhari et al. (1986) reported so much variability in the yield of Ocimum spp. They also attributed various reasons for the yield potential. Progressive increase in herbage yield with age of the plants, effect of temperature and day length, inter relation between the plant density and cuttings, progressive increase in height, number of branches and improvement in the over all growth of the plant were the major reasons attributed for the yield potential.

In this study the lines which produced higher herbage yield recorded higher leaf areas also. And the major factor which is influencing the herbage yield is the leaves, tender stems and inflores ence. And thus this relationship has an important role.

In general if we examine the role of leaves in the plants the following discussion will establish its importance. Leaves are the principal organs of production

of photosynthates and hence the higher the leaf area the more is the interception of light, leading to higher net canopy photosynthesis and higher dry matter production (Nichiporovich, 1954). He opined that to obtain higher yields, leaves must photosynthesize as much as possible. But increase in leaf area beyond optimum, only resulted in decreased net assimilation rate due to self shading. He was of the opinion that leaf area variation is mainly responsible for the yield variation in plants.

Watson (1952, 1956) suggested that variation in yield due to varietal, fertilizer and seasonal effects are manifested mainly through variation in leaf area. The yield depended on size and duration of photosynthetic system. He concluded that leaf area contributed more to biological yield. In other words the leaf surface, which intercepts solar radiation was more important than photosynthetic efficiency per unit area.

Thorne (1971) observed that growth and yield of crops were frequently correlated with leaf area index. Yoshida (1972) concluded that leaf area index and photosynthetic rate appeared to be the major determinants of crop growth rate and total dry matter production in rice. Nath and Bharadwaj (1975) observed that total dry matter production

is positively correlated with leaf area, leaf area index and photosynthetic efficiency. Emphasising the importance of leaf area Watson and French (1962) opined that varieties differed from one another in leaf area production and net assimilation rate. Muramato et al. (1965) observed that differences in the rate of leaf area development were associated with dry matter production in cotton. Heath and Gregory (1938) found that dry matter production could be determined by leaf area and net assimilation rate and hence, the variation in dry matter production was mainly attributable to variation in leaf area among the genotypes.

Stern and Donald (1961) reported that crop growth rate was influenced by leaf area index; dry matter production increased with increase in leaf area index.

Loomis and Williams (1963) were of opinion that leaf photosynthetic rate was a powerful factor in determining crop growth rate. The total dry matter production of crop community was influenced by crop growth rate which in turn was affected by leaf area index, leaf photosynthetic rate and leaf angle. Wallace and Munnger (1965) noted in bean varieties that high leaf areas and leaf area ratio lead to higher yields. Kalpan and Koller (1977) observed that leaf area growth rate was positively correlated with plant growth rate in soyabean.

The above discussion clearly upholds the influence of leaf area on crop growth and dry matter production in various crops. Thus in this study also differences in leaf area may be the major factor which influenced the growth and dry matter production. But in the present study the leaves themselves were cut and removed as the herbage at a particular stage of growth i.e. full bloom stage. And so the regeneration capacity of the plants (lines) may be another factor contributing to the yield. This relationship have been pointed out in earlier paragraphs. The photosynthates and other growth inducing chemicals stored in the lower parts of the plants (lines) might have influenced the regeneration of plants. The differences in the root system may be another factor which influenced the intake of nutrients and water from the soil. This can also be supported by the favourable weather conditions prevailed during that period especially rainfall and humidity which favour vegetative growth of plants (Fig.6, Appendix-I).

In conclusion we can emphasise that all the growth contributing factors might have influenced the various lines in certain levels which in turn had influenced the higher herbage yield. These factors may be in a better combination in O. gratissimum than in O. sanctum and

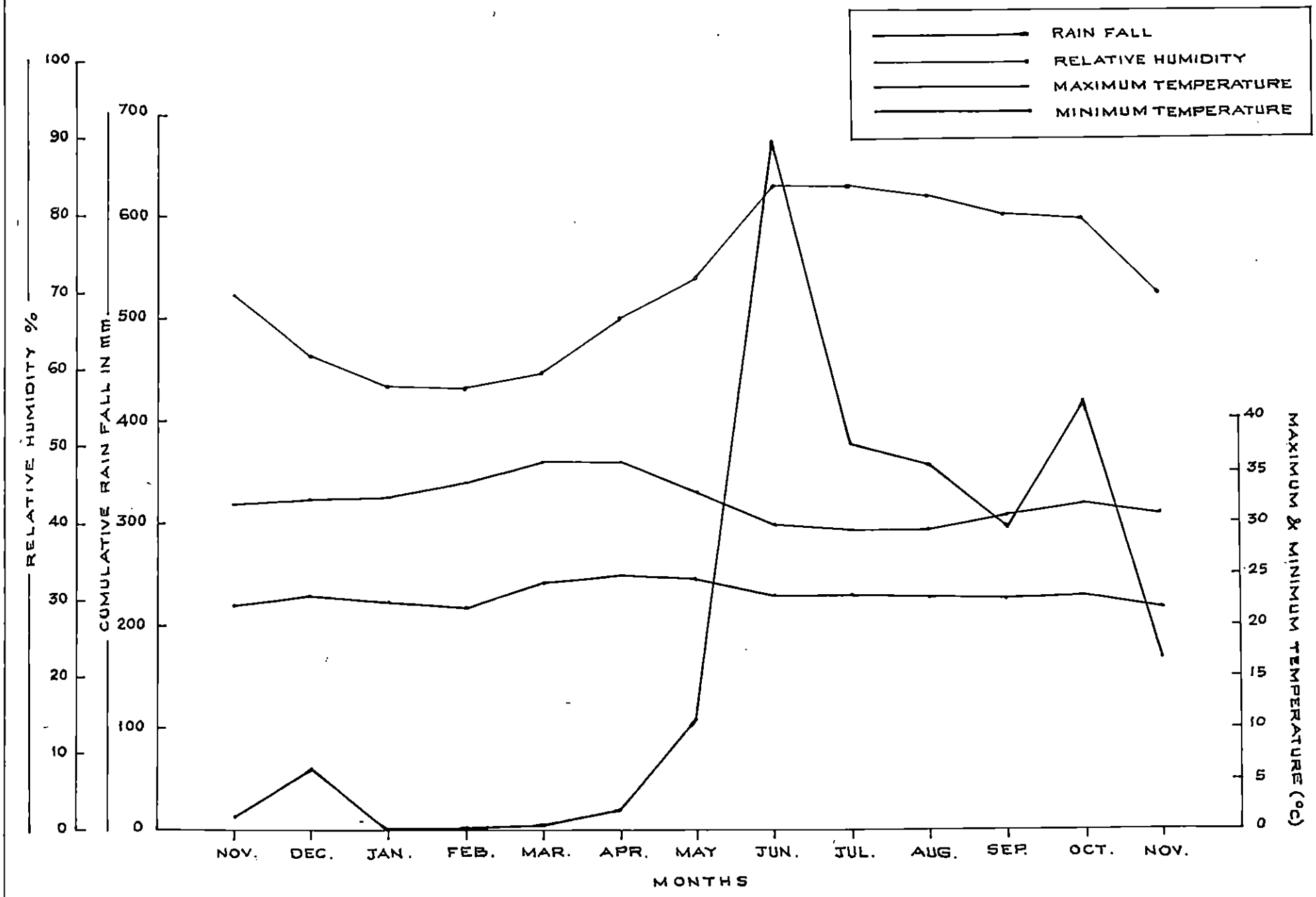

FIG. 6 METEOROLOGICAL DATA FOR THE PERIOD NOVEMBER 1985 TO NOVEMBER 1986

hence the better performance of the O. gratissimum lines and Clocimum.

The high positive and significant correlation noted between fresh herbage yield and leaf area in this study further confirms the effect of leaf area on herbage yield.

5.3 Chemical analysis

5.3.1 Oil content

Two points are important here. The first one is that three harvestings were done and oil content in these three harvests were found out. The second point which require consideration is that different lines coming under two species of Ocimum were compared.

Among the three harvests undertaken maximum oil content was recorded in the third harvest. There was progressive increase in oil content with the progressive increase in age of the plant except in lines 2, 8, 9 and 23. These four lines recorded higher oil content in the initial harvests than the second harvest.

Various reasons are attributed by various workers about the variation in oil content. The findings of

Pareek et al. (1980) that oil content increases from vegetative phase to seeding stage will hold good here because the harvesting was done at full bloom stage in all the three harvests. Harvesting at full bloom stage was reported to be superior to get better yield of eugenol (Pareek et al., 1982 a,1982 b).

Maximum herbage yield was recorded in the second harvest and leaf is the major contributing factor towards the total herbage yield. And so the higher the herbage yield the higher is the oil content. This can be supported by the views of Choudhari (1979) and Dey and Choudhari (1984) that maximum oil content is in the leaves than in the stem or inflorescence.

The poor oil content in the first harvest may be due to the fact that the total herbage contained more tender stem portion also as the plants are in the active growth period. It can also be attributed to the effect of developmental stage of the plant.

The influence of climatic conditions prevailed during the harvesting time can be the possible reason for the poor oil content in second harvesting done at July and for the higher oil content in the third harvesting done at November. The meterological data appended will clearly

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clarify the above point. The best oil content obtained in the third harvesting done at November may be due to the relatively low rainfall, low relative humidity and comparatively high temperature which helped the plant to produce more oil (Fig.6, Appendix I). The poor oil content for the second harvest done at July can be releted to the high rainfall, high relative humidity and comparatively low temperature prevailed during July. These factors might have adversely affected the oil production by the Ocimum plants. This can be supported by the views expressed by the previous workers like Dey and Choudhuri (1980), Hotin (1968). Dey and Choudhuri (1980) reported that oil content was low in October which gradually increased and reached a peak in December and declining thereafter in case of O. sanctum. Hotin (1968) revealed that atmospheric temperature had the greatest favourable effect on essential oil accumulation. He observed that a raise in temperature increased the essential oil content in menthol mint, East Indian basil leaves, lavender etc. Yoshida (1959) opined that atmospheric temperature was the major environmental factor controlling oil content in Pelargonium roseum. He observed that oil content was higher in October and November than in May and June owing to factors of humidity rainfall and temperature.

The above discussion clearly shows the influence of rainfall, humidity and temperature in essential oil production. And these confirm the reasons for the poor oil content in July and better oil content in November in the present study.

The second point of consideration is the variation in oil content among the 25 Ocimum lines evaluated in the present study. In all the harvests the lines 1, 5, 10, 15, 19, 20, 23 and 25 recorded higher oil content than the other lines. The mean oil content were also higher for the above lines than other lines.

The main inference is that the Clocimum and other O. gratissimum lines have a higher oil content than O. sanctum lines with one exception of line 23 from Lucknow. This clearly confirms the superiority of the O. gratissimum and Clocimum lines over the O. sanctum lines. The one exceptionally good O. sanctum having higher oil content is obtained from CIMAP Lucknow. This may be an advanced selection for oil content from that institute.

The positive correlation revealed between herbage yield with leaf area and oil content in this study confirms the superiority of O. gratissimum and Clocimum lines. But

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this will not hold good in case of the superior O.sanctum line 23 as it is having lower leaf area and low herbage yield. This may be a synthetic superior line from CIMAP Lucknow.

The oil content recorded in this study for Clocimum, O. gratissimum and O. sanctum lines revealed that the values are higher then that of the previous workers (Gunther, 1974; Lal et al. 1978; Pareek et al., 1980; Sobti et al., 1978).

5.3.2 Oil yield per hectare

The maximum oil yield for all the lines was recorded during the second harvest, followed by the third and first harvests. The main reason is that the oil yield is a function of oil content and the total herbage yield. And the herbage yield was maximum during the second harvest, which was the peak growing season. The herbage yield, leaf area and oil content are having a significant positive correlation for the second harvest. This explains why there is higher oil yield during the second harvesting. The poor oil yield in the third harvesting is mainly due to the poor herbage yield through the oil content was the highest at the third harvesting. The minimum oil yield during the first harvesting is due to the poor oil content as well as the

poor herbage yield. Though the maximum oil content is at the third harvest due to seasonal influence its effect on oil yield was masked by the lower herbage yield.

Clocimum possessed highest oil yield in all the harvests and the mean oil yield was also maximum (278.11 l/ha). Relatively higher oil yield during second and third harvests by all the O. gratissimum lines, clearly indicated the superiority of these lines over the O. sanctum lines. But this trend is not clear in the first harvest because of the variations in oil content and herbage yield.

The total oil yield from a hectare in an year was unusually high for Clocimum (834.34 l/ha) followed by other O. gratissimum lines (326.65 - 408.48 l per ha) (Table 11, Fig.7). This is also a factor controlled by the oil content and herbage yield, so wherever these factors had better combinations, it will influence the total oil yield. The oil content and herbage yield were more for the Clocimum and O. gratissimum lines than that of the O. sanctum lines. Though the line 23 of O. sanctum had higher oil content its total oil yield was less because it had poor herbage yield.

Sobti et al. (1979) reported oil yields of 57.5, 37.5, 50.25, 62.5 and 98.75 kg per ha in RRL-07, O. sanctum, O. gratissimum (strain 1, strain 2) and improved

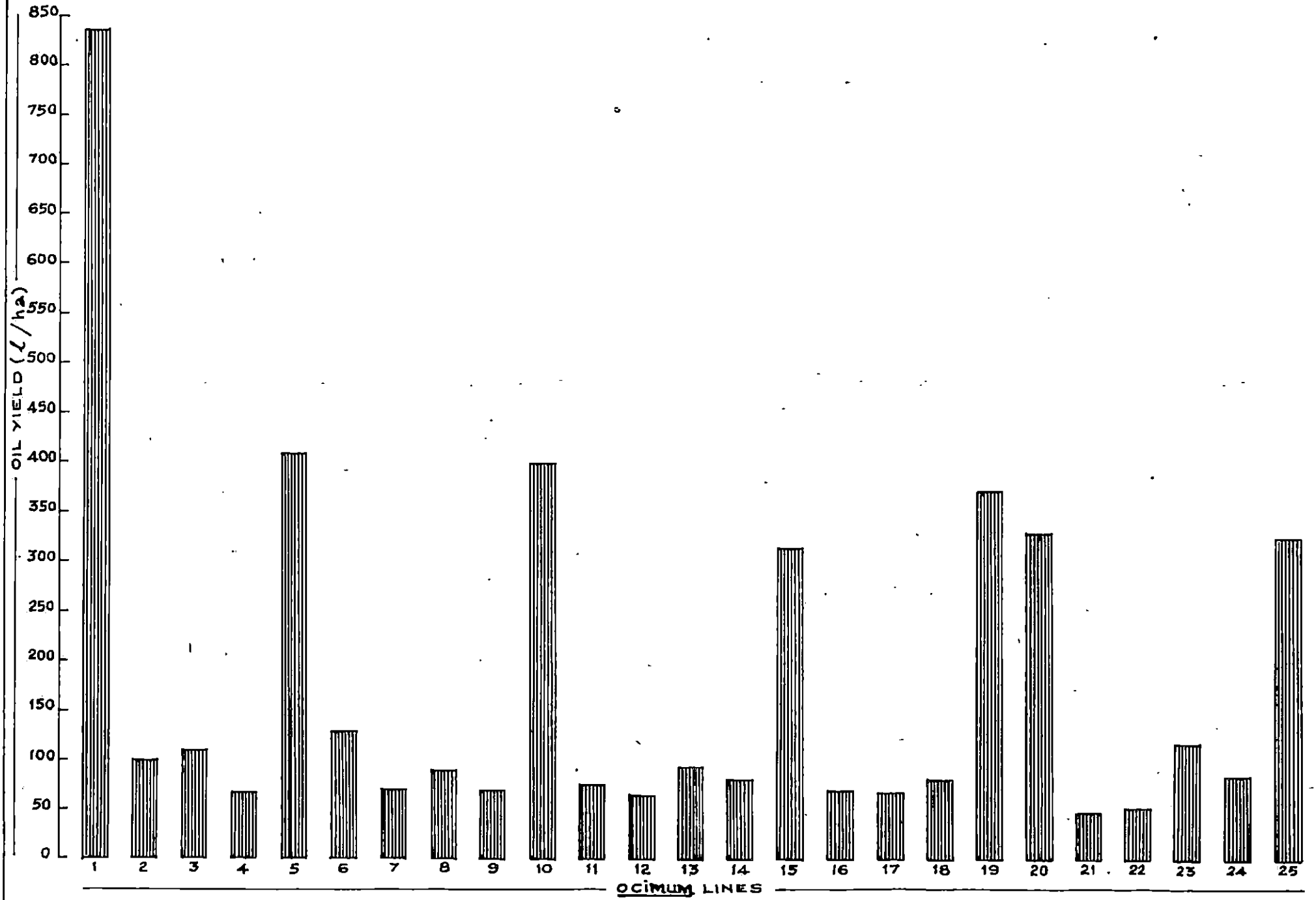

FIG.7. TOTAL OIL YIELD OF OCIMUM LINES IN AN YEAR.

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strain of O. gratissimum respectively. Trivedi et al. (1981) reported an oil yield of 63.47 l/ha for O. gratissimum under Indore conditions. Sobti and Pushpangadhan (1982) observed an oil yield of 160 kg/ha for improved strain of O. gratissimum (RRL-09). Choudhari et al. (1986) reported oil yields of 190.7 and 268.9 kg per ha in the first and second year respectively for O. gratissimum which is in agreement with the present study. Other reports are not in agreement with the data of the present investigations (Salyan et al. 1982, Asthana and Gupta, 1984, Choudhari and Bordoloi, 1986, Kurian et al. 1984). They have reported less oil yield than that was observed in the present study.

The oil yield reported in the present study by the Clocimum is unusually high. This may be due to the fact that it had higher oil content and high herbage yield. These contributing factors had influenced the substantial increase in total oil yield. This also points to the acclimatisation of Clocimum under Kerala conditions.

5.3.3. Eugenol content and eugenol yield per hectare

Clocimum had the highest eugenol content of 71.82 per cent among all the 25 lines evaluated in the present study. The other O. gratissimum lines except

line 25 (17.59 per cent) possessed moderate content of eugenol. This study enabled to isolate O. sanctum lines having higher eugenol content (lines 13, 9, 18, 17 and 3). The low eugenol content reported in certain lines in the present study may be due to the predominance of chemical constituents other than eugenol. Philip and Damodaran (1985) identified different chemotypes based on the chemical composition of O.sanctum like eugenol, isoeugenol and caryophyllene content. They identified types having purple and green leaves in the local cultivars of O. sanctum having methyl eugenol as the major constituent and another green type having eugenol as the major constituent. But in the present study only eugenol was studied.

The higher eugenol content reported in Clocimum in the present study was in agreement with the previous workers like Puri (1982); 65 per cent, Nair and Kurien (1983) 70 per cent. The eugenol contents for other lines in O. gratissimum in the present study ranged from 17.59 (line 25) to 48.65 per cent (line 15). Sobti et al.(1978a) reported that O. gratissimum contained 70 per cent eugenol in oil and Sobti et al. (1980) observed oil contents of 45 - 85 and 50 - 80 per cent for two parental strains of Clocimum. The value reported in the present study seems to be low, when we compare with the above values.

In the case of O. sanctum lines the eugenol content ranged from 6.85 (line 24) to 59.05 per cent (line 13). This range is also very low when we compare the eugenol percentage reported by the previous workers. Vaidhya (1977) reported an eugenol content of 65-70 per cent, Lal et al. (1978) 70.5 per cent, Pareek et al. (1980) 52.2 per cent and Pareek et al. (1982a) 53.5 per cent. This low eugenol content may be due to the predominance of other chemical constituents. Thus the presence of chemotypes as suggested by Philip and Damodaran (1985) in O. sanctum is in support of the present study.

All the O. gratissimum lines and Clocimum had more eugenol yield than O. sanctum lines (Table 12, Fig.8). The total eugenol yield in case of O. gratissimum lines and Clocimum were abnormally high. It ranged from 57.46 (line 25) to 599.22 l per ha per year for Clocimum. In the case of O. sanctum the eugenol yield ranged from 3.6 (line 21) to 55.74 l per ha per year (line 13). The reported eugenol yields by Pareek et al. (1982a) ranged from 11.23 to 20.50 l per ha for O. sanctum at vegetative and seed maturity stage and maximum was 27.16 l/ha at full bloom stage. Pareek et al. (1980) also reported eugenol yield range of 13.68 to 19.97 l per ha per year.

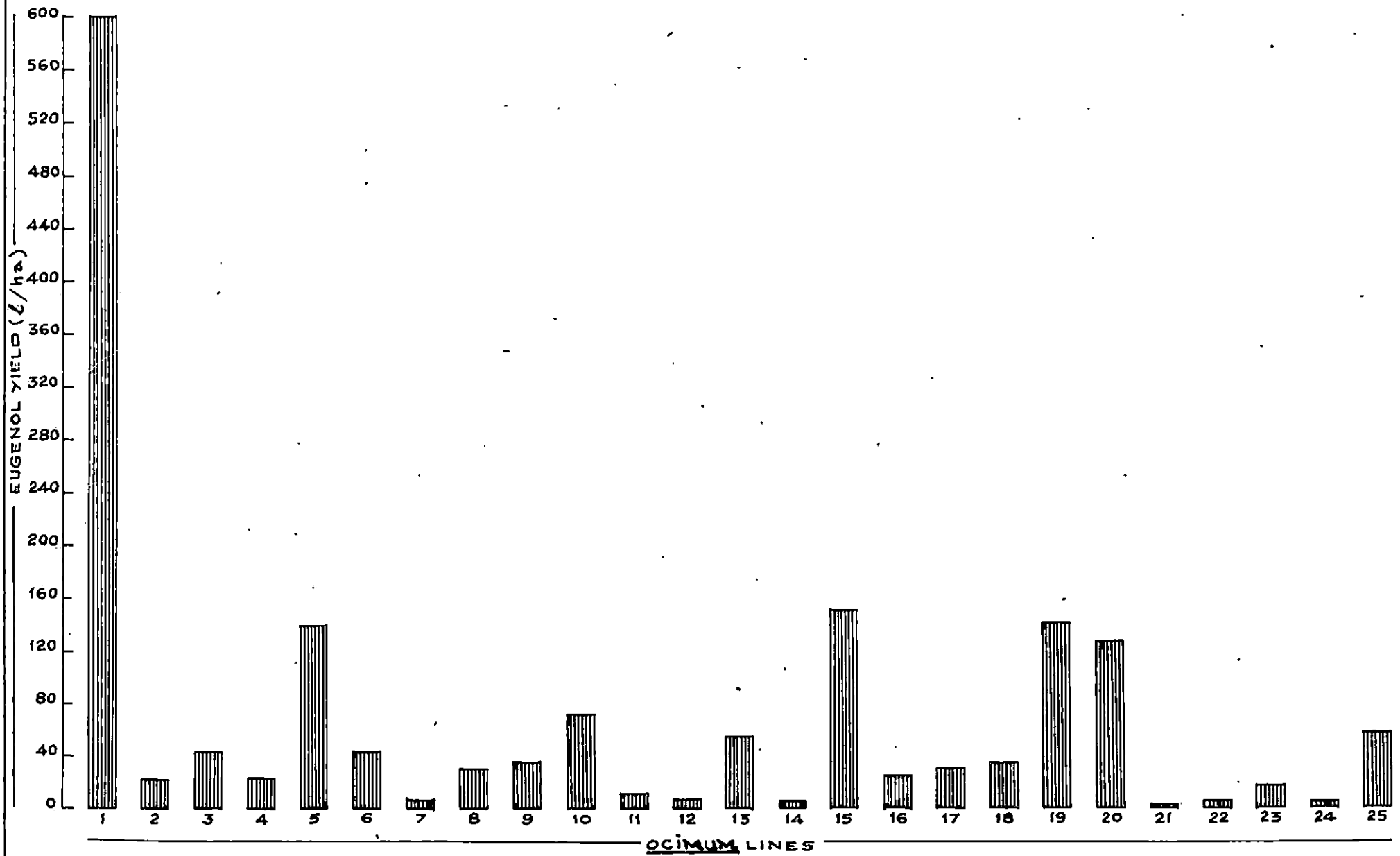

FIG.8. TOTAL EUGENOL YIELD OF OCIMUM LINES IN AN YEAR.

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The results indicated that the O. gratissimum and Clocimum lines were having higher oil yield and higher eugenol content and thus the eugenol yield is also high. Whereas in case of O. sanctum lines the poor eugenol yield by certain lines may be due to poor oil yield and low eugenol content. But in certain cases the eugenol was higher than the reported values possibly due to the combination of high oil yield and eugenol content.

5.4 Selection of better types based on leaf colour, aroma and flavour

Majority of green types are more aromatic the best being the Clocimum followed by lines 9, 18, 19, 20, 4 and 5. On perusal of the data on eugenol content and oil content it can be seen that these lines are also having higher values for the above factors. Best purple type which is highly aromatic is line 13 which is also having higher oil content and eugenol content. In general the green types and types having more greenish tinge are superior than the purple types, with the exception of the purple type (line 13). These studies also indicated the possibility of chemotypes in O.sanctum having varying colouration of leaves which is in agreement with Philip and Damodaran (1985).

5.5 Correlation studies

In order to assess the nature and degree of association of morphological characters and oil content with the herbage yield per plant during the peak harvest season (second harvest), correlations were worked out with reference to six characters. Out of these highly significant or significant positive correlations were observed between leaf area as well as oil content with fresh herbage yield per plant. There is negative nonsignificant correlation with height of the plant and herbage yield per plant during second harvest. This can be made clear from the observations of the present study that eventhough the height of the plants were more during the third harvest the herbage yield was maximum during the second harvest. In general, the lines having higher leaf area and oil content generally have higher herbage yield also eg. Clocimum and other O.gratissimum lines. The studies thus indicated that leaf area and oil content could be useful characters in selecting Ocimum plants which could give higher herbage yield. Choudhuri et al. (1986) also observed a positive correlation (r value = 0.99) between herberage and oil yield.

5.6 Economics of cultivation

The oil yield is the major interest of the study. Hence three lines Clocimum (line 1), O. gratissimum (line 5)

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and O. sanctum (line 6) which are higher oil yielders (834.34, 402.48, and 127.93 l per ha respectively) were selected for working out the economics of cultivation. Considering the present market price of Ocimum oil the net profit per ha worked out to Rs. 65,935/-, Rs.25,005/- and Rs. 108.50 respectively.

With reference to the profit obtainable from the commercial cultivation of Ocimum the available reports showed considerable variation. A net profit of Rs.1,200 per ha was recorded by Sobti et al. (1980) in Clocimum during the first year and Rs.7000 per ha in the second and third years each. Pareek et al. (1982b) obtained a net profit of Rs.3000 per ha for O. sanctum.

In the present study the net profit per ha from Clocimum is abnormally high. This is because of high herbage yield and good oil content which in turn had produced higher oil yield.

The present investigation brought out the potentiality of Clocimum and O. gratissimum in herbage yield, oil content and eugenol content over O. sanctum and indicated about the possibility of commercial exploitation of Clocimum under Kerala conditions. The inter relationship between

herbage yield; oil content and leaf area are also explained. The character expressions by the various lines in growth behaviour, yield attributes, oil and eugenol contents indicated the high degree of variability in Ocimum spp. The higher degree of variation in eugenol content brought out the possibility of the existence of chemotypes. Highly significant positive correlation between herbage yield per plant with leaf area and oil content can be further utilized in the crop improvement programmes of this crop. This study also helped in identifying a O.sanctum line (line 13) from Nellankara, near Trichur as the most suitable purple (Krishna Thulsi) type for the homesteads.

Summary

SUMMARY

An experiment in simple lattice design was conducted at the College of Horticulture, Vellanikkara during 1985-86 to evaluate 25 different Ocimum lines for herbage yield, oil content and eugenol. The salient results are summarised below.

1. All the Ocimum lines except very few had an increase in height from January to November. Eventhough initial height was less for Ocimum gratissimum lines and Clocimum, with the onset of rainy season from June onwards they exhibited a substantial increase in height. Generally during June, July and August all the Ocimum lines exhibited a higher relative increase in height compared to other months.

2. Majority of the O. sanctum lines studied expressed maximum spread during July and after this a definite pattern could not be observed. From July onwards Clocimum and other O. gratissimum linds expressed comparatively high significant values for spread.

3. Compared to O. sanctum lines Clocimum and O. gratissimum lines except line 20 showed branching at

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lower heights. All the lines had maximum number of branches during July and after that a definite pattern was not observed.

4. All the lines took longer time for blooming after transplanting, while the time interval required for flowering after first and second harvests were less and were almost on par. Clocimum and other O.gratissimum lines took more number of days for flowering when compared to O.sanctum lines which indicetes the longer vegetative phase and longivity of these lines.

5. The intervals of flushing in the different lines studied ranged from 8.23 to 13.10 days. Generally O. gratissimum lines including Clocimum took comparatively less number of days for flushing. This revealed the quicker regeneration capacity of these lines.

6. Clocimum and O. gratissimum lines had larger leaf area than O. sanctum lines and it ranged from 3.89 to 36.37 cm^2. This character is very important due to its high positive association with the herbage yield.

7. Among the three harvests taken during April, July and November the second harvest during monsoon season

contributed maximum towards the total herbage yield. All the O. gratissimum lines including Clocimum recorded a substantially high herbage yield per hectare in an year compared to other O. sanctum lines. Of the different Ocimum lines studied, Clocimum was the highest yielder and line 22, the lowest yielder. Among the O. sanctum lines line-3, line-6, line-8 and line-2 produced higher herbage yields.

8. Essential oil recovery of the different lines revealed highly significant differences. The maximum essential oil recovery was recorded from the third harvest and minimum from the first harvest. Clocimum and other O. gratissimum lines and line-23 of O.sanctum recorded maximum recovery of oil during all the three harvests. The average oil content was maximum in Clocimum followed by line 23; line 8 had the least oil content.

9. Oil yield recorded for the different lines during each harvest differed significantly. The line Clocimum recorded maximum oil yield of 834.34 l/ha/year. Highest oil yield was obtained from the second harvest followed by the third harvest. In all the three harvests, Clocimum and other O. gratissimum lines produced higher quantities of oil compared to O. sanctum lines. Among the

various O. sanctum lines studied, line-6 was the highest oil yielder followed by line-23.

10. Clocimum possessed maximum eugenol in oil, followed by line 13, 9 and 15. Clocimum which recorded maximum oil yield also yielded highest amount of eugenol. Eventhough O. gratissimum had moderate or less eugenol in oil, they gave high eugenol yield than O. sanctum because of their comparatively high oil yields.

11. Scoring of different lines based on leaf colour and aroma with respect to eugenol content revealed that Clocimum was superior with highly aromatic green leaves. The lines having green or greenish tinge leaves had good or average percentage of eugenol.

12. The characters such as leaf area and oil content exhibited a highly significant or significant positive correlation with the fresh herbage yield per plant during second harvest period. The height of the plant showed a negative correlation and other characters like spread of the plant, number of branches per plant, number of days for flowering did not show any significant correlation with the fresh herbage yield during the peak harvest period (second harvest).

13. Clocimum gave maximum returns followed by O. gratissimum lines, and O. sanctum lines gave the least profit.

14. In short the studies revealed the superiority of Clocimum and O. gratissimum lines with regard to their better vegetative growth and eugenol content. Hence Clocimum can be cultivated under Kerala conditions on a commercial scale. Among the O. sanctum lines evaluated line 13 having purple coloured leaves has shown high values for eugenol content. Hence it is suggested that further studies may be carried out for the improvement of line 13 of O. sanctum as purple types are preferred by the people especially for homestead cultivation. Other types may be screened to find out the possibility of chemotypes, which may be rich in methyl eugenol, thymol and caryophyllene. The superior lines also can be tested under different shade conditions and effect of shade on chemical constituents and pigmentation can be observed and thus the possibility for cultivation on large scale as intercrop in coconut plantations can be exploited.

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Appendices

Appendix-I

Weather data (monthly average) for the period from November 1985 to November 1986

Month	Temperature °C		Relative humidity (%)	Total rainfall (mm)
	Maximum	Minimum		
1985				
November	31.8	22.3	70.0	14.4
December	32.2	22.9	62.0	58.8
1986				
January	32.5	22.4	58.0	1.2
February	34.2	22.1	58.0	1.9
March	36.2	24.3	60.0	8.4
April	36.0	25.2	67.0	23.2
May	34.2	24.7	72.0	108.8
June	30.0	23.06	84.0	669.9
July	29.5	23.2	84.0	381.4
August	29.4	22.7	83.0	358.7
September	30.5	22.7	81.0	296.3
October	31.8	22.9	80.0	421.3
November	31.2	22.0	71.0	176.2

Appendix-II

Analysis of variance for plant height of Ocimum lines from January 1986 to November 1986

Months	Source of variation	Varieties	Error
January	d.f.	24	56
	Mean squares	172.932**	5.855
February	d.f.	24	56
	Mean squares	108.242**	6.624
March●	d.f.	24	72
	Mean squares	82.643**	5.889
April●	d.f.	24	72
	Mean squares	101.096**	8.075
May	d.f.	24	56
	Mean squares	169.557**	7.95
June	d.f.	24	56
	Mean squares	229.392**	9.898
July●	d.f.	24	72
	Mean squares	772.203**	11.155
August	d.f.	24	56
	Mean squares	1254.882**	13.715
September	d.f.	24	56
	Mean squares	1258.068**	17.682
October●	d.f.	24	72
	Mean squares	1425.870**	16.684
November	d.f.	24	56
	Mean squares	2113.013**	19.503

NS = Not significant
* = Significant at 5% level
** = Significant at 1% level
● = The analysis was done in RBD as the between blocks within replicate mean square was less than error mean square.

Appendix-III

Analysis of variance for spread of Ocimum lines from January 1986 to November 1986

Months	Source of variation	Varieties	Error
January●	d.f.	24	72
	Mean squares	82095.842**	461.993
February●	d.f.	24	72
	Mean squares	1358963.966**	4024.223
March	d.f.	24	56
	Mean squares	1801816.940**	1428.534
April●	d.f.	24	72
	Mean squares	2646250.831**	25230.224
May	d.f.	24	56
	Mean squares	3485085.725**	10586.796
June	d.f.	24	56
	Mean squares	6312797.546**	13261.609
July	d.f.	24	56
	Mean squares	4068261.146**	1251.246
August●	d.f.	24	72
	Mean squares	18386154.174**	1020.444
September	d.f.	24	56
	Mean squares	5953550.338**	1287.645
October●	d.f.	24	72
	Mean squares	8433856.010**	1336.889
November●	d.f.	24	72
	Mean squares	8307861.328**	51221.337

NS = Not significant
* = Significant at 5% level
** = Significant at 1% level
● = The analysis was done in RBD as the btween blocks within replicate mean square was less than error mean square.

Appendix-IV

Analysis of variance for height at first branching of Ocimum lines

Source of variation	Variation	Error
d.f.	24	56
Mean squares	63.626**	3.329

** Significant at 1% level

Appendix-V

Analysis of variance of number of branches of Ocimum lines from January 1986 to November 1986

Months	Source of variation	Varieties	Error
January●	d.f.	24	72
	Mean squares	32.584**	3.044
February●	d.f.	24	72
	Mean squares	112.550**	5.928
March●	d.f.	24	72
	Mean squares	475.255**	11.228
April	d.f.	24	56
	Mean squares	3572.991**	17.365
May●	d.f.	24	72
	Mean squares	15185.010**	21.188
June●	d.f.	24	72
	Mean squares	28957.281**	52.757
July	d.f.	24	56
	Mean squares	32127.692**	49.625
August●	d.f.	24	72
	Mean squares	19284.458**	43.507
September●	d.f.	24	72
	Mean squares	13565.770**	29.528
October	d.f.	24	56
	Mean squares	8992.089**	29.859
November●	d.f.	24	72
	Mean squares	8384.865**	52.427

NS = Not significant
* = Significant at 5% level
** = Significant at 1% level
● = The analysis was done in RBD as the between blocks within replicate mean square was less than error mean square.

Appendix-VI

Analysis of variance for number of days taken for blooming after transplanting, first and second harvest by Cucumis lines.

No.of days for flowering	Source of variation	Varieties	Error
After transplanting			
	d.f.	24	56
	Mean squares	688.964**	14.179
After first harvest@			
	d.f.	24	72
	Mean squares	441.750**	9.767
After second harvest@			
	d.f.	24	72
	Mean squares	438.135**	7.056

NS = Not significant
* = Significant at 5% level
** = Significant at 1% level
@ = The analysis was done in RBD as the between blocks within replicate mean square was less than error mean square.

Appendix-VII

Analysis of variance for intervals of flushing of Ocimum lines after each harvest

Intervals of flushing	Source of variation	Varieties	Error
After first harvest@			
	d.f.	24	72
	Mean squares	5.632**	0.475
After second harvest			
	d.f.	24	56
	Mean squares	2.011**	0.285
After third harvest			
	d.f.	24	56
	Mean squares	2.257**	0.093

NS = Not significant
** = Significant at 1% level
@ = The analysis was done in RBD as the between blocks within replicate mean square was less than error mean square

Appendix-VIII

Analysis of variance for herbage yield/plant of *Ocimum* lines

Herbage yield	Source of variation	Varieties	Error
I. First harvest			
Fresh weight basis●			
	d.f.	24	72
	Mean squares	3474.134**	32.966
Dry weight basis			
	d.f.	24	56
	Mean squares	413.322**	5.348
II. Second harvest			
Fresh weight basis			
	d.f.	24	56
	Mean squares	138704.635**	744.630
Dry weight basis			
	d.f.	24	56
	Mean squares	7238.519**	83.000
III. Third harvest			
Fresh weight basis			
	d.f.	24	56
	Mean squares	63423.585**	102.057
Dry weight basis			
	d.f.	24	56
	Mean squares	4877.485**	7.543

NS = Not significant
** = Significant at 1% level
● = The analysis was done in RBD at the between blocks within replicate mean square was less than error mean square

Appendix-IX

Analysis of variance for herbage yield/ha of Ocimum lines

Herbage yield	Source of variation	Varieties	Error
I. First harvest			
Fresh weight basis●			
	d.f.	24	72
	Mean squares	5.568**	0.051
Dry weight basis			
	d.f.	24	56
	Mean squares	0.659**	0.011
II. Second harvest			
Fresh weight basis			
	d.f.	24	56
	Mean squares	222.050**	1.191
Dry weight basis			
	d.f.	24	56
	Mean squares	11.598**	0.133
III. Third harvest			
Fresh weight basis			
	d.f.	24	56
	Mean squares	101.463**	0.163
Dry weight basis			
	d.f.	24	56
	Mean squares	7.947**	0.012

NS = Not significant
** = Significant at 1% level
● = The analysis was done in RBD as the between blocks within replicate mean square was less than error mean square

Appendix-X

Analysis of variance for oil content in different *Cajanus* lines as influenced by harvests

Recovery of oil	Source of variation	Varieties	Error
I. *First harvest*			
Fresh weight basis●			
	d.f.	24	72
	Mean squares	0.111**	0.006
Dry weight basis●			
	d.f.	24	72
	Mean squares	0.821**	0.015
II. *Second harvest*			
Fresh weight basis			
	d.f.	24	56
	Mean squares	0.187**	0.001
Dry weight basis●			
	d.f.	24	72
	Mean squares	3.841**	0.017
III. *Third harvest*			
Fresh weight basis			
	d.f.	24	56
	Mean squares	0.618**	0.001
Dry weight basis			
	d.f.	24	56
	Mean squares	6.215**	0.014

NS = Not significant
** = Significant at 1% level
● = The analysis was done in RBD as the between blocks within replicate mean square was less than error mean square.

Appendix-XI

Analysis of variance for oil yield of *Ocimum* lines from different harvests

Oil yield	Source of variation	Varieties	Error
First harvest@			
	d.f.	24	72
	Mean squares	274.553**	1.029
Second harvest@			
	d.f.	24	72
	Mean squares	37706.692**	46.359
Third harvest@			
	d.f.	24	72
	Mean squares	25901.284**	591.336

NS = Not significant
** = Significant at 1% level
@ = The analysis was done in RBD as the between blocks within replicate mean square was less than error mean square.

Appendix - XII

Economics of Ocimum cultivation for one hectare*

Items	Clocimum				O. gratissimum				O. sanctum			
	Men 25.50	Women 24/=	Quantity	Amount Rs.	Men 25.50	Women 24/=	Quantity	Amount Rs.	Men 25.50	Women 24/=	Quantity	Amount Rs.
1	2	3	4	5	6	7	8	9	10	11	12	13
I. Seeds and sowing												
a) Preparation of nursery and seed sowing	2	10	-	290.00	2	10	-	290.00	2	10	-	290.00
b) Cost of seed	-	-	250 g	100.00	-	-	250 g	100.00	-	-	250 g	100.00
II. Cultivation and Land preparation												
a) Ploughing and digging the land	35	20	-	1372.50	35	20	-	1372.50	35	20	-	1372.50
b) Taking furrows and bunds	35	-	-	892.50	35	-	-	892.50	35	-	-	892.50
c) Transplanting in the field	-	20	-	480.00	-	20	-	480.00	-	20	-	480.00
III. After cultivation operations												
a) Irrigation	30	20	-	1245.00	30	20	-	1245.00	30	20	-	1245.00
b) Weeding and earthing up	20	20	-	990.00	20	20	-	990.00	20	20	-	990.00
IV. Manures and manuring												
a) Farm yard manure @ Rs.125/tonne	-	-	10t	1250.00	-	-	10 t	1250.00	-	-	10 t	1250.00
b) Nitrogen @ Rs. 5.30/kg	-	--	170 kg	900.00	-	-	170 kg	900.00	-	-	170 kg	900.00
c) P_2O_5 @ Rs.4.70/kg	-	-	440 kg	2060.00	-	-	440 kg	2060.00	-	-	440 kg	2060.00
d) K_2O @ Rs.2.25/kg	-	-	50 kg	112.50	-	-	50 kg	112.50	-	-	50 kg	112.50
e) Transport and application	5	10	-	367.50	5	10	-	367.50	5	10	-	367.50
V. Harvesting												
a) Cutting and transportation of herbage	90	-	-	2295.00	50	-	-	1275.00	30	-	-	765.00
b) Cleaning and chopping	-	90	-	2160.00	50	-	-	1200.00	-	30	-	720.00
c) Total cost of cultivation	-	-	-	14515.00	-	-	-	12475.00	-	-	-	11545.00
VI. Processing and distillation												
a) Cost of distillation of oil	-	-	59.36 t	2950.00	-	-	46.46 t	2320.00	-	-	22.93 t	1146.50
b) Values of oil Rs. 100/= per litre			834 l	83400.00	-	-	408. l	40800.00	-	-	128 l	12800.00
c) Total expenditure of cultivation and extraction		-	-	17465.00	-	-	-	14795.00	-	-	-	12691.50
d) Income from one hectare		-	-	65935.00	-	-	-	25005.00	-	-	-	108.50

* Worked out based on the expenditure incurred at the experimental plot

EVALUATION OF *Ocimum* LINES FOR HERBAGE YIELD, OIL CONTENT AND EUGENOL

By

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ABSTRACT OF THE THESIS

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ABSTRACT

Investigations on "Evaluation of Ocimum lines for herbage yield, oil content and eugenol" was carried out at the Department of Plantation Crops and Spices, College of Horticulture, Vellanikkara during 1985-86. Twentyfour Ocimum lines collected from different places from the State and the country along with one strain (Clocimum) released from RRL-Jammu were evaluated adopting simple lattice design with the following objectives.

1) To select better types based on leaf colour, aroma and flavour;
2) To study the growth and flushing behaviour of each type and to isolate superior ones having better flushing characters;
3) To select a purple coloured O. sanctum line for the Kerala homesteads;
4) To select eugenol rich strains to undertake large scale cultivation of Ocimum for essential oil production;
5) To explore the possibility of growing Clocimum under Vellanikkara conditions.

The crop was raised adopting the standard Package of Practices recommendations. The main growth parameters studied were plant height, spread, height at first branching, total number of branches per plant, number of days to blooming, intervals of flushing and leaf area. The yield parameters studied were herbage yield per plant, herbage yield per hectare, oil content, oil yield per hectare, eugenol content and total eugenol yield per hectare. An attempt was also made to relate leaf colour and aroma with the eugenol content of different Ocimum lines.

The results indicated that the plant height increased with the age of plants. The plant spread and total number of branches per plant were maximum during July-August and afterwards a definite pattern was not observed. Clocimum and O. gratissimum lines branched at lower heights compared to O. sanctum lines. In general, all the lines tested took more time to initial flowering after transplanting, than, after first or second harvests. Clocimum and O. gratissimum lines exhibited a tendency for quick flushing but took more days for flowering after each harvest compared to O. sanctum lines. O. gratissimum lines including Clocimum have higher leaf area.

The studies on yield parameters revealed that Clocimum was most superior with regard to herbage yield, oil content and eugenol followed by O. gratissimum lines. Clocimum produced a herbage yield of 59.36 tonnes/ha/year, while the highest yielder of O. sanctum produced only 22.93 tonnes/ha/year. The different lines in general, produced maximum herbage and oil yield during second harvest, followed by the third and first harvests, whereas the oil content was maximum during the third harvest followed by the second and first harvests. The percentage of eugenol was maximum in Clocimum (71.82 per cent) followed by a purple coloured O. sanctum line (59.05 per cent) collected from Nellankara, near Trichur. Clocimum produced maximum eugenol per hectare followed by O. gratissimum lines.

The scoring on leaf colour and aroma with respect to eugenol content revealed that, green leaved lines had better aroma than purple leaved with one purple coloured line as exception. Here also Clocimum proved its superiority.

Economics of cultivation and distillation of different Ocimum lines revealed that cultivation of Clocimum is more profitable than all other Ocimum lines evaluated.

When we consider the various characters of 35 different Ocimum lines, it is very well clear that Clocimum can be groomed as a commercial crop under Kerala conditions. If there is a preference for purple coloured type of O.sanctum (Krishna Thulsi) the line from Nellenkara can be recommended especially for the homesteads. Hence, further investigation to probe the possibilities of growing these promising lines as pure and mixed crops in Kerala and techniques for identifying valuable chemical constituents other then eugenol is suggested.