INFLUENCE OF APPLIED NUTRIENTS AND STAGE OF HARVEST ON THE YIELD AND PHYSICO-CHEMICAL PROPERTIES OF ESSENTIAL OIL OF PALMAROSA (*Cymbopogon martini* Stapf var. motia)

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "Influence of applied nutrients and stage of harvest on the yield and physico-chemical properties of essential oil of palmarosa (Cymbopogon martini Stapf var. motia)" is a bonafide record of research work done by me during the course of research and that 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.

Vellayani,
25-3-1985.

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CERTIFICATE

Certified that the thesis entitled "Influence of applied nutrients and stage of harvest on the yield and physico-chemical properties of essential oil of palmarosa (*Cymbopogon martini* Stapf var. motia)" is a record of research work done independently by Smt. N.P. CHINNAMMA 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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INTRODUCTION

Aromatic plants constitute a group of industrially important crops which bring to the country appreciable income by way of export earnings. The essential oils obtained from such plants go into the preparation of innumerable cosmetic products and medicinal preparations which are in great world demand. Developing countries have been the producers of essential oils - the raw materials for such products. India had a great past in the extraction of athars and had its own perfumery products, besides exporting raw materials for perfumery and cosmetics. Many of them are cultivated with the wisdom that has accumulated and which has been handed over from generation to generation rather than on a scientific basis. Therefore, it is imperative that innovations have to be made in the agro-techniques on some of the important essential oil crops for increasing both the productivity and quality of oils and for releasing more value added products to the world markets.

The major items of essential oils that are being exported from India are sandalwood oil, lemongrass oil, palmarosa oil, and vetiver oil. India is one of the principal producers and exporters of palmarosa oil. Palmarosa oil ranks third in the list of exported essential oils from India and exported mainly to France, West Germany, U.S.A., Switzerland, United Kingdom and Sudan. During 1984 the export was to the tune of about 14 tonnes valued at Rs. 47 lakhs. In 1984 the average market price of this oil at Bombay as per the Agmark Bulletin, published by the Directorate of Marketing and Inspection, Nagpur, was around Rs.300/- per kg. There is a growing and consistent demand for this oil in the world markets.

Palmarosa oil is obtained from the grass Cymbopogon martini Stapf var. motia. The distillation of the flowering shoots, leaves and overground parts of the plant gives the commercially important oil of palmarosa or East Indian geranium oil.

The oil of palmarosa is an important raw material in perfumary and is extensively used for imparting rose like aroma to a wide range of soaps, cosmetic products, toiletary goods, tobacco products etc. Geraniol $C_{10}H_{18}O$, an unsaturated terpene alcohol is the principal constituent of palmarosa oil. Geranyl acetate $C_{12}H_{20}O_2$ is another major component.

Palmarosa plants are widely grown in Madhya Pradesh, Maharashtra, Andhra Pradesh and Uttar Pradesh. It was introduced into Kerala at the erstwhile Lemongrass Research Station, now the Aromatic and Medicinal Plants Research Station (AMPRS), Odakkaly, about 20 years ago from Maharashtra. During these few years the cultivation of palmarosa has expanded considerably especially in the plains and midlands in the districts of Cannanore, Koshikode, Ernakulam etc. Further, seeds are being sent from this Station to adjacent States for cultivation.

The studies so far conducted on various aspects have clearly shown that it is a suitable crop under the agro-climatic conditions of Kerala and that it is a more profitable crop compared to lemongrass. This is probably one of the main reasons for the gradual and partial dis-placement of lemongrass by palmarosa in Kerala. Though the cultivation practices are similar for both, palmarosa is different from lemongrass in that its optimum stage of harvest is closely related to the blossoming of the plant. The plant is found to flower more frequently under the humid tropical conditions of Kerala. In contrast to this lemongrass flowers only once in a year. Further, the inflorescence of palmarosa is reported to contain a higher percentage of the oil than its leaves and stem (Gupta et al., 1978; Alice et al., 1982, Naresh et al., 1982). Thus this frequency of blossoming leads to narrowing harvest intervals of the crop and is likely to ensure a greater per hectare production of the oil per year.

In order to increase the quantity and quality of palmarosa oil, studies are being conducted on the culti-vation and distillation aspects of the crop by various agencies like the Central Institute of Medicinal and Aromatic Plants, Regional Research Laboratories, Indian

Agricultural Research Institute etc. But precise information on nutrient requirements of this crop and their influence on the quality of the oil are very sparse. As the stage of harvest has not been properly standardised the oil produced under Kerala situations is reported to contain a higher geranyl acetate content and a lower content of geraniol than the prescribed ISI limits. The high acetate content in the oil is not a desirable character for perfumery purposes. Several workers (Gupta et al., 1978, Gupta et al., 1981; Alice, 1982) have reported that the oil obtained from the leaves are of better quality since they contain lesser amount of geranyl acetate and more of geranyl alcohol. These studies reported earlier in literature are based on chemical analysis of the oil separately distilled and obtained from the inflorescence and the leaves harvested after blossoming.

The present state of our knowledge is scanty especially on the nutrition of palmarosa, optimum harvest intervals to ensure maximum herbage yield, oil yield and its quality, factors affecting major yield attributes of the crop and thereby the yield and quality of oil etc. In view of this the present study was taken up with the following main objectives:

(1) Find out the NPK requirements for palmarosa based on studies on nutrient removal, and response patterns by the crop.

(2) Find out the optimum harvest interval to ensure maximum herbage and oil yield.

(3) Study the effect of harvest intervals and nutritional factors on the quality of oil especially the geraniol (free alcohol) and geranyl acetate contents.

(4) Find out a suitable combination of harvest interval and manurial schedule in order to manipulate the usually higher content of geranyl acetate observed in Kerala situations to a level below the prescribed ISI tolerance limits.

(5) Find out the combination of manurial treatments and harvest intervals to ensure the highest net return in terms of rupees over a continuous period of two years of cultivation of palmarosa.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Palmarosa is an essential oil yielding perennial grass found in the tropics. It comes up well under the agroclimatic conditions existing in Kerala. Most of the available literature relating to the influence of nutrients and stage of harvest on oil yield, physico-chemical properties of oil, composition of the plant and uptake of nutrients relevant to the study are presented here. Since the literature on uptake studies in palmarosa is very scanty, observations on other grasses which have relevance to the studies of palmarosa have also been reviewed.

Cultivation of palmarosa in India

Palmarosa grass, Cymbopogon martini Stapf var. motia is the original native of the forests of Madhya Pradesh, Assam and Maharashtra, where it is known to grow in scattered patches. Many different cultivars have been identified from the natural habitat. It is a hardy plant which can grow in varying altitudes and is generally found on the slopes of mountains and well-drained soils. However, the content and quality of oil is very much influenced by the climate and the altitude at which it is grown. In India the main bulk of palmarosa oil is produced from the forests of Madhya Pradesh, Bombay and Assam (Singh, 1977).

Studies conducted by the Kerala Agricultural University have shown that palmarosa comes up well under the agroclimatic conditions of Kerala and that it is a profitable substitute for lemongrass (Nair and Mariam, 1978).

During the past 15 years, attempts have been made at the Central Institute of Medicinal and Aromatic Plants at Lucknow and its regional centre at Bangalore to evolve improved agrotechnology for palmarosa and to introduce better clones. As a result of these efforts good quality palmarosa oil is reported to be produced in Uttar Pradesh, Andhra Pradesh and Karnataka where it is grown as a cultivated crop (Akhtar Hussain, 1979).

Soil and climate

Gupta (1972) has reported that the crop performs well in dry and hot climate with a low rainfall. High rainfall does not adversely affect its growth, if water stagnation is absent. The important contributing factor for economic yield is a well-drained soil with pH varying from 6.0 to 7.5. It prefers open lands with an elevation upto 300 m. Heavy soils should be avoided.

Yield attributes

Effect of nutrition on yield attributes

Investigations conducted by Gupta et al. (1978) at the IARI, New Delhi on the effect of fertilizers on the herbage yield, oil content and its composition have revealed that the number of tillers per plant increased significantly with N and P_2O_5 upto 80 kg but decreased with increase in the levels of K_2O from 40 to 80 kg/ha. The number of tillers corresponding to 0, 40 and 80 kg N/ha were 57.3, 75.2 and 85.8 respectively. The number of tillers produced at 0, 40 and 80 kg P_2O_5/ha were 64.7, 74.0 and 79.7 respectively and the corresponding numbers for 0, 40 and 80 kg K_2O/ha were 68.2, 81.8 and 68.5. The plant height was increased due to different levels of N and the mean height at 0, 40 and 80 kg N/ha were 1.57, 1.70 and 1.75 m respectively. The effcot of P_2O_5 was also significant and the height recorded at 0, 40 and 80 kg P_2O_5/ha were respectively 1.60, 1.69 and 1.74 m. The influence of K was not significant and the plant height was increased due to balanced dose of 80 kg each of N, P_2O_5 and K_2O. The length of the inflorescence increased only upto 40 kg N/ha and there was no effect for P and K application. The length of inflorescence at 0, 40 and 80 kg N/ha were 41.0, 46.1 and 45.8 cm respectively. The number of tillers per plant made a significant contribution towards yield. It was also noted that the increase in plant height did not result in a corresponding increase in the length of the flowering shoots. On the contrary a slight reduction in the size of floral shoot was noticed in taller plants particularly for the autumn crops. They have also noted that more than 90 per cent of the tillers had inflorescence at the time of harvest.

Experiments conducted by Pareek et al. (1981 a) at

Issapur Farm, Delhi during 1978-79 and 1979-80 on the effect of NPK fertilizers on yield and quality of oil of palmarosa showed that the number of tillers was significantly influenced by the different levels of N applied in the first and third harvests. Tiller number increased with increase in the levels of N in all the three harvests and the mean number of tillers per metre row recorded at 0, 40 and 80 kg N/ha were 208.2, 215.3 and 223.0 respectively. Different levels of P_2O_5 and K_2O had no significant effect on the number of tillers and the mean values recorded at 0 and 40 kg P_2O_5/ha were 218.8 and 215.0 and that for 0 and 40 kg K_2O/ha were 212.0 and 220.1 respectively.

Application of N at 0, 40 and 80 kg/ha affected significantly the height of the plants in two out of the three cuttings. In the first cutting application of N at 40 kg/ha recorded the maximum height (197.3 cm) while in the second and third harvests, application of N at 80 kg/ha recorded the highest value.

The mean values of three cuttings recorded at 0, 40 and 80 kg N/ha were 180.6, 199.3 and 200.9 cm respectively. Application of P_2O_5 and K_2O at 0 and 40 kg/ha had, however, no influence on the height of the plants. Length of the inflorescence was influenced by the different levels of N in the second and third harvests, but in the first harvest there was no significant difference with different levels of N. Application of N at 40 kg/ha recorded the maximum length in the first harvest, while in the second and third cuttings application of N at 80 kg/ha recorded the maximum length. The mean values recorded at 0, 40 and 80 kg N/ha were 37.6, 41.3 and 41.3 cm respectively. The effect of P_2O_5 was significant only in the second harvest. Application of P_2O_5 at 40 kg/ha produced longer inflorescence than those at zero level in all the three harvests and the mean length for the three harvests recorded at 0 and 40 kg/ha were 38.8 and 41.2 cm respectively. Application of K_2O at different levels did not influence the length in any of the harvests. But 40 kg K_2O/ha recorded higher inflorescence length than a zero level application and the values recorded at 0 and 40 kg K_2O/ha were 39.5 and 40.6 cm respectively.

Studies conducted by Singh et al. (1981) on the NPK requirements of palmarosa under the agroclimatic conditions of Jorhat, Assam with all possible combinations of N at three levels 0, 50, and 100 kg/ha, P_2O_5 at three levels 0, 40 and 80 kg/ha and K_2O at two levels 0 and 40 kg/ha revealed that the difference obtained with different levels of N, P and K on the number of tillers per plant and on the height of the plant were not significant, though a tendency for higher number of tillers per plant and height was observed with increased N, P_2O_5 and K_2O levels.

Effect of stage of harvest on yield attributes

The studies conducted by Nair et al. (1980 a) at the AMPRS, Odakkaly, showed that the average number of tillers per clump was 18, height of the plants 162 cm, number of inflorescence bearing tillers 14 and length of inflorescence 50 cm at the time of full flowering for the variety ODP-2, in the first year of planting.

Pareek et al. (1981 b) observed in the Issapur Research Farm that the tiller number was not affected by the increase in age from the vegetative phase (75 days after sowing) to the commencement of flowering (83 days), the bloom period with most flowers open (103 days), or the early seeding (115 days) and late seeding stages (125 days). But the height of plants significantly increased from vegetative phase to the bloom period, i.e. the stage of opening of most flowers. The treatments did not influence the length of inflorescence. The number of tillers per metre row during the vegetative stage, commencement of flowering, bloom period with most flowers open, early seeding stage and late seeding stage were 176.0, 175.3, 178.9, 176.0 and 176.7 respectively and the height of the plants at the above growth stages were 83.3, 164.7, 219.0, 221.7 and 224.7 cm respectively. Length of inflorescence during the bloom period with most flowers open, early seeding stage and late seeding stage was 45.7, 48.0 and 54.7 cm respectively.

Yield of herbage and oil

Influence of nutrients on yield of herbage and oil

An experiment conducted at Bhubaneswar, Orissa to study the effect of fertilisers on herbage yield and oil content of palmarosa revealed that application of NPK fertilizers singly and in combination (N at 0, 50 and 100 kg/ha), P_2O_5 at 0, 50 and 100 kg/ha and K_2O at 0, 25 and 50 kg/ha) increased the fresh herbage yield over the control. The highest fresh herbage yield of 47 t/ha was obtained with N_{100} P_{100} K_{50} as against 25 t/ha from the control plot (Dutta and Paul, 1976).

According to Hazarika and Bora (1977), the yield of herbage was significantly increased with the increase in the level of N from 0 to 60 kg/ha. But at 80 kg/ha, the yield of green herbage decreased. The combination of P and K with N also showed a direct effect in increasing the yield of the herbage. The best results were obtained for the treatment, N_{60} P_{40} K_{40} and this dose was recommended for palmarosa grass under Jorhat conditions. The herbage and oil yields obtained in the first year for the treatment N_{60} P_{40} K_{40} were 4.43 t/ha and 39.87 kg/ha respectively.

Sarma et al. (1977) while studying the influence of N and P application at the Punjab Agricultural University, Ludhiana (N at 0, 75 and 150 kg/ha, P_2O_5 at 0, 50 and 100 kg/ha) found that increase in the herbage and oil yields was significant upto 75 kg N/ha, while P did not produce any significant difference in either of these. Herbage yields at 0, 75 and 150 kg N/ha during the first year were 36.78, 42.60 and 45.49 t/ha respectively, while those in the second year were 17.9, 21.3 and 21.5 t/ha respectively.

The oil yields at 0, 75 and 150 kg N/ha during the first year were respectively 161.6, 202.1 and 222.9 kg/ha and those in the second year were 84.1, 102.3 and 100.8 kg/ha.

Gupta et al. (1978) conducted a trial with three levels of N, P_2O_5 and K_2O at 0, 40 and 80 kg/ha singly and in all combinations during the period from August 1973 to November 1974. They observed that the herbage yield increased with increase in the levels of N and the yields recorded at 0, 40 and 80 kg/ha were 69.53, 85.83 and 99.16 t/ha respectively. Increase in the levels of P_2O_5 also resulted in an increase in herbage yield, the yields recorded at 0, 40 and 80 kg P_2O_5/ha being 92.23, 102.22 and 108.34 t/ha respectively. However, the herbage yield decreased as the level of K_2O increased from 40 to 80 kg/ha and the yields obtained at 0, 40 and 80 kg/ha being respectively 96.15, 102.27 and 100.37 t/ha.

In a trial conducted to find out the optimum dose of N and the response of palmarosa to P, K and Zn in Central Uttar Pradesh, Sharma et al. (1980) observed that application of 150 kg N/ha raised the herbage and oil yields in all the four harvests of the crop. However, significant increase was noticed only in the first and fourth harvests. Application of P_2O_5 at the rate of 50 kg/ha increased the herbage and oil yields significantly. Potassium application showed no influence on the yields of either the oil or the herbage.

Pareek et al. (1981 a) observed from a study conducted at Issapur Farm, Delhi that fresh herbage yield and oil yield were influenced by different levels of N (0, 40 and 80 kg/ha) in all the harvests obtained in two years. But there was no significant difference between 40 and 80 kg N/ha and the total herbage yield obtained for two years at 0, 40 and 80 kg N/ha were 63.7, 78.8 and 78.6 t/ha respectively and the corresponding values for oil yield were 276.4, 339.1 and 345.3 kg/ha. Different levels of P_2O_5 and K_2O showed no significant influence on herbage and oil yields.

Singh et al. (1981) found from the studies on the NPK requirements of palmarosa with three levels of N (0, 50 and 100 kg/ha), three levels of P_2O_5 (0, 40 and 80 kg/ha) and two levels of K_2O (0 and 40 kg/ha) that only the effect of P was significant in the yield of green matter and essential oil. The yield of herbage with different levels of N, P and K varied from 12.28 to 12.98, 12.15 to 13.23 and from 12.55 to 12.85 t/ha respectively. The oil yield with different levels of N, P and K ranged from 95.51 to 101.98, 93.88 to 103.43 and from 98.30 to 99.48 kg/ha respectively.

Based on the experiments conducted at the Calcutta University Farm during 1976-'78, Munsi and Mukherjee (1982) concluded that there was significant increase in the yield of oil with application of nitrogenous as well as phosphatic fertilisers (levels of N tried were 0, 20, 40 and 60 kg/ha, and levels of P_2O_5 tried 0, 40, 50 and 80 kg/ha). The integaction between N and P on oil yield was also significant and N_{60} P_{60} was the most optimum level. Application of N increased oil yield from 96.56 kg/ha in the control to 152.42 kg/ha for the highest level of N tried. Similarly the application of P increased the oil yield from 114.33 kg/ha in the control to 136.07 kg/ha in the highest level tried. The most effective level of P_2O_5 application was 60 kg/ha.

Effect of stage of harvest on yield of herbage and oil

According to Lal (1935) the distillation of the whole plant yields the maximum amount of oil when harvested about a week after flowering.

Rao et al. (1949) reported that the maximum yield of oil was obtained from the entire plant one week after flowering.

According to Singh (1958), palmarosa grass gave the maximum yield of essential oil when harvested between budding to flowering while the yield of oil was low when harvested after seeding.

Several workers have reported that the maximum yield of palmarosa oil was achieved when the plants were harvested at full flowering stage (Virmani et al., 1977 and Gupta and Jain, 1978).

Nair and Mariam (1978) were of the opinion that the stage of harvest was the crucial factor contributing to optimum yield of oil with high geraniol content. The study conducted at the AMPRS, Odakkaly revealed that the sixth or seventh day after the full flowering of the crop was the optimum stage of harvest for obtaining maximum oil yield.

Pareek et al. (1981 b) reported from a study conducted for two years on the yield and composition of essential oil at various growth stages, namely vegetative phase, commencement of flowering, bloom period with most flowers open and the early seeding and late seeding stages that the treatments influenced the herbage yield and oil content significantly. Bloom period, when most of the flowers were open, gave the highest herbage yield and oil yield. The total herbage yield obtained for the first and second year at the various stages discussed earlier were sequentially found to be 73.9, 76.2, 94.3, 81.5 and 71.5 t/ha while the corresponding values for oil yield were 340.4, 387.4, 463.4, 409.1 and 316.6 kg/ha.

Effect of the age of the crop on the yield of grass

The average oil yield of palmarosa was estimated at 25 kg/ha in the first year and 50 to 60 kg/ha per year thereafter (Gupta [illegible]., 1972).

In all the species of Cymbopogons the yield of the grass was the lowest in the first year and highest in the second and third year after planting (Gupta and Jain, 1978).

Moisture content and dry matter yield

Guenther (1950) has reported the average moisture content of the plant to be between 62 - 63 per cent.

According to Anjali (1982), the dry matter content of the various plant parts such as very young leaves (first leaf from top) mature leaves (third and fourth leaves) old leaves (below fifth leaf) stems and rhizomes were 30.7, 34.2, 35.4, 38.6 and 25.1 per cent respectively.

Oil content

Influence of fertilizers on the oil content

Dutta and Paul (1976) observed from the experiments conducted at Bhubaneswar, that application of N, P, K singly and in combination produced no consistent effect on the oil content of palmarosa. The average oil content of the fresh herbage was 0.35 per cent.

Investigations carried out by Sarma et al. (1977) at the Punjab Agricultural University, Ludhiana on the effect of N and P application on the yield of palmarosa showed that the percentage recovery of oil at 0, 75 and 150 kg N/ha were 0.44, 0.48 and 0.48 respectively and that at 0, 50 and 100 kg P_2O_5/ha were 0.46, 0.49 and 0.46 respectively on the fresh weight basis.

Increase in the level of N from 75 to 150 kg/ha significantly reduced the oil content in Java citronella, but higher levels of K neither increased the percentage of oil significantly nor showed any definite trend for increase (Bommegowda, 1978).

Hazarika et al. (1978) observed that out of the 16 NPK combinations of N at 4 levels 0, 60, 90 and 120 kg/ha and P_2O_5 and K_2O at two levels of 0 and 40 kg/ha, the combinations N_{120} P_{40} K_0 and N_{60} P_{40} K_{40} yielded the maximum percentage of oil (0.48 per cent). These two combinations were highly significant over most of the other combinations. The percentage of oil due to application of fertilizers varied from 0.37 to 0.48 on the fresh weight basis.

In an experiment conducted at Odakkaly to compare the performance of two varieties of palmarosa viz., ODP-1 and ODP-2, Nair et al. (1980 a) observed that the oil content of ODP-2 was 0.28 per cent.

Pareek et al. (1981 a) reported from a study on the effect of NPK fertilizers on yield and quality of oil that the essential oil content was not influenced by the different levels of N, P_2O_5 or K_2O and the values recorded at 0, 40 and 80 kg N/ha on dry weight basis were 1.10, 1.08 and 1.10 per cent respectively. The values recorded at 0 and 40 kg P_2O_5/ha were 1.09 and 1.11 per cent respectively and those at 0 and 40 kg K_2O/ha were 1.11 and 1.10 per cent respectively.

Singh et al. (1981) reported that there was no significant difference in oil content with different levels of application of N (0, 50 and 100 kg/ha), P_2O_5 (0, 40 and 80 kg/ha) and K_2O (0 and 40 kg/ha). The oil content with different levels of application of N, P and K varied from 0.77 to 0.79 per cent, 0.77 to 0.80 per cent and from 0.78 to 0.79 per cent respectively on fresh weight basis.

Pareek et al. (1983) concluded from an experiment conducted at Issapur Research Farm, Delhi that application of all combinations of three levels of N (0, 40 and 80 kg/ha) and two levels of P_2O_5 and K_2O (0 and 40 kg/ha) did not affect the essential oil content.

Effect of stage of harvest on the oil content

According to Lal (1935) the oil content of leaves of palmarosa ranges between 1.22 and 1.30 per cent of the dry weight in the month of September and gradually rises to a maximum of 1.39 per cent by the middle of October when flowers appear. Thereafter it shows a gradual decline till the end of November. With a further advance in the season, by the beginning of March the oil content gradually falls to a minimum of 0.77 per cent. Oil content of the flowers reaches a maximum of 1.37 per cent (on dry weight) by the end of October and then declines to a value of 0.59 per cent by the second week of January. Oil content of the stems was negligible being only 0.03 per cent (on dry weight) during the month of September. From October onwards, the stems thicken and become tough. During the period immediately preceding maturity (third week of October to the end of November) the oil content in the whole plant ranges from 0.15 to 0.22 per cent on fresh weight basis and from 0.27 to 0.40 per cent on dry weight basis. He recommended the period from the fourth week of October to the third week of November as the ideal maturity period and best suited for harvest and distillation.

Karira and Beri (1966) found that the percentage of oil on zero moisture basis at full bloom stage in October was 1.50 in the 1/3rd top and 0.19 in the 2/3rd lower part of the plant, while in the late flowering stage about one month later it decreased to 0.63 and 0.11 in the 1/3rd top and 2/3rd lower portions respectively.

The essential oil content of palmarosa was highest during the reproductive stage of growth and declined thereafter (Ghosh and Chatterjee, 1976).

Pareek et al. (1981 b) noted that the mean essential oil content on fresh weight basis at the vegetative stage, commencement of flowering, bloom period with most flowers open and the early seeding and late seeding stages were 0.45, 0.49, 0.50, 0.50 and 0.44 per cent respectively and the corresponding values on dry weight basis were 1.25, 1.23, 1.16, 1.14 and 1.04 per cent.

The Kerala Agricultural University has recommended that palmarosa grass should be harvested one week after flowering when the essential oil content reaches a maximum (Anon, 1982).

Studies conducted in the quantitative changes in levels of essential oil in palmarosa during different growth stages showed that the oil content of the plants at anthesis was appreciably higher (0.60 per cent) than before (0.52 per cent) or at the full flowering stage (0.44 per cent)

(Naresh et al., 1982).

<u>Oil content in different portions of the plant and their influence on the oil yield</u>

Rakshit and Dutt (1947) noticed that the oil content on dry weight basis varied within the following units; whole plant (before inflorescence appear) 0.13, to 1.21 per cent; flowering tops 0.70 to 0.98 per cent and lower portion of the plant 0.39 to 0.61 per cent.

According to Narian and Das Gupta (1948) the oil content from each portion on fresh weight basis when distilled separately were as follows, stalks 0.04 per cent; leaves 0.32 per cent and flowers 1.71 per cent. Flowers were the richest source of the oil.

Rao et al. (1949) found that the oil content on fresh weight basis from the whole plant was 0.16 per cent, flowering tops 0.52 per cent, leaves 0.20 per cent and stalks 0.12 per cent.

Karira and Bori (1966) reported that the first 1/3rd of the tops which included inflorescence contained much more oil than the remaining 2/3rd portion of the plant. The oil content in the 1/3rd top ranged from 0.63 to 1.62 per cent, while in the remaining 2/3rd it ranged from 0.11 to 0.37 per cent on a fresh weight basis.

According to Virmani et al. (1967) the oil content in the whole plant varied from 0.12 to 0.28 per cent on fresh weight basis while the flowers and leaves contained the maximum quantity of oil.

Experiments conducted at Bhubaneswar, Orissa revealed that the percentage of oil in the inflorescence varied from 0.80 to 1.00 per cent, in the leaves it varied from 0.64 to 0.86 per cent and that the stems contained only traces of the oil (Dutta and Sahoo, 1977).

Based on the studies conducted on the effect of fertilizers on yield, oil content and oil composition of palmarosa, Gupta et al. (1978) reported that the flowering shoots contained maximum oil content of 1.06 to 2.72 per cent and the leaves 0.88 to 1.18 per cent. It was also noted that the maximum oil content in the leaves synchronised with the appearance of flower buds in the crop.

Alice (1982) reported from a study conducted at AMPRS, Odakkaly that the flower top recorded the highest essential oil content of 0.87 per cent followed by the whole plant (0.35 per cent), the 2/3rd top portion without the inflorescence (0.34 per cent) and 1/3rd bottom portion 0.18 per cent on fresh weight basis.

Naresh et al. (1982) found that the flowers of palmarosa had a comparatively higher content of essential oil (1.67 to 1.70 per cent) than the leaves (1.07 to 1.10 per cent) while the stems had only traces. The leaf lamina had comparable essential oil content (1.58 per cent) while leaf sheath had only 0.62 per cent and these authors have suggested that only flowers and leaves can be used for the extraction of oil.

Effect of photo-period on the essential oil content

Ghosh and Chatterjee (1977) studied the effect of photo-period on the growth, development and essential oil content of palmarosa in West Bengal and reported that the formation of essential oil increased appreciably upto 20 photo inducing cycles of long day treatments. In short-day treated plants a decrease in essential oil formation was noticed. Promotive effects of light on biogenesis of essential oil was also clear and augumentation of essential oil formation under long day condition was accompanied by increased foliar growth and accumulation of dry matter. They also observed that palmarosa possessed characteristics of long day plants and that different inducive cycles of long days hastened flowering and increased the reproductive growth.

Number of harvests as influenced by climatic conditions

The number of harvests during an year was found to vary depending upon the climatic conditions of the place of cultivation. Rao et al. (1949) obtained seven cuttings in two years in Malabar in Kerala.

In West Africa, Burger (1958) normally obtained two harvests in an year, with a late rain an additional smaller harvest could be obtained.

According to Singh (1958) palmarosa crop gave two cuttings in an year (July and October - November) in Dehra Dun and Punjab.

Karira and Beri (1966) found that the seeds sown in nursery in July, and seedlings transplanted in September, started flowering only in the middle of July in the second year and were in full bloom by the middle of October.

Gupta (1972) noted that the plant usually flowers in September - October in the first year and then during the next April and again in September - October in the subsequent years. The crop was ready for harvest between 10 and 15 days of flowering.

In Burdwan, West Bengal, Ghosh and Chatterjee (1976) observed that motia grass yielded one harvest in the first year (October) and two harvests (May and October) from second year onwards.

Hazarika and Bora (1977) have reported that they made two harvests in a year in an experiment conducted at Central Institute of Medicinal and Aromatic Plants, Lucknow on the effect of varying doses of N K on yield of palmarosa.

Under the climatic conditions of Lucknow one crop could be taken during October - November in the first year, whereas two to three cuttings could be obtained in the subsequent years (Virmani et al., 1977).

Gupta et al. (198[illegible]) have reported that the palmarosa growing in Madhya Pradesh and Maharashtra State forests was usually harvested only once in an year by the end of October or early November.

Experiments conducted on the influence of variety on the herbage yield, oil yield and quality of oil of palmarosa at AMPRS, Odakkaly showed that for ODP-2 four harvests could be obtained at the post blossom period in the first year of planting (Nair et al., 1980 a).

In another study on the influence of spacing on the herbage and oil yields of another variety of palmarosa ODP-1 at AMPRS, Odakkaly two harvests were made in the first year and the number of harvests made in the subsequent three years were respectively four, three and four (Nair et al., 1980 b).

Kanjilal et al. (1981) have reported that they harvested the crop thrice in the first year in an experiment conducted at the Regional Research Laboratory, Jorhat, to study the influence of spacing and nature of planting materials on the yield of palmarosa.

Singh et al. (1981) observed that under the agro-climatic conditions of Jorhat, the crop was harvested at four monthly intervals with three harvests in an year.

Experiments carried out at AMPRS, Odakkaly, showed that six harvests could be taken during the period from April 1979 to April 1980 (Alice, 1982).

Generally two cuttings are made during the first year of planting. From second year onwards three to five cuttings are possible under Kerala conditions (Anon., 1982).

<u>Biochemistry of essential oils</u>

<u>Biosynthesis of monoterpenes</u>

The biosynthesis of monoterpenes appears to be entirely based on the pattern of biosynthesis hypothetically rationalised on the basis of the known chemical structure and reactions well before any biochemical studies were available (Ruzicka, 1953).

The latest findings on biosynthesis of monoterpenes have been excellently reviewed by Akhila and Nigam (1983) wherein they have pointed out that some of the work on monoterpene biosynthesis was invalidated by faulty experimental techniques as radiochemically impure biosynthetic products were used which were later separated by GLC or by TLC. However no attempt was made to purify them. Over the last hundred years isoprene (I) has been identified as the product of thermal decomposition of fragrant and natural compounds of low molecular weight. According to Ruzicka (1953) the vast majority of monoterpenes are formed by "head-to-tail" linkage of isoprene units and this idea was encapsulated in what is called the isoprene rule. The proposed pathways of Ruzicka has been confirmed by later work. The actual reactants may be pyrophosphate esters, glycosides or protein bonded species. Linear combination of isoprene units occurs to give geraniol (II)(C_{10}), Isopentenyl pyrophosphate (IPP), geranyl pyrophosphate (GPP) etc. are involved in the synthesis. Studies have been carried out with labelled precursors and the monoterpenes (of all the main types) have been degraded to elucidate the position of the label. This pattern of work confirms the broad correctness of Rusicka's hypothesis.

The studies on the formation of isothujone, geraniol and nerol in Tanacetum vulgare have shown that GPP is first converted into neryl pyrophosphate (NPP) and then into cyclic terpenes. The interconversion of geraniol and nerol occurs via a redox process involving dephosphorylation and stereospecific oxidation to the corresponding aldehydes (Banthorpe et al., 1978a, b).

Pattern of essential oil formation in Cymbopogons

According to Pridham (1967), certain compounds like sugars and aminoacids are capable of being translocated into the secretary cells which produce the monoterpenes. He has shown that aminoacids like alanine, valine etc. are the possible precursors of monoterpene biosynthesis in plants. It has been also claimed that the precursors of essential oils could be obtained through degradation of carbohydrates and proteins.

Ghosh and Chatterjee (1976) reported that the essential oil content of Cymbopogon flexuosus and Cymbopogon martini were most pronounced during the reproductive stage of development which declined thereafter. Total nitrogen and protein nitrogen contents increased appreciably during pre-reproductive stage of both the species and this trend, continued during the post reproductive stage of the plants. On the contrary total nitrogen and protein nitrogen decreased during the reproductive stage, wheras soluble nitrogen increased appreciably during this period in both the species. During the reproductive stage decomposition of protein may occur and the decomposed products may serve as substrates for essential oil formation. Decrease in total nitrogen and protein nitrogen can be justified by an increase of soluble nitrogen during this period. However, during the pre-reproductive stage, a greater demand of total and protein nitrogen for enhanced growth rate may result in a comparatively lesser degree of essential oil synthesis. During post reproductive stage, as senescence approaches, the nutrients are mobilized into developing fruits, which are likely to disturb the relationship between the decrease in total nitrogen and protein nitrogen and increase in essential oil contents.

Physico-chemical properties of the oil

Physico-chemical properties of the palmarosa oil

The earliest research on the chemical composition of palmarosa oil derived from the true Cymbopogon martini (Stapf var. motia was carried out by Jacobson (1871) who identified an alcohol $C_{10}H_{18}O$ as the main constituent for which he assigned the name geraniol. Later Semmler (1880) confirmed the validity of the formula $C_{10}H_{18}O$ and found that this terpene alcohol belongs to the aliphatic series.

The presence of the following components in palmarosa oil has been reported by Guenther (1950) and attributed to different workers.

Citral, Geranyl acetate, Limonene, Farnesol, Citronellal, Methyl heptenone, Formaldehyde, Dipentene, Isovaleraldehyde, Geranyl-n-Caproate.

About 3 to 15 per cent of geraniol present in Indian palmarosa oil is in the form of acetic and n-caproic esters.

He has further reported that geraniol is a colourless oil, possessing an agreeable rose like odour with the following physical properties.

Density	- $d\ 16_4$ 0.8812
Optical rotation	- $\alpha D \pm 0°$
Refractive index	- $n\ 20_D$ 1.4766

Guenther has also reported that geranyl acetate which is the other major component of palmarosa oil is a colourless liquid, possessing a pleasant fruity odour reminiscent of rose with the following physical properties.

Density	- $d\ 15_4$ 0.9163
Refractive index	- $n\ 20_D$ 1.4655

According to Nabney (1973) the composition of Indian palmarosa oil is given below:

Constituents	Percentage
Myrcene	0.07
Limonene	0.26
Ocimene	0.11
Terpinene	0.35
Methyl heptenone	Trace
Linalool	0.59
Caryophyllene	0.35

Neral	0.24
Geranyl acetate	6.85
Nerol	0.33
Geraniol	88.37
Caryophyllene oxide	Trace

On Gas liquid chromatographic analysis, Mohammed *et al.* (1981) found that the peak number of the constituents of palmarosa oil, their relative retention time and quantity are as follows:

Constituents	Peak No.	Relative retention time	Per cent weight/weight
Limonene	1	0.29	0.1
P-cymene	2	0.29	0.1
Methyl heptenone	3	0.29	0.1
2-Nonanol	4	0.40	0.1
Linalool	5	0.40	2.4
Citronellol	6	0.48	6.4
Farnesene	7	0.57	0.6
β Terpineol	8	0.64	1.0
α Humulene	9	0.74	0.6
α Terpineol	10	0.84	0.4
Geraniol	11	1.00	81.7
Geranyl acetate	12	1.77	5.7
Farnesol	13	2.20	0.4

On analysing 12 samples of oil they found that the geraniol content varied from 65.0 to 84.9 per cent and geranyl acetate varied from 6.4 to 13.0 per cent. Some of the constituents such as limonene, P-cymene, methyl heptenone, 2-nonanol, farnesene β-terpineol, β-humulene, α-terpineol, farnesol etc. were absent in certain samples. They have also reported that apart from determining the major constituents, the presence of the trace constituents like limonene, P-cymene, methyl heptenone, 2-nonalol, linalool, citronellol, farnesene, β-terpineol, humulene, α terpineol and farnesol were also established, which are of great significance in determining the real note, of the Indian variety of palmarosa oil.

Role of physical and chemical methods in the analysis of essential oils

Thappa et al. (1982) were of the opinion that no single method for the evaluation of essential oils can be relied upon. All the analytical/chemical/spectroscopic methods have their advantages as well as disadvantages. Therefore, a suitable combination, of the techniques should be utilised for reproducible results.

Gas Liquid Chromatographic analysis compared to chemical analysis

Alice (1982) reported that the values obtained for geraniol (free alcohol) and geranyl acetate (ester content) by GLC analysis were in conformity with the values obtained by the chemical method. However GLC analysis recorded a slightly low value with regard to the geraniol and geranyl acetate contents.

ISI specification for palmarosa oil

The Indian Standards Institution specifications for b

Indian palmarosa oil (Anon., 1968) are as follows:

Colour	- Light yellow to yellow
Odour	- Rosaceous with a characteristic grassy background
Specific gravity at 30°C	- 0.8740 to 0.8860
Optical rotation	- -2° to +3°
Refractive index at 30°C	- 1.4690 to 1.4735
Acid value	- Maximum 3
Ester value	- 9 to 36 (geranyl acetate 3.1 to 12.5 per cent)
Saponification value after acetylation	- 266 to 284
Total alcohol calculated as geraniol	- Minimum 90 per cent
Solubility	- Soluble in 2 volumes of 70 per cent alcohol.

Influence of nutrients on physico-chemical properties of the oil

Hazarika et al. (1978) found that out of the 16 NPK combinations tried in the experiment on the yield and quality of palmarosa oil at Jorhat, Assam higher geraniol containing oil (75.4 per cent) was obtained by applying N, P and K at 120:0:40 kg/ha. However, the oil yield for the aforesaid fertilizer combination was low. In view of this they considered the NPK combination which recorded the maximum oil yield and fairly high geraniol content (74.8 per cent) to be the optimum dose to get the highest yield of good quality oil. This combination was $N_{60}P_{40}K_{40}$.

The percentage of geraniol with fertilizer applications varied over a wide range from 66.1 to 75.4.

Pareek et al. (1981 a) reported that the quality of oil, in general, was neither improved nor deteriorated by N, P and K treatments either when applied singly or in combination. According to them, the specific gravity of the oil at 30°C varied from 0.8643 to 0.8914, optical rotation ranged from +0.04° to +0.54°, acid value from 0.7 to 6.6. The variation in the contents of geraniol, geranyl acetate and total alcohol calculated as geraniol were from 78.8 to 92.7, 4.5 to 14.1 and from 86.5 to 99.9 per cent respectively.

Singh et al. (1981) observed from a study conducted on the NPK requirements of palmarosa under the agroclimatic conditions of Jorhat that though N had no significant effect on geraniol, application of P and K brought about a positive significant difference in geraniol over control. The geraniol content with different levels of application of N, P and K varied from 64.1 to 65.0, 62.9 to 65.5 and from 63.8 to 65.1 per cent respectively. The geraniol content recorded at higher levels of P and K were respectively 65.5 and 65.1 per cent.

According to Munsi and Mukerjee (1982) the total alcohol content of oil obtained had been influenced by N and P. A gradual increase in total alcohol content had been observed with successively increased doses. Application of N and P_2O_5 at 60 kg each per/ha recorded the highest geraniol content of 90.5 as against 90.3 per cent in the control.

Effect of stage of harvest and different portions of the plant on physico-chemical properties of the oil

Lal (1935) reported that stalks and flowers yield an oil of subnormal quality.

According to Karira and Beri (1966) the quality of oil obtained at the flowering stage was better than that obtained at the late flowering stage. The density of the oil of the 1/3rd top and 2/3rd bottom of the flowering stage at 30°C ranged from 0.8787 to 0.9017 and from 0.8738 to 0.8997 respectively. The corresponding figures at the late flowering stage ranged from 0.8787 to 0.8977 and from 0.8777 to 0.8977. Refractive index of the oil obtained from the late flowering stage was higher than that obtained from the flowering stage. The values of the 1/3rd top and 2/3rd bottom at the flowering stage ranged from 1.467 to 1.468 and from 1.470 to 1.478 respectively and those at the late flowering stage ranged from 1.474 to 1.476 and from 1.476 to 1.482 respectively. Refractive index of the oil of the 2/3rd bottom portion of the plant was higher than that at the 1/3rd top in both the flowering and late flowering stages. Acid value of the oil obtained from the 1/3rd top was higher than that of the 2/3rd bottom portion in both the flowering and late flowering stages. The acid value of the oil obtained at the flowering stage from the 1/3rd top and 2/3rd bottom portions of the plant ranged from 1.0 to 4.5 and from 0.5 to 3.2 respectively. The corresponding figures at the late flowering stage ranged from 1.5 to 4.5 and from 1.0 to 4.0. Saponification value after acetylation of the oil decreased in the late flowering stage. The values recorded in the flowering stage by the 1/3rd top and 2/3rd bottom portion varied from 244.0 to 285.4 and from 241.8 to 279.1 respectively. The corresponding values at the late flowering stage ranged from 219.1 to 259.9 and from 213.0 to 238.1. The total alcohol content of the oil decreased in the late flowering stage and the values obtained in the flowering stage for the 1/3rd top and 2/3rd bottom portions of the plant ranged from 82.2 to 98.3 per cent and from 81.1 to 95.7 per cent respectively and the corresponding figures at the late flowering stage were 72.0 to 87.7 per cent and 69.7 to 79.6 per cent. Geraniol content was higher in the flowering stage than in the late flowering stage. However, the ester content decreased in the late flowering stage.

Virmani et al. (1967) reported from the studies conducted at Haldwani that the refractive index of oil decreased as the duration of harvest increased from 12-14 to 60 weeks. The values varied from 1.4674 to 1.4608. Specific gravity of oil decreased upto 20 weeks. Values recorded at 12-14, 20, 36 and 60 weeks were 0.8795, 0.8770, 0.8811 and 0.8812 respectively. Optical rotation of the oil recorded at 12-14, 20, 36 and 60 weeks intervals were -1.0°, -3.0°, -1.1° and -0.2° respectively. Acid values for the corresponding periods were 0.44, 1.54, 0.56 and 0.43. Saponification values of unacetylated oil recorded at 12-14, 20, 36 and 60 weeks were 58.9, 44.1, 46.7 and 50.8 respectively. Saponification value after acetylation showed no definite trend and the values recorded at the above intervals were 266.6, 278.2, 262.2 and 277.2 respectively. Ester content as geranyl acetate decreased as the interval between harvests increased from 12-14 weeks (20.4 per cent) to 20 weeks (15.4 per cent) and then increased at 36 and 60 weeks (16.3 and 17.7 per cent respectively). Free alcohol content of oil also increased from 12-14 (80.4 per cent) to 20 weeks (86.4 per cent) and then decreased to 76.2 per cent at 60 weeks.

Gupta et al. (1978) reported that a higher percentage of free alcohol calculated as geraniol was observed in the oil of leaves as compared to the exclusively flower crop and composite flower and leaf crop. The oil of leaves was stated to possess the best odour with good fruity smell and least terpenic note, while the oil of flower contained terpenic note on account of higher ester content in the oil and was given a lower rank for perfumary purpose. The physico-chemical properties reported by the above workers for oil of leaves were specific gravity 0.8759, refractive index 1.4725, optical rotation +0.40°, geranyl acetate

14.6 - 21.9 per cent, free alcohol 72.0 to 73.0 per cent and total alcohol 89.2 to 91.4 per cent. For the oil of flower they obtained a specific gravity 0.8785, refractive index 1.4709, optical rotation +0.50°, geranyl acetate 23.3 to 38.3 per cent, free alcohol 50.0 to 62.8 per cent and total alcohol 80.3 to 85.9 per cent.

Based on the experiments conducted at AMPRS, Odakkaly, Nair et al. (1980 a) reported that the specific gravity of the oil at full flowering stage of ODP-2 was 0.8823, optical rotation 0°, refractive index 1.4692, geranyl acetate 16.3 per cent and total alcohols calculated as geraniol 92.3 per cent. They have also reported that the plants were distilled after the full flowering stage of the crop and that this may be the reason for the high ester value. But they had also noted that variety ODP-2 flowered earlier than ODP-1 and at the time of harvest, the harvested material from ODP-2 contained more of the inflorescence. Though reported literature generally is in favour of higher ester content for oil from harvests containing inflorescence, the reverse was observed in the present study. This might be due to varietal character.

In a study conducted on the quantitative changes induced by low dose gamma irradiation in essential oil of palmarosa, Gupta et al. (1981) found that the density at 30°C of oil from leaves varied from 0.8910 to 0.9036 and that of inflorescence varied from 0.8879 to 0.9013. Refractive index at 30°C of oil obtained from leaves varied from 1.4728 to 1.4734 and that of oil obtained from inflorescence varied from 1.4721 to 1.4726. Acid value of oil from leaves and inflorescence varied from 1.59 to 3.82 and from 2.77 to 6.63 respectively. Geraniol content of the oil of leaves and inflorescence varied from 69.4 to 77.5 per cent and from 64.0 to 73.0 per cent respectively. Total alcohol of oil of leaves and inflorescence ranged from 73.9 to 83.2 per cent and from 68.1 to 79.2 per cent. Geranyl acetate of the oil of leaves and inflorescence varied from 5.7 to 8.5 per cent, and from 5.1 to 9.2 per cent respectively.

Pareek et al. (1981 b) reported that the specific gravity of oil was lowest at the vegetative phase (0.8722) and highest at the commencement of flowering (0.9030) and it showed a downward trend from commencement of flowering to late seeding stage (0.8821). Optical rotation of the oil also increased from vegetative phase (+0.43) to the commencement of flowering (+0.52) and thereafter it decreased. Refractive index of the oil was lowest at the vegetative stage (1.4676) and in all other stages it was higher and the values at commencement of flowering, full bloom stage, and the early seeding and late seeding stages were 1.4723, 1.4731, 1.4727 and 1.4724 respectively. Acid value of the oil showed no definite trend either to increase or decrease with increase in the intervals of harvest and the values recorded varied from 3.5 to 6.2. The highest value for geranyl acetate was recorded at commencement of flowering (21.3 per cent) and it decreased progressively to 6.5 per cent at the late seeding stage. Geraniol content first decreased from 72.9 per cent at vegetative phase to 70.6 per cent at commencement of flowering and thereafter it increased progressively to 87.5 per cent at late seeding stage. Concentration of terpenes and linalool also was highest at the commencement of flowering. In all other stages it recorded a lower value. Evaluation of the oil samples for odour showed that the oil at early seed formation stage was best in quality, with a rosaceous green odour. It has been observed that the oil will possess an undesirable note when the higher terpenic and geranyl ester is accompanied by a low percentage of geraniol. Therefore, it is necessary that the oil should have low terpenic and ester portions and high geraniol content for good odour value and consequent superiority in quality.

From an experiment conducted to find out the influence of different portions of palmarosa plant namely the inflorescence, 2/3rd top and 1/3rd bottom portions of the plant after removing the inflorescence and the whole plant on the quantity and quality of oil at the AMPRS, Odakkaly (Alice, 1982) observed that specific gravity of oil of the inflorescence, 2/3rd top, 1/3rd bottom and whole plant were 0.8876, 0.8864, 0.8857 and 0.8867 respectively. Optical rotation of the oil was +0.3° irrespective of the treatment tried in the study. Refractive index of the oil obtained from different portions showed significant variation. The lowest value was recorded by the flower top (1.4701) and it was not significantly different from that of the whole plant (1.4702). The maximum value was recorded by the 1/3rd bottom portion (1.4705) and it was on par with the 2/3rd top (1.4704). As regards the solubility of the oil obtained from different portions of the plant there was no significant difference between the treatments. Oil obtained from different portions of the plant showed acid values of significant variation. The lowest value was recorded with the whole plant (2.76) and it was on par with that of the 1/3rd bottom portion (2.87). There was no significant difference between flower top (3.40) and 2/3rd top (3.23). However, they varied significantly from the whole plant and 1/3rd bottom portion of the plant. Ester value followed the same trend as that of the saponification value for unacetylated oil. The lowest value for ester content was recorded by 1/3rd bottom (17.8 per cent) followed by 2/3rd top (18.1 per cent) whole plant (21.4 per cent) and the flower top (21.5 per cent). The saponification value after acetylation of oil also showed significant variation among treatments. The highest value was recorded with the 2/3rd top portion (273.6) followed by whole plant (271.6), 1/3rd bottom portion (270.0) and the flower top (264.2). The treatments differed significantly with regard to the free alcohol content of the oil and the 2/3rd top portion ranked first with a value of 76.8 per cent followed by 75.6 per cent for the 1/3rd bottom, 72.7 per cent for the whole plant and 69.7 per cent for the flower top. Combined alcohol also showed significant variation with varying treatments and the flower top topped the list with a value of 16.9 per cent closely followed by the whole plant (16.8 per cent). Though there was no significant difference between the combined alcohol content of oil obtained from the flower top and the whole plant they varied significantly from other treatments and the values recorded with the 2/3rd top and 1/3rd bottom portions were 15.5 and 15.1 per cent, respectively. Total alcohol content showed significant variation. The highest percentage was recorded with the 2/3rd top (91.0 per cent) and the lowest with the flower top (86.6 per cent). Whole plant (89.4 per cent) and 1/3rd bottom portion (88.3 per cent) were on par.

Effect of method of extraction of oil and soil and climate on the quality of oil

Effect of method of extraction of the oil

According to Guenther (1950) the ester content of Indian palmarosa oil is low and this may partly be due to the hydrolysis of esters taking place by the crude methods employed for distillation of the herbage by the farmers. He has also reported that the oil produced in Java from introduced Indian grass was different from the usual commercial oil produced in India itself. Javanese oil contained a much higher ester content. He attributed this to both differences in the environment under which the grasses were grown and superior and cleaner methods of distillation followed in Java.

Effect of soil and climate

The ester value is usually reported to be high for summer harvest in May-June (Anon., 1968).

Analysis of essential oil of palmarosa from different tracts in Maharashtra and Madhya Pradesh was carried out by Gupta et al. (1980). They found that the oil showed much variability with regard to their geraniol and geranyl acetate contents, and the tract having a cooler climate at harvest time produced oil of superior quality. They concluded that palmarosa grass yielding more herbage with higher oil content of superior quality occur in forest ranges where soil is comparatively medium in texture, rich in nutrients and climate is cool at harvest time. They also found that the oil from these tracts showed much variability with regard to their physical and chemical properties. The ranges obtained in the physical properties were: specific gravity 0.8702 to 0.9174, refractive index

1.4712 to 1.4787; optical rotation -0.05° to +0.60°; linalool 1.0 - 5.1 per cent; geranyl acetate 2.0 - 24.5 per cent and geraniol 59.6 - 93.4 per cent.

The mineral nutrition of plants

Effect of different levels of nitrogen, phosphorus and potassium on nutrient contents and uptake by palmarosa

Chandra (1978) found that palmarosa grown in saline alkaline soils, contained Na, Ca and K at 1.2, 0.6 and 0.6 per cent, respectively.

Munsi and Mukherjee (1982) reported higher accumulation of N in plants grown under increased levels of N and P. The maximum concentration of N was noted in plants treated with the highest level of both N and P. The effect of N was more pronounced than that of P. Nitrogen concentration increased from 1.49 in the control to 2.09 per cent in the highest level of N tried i.e. N_{90}. Increased levels of N increased the content of P and K also. Phosphorus content of plants also increased progressively with increase in levels of N and P. The P content of plants varied from 0.167 to 0.221 per cent. Potassium content was also markedly influenced by N and P and its concentration increased with increase in the levels of both N and P. The maximum assimilation of K was observed under the treatment N_{80} P_{80} and its content varied from 1.94 to 2.06 per cent.

Pareek et al. (1983) found that application of N at 40 kg/ha increased the contents of K, Ca, Mg, and Mn and Zn in the palmarosa crop by 5.4, 11.3, 6.7, 5.5, 3.5 and 10.3 per cent respectively over control, but the results were statistically significant only for K, Mg, Mn and Zn. The contents of P and S were not affected by N applications. On increasing the level of N to 80 kg/ha, there was a relative decrease in the percentage of the listed elements but the difference was not significant between the two N levels. Application of P_2O_5 and K_2O each at 40 kg/ha did not bring about any significant change in nutrient contents and the uptake of the nutrients by the palmarosa crop. But increase in the levels of P_2O_5 and K_2O increased slightly the Ca and Mg contents. The mean values recorded for N, P, K, Ca, Mg and S were 0.28, 0.07, 0.66, 0.33, 0.17 and 0.19 per cent respectively and the contents of Mn and Zn were 88.0 and 3.08 ppm respectively. Application of 40 kg N/ha resulted in significantly higher uptake of N, P, K, Ca, Mg, S, Mn and Zn by 35.3, 24.6, 42.8, 36.9, 35.4, 20.2, 31.5 and 14.8 per cent respectively over control. Higher levels of N at 80 kg/ha though showed a higher uptake value as compared to control but in comparison with 40 kg the difference between the N levels was statistically not significant. Application of P_2O_5 and K_2O each at 40 kg/ha did not bring about any change in the uptake of nutrients by the palmarosa crop. These authors have also reported that the uptake of K is sizeable and it increased with increase in the herbage yield. An average production of 108 q/ha of dry grass (obtained in one of the three harvests) containing 1.0 per cent essential oil removed 31.6, 7.4 and 75.0 kg of N, P, K, 34.8, 20.6 and 20.6 kg of Ca, Mg and S and 0.9 and 0.034 kg per hectare of Mn and Zn respectively from medium fertile soil.

Effect of different growth stages on nutrient contents of palmarosa

Anjali (1982) reported that the NPK content of palmarosa was high at young and immature stages and decreased with increasing maturity, as the moisture percentage decreased. The nitrogen content of very young leaves, young leaves, mature leaves, old leaves, stems and roots with rhizomes were 2.50, 2.80, 1.80, 1.87, 1.67 and 1.20 per cent respectively on moisture free basis.

Potassium content of these plant parts were 1.8, 1.3, 0.88, 0.60, 1.22 and 0.20 per cent, respectively on dry weight basis. The corresponding P and Ca percentages were respectively 0.25, 0.22, 0.20, 0.12, 0.20, 0.05 and 1.3, 0.4, 0.8, 1.26, 0.30 and 0.10.

Effect of different levels of nitrogen, phosphorus and potassium on nutrient contents and uptake in other essential oil yielding plants belonging to other species of Cymbopogon

Based on the experiments conducted at Bangalore on Java citronella, another essential oil yielding crop of

Cymbopogon species Bommegowda (1978) reported that increase in the levels of N application from 75 to 150 kg/ha/harvest increased the N uptake by the plants in each harvest and that this increase was directly related to the total herbage and per cent composition of N in the herbage. Increase in the levels of N did not increase the P content in the plant, but the uptake of P increased significantly and this was mainly due to the increased herbage yield through N nutrition. Similarly increase in the levels of N application did not increase the K content in the plant, but the total uptake increased significantly from 352 to 532 kg/ha in five harvests.

With increase in the levels of K_2O from 42 to 82 kg/ha/harvest the per cent composition of N in the herbage increased slightly in all harvests but not significantly. The uptake values also showed no significant difference. Due to increase in the levels of K_2O the per cent composition of P_2O_5 in the herbage as well as its uptake did not vary. Likewise, the K_2O per cent in the herbage and its uptake did not vary with the levels of K. He has also reported that a Java citronella crop producing 5 to 7 tonnes of dry matter per harvest removed 40 to 70 kg N, 15 to 35 kg P_2O_5 and 60 to 140 kg K_2O per hectare in each harvest.

Based on an experiment conducted at AMPRS, Odakkaly Rajan (1982) reported that increase in N levels increased the N content of lemongrass, *Cymbopogon flexuosus*. There was a decreasing trend in the P content with higher levels of N, but the K content was not affected by N treatment.

<u>Influence of interval of harvests on nitrogen, phosphorus, potassium, calcium and magnesium contents of fodder grasses</u>

Widening the interval between harvests was found to decrease the percentages of N, P, K, Ca and Mg in guinea and hybrid napier grasses (Vicente-Chandler, 1959). Vilaipol (1967) concluded that decreased cutting frequency reduced the contents of P and Ca in hybrid napier. Kothandaraman et al. (1973) reported decrease in the P and K contents and an increase in Ca and Mg contents of guinea grass when the cutting interval was increased from 30 to 60 days.

Thomas (1978) also reported decrease in N, P, K and Ca contents of guinea and hybrid napier grasses with increase in cutting intervals from 30 to 45 days.

A similar finding of decrease of nitrogen with increase in the cutting interval has been reported by Kanodia et al. (1981) for Dhawlu grass.

MATERIALS AND METHODS

MATERIALS AND METHODS

Field experiments

A major field experiment was conducted in the Aromatic and Medicinal Plants Research Station, Odakkaly during 1980-'82. In this experiment the growth and yield characters of palmarosa and its composition as well as the quality parameters of the oil for various treatments were studied in detail. The experiment was continued for another two years during 1982-'84 restricting the observations to the major parameters viz., yield of herbage and oil. Based on the results of the major experiment an observation trial was also conducted during 1983-'84 with even longer cutting intervals to arrive at the most suitable interval for harvests.

All these field studies were conducted in the AMPRS, Odakkaly, Kerala Agricultural University during the period from 1980 to 1984. The Station is situated at an elevation of 66 m above MSL with an average annual rainfall of 3600 mm with around 160 rainy days in an year.

The field studies are described under three sections namely the main field experiment, the observations made on the field experiment beyond the originally contemplated experimental period of two years and the observation trial conducted to verify and confirm the results of the main field experiment.

Plate 1. "A CROP OF PALMAROSA"

Main field experiment

The site selected for the main field experiment was cultivated with a bulk crop of palmarosa from 1975 onwards wherein only recycling of organic matter in the form of spent grass had been resorted to as part of the manuring schedule.

Soil analysis

The soil of the experimental site was lateritic clay loam with the following mechanical and chemical composition.

Mechanical composition

Coarse sand	25.6 per cent
Fine sand	20.2 ,,
Silt	20.2 ,,
Clay	34.0 ,,

Chemical characteristics

Total N	0.102 per cent
Total P_2O_5	0.082 ,,
Total K_2O	0.212 ,,
Total CaO	0.208 ,,
Total MgO	0.085 ,,
Available N	286 kg/ha
Available P_2O_5	15.11 kg/ha
Available K_2O	174.24 ,,
pH (Soil:Water ratio 1:2.5)	5.9

Season and climate

The experiment was started in the month of May 1980 and continued upto March 1982. The meteorological data for the above period are presented in Appendix I.

Planting materials

Seedlings of an improved variety of palmarosa grass developed at the Central Institute of Medicinal and Aromatic Plants, Haldwani was used for the present investigation. This variety has been found to come up well under the agroclimatic conditions of Kerala and it has been released as a variety from this station under the name ODP-2. Seeds were sown in the nursery on the 4th May, 1980 and 69 to 72 day old seedlings were used for transplanting in the main field.

Experimental details

The treatments consisted of three levels each of N, P and K and six intervals of harvest (H) and their combinations thereof. The design was 3^3x6 confounded asymmetrical factorial in 18 plot blocks in single replication for the four factors, N, P, K and H. Being an asymmetrical factorial, the block contents were determined by converting into a symmetrical factorial experiment by introducing two pseudo factors X_1 and X_2 with respect to H and then omitting the unwanted treatment combinations used to design the experiment. The confounded effects were NPK^2, NKH^2, NP^2H and PKH. The treatment details were as given below:

Levels of nitrogen

n_1	:	25 kg N/ha/year
n_2	:	50 ,,
n_3	:	75 ,,

Levels of phosphorus

p_1	:	25 kg P_2O_5/ha/year
p_2	:	50 ,,
p_3	:	75 ,,

Levels of potassium

k_1	:	25 kg K_2O/ha/year
k_2	:	50 ,,
k_3	:	75 ,,

Intervals of harvest

h_1	:	Harvesting at 35 - 40 days interval
h_2	:	,, 40 - 45 ,,
h_3	:	,, 45 - 50 ,,
h_4	:	,, 50 - 55 ,,
h_5	:	,, 55 - 60 ,,
h_6	:	,, 60 - 65 ,,

Justification for fixing the treatments

N, P and K levels were fixed based on the responses obtained by the crop elsewhere in the country.

The oil produced at AMPRS, Odakkaly from the crop harvested at full flowering stage usually contained a higher acetate content above the limits fixed by the Indian

Standards Institution. Several workers have reported that the acetate content of the leaves harvested at the time of flowering are low compared to that of the inflorescence. Hence the harvest treatments were fixed with a decreased number of days between harvests with a minimum of 35-40 days and a maximum of 60-65 days when the crop will be at full flowering stage.

Treatment combinations

1. $n_1\ p_1\ k_1\ h_1$
2. $n_1\ p_1\ k_1\ h_2$
3. $n_1\ p_1\ k_1\ h_3$
4. $n_1\ p_1\ k_1\ h_4$
5. $n_1\ p_1\ k_1\ h_5$
6. $n_1\ p_1\ k_1\ h_6$
7. $n_1\ p_1\ k_2\ h_1$
8. $n_1\ p_1\ k_2\ h_2$
9. $n_1\ p_1\ k_2\ h_3$
10. $n_1\ p_1\ k_2\ h_4$
11. $n_1\ p_1\ k_2\ h_5$
12. $n_1\ p_1\ k_2\ h_6$
13. $n_1\ p_1\ k_3\ h_1$
14. $n_1\ p_1\ k_3\ h_2$
15. $n_1\ p_1\ k_3\ h_3$
16. $n_1\ p_1\ k_3\ h_4$
17. $n_1\ p_1\ k_3\ h_5$
18. $n_1\ p_1\ k_3\ h_6$
19. $n_1\ p_2\ k_1\ h_1$
20. $n_1\ p_2\ k_1\ h_2$
21. $n_1\ p_2\ k_1\ h_3$
22. $n_1\ p_2\ k_1\ h_4$
23. $n_1\ p_2\ k_1\ h_5$
24. $n_1\ p_2\ k_1\ h_6$
25. $n_1\ p_2\ k_2\ h_1$
26. $n_1\ p_2\ k_2\ h_2$
27. $n_1\ p_2\ k_2\ h_3$
28. $n_1\ p_2\ k_2\ h_4$
29. $n_1\ p_2\ k_2\ h_5$
30. $n_1\ p_2\ k_2\ h_6$
31. $n_1\ p_2\ k_3\ h_1$
32. $n_1\ p_2\ k_3\ h_2$
33. $n_1\ p_2\ k_3\ h_3$
34. $n_1\ p_2\ k_3\ h_4$
35. $n_1\ p_2\ k_3\ h_5$
36. $n_1\ p_2\ k_3\ h_6$
37. $n_1\ p_3\ k_1\ h_1$
38. $n_1\ p_3\ k_1\ h_2$
39. $n_1\ p_3\ k_1\ h_3$
40. $n_1\ p_3\ k_1\ h_4$
41. $n_1\ p_3\ k_1\ h_5$
42. $n_1\ p_3\ k_1\ h_6$
43. $n_1\ p_3\ k_2\ h_1$
44. $n_1\ p_3\ k_2\ h_2$
45. $n_1\ p_3\ k_2\ h_3$
46. $n_1\ p_3\ k_2\ h_4$
47. $n_1\ p_3\ k_2\ h_5$
48. $n_1\ p_3\ k_2\ h_6$
49. $n_1\ p_3\ k_3\ h_1$
50. $n_1\ p_3\ k_3\ h_2$
51. $n_1\ p_3\ k_3\ h_3$
52. $n_1\ p_3\ k_3\ h_4$
53. $n_1\ p_3\ k_3\ h_5$
54. $n_1\ p_3\ k_3\ h_6$

55. $n_2\ p_1\ k_1\ h_1$
56. $n_2\ p_1\ k_1\ h_2$
57. $n_2\ p_1\ k_1\ h_3$
58. $n_2\ p_1\ k_1\ h_4$
59. $n_2\ p_1\ k_1\ h_5$
60. $n_2\ p_1\ k_1\ h_6$
61. $n_2\ p_1\ k_2\ h_1$
62. $n_2\ p_1\ k_2\ h_2$
63. $n_2\ p_1\ k_2\ h_3$
64. $n_2\ p_1\ k_2\ h_4$
65. $n_2\ p_1\ k_2\ h_5$
66. $n_2\ p_1\ k_2\ h_6$
67. $n_2\ p_1\ k_3\ h_1$
68. $n_2\ p_1\ k_3\ h_2$
69. $n_2\ p_1\ k_3\ h_3$
70. $n_2\ p_1\ k_3\ h_4$
71. $n_2\ p_1\ k_3\ h_5$
72. $n_2\ p_1\ k_3\ h_6$
73. $n_2\ p_2\ k_1\ h_1$
74. $n_2\ p_2\ k_1\ h_2$
75. $n_2\ p_2\ k_1\ h_3$
76. $n_2\ p_2\ k_1\ h_4$
77. $n_2\ p_2\ k_1\ h_5$
78. $n_2\ p_2\ k_1\ h_6$
79. $n_2\ p_2\ k_2\ h_1$
80. $n_2\ p_2\ k_2\ h_2$
81. $n_2\ p_2\ k_2\ h_3$
82. $n_2\ p_2\ k_2\ h_4$
83. $n_2\ p_2\ k_2\ h_5$
84. $n_2\ p_2\ k_2\ h_6$
85. $n_2\ p_2\ k_3\ h_1$
86. $n_2\ p_2\ k_3\ h_2$
87. $n_2\ p_2\ k_3\ h_3$
88. $n_2\ p_2\ k_3\ h_4$
89. $n_2\ p_2\ k_3\ h_5$
90. $n_2\ p_2\ k_3\ h_6$
91. $n_2\ p_3\ k_1\ h_1$
92. $n_2\ p_3\ k_1\ h_2$
93. $n_2\ p_3\ k_1\ h_3$
94. $n_2\ p_3\ k_1\ h_4$
95. $n_2\ p_3\ k_1\ h_5$
96. $n_2\ p_3\ k_1\ h_6$
97. $n_2\ p_3\ k_2\ h_1$
98. $n_2\ p_3\ k_2\ h_2$
99. $n_2\ p_3\ k_2\ h_3$
100. $n_2\ p_3\ k_2\ h_4$
101. $n_2\ p_3\ k_2\ h_5$
102. $n_2\ p_3\ k_2\ h_6$
103. $n_2\ p_3\ k_3\ h_1$
104. $n_2\ p_3\ k_3\ h_2$
105. $n_2\ p_3\ k_3\ h_3$
106. $n_2\ p_3\ k_3\ h_4$
107. $n_2\ p_3\ k_3\ h_5$
108. $n_2\ p_3\ k_3\ h_6$

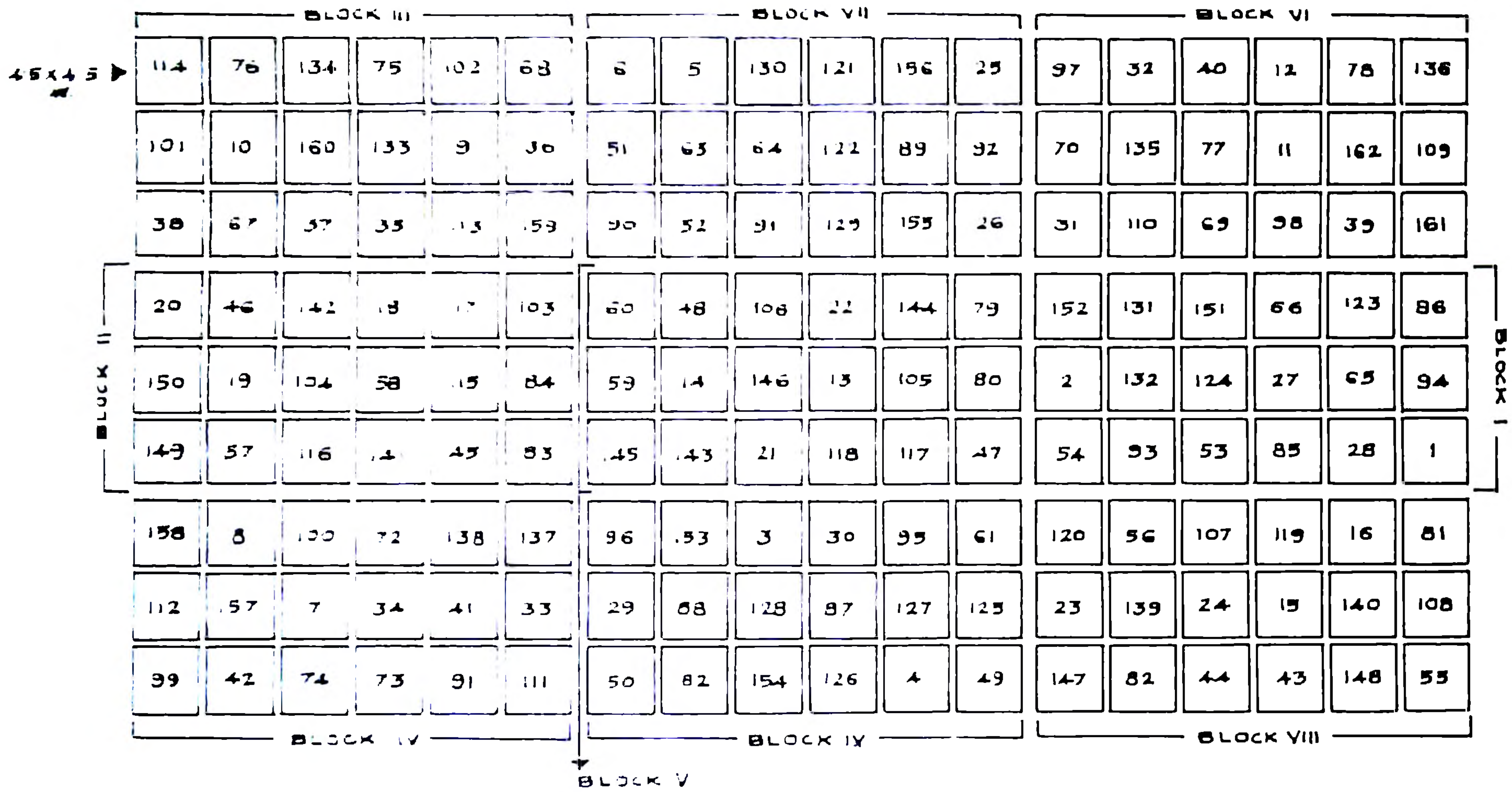
109. $n_3\ p_1\ k_1\ h_1$
110. $n_3\ p_1\ k_1\ h_2$
111. $n_3\ p_1\ k_1\ h_3$
112. $n_3\ p_1\ k_1\ h_4$
113. $n_3\ p_1\ k_1\ h_5$
114. $n_3\ p_1\ k_1\ h_6$
115. $n_3\ p_1\ k_2\ h_1$
116. $n_3\ p_1\ k_2\ h_2$
117. $n_3\ p_1\ k_2\ h_3$
118. $n_3\ p_1\ k_2\ h_4$
119. $n_3\ p_1\ k_2\ h_5$
120. $n_3\ p_1\ k_2\ h_6$
121. $n_3\ p_1\ k_3\ h_1$
122. $n_3\ p_1\ k_3\ h_2$
123. $n_3\ p_1\ k_3\ h_3$
124. $n_3\ p_1\ k_3\ h_4$
125. $n_3\ p_1\ k_3\ h_5$
126. $n_3\ p_1\ k_3\ h_6$
127. $n_3\ p_2\ k_1\ h_1$
128. $n_3\ p_2\ k_1\ h_2$
129. $n_3\ p_2\ k_1\ h_3$
130. $n_3\ p_2\ k_1\ h_4$
131. $n_3\ p_2\ k_1\ h_5$
132. $n_3\ p_2\ k_1\ h_6$
133. $n_3\ p_2\ k_2\ h_1$
134. $n_3\ p_2\ k_2\ h_2$
135. $n_3\ p_2\ k_2\ h_3$
136. $n_3\ p_2\ k_2\ h_4$
137. $n_3\ p_2\ k_2\ h_5$
138. $n_3\ p_2\ k_2\ h_6$
139. $n_3\ p_2\ k_3\ h_1$
140. $n_3\ p_2\ k_3\ h_2$
141. $n_3\ p_2\ k_3\ h_3$
142. $n_3\ p_2\ k_3\ h_4$
143. $n_3\ p_2\ k_3\ h_5$
144. $n_3\ p_2\ k_3\ h_6$
145. $n_3\ p_3\ k_1\ h_1$
146. $n_3\ p_3\ k_1\ h_2$
147. $n_3\ p_3\ k_1\ h_3$
148. $n_3\ p_3\ k_1\ h_4$
149. $n_3\ p_3\ k_1\ h_5$
150. $n_3\ p_3\ k_1\ h_6$
151. $n_3\ p_3\ k_2\ h_1$
152. $n_3\ p_3\ k_2\ h_2$
153. $n_3\ p_3\ k_2\ h_3$
154. $n_3\ p_3\ k_2\ h_4$
155. $n_3\ p_3\ k_2\ h_5$
156. $n_3\ p_3\ k_2\ h_6$
157. $n_3\ p_3\ k_3\ h_1$
158. $n_3\ p_3\ k_3\ h_2$
159. $n_3\ p_3\ k_3\ h_3$
160. $n_3\ p_3\ k_3\ h_4$
161. $n_3\ p_3\ k_3\ h_5$
162. $n_3\ p_3\ k_3\ h_6$

The layout plan of the experiment is shown in Fig. 1.

.ig. -.   Lay out of the field experiment

Fig. 1

LAY OUT OF EXPERIMENT



PLOT SIZE - 4.5 x 4.5 M.

NUMBER OF BEDS PER PLOT - 3

BED SIZE - 1.2 x 4.5 M

INTER SPACE BETWEEN BEDS - 45 cm

INTERSPACE BETWEEN PLOTS - 50 cm.

INTERSPACE BETWEEN BLOCKS - 1 m.

SPACING BETWEEN PLANTS - 30 x 30 cm.

Preparatory cultivation

The experimental field was thoroughly prepared to get uniform condition and laid out into 9 blocks, each with 18 plots. Then the individual plots were once again dug and levelled. Three raised beds of 1.2 x 4.5 m were prepared in each plot with an inter space of 45 cm between beds.

Fertilizers and fertilizer application

The fertilizers used in this experiment were urea (46 per cent N), single superphosphate (16 per cent P_2O_5) and muriate of potash (60 per cent K_2O).

During the first year, the full doses of P_2O_5 and K_2O and one-third dose of N were applied as basal dose. The remaining quantity of N was applied in two split doses, one-third N after the first harvest and the remaining one-third after the second harvest.

In the second year, the full dose of P_2O_5 and K_2O and one-third N were applied after the first uniform harvest in all plots. The remaining N was applied in two equal doses one each after the second and third harvests.

Planting

Healthy 69 to 72 day old seedlings were planted at the rate of two seedlings per hill. Planting which was started on 11th July, 1980 was completed on 14th July, 1980. Seedlings which exhibited poor growth in the main field were removed after two weeks and planted with fresh seedlings.

Interculture and weeding

Weeds were removed before top dressing with N and earthing up was done once during a year. It was done in the month of September in the first year and in July in the second year. Spent lemongrass at the rate of five t/ha was applied as a mulch to prevent weed growth after the first weeding in both the years but before earthing up in all the experimental plots. The N, P and K contents of spent lemongrass were 1.13, 0.088 and 1.01 per cent respectively.

Plant protection Nil

Harvest

The first harvest of the herbage of all the treatments was done 85 days after planting when the crop was at full flowering and subsequent harvests were made at intervals of 35-40, 40-45, 45-50, 50-55, 55-60 and 60-65 days as per treatments. As far as possible harvests were done at 40, 45, 50, 55, 60 and 65 day intervals respectively for h_1, h_2, h_3, h_4, h_5 and h_6 treatments. In summer months no harvests were taken from the last week of February onwards till the onset of monsoon and establishment of good growth. This was necessitated since the crop was grown under rainfed conditions.

In the second year, a uniform harvest was made with the onset of monsoon in April for all the treatments and thereafter the harvests were made at the specified intervals.

The herbage was cut from all the plants in the plot except those plants left for collection of plant samples for chemical analysis. The fresh weight of the herbage was recorded immediately after harvest. The plants tag-marked for chemical analysis were separately harvested initially before the plot-wise harvest.

The essential oil content was determined on fresh weight basis by steam distillation. The distillation was conducted treatment wise in small stills installed for experimental purpose. The oil obtained after distillation was further clarified to make it free of sediments and water drops before the quantity was measured. The oil from each plot was measured and kept in amber coloured bottles with tight fitting corks for physico-chemical analysis.

Observations

Growth characters

For recording growth characters twelve plants were selected from each plot at random and the observations were taken on the day previous to each harvest.

1. Total tillers

The total number of tillers per clump of the selected plants was recorded.

2. Plant height

Height of the plant from the ground level to the top of the longest tiller was measured.

3. Length of inflorescence

The length of the inflorescence was measured from the point of sheath union of boot leaf to the tip of the inflorescence.

4. Number of tillers with inflorescence

The number of tillers per clump that had inflorescence by the time of the harvest was recorded.

5. Number of tillers without inflorescence

The number of tillers without inflorescence per clump was noted.

Yield characters

1. Herbage yield from plant

The weight of the herbage of the selected plants separately harvested for chemical analysis was recorded as and when they were harvested.

2. Herbage yield per hectare

The herbage yield from each plot was noted immediately after harvest and the yield per hectare calculated.

3. Dry matter yield

The samples from each harvest of tag-marked plants meant for chemical analysis of herbage were first sundried and then ovendried at 80°C to constant weight. The dry matter yield from each plot was computed for each harvest using this dry matter percentage.

4. Oil yield

The oil yields in l/ha and kg/ha were calculated from the yield of oil from each plot.

5. The essential oil content

The quantity of oil obtained from each treatment was used for working out the oil content (volume of oil/weight of herbage) on the fresh weight basis of the herbage.

Continuation of the field experiment during 1982 to 1984

The layout of the plants originally planted in 1980 was maintained for another two year period beyond the originally contemplated experimental period restricting the observations to the major factors, viz., the yield of herbage and yield of oil. All manurial treatments and harvest intervals as adopted in the field experiment of the first two years (1980-'82) were continued during the 1982-'84 period also.

Observation trial

As stated earlier an observation trial with nine cutting intervals was conducted during 1983-'84. For this a bulk crop which had been planted in an adjoining period in 1980 along with the crop in the main experiment was used. The cutting intervals were 55, 65, 75, 85, 95, 105, 115, 125 and 135 days and harvests were conducted at these intervals from the month of May 1983 onwards.

Physical properties and chemical constituents of the oil

Details of oil samples used

The oil yield obtained from many of the treatments of the main field experiment during the first year was insufficient for the estimation of all the physical properties and analysis of chemical constituents by conventional chemical methods. The quantities were sufficient only for the determination of chemical constituents by Gas Liquid Chromatography. The GLC was conducted on the pooled samples from each plot.

For conducting chemical analysis and determining the physical properties during the second year, the samples of the oil collected from different harvests of a treatment during the monsoon season (May to September) were pooled separately as distinct from those of the summer season (October to February). The samples so obtained were examined for all important physical parameters and chemical constituents by standard analytical procedures. The oil collected in the summer season was analysed by GLC also.

The oil samples obtained from the observational trial were also similarly analysed for physical and chemical parameters.

Physical properties

Physical properties such as specific gravity, refractive index, optical activity and solubility in 70 per cent alcohol were determined by the methods prescribed by ISI (Anon., 1968).

Chemical properties and chemical constituents

Acid value, saponification value, ester value, ester content, saponification value after acetylation, total alcohol calculated as geraniol, free alcohol and combined alcohol were determined by the ISI methods.

The geraniol and geranyl acetate contents were also determined by the GLC method as already indicated. During the first year, the GLC analysis was carried out using a gas chromatograph (Model No.S.17410) of the Chromatography and Instruments Company, Baroda. The oil (0.2 μ ml) was injected into the Gas Chromatograph fitted with SE-30 three m long column, flame ionisation detector and potentiometric strip chart recorder. Nitrogen was used as the carrier gas. The operating conditions were:- oven temperature 160°C, attenuation 526, hydrogen one kg/cm^2 and chart speed one cm/minute.

In the second year GLC analysis was conducted using a Hewlitt Packard 5840 gas chromatograph. The carrier gas used was nitrogen, flow rate 20 ml/min, column:carbowax 20 M, Isothermal condition 100°C and FID temperature 250°C or 270°C.

The compounds were identified by comparing their retention times with those of authentic reference samples. In the gas chromatograph (Model No.S 17410) of Chromatography and Instruments Company, Baroda, the percentage of each constituent was calculated by assessing the peak area by the triangle method. In the Hewlitt Packard 5840 Gas chromatograph, the percentage of geraniol and geranyl acetate were recorded automatically.

Analysis of soil samples

Mechanical composition of the soil was determined by the International Pipette Method (Piper, 1950).

Total N was determined by the microkjeldahl method (Jackson, 1967) and available N by alkaline permanganate method (Subbiah and Asija, 1956).

Total P_2O_5 and total K_2O in the soil were determined using standard procedures as outlined by Jackson (1967). Available P_2O_5 was determined by Bray's No.1 method (Jackson, 1967) and available K_2O was estimated by using EEL flame photometer. Total Ca and Mg were determined in the hydrochloric acid extract using an Atomic Absorption Spectrophotometer.

Analysis of plant samples

The plant samples were dried in an oven at 80°C and ground in a Wiley Mill.

The total N content of the samples was determined by the modified microkjeldahl method (Jackson, 1967).

Phosphorus, potassium, calcium and magnesium were determined in the triple acid extract of the plant material. Phosphorus was determined by the Vanado-molybdo-phosphoric yellow colour methods (Jackson, 1967). Potassium was determined by using EEL flame photometer and calcium and magnesium were estimated in the extract by the versenate titration method as given by Cheng and Bray (1951).

Statistical analysis

Analysis of variance

The main effects of each factor and their interaction effects were studied for each character by the analysis of variance technique for a $3^3 \times 6$ confounded factorial experiment (Cochran and Cox, 1965). The split up of the degrees of freedom for main effects and interaction effects is given below.

Sources	df
Block	8
N	2
P	2
K	2
NP	4
NK	4
PK	4
H	5
NH	10
PH	10
KH	10
NPK	2
NP^2K	2
NP^2K^2	2
Error	94

The mean values for various levels of each treatment and also their combinations were compared with critical differences (CD) where

$$\text{C.D.} = t_{0.05}(94) \sqrt{\frac{2\text{MSE}}{\text{Effective number of replication}}}$$

and MSE = SE/Plot

<u>Yield trends at different harvest intervals for the main experiment (from 1980 to 1982)</u>

The pattern of trend in herbage and oil yield is explained by Cobb-Doughlus function (Heady and Dillon, 1961)

$Y = a\,x^b$ where

Y = yield of herbage/oil

X = harvest interval

a, b = constants

This function is generally used to explain an increasing, constant or decreasing return to scale according to in Econometrics. The conformity of the fitted relationship was tested by the magnitude of the coefficient of determination.

<u>Relationship between the yield of herbage and oil and harvest intervals for the period from 1980-1984</u>

The trend functions fitted by the application of Cobb-Doughlus function does not indicate any optimum in yield at different harvest intervals studied. So by taking additional data on yield for two more years (total four years' yield data) the following relationship was examined.

$$Y = b_0 + b_1H + b_2H^2,\ b_2 < 0$$

where b-values are constants (Heady and Dillon, 1961).

This is the quadratic regression equation of yield on harvest intervals. The optimum yield was determined by the formula $H_{opt} = \frac{-b_1}{2b_2}$

Path analysis

The cause and effect relationship of yield (herbage, oil and geraniol) with various yield contributing characters was studied by the method of path analysis developed by Wright (1921), originally for the inbreeding theory. This method is based on the construction of a qualitative diagram known as path diagram in which the whole system of variables is represented. The advantage of this diagram is that a set of simultaneous equations can be written directly from the diagram and a solution of these equations provides information on the direct and indirect contribution of these causal factors to the effect. The simultaneous equations were given by

A = BC. Where, A is the vector or correlation coefficients of various characters (x) with yield (y). B is the matrix of correlation coefficients of various characters, and C is the vector of path coefficients. The residual effect (R) is estimated from the relationship

$R^2 = 1-(\Sigma P_{iy} r_{iy})$

where P_{iy} is the direct effect of i^{th} character, and r_{iy} is the correlation of i^{th} character (x_i) on Y.

<u>**Economics**</u>

Cost of production for the different levels of phosphorus application were worked out on the basis of prevailing input cost and market price of oil and spent grass. Cost of production related to different levels of N and K_2O application were not worked out since there was no significant difference in oil yield due to different levels of N and K application.

Cost of production of all the harvest intervals from 55 to 135 days were worked out based on the data obtained from the observation trial.

RESULTS

RESULTS

The detailed observations on the major field experiment conducted from 1980-'82 in $3^3 \times 6$ confounded asymmetrical factorial design with three levels each of nitrogen, phosphorus, potassium and six intervals of harvest are presented under results. The results obtained for the major parameters viz., yield of herbage and oil for the main experiment continued during 1982-'84 and the results obtained from a subsequent observation trial conducted in 1983-'84 has also been presented.

Main field experiment

Biometric characters

Number of tillers per clump

Data presented in Tables 1 a, b and c represent the number of tillers per clump obtained during the first year, second year and the mean data for two years as influenced by the different levels of N, P, K and H.

Effect of nitrogen

There was no significant difference in the total number of tillers per clump with the different levels of N during the first year, second year and in their mean value. The number of tillers per clump recorded at 25, 50 and 75 kg N/ha were 17.3, 17.0 and 17.9 respectively in the first year and the corresponding figures for the second year were 26.2, 25.9 and 26.4.

Table 1(a). Effect of different levels of nutrients and harvest intervals on the number of tillers per clump in the first year: 1980-81.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	16.7	17.3	16.6	18.3	18.3	16.5	17.3	16.1	17.8	18.0	15.4	18.0	18.5
n_2	17.1	16.6	17.1	17.8	16.4	16.8	17.0	17.0	16.7	17.2	16.4	16.0	18.5
n_3	17.2	16.2	13.8	20.5	20.8	18.6	17.9	18.3	17.7	17.6	17.3	18.1	18.2
p_1	14.1	14.7	16.3	18.4	17.9	17.0	16.4	15.0	16.2	17.8	-	-	-
p_2	17.4	18.2	15.8	18.2	18.5	18.5	17.9	18.2	17.2	18.3	-	-	-
p_3	19.5	17.3	15.4	19.5	19.3	16.4	17.9	18,2	18.8	16.7	-	-	-
k_1	16.2	17.2	15.7	19.0	18.9	15.8	17.1	-	-	-	-	-	-
k_2	16.8	16.7	16.2	17.4	19.6	17.9	17.4	-	-	-	-	-	-
k_3	18.0	16.3	15.7	20.3	17.0	18.2	17.6	-	-	-	-	-	-
Mean (H)	17.0	16.7	15.3	18.9	18.5	17.3	17.4						

Mean	C.D.(0.05)	S.E.
N, P or K	-	0.51
H	2.02	0.72

Table 1(b). **Effect of different levels of nutrients and harvest intervals on the number of tillers per clump in the second year: 1981-82.**

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	27.0	27.3	26.7	27.1	26.8	22.3	26.2	25.2	26.7	26.7	25.3	27.3	26.1
n_2	25.7	27.6	25.0	26.7	26.6	24.0	25.9	24.8	25.7	27.3	26.0	26.7	25.1
n_3	27.7	26.4	24.0	28.2	28.5	23.9	26.4	27.3	25.3	26.6	24.8	27.2	27.3
p_1	24.0	26.7	26.4	26.7	26.7	21.6	25.4	24.0	24.6	27.4	-	-	-
p_2	27.4	27.8	24.3	27.6	29.9	25.4	27.1	26.4	27.2	27.6	-	-	-
p_3	28.9	26.8	24.9	27.6	25.4	23.4	26.2	26.9	25.9	25.6	-	-	-
k_1	28.2	27.9	23.3	25.4	27.1	22.[illegible]	25.8	-	-	-	-	-	-
k_2	25.1	26.5	25.3	28.1	27.4	23.2	25.9	-	-	-	-	-	-
k_3	27.1	26.9	27.0	28.5	27.5	24.3	26.9	-	-	-	-	-	-
Mean (H)	26.8	27.1	25.2	27.3	27.3	23.4	26.9						

Mean	C.D.(0.05)	S.E.
N, P or K	-	0.67
H	2.66	0.95

Table 1(c). Effect of different levels of nutrients and harvest intervals on the number of tillers per clump: Mean values for two years.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	22.1	22.1	20.9	22.5	22.5	19.4	21.6	20.6	21.7	22.4	20.1	23.5	21.2
n_2	21.1	21.8	20.7	22.0	21.2	20.2	21.2	20.7	20.9	22.0	20.9	21.1	21.5
n_3	22.2	20.5	18.7	24.1	24.4	21.7	21.9	23.0	21.3	21.6	21.0	22.2	22.5
p_1	18.8	20.3	21.1	22.3	21.9	19.7	20.7	19.6	20.1	22.4	-	-	-
p_2	22.2	22.4	19.8	23.0	24.2	22.0	22.3	22.1	22.0	22.7	-	-	-
p_3	24.4	21.8	19.3	23.3	22.0	19.7	21.8	22.6	21.8	20.9	-	-	-
k_1	22.4	22.4	19.3	22.0	22.7	19.7	21.4	-	-	-	-	-	-
k_2	20.8	21.3	19.9	22.4	23.1	20.3	21.3	-	-	-	-	-	-
k_3	22.3	20.8	21.1	24.2	22.3	21.3	22.0	-	-	-	-	-	-
Mean (H)	21.8	21.5	20.1	22.9	22.7	20.4	21.6						

Mean	C.D.(0.05)	S.E.
N, P or K	-	0.49
H	1.93	0.69

Effect of phosphorus

The effect of different levels of P_2O_5 was also not significant and the number of tillers recorded at 25, 50 and 75 kg P_2O_5/ha during the first year were 16.4, 17.9 and 17.9 respectively and those in the second year were 25.4, 27.1 and 26.2 respectively.

Effect of potassium

Different levels of K_2O also showed similar effect on the production of tillers and the number of tillers at 25, 50 and 75 kg K_2O/ha during the first and second year were 17.1, 17.4, 17.6 and 25.8, 25.9 and 26.9 respectively.

Effect of harvest intervals

Significant difference in the total number of tillers per plant was however noticed both in the first year, second year and also in the mean data for the two years. In the first year, the maximum number of tillers per clump was recorded in the treatment where harvesting was done at 55 day intervals. The number of tillers obtained at 40, 45, 50, 55, 60 and 65 day intervals were 17.0, 16.7, 15.8, 18.9, 18.5 and 17.3 respectively.

In the second year, the maximum number was recorded by the two harvest interval treatments of 55 and 60 days. The treatment 65 days produced the minimum number of tillers. There was no significant difference in the tiller numbers as the interval increased from 40 to 60 days. The highest harvest interval of 65 days recorded the lowest tiller number.

The number of tillers obtained at 40, 45, 50, 55, 60 and 65 day intervals were 26.8, 27.1, 25.2, 27.3, 27.3 and 23.4 respectively.

In the mean data for two years also the interval of 55 days recorded the highest number. It was on par with 60, 40 and 45 day harvest intervals. The treatments harvested at 50 and 65 day intervals recorded significantly lower values than the other harvest interval treatments.

Height of the plant

Data on the height of the plant as influenced by the different levels of N, P, K and H are presented in Tables 2 a, b and c.

Effect of nitrogen

Levels of N did not have any effect on the height of the plants when the data were considered either separately for each year or combined. However, the mean height of plants for the two years at 25, 50 and 75 kg N/ha were 109.6, 109.4 and 108.3 cm respectively which indicate a slight tendency for the height of plants to decrease with increasing levels of N application.

Effect of phosphorus

During the first year, the height of plants for the P_2O_5 applications of 25, 50 and 75 kg/ha were 110.2, 111.8 and 114.3 cm respectively. The differences were not significant, although the trend was for the height of the plants to increase with increasing levels of P_2O_5. During the

Table 2(a). Effect of different levels of nutrients and harvest intervals on height of the plant (cm) in the first year: 1980-81.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	103.1	116.1	103.2	111.9	117.1	123.3	112.5	107.0	116.6	114.0	114.0	112.2	111.4
n_2	100.1	118.9	104.3	120.1	113.6	118.5	112.6	113.3	111.3	113.2	112.1	112.3	113.3
n_3	97.1	108.2	90.0	115.2	120.4	126.6	111.1	108.2	113.6	112.0	104.3	110.8	118.1
p_1	94.7	110.0	104.5	117.2	116.7	117.9	110.2	105.9	111.1	113.5	-	-	-
p_2	99.2	114.4	101.6	109.3	119.6	126.6	111.8	111.3	110.9	113.3	-	-	-
p_3	106.5	118.8	100.4	120.7	114.8	124.5	114.3	111.6	118.9	112.4	-	-	-
k_1	101.5	111.1	97.6	112.6	116.7	117.5	109.5	-	-	-	-	-	-
k_2	99.6	116.6	103.8	117.4	118.1	126.1	113.6	-	-	-	-	-	-
k_3	99.2	115.5	105.0	117.1	116.2	125.4	113.1	-	-	-	-	-	-
Mean (H)	100.1	114.4	102.2	115.7	117.0	123.0	112.1	-	-	-	-	-	-

Mean	C.D.(0.05)	S.E.
N, P or K	-	1.45
NP, NK or PK	7.08	2.52
H	5.78	2.05

Table 2(b). Effect of different levels of nutrients and harvest intervals on height of the plant (cm) in the second year: 1981-82.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	78.6	85.4	108.6	114.1	115.7	139.1	106.9	101.2	109.2	110.3	107.9	104.5	108.4
n_2	81.0	88.3	98.3	113.7	117.8	140.4	106.6	106.7	105.2	107.8	104.3	108.4	107.0
n_3	78.5	81.7	98.0	109.3	126.2	135.2	104.8	104.6	102.6	107.1	97.4	104.9	112.3
p_1	75.9	85.5	104.3	109.[illegible]	114.6	130.0	103.2	100.8	102.4	106.4	-	-	-
p_2	80.0	85.6	98.9	107.7	122.0	141.2	105.9	103.2	104.9	109.7	-	-	-
p_3	82.2	84.2	101.7	120.5	123.1	143.5	109.2	108.7	109.8	109.1	-	-	-
k_1	80.4	84.1	93.0	109.9	118.6	134.1	104.2	-	-	-	-	-	-
k_2	77.6	85.6	100.7	108.5	123.0	133.8	105.7	-	-	-	-	-	-
k_3	80.0	85.8	106.1	118.8	117.9	141.9	108.4	-	-	-	-	-	-
Mean (H)	79.4	85.1	101.6	112.4	119.9	138.3	106.1						

Mean	C.D.(0.05)	S.E.
N, P or K	3.49	1.24
NP, NK or PK	6.05	2.15
H	4.94	1.75

Table 2(c). Effect of different levels of nutrients and harvest intervals on height of the plant (cm) mean values for two years.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	90.9	100.8	105.9	113.0	114.8	131.4	109.6	104.1	112.9	112.1	111.0	108.3	109.9
n_2	90.6	103.3	101.3	116.9	115.7	128.7	109.4	110.0	107.8	110.5	107.7	110.4	110.2
n_3	87.8	95.0	98.5	112.3	125.0	131.0	108.3	106.5	107.8	109.6	100.7	107.9	115.2
p_1	85.3	97.5	104.4	113.1	115.7	123.1	106.5	103.3	106.3	110.0	-	-	-
p_2	89.5	100.0	100.3	108.5	120.8	133.9	108.8	107.1	107.9	111.5	-	-	-
p_3	94.4	101.6	101.1	120.6	119.0	134.0	111.8	110.2	114.1	110.8	-	-	-
k_1	91.0	97.5	97.8	111.3	117.8	125.8	106.9	-	-	-	-	-	-
k_2	88.7	100.9	102.3	113.0	120.6	131.6	109.5	-	-	-	-	-	-
k_3	89.6	100.6	105.6	118.0	117.0	133.6	110.8	-	-	-	-	-	-
Mean (H)	89.8	99.7	101.9	114.1	116.5	130.3	109.0						

Mean	C.D.(0.05)	S.E.
N, P or K	3.23	1.15
NP, NK or PK	5.59	1.99
H	4.57	1.62

second year however, higher levels of P_2O_5 increased the height of the plants significantly. The height recorded for the three levels of P_2O_5 application were 103.2, 105.9 and 109.2 cm respectively. The mean values for two years were also statistically significant.

Effect of potassium

Application of different levels of K_2O did not influence the height of the plants significantly in either of the years or as per the mean data for the two years. But the height of the plants increased with increasing levels of K_2O in both the years. The mean height recorded for the two years at 25, 50 and 75 kg K_2O/ha were 106.9, 109.5 and 110.8 cm respectively,

Nutrient interactions

The interaction between N and P was significant separately for the two years as well as for the combined data. The maximum height was recorded for the treatment combination n_3p_3 in both the years.

Effect of harvest intervals

Increasing the interval of harvest from 40 to 65 days significantly increased the height of the plants in both the years. The crop harvested at 65 day interval recorded the maximum height in both the years and it was significantly superior to all other harvest intervals in both the years. The height of the plants with different intervals of harvest ranged from 100.1 to 123.0 cm in the first year and from 79.4 to 138.3 cm in the second year and the mean values for the two years recorded at 40, 45, 50, 55, 60 and 65 day harvest intervals were 89.8, 99.7, 101.9, 114.1, 118.5 and 130.3 cm respectively.

Length of inflorescence

The data on the length of inflorescence as influenced by the application of different levels of N, P, K and H are presented in Tables 3 a, b and c.

Effect of nitrogen

Different levels of N did not influence the length of inflorescence significantly in either of the years. In the first year, the values recorded at 25, 50 and 75 kg N/ha were 29.2, 29.1 and 29.0 cm respectively.

In the second year, application of N at 50 and 75 kg/ha increased the length of the inflorescence over that at 25 kg N/ha.

In the mean values for the two years 50 kg N/ha recorded the highest length of inflorescence and the measurements for 25, 50 and 75 kg N/ha were respectively 29.0, 29.2 and 29.0 cm.

Effect of phosphorus

Increasing levels of P_2O_5 increased the length of inflorescence in both the years but the results were significant only for the first year and for the mean data for the two years. During the first year, application of P_2O_5 at 75 kg/ha recorded the highest length of 30.2 cm and it

Table 3(a). Effect of different levels of nutrients and harvest intervals on inflorescence length (cm) in the first year: 1980-81.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	26.3	31.4	25.1	29.7	29.9	32.5	29.2	27.5	30.7	29.0	28.9	29.9	28.7
n_2	23.0	30.6	27.6	33.1	29.9	30.5	29.1	29.7	29.0	28.7	28.3	29.3	29.9
n_3	24.4	27.7	25.3	32.2	31.2	33.2	29.0	28.1	29.9	29.1	26.3	28.8	32.0
p_1	22.0	27.6	25.5	32.6	28.6	30.7	27.8	27.1	28.2	28.2	-	-	-
p_2	24.5	30.1	26.7	29.7	31.5	33.2	29.3	29.4	29.1	29.3	-	-	-
p_3	27.2	31.9	25.8	32.8	31.0	32.4	30.2	29.1	32.3	29.2	-	-	-
k_1	25.9	28.3	24.9	30.7	30.8	30.4	28.5	-	-	-	-	-	-
k_2	24.3	30.3	26.3	33.5	30.6	33.1	29.9	-	-	-	-	-	-
k_3	23.5	31.0	26.8	30.8	29.6	31.8	28.9	-	-	-	-	-	-
Mean (H)	24.6	29.9	26.0	31.7	30.4	32.1	29.1	-	-	-	-	-	-

Mean	C.D.(0.05)	S.E.
N, P or K	1.59	0.57
H	2.25	0.80

Table 3(b). Effect of different levels of nutrients and harvest intervals on inflorescence length (cm) in the second year: 1981-82.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	20.8	23.4	28.0	29.5	28.9	38.5	28.2	27.1	29.1	28.3	28.3	27.8	28.5
n_2	21.8	25.7	25.9	31.3	32.3	37.5	29.1	30.0	29.0	28.3	28.9	28.9	29.5
n_3	21.7	23.3	27.7	28.7	36.0	37.1	29.2	29.0	28.2	29.9	28.0	29.4	29.7
p_1	21.6	24.2	27.1	29.8	31.6	35.9	28.4	28.8	27.9	28.3	-	-	-
p_2	20.5	23.9	27.1	30.2	33.1	37.4	28.7	27.5	29.4	29.2	-	-	-
p_3	22.2	24.4	27.4	29.5	32.3	39.8	29.3	29.9	28.9	29.0	-	-	-
k_1	23.0	23.4	27.5	30.2	30.3	37.5	28.7	-	-	-	-	-	-
k_2	21.0	23.6	27.8	29.2	34.7	36.4	28.8	-	-	-	-	-	-
k_3	20.4	25.5	26.3	30.1	31.4	39.3	28.8	-	-	-	-	-	-
Mean (H)	21.5	24.2	27.2	29.8	32.3	37.7	28.9						

Mean	C.D. (0.05)	S.E.
N, P or K	-	0.48
H	1.91	0.68

Table 3(c). Effect of different levels of nutrients and harvest intervals on inflorescence length (cm) mean values for two years.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	23.7	28.8	26.7	29.7	29.4	35.5	29.0	27.6	30.0	29.3	28.7	28.9	29.3
n_2	22.6	28.3	25.9	32.3	31.2	34.1	29.2	30.0	29.0	28.7	28.7	29.2	29.8
n_3	23.1	25.7	26.7	30.6	32.5	35.2	29.0	28.6	28.7	29.6	26.7	29.3	31.0
p_1	21.7	25.6	26.4	31.3	29.1	33.4	28.0	28.1	27.6	28.4	-	-	-
p_2	22.7	27.2	27.0	30.0	32.4	35.3	29.1	28.5	29.4	29.3	-	-	-
p_3	25.0	29.3	26.7	31.3	31.7	36.0	30.0	29.6	30.7	29.7	-	-	-
k_1	24.6	26.0	26.4	30.4	30.9	34.0	26.7	-	-	-	-	-	-
k_2	22.6	27.1	27.0	31.5	31.7	35.3	29.2	-	-	-	-	-	-
k_3	22.1	29.6	27.1	30.5	30.6	35.4	29.2	-	-	-	-	-	-
Mean (H)	23.1	27.6	26.8	30.9	31.0	34.9	29.0						

Mean	C.D.(0.05)	S.E.
N, P or K	1.19	0.42
H	1.67	0.59

was on par with P_2O_5 at 50 kg/ha (29.3 cm) and significantly superior to the length for P_2O_5 application at 25 kg/ha (27.8 cm).

Increasing the levels of P_2O_5 progressively increased the length of inflorescence in the second year also and the values recorded at 25, 50 and 75 kg P_2O_5/ha were 28.4, 28.7 and 29.3 cm respectively.

From the mean values for two years it was observed that the length of inflorescence recorded at 75 kg P_2O_5/ha was on par with 50 kg P_2O_5/ha and they were significantly superior to the length recorded at the lowest level of P_2O_5.

Effect of potassium

Though the application of different levels of K_2O could not produce any significant effect on the length of the inflorescence, application at 50 and 75 kg K_2O/ha did increase the length of inflorescence over that at 25 kg K_2O/ha in both the years. The mean values for the two years for application of K_2O at 25, 50 and 75 kg/ha were 28.7, 29.2 and 29.2 cm respectively.

Effect of harvest intervals

The influence of different intervals of harvest was significant in both the years and in the mean value for the two years. Plants harvested at 65 day intervals recorded the maximum length of inflorescence in both the years. It was on par with 55 and 60 day intervals in the first year and was significantly superior to all other harvest treatments.

In the second year and in the mean value for both the years, the length of inflorescence increased with the increase in the interval between harvests and the maximum value was recorded for the 65 day harvest interval. This was significantly superior to all other harvest treatments. The shortest interval tried (40 days) recorded the minimum length of inflorescence in both the years. The length of inflorescence with different intervals of harvest varied from 24.6 to 32.1 cm in the first year and from 21.5 to 37.7 cm in the second year. The mean values for both the years recorded at 40, 45, 50, 55, 60 and 65 day intervals were 23.1, 27.6, 26.8, 30.9, 31.0 and 34.9 cm respectively.

Number of tillers with inflorescence

The results on the number of tillers with inflorescence observed during the first and second years and their mean values are presented in Tables 4 a, b and c.

Effect of nitrogen

The number of tillers with inflorescence was not influenced significantly by the levels of N in either of the years. The values recorded at 50 and 75 kg N/ha were higher than those at the lowest level of N in both the years. The number of tillers with inflorescence produced during the first year at 25, 50 and 75 kg N/ha were 7.2, 7.3 and 7.8 respectively and the corresponding figures for the second year were 8.1, 8.9 and 8.7.

Table 4(a). Effect of different levels of nutrients and harvest intervals on the number of tillers with inflorescence per clump in the first year: 1980-81.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	5.1	7.5	5.3	8.3	8.0	8.7	7.2	6.7	7.3	7.4	6.9	8.1	6.5
n_2	4.8	7.1	5.8	8.9	8.5	9.0	7.3	7.4	7.4	7.1	7.1	7.2	7.7
n_3	4.5	7.1	5.8	10.1	8.9	10.2	7.8	7.6	7.7	8.0	7.2	7.6	8.1
p_1	4.0	6.1	5.7	9.6	7.9	8.9	7.0	6.6	6.8	7.7	-	-	-
p_2	4.8	7.8	5.4	8.7	8.1	10.9	7.6	7.3	7.5	8.0	-	-	-
p_3	5.7	7.7	5.8	8.8	9.0	8.2	7.5	7.9	8.0	6.8	-	-	-
k_1	5.2	7.1	5.7	9.1	8.0	8.4	7.3	-	-	-	-	-	-
k_2	4.4	7.7	5.2	8.5	9.2	10.0	7.4	-	-	-	-	-	-
k_3	5.0	6.8	5.9	9.7	8.1	9.6	7.5	-	-	-	-	-	-
Mean (H)	4.8	7.2	5.6	9.1	8.4	9.3	7.4						

Mean	C.D.(0.05)	S.E.
N, P or K	-	0.27
H	1.05	0.38

Table 4(b). Effect of different levels of nutrients and harvest intervals on the number of tillers with infloresecence per clump in the second year: 1981-82.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	5.6	5.2	8.0	10.2	9.6	9.9	8.1	8.1	8.8	7.6	7.6	8.5	8.2
n_2	5.5	6.6	8.2	9.9	10.9	12.1	8.9	8.5	8.6	9.5	8.7	8.7	9.3
n_3	5.4	6.1	7.9	10.4	11.3	10.[illegible]	8.[illegible]	9.0	8.1	8.9	6.8	9.8	9.4
p_1	5.5	5.1	8.0	9.7	9.0	8.9	7.7	8.0	7.3	7.8	-	-	-
p_2	5.1	7.0	7.1	10.8	12.4	11.4	9.0	8.5	9.3	9.1	-	-	-
p_3	5.9	5.9	9.0	10.0	10.4	12.5	9.[illegible]	9.1	8.5	9.2	-	-	-
k_1	5.7	6.0	[illegible].3	9.7	11.0	10.5	8.5	-	-	-	-	-	-
k_2	5.1	5.6	7.9	10.1	10.1	11.4	8.4	-	-	-	-	-	-
k_3	5.6	6.4	7.9	10.7	10.7	10.9	8.[illegible]	-	-	-	-	-	-
Mean (H)	5.5	6.0	[illegible].0	10.2	10.6	10.9	8.5						

Mean	C.D.(0.05)	S.E.
N, P or K	0.94	0.33
H	1.33	0.47

Table 4(c). Effect of different levels of nutrients and harvest intervals on the number of tillers with inflorescence per clump: mean values for two years.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	5.4	6.4	6.6	9.2	8.9	9.3	7.7	7.4	7.9	7.6	7.3	8.3	7.4
n_2	5.2	6.9	7.0	9.5	9.6	10.5	8.1	7.9	8.0	8.4	7.9	8.0	8.6
n_3	5.0	6.6	6.8	10.5	10.1	10.6	8.2	8.3	7.9	8.5	7.0	8.7	9.0
p_1	4.8	5.6	6.8	9.7	8.4	8.9	7.4	7.3	7.1	7.7	-	-	-
p_2	4.9	7.4	6.2	9.8	10.3	11.1	8.3	7.9	8.4	8.6	-	-	-
p_3	5.8	6.8	7.4	9.4	9.7	10.4	8.3	8.5	8.3	8.1	-	-	-
k_1	5.4	6.6	7.0	9.4	9.5	9.5	7.9	-	-	-	-	-	-
k_2	4.8	6.7	6.6	9.2	9.6	10.7	7.9	-	-	-	-	-	-
k_3	5.3	6.6	6.9	10.4	9.4	10.2	8.1	-	-	-	-	-	-
Mean (H)	5.2	6.6	6.8	9.6	9.5	10.1	8.0						

Mean	C.D.(0.05)	S.E.
N, P or K	0.65	0.23
H	0.91	0.32

Effect of phosphorus

The effect of P_2O_5 was not significant in the first year, but the number of tillers obtained with inflorescence at 50 and 75 kg P_2O_5/ha were higher than that for 25 kg P_2O_5/ha and the values recorded for 25, 50 and 75 kg P_2O_5/ha were 7.0, 7.6 and 7.5 respectively.

In the second year, the application of P_2O_5 at 75 and 50 kg/ha significantly increased the number of flowered tillers over that at 25 kg/ha and the number of flowered tillers at 50 and 75 kg P_2O_5/ha were the same. The number of tillers at 25, 50 and 75 kg P_2O_5/ha were 7.7, 9.0 and 9.0 respectively. Similar results were obtained in the mean data for both the years also and the values recorded at 25, 50 and 75 kg P_2O_5/ha were 7.4, 8.3 and 8.3 respectively.

Effect of potassium

Application of different levels of K_2O did not significantly influence the number of flowered tillers in both the years and in the mean value for the two years. The number of flowered tillers at 25, 50 and 75 kg K_2O/ha during the first year were 7.3, 7.4 and 7.5 respectively and that in the second year were 8.5, 8.4 and 8.7 respectively.

Effect of harvest intervals

Significant difference was observed with different intervals of harvest in both the years and the number of tillers with inflorescence rose as the interval between harvests increased. The maximum number was recorded with 65 days. However this was on par with 60 and 55 day intervals. The number of flowered tillers ranged from 4.8 to 9.3 in the first year and from 5.5 to 10.9 in the second year.

Number of tillers without inflorescence

The data on the number of tillers without inflorescence as influenced by different levels of N, P, K and H are presented in Tables 5 a, b and c.

Effect of nitrogen

The number of tillers without inflorescence was not influenced significantly with different levels of N in any of the years or as per the mean data. The values recorded at 50 and 75 kg N/ha were lower than that at 25 kg/ha in both the years. The number of non-flowered tillers produced at 25, 50 and 75 kg N/ha were respectively 10.3, 9.5 and 9.8 in the first year and 18.2, 17.1 and 17.4 in the second year.

Effect of phosphorus

Different levels of P_2O_5 also showed no influence on the number of tillers without inflorescence in the two years and as per the mean data. No definite trend was noticed in the number of non-flowered tillers for the different levels of P_2O_5. The lowest number was recorded in the first year with 25 kg P_2O_5/ha while in the second

Table 5(a). Effect of different levels of nutrients and harvest intervals on the number of tillers without inflorescence per clump in the first year: 1980-81.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	12.0	9.9	10.2	10.6	10.8	8.3	10.3	9.9	10.2	10.7	8.6	12.3	10.0
n_2	11.9	9.5	11.0	8.3	8.3	7.7	9.5	9.1	9.0	10.3	9.4	8.7	10.2
n_3	12.7	9.1	9.1	10.5	10.8	7.7	9.8	9.8	10.3	9.3	9.4	10.0	10.0
p_1	9.8	8.3	10.6	8.8	10.3	6.9	9.1	7.7	9.2	10.4	-	-	-
p_2	12.0	11.0	10.3	10.5	9.9	8.2	10.3	10.6	9.9	10.5	-	-	-
p_3	14.2	8.4	8.4	10.2	9.9	8.2	10.0	10.6	10.4	9.4	-	-	-
k_1	11.8	12.1	9.9	9.3	9.9	5.8	9.6	-	-	-	-	-	-
k_2	12.0	8.2	9.7	9.4	10.2	7.8	9.8	-	-	-	-	-	-
k_3	11.7	8.1	9.7	10.8	9.9	9.9	10.1	-	-	-	-	-	-
Mean (H)	12.2	9.5	9.8	9.8	10.0	7.9	9.9						

Mean	C.D.(0.05)	S.E.
N, P or K	-	0.49
H	1.94	0.69

Table 5(b). Effect of different levels of nutrients and harvest intervals on the number of tillers without inflorescence per clump in the second year: 1981-82.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	21.4	22.1	18.8	17.4	17.2	12.5	18.2	17.1	18.5	19.1	17.9	18.9	17.9
n_2	19.0	20.9	16.7	17.1	15.8	12.8	17.1	15.7	17.1	18.3	16.7	18.0	16.4
n_3	20.1	19.8	16.1	17.9	17.2	13.4	17.4	17.8	16.6	17.7	18.1	16.7	17.4
p_1	17.4	21.6	18.4	17.7	17.7	12.6	17.6	15.4	17.7	19.6	-	-	-
p_2	21.3	20.4	17.3	16.7	17.5	14.0	17.9	18.0	17.1	18.5	-	-	-
p_3	21.9	20.9	15.9	18.0	15.0	11.7	17.2	17.3	17.4	17.0	-	-	-
k_1	20.3	21.9	15.0	15.7	16.1	12.3	16.9	-	-	-	-	-	-
k_2	18.9	20.4	17.5	18.7	17.2	11.8	17.4	-	-	-	-	-	-
k_3	21.3	20.5	19.1	18.1	16.8	14.2	18.3	-	-	-	-	-	-
Mean (H)	20.2	20.9	17.2	17.5	16.7	12.8	17.6						

Mean	C.D.(0.05)	S.E.
N, P or K	-	0.57
H	2.28	0.81

Table 5(c). Effect of different levels of nutrients and harvest intervals on the number of tillers without inflorescence per clump: mean values for two years.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	16.7	16.1	14.5	14.0	14.1	10.4	14.1	13.6	13.9	14.9	13.3	15.6	13.5
n_2	15.2	15.3	13.9	12.8	12.1	10.2	13.2	12.4	13.1	14.2	13.1	13.2	13.4
n_3	16.4	14.4	12.1	14.2	14.0	10.2	13.5	13.7	13.5	13.3	13.7	13.2	13.7
p_1	13.6	14.9	14.5	13.2	14.1	9.8	13.4	11.6	13.5	15.0	-	-	-
p_2	16.6	15.5	13.8	13.6	13.6	11.1	14.0	14.2	13.6	14.2	-	-	-
p_3	18.0	14.7	12.2	14.1	12.4	9.9	13.6	14.0	13.5	13.2	-	-	-
k_1	16.1	17.2	12.5	12.5	13.0	9.2	13.3	-	-	-	-	-	-
k_2	15.7	14.4	13.5	14.0	13.7	9.8	13.5	-	-	-	-	-	-
k_3	16.5	14.4	14.4	14.4	13.4	11.7	14.1	-	-	-	-	-	-
Mean (H)	16.1	15.3	13.5	13.7	13.4	10.3	13.6						

Mean	C.D.(0.05)	S.E.
N, P or K	-	0.39
H	1.55	0.55

year the lowest number was obtained for 75 kg P_2O_5/ha. The number of tillers without inflorescences ranged from 9.1 to 10.3 in the first year and from 17.2 to 17.9 in the second year.

Effect of potassium

Increase in the levels of K_2O had also no significant influence on the number of tillers without inflorescence separately for the two years and in the mean value for both the years. The number of non-flowered tillers increased with increasing levels of K_2O in both the years. The numbers recorded at 25, 50 and 75 kg K_2O/ha in the first year were 9.6, 9.8 and 10.1 respectively and those in the second year were 16.9, 17.4 and 18.3.

Effect of harvest intervals

Increasing the intervals of harvest decreased the number of tillers without inflorescences significantly for both the years. The harvest interval of 65 days recorded the minimum number of non-flowered tillers in both the years and it was significantly lower than all other harvest intervals as per the mean value for the two years. The number of non-flowered tillers recorded with this treatment was 7.9 in the first year and 12.8 in the second year. The mean number of non-flowered tillers for two years together ranged from 10.3 at the longest interval to 16.1 for the treatment harvested at 40 days interval.

Herbage yield, oil yield, oil content and dry matter yield.

Herbage yield

The results on fresh herbage yield as influenced by the levels of N, P, K and H are presented in Tables 6 a, b and c and in Fig.2 and 6.

Effect of nitrogen

There was significant difference in the herbage yield with different levels of N in the first year. The highest yield (14.15 t/ha) was recorded with 50 kg N/ha and it was significantly higher than the other two levels of N at 75 (13.33 t/ha) and 25 kg/ha (13.17 t/ha).

N levels did not show a significant result in the second year. However, higher levels showed a tendency to increase the yield of herbage.

The total grass yield for two years also showed no significant difference due to different levels of N and the herbage yields obtained at 25, 50 and 75 kg/ha were 40.62, 42.63 and 42.59 t/ha respectively.

Effect of phosphorus

Increasing the levels of P_2O_5 increased the herbage yield significantly in both the years and the total yield for two years. The highest herbage yield was recorded with P_2O_5 at 75 kg/ha followed by 50 kg and 25 kg/ha and all the three levels were significantly different in both the years. The yields obtained at 25, 50 and 75 kg P_2O_5/ha were 12.32, 13.72 and 14.60 t/ha respectively in the first

Table 6(a). Effect of different levels of nutrients and harvest intervals on herbage yield (t/ha) in the first year: 1980-81.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	11.93	12.64	13.14	14.58	12.69	14.02	13.17	12.85	13.17	13.47	11.60	13.91	13.99
n_2	12.39	13.27	14.08	14.51	14.24	16.45	14.15	14.31	13.59	14.56	13.46	14.26	14.74
n_3	12.10	13.46	12.05	13.15	14.32	14.69	13.33	13.16	13.21	13.60	11.90	13.00	15.06
p_1	10.49	12.21	11.91	13.29	12.31	13.72	12.32	12.00	12.49	12.47	-	-	-
p_2	12.41	12.91	12.89	13.45	14.88	15.79	13.72	13.26	13.41	14.49	-	-	-
p_3	13.51	14.26	14.44	15.48	14.05	15.85	14.60	15.05	14.06	14.68	-	-	-
k_1	12.71	12.60	12.69	13.55	14.07	15.02	13.44	-	-	-	-	-	-
k_2	11.55	12.97	12.75	14.34	13.39	14.93	13.32	-	-	-	-	-	-
k_3	12.15	13.80	13.79	14.33	13.79	15.41	13.88	-	-	-	-	-	-
Mean (H)	12.14	13.12	13.08	14.07	13.75	15.12	13.55						

Mean	C.D.(0.05)	S.E.
N, P or K	0.674	0.239
NP, NK or PK	1.168	0.415
H	0.954	0.339

Table 6(b). Effect of different levels of nutrients and harvest intervals on herbage yield (t/ha) in the second year: 1981-82.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	25.29	27.94	24.86	28.92	28.02	29.73	27.45	26.55	28.46	27.37	25.67	27.28	29.41
n_2	24.84	26.81	25.41	29.90	30.50	33.19	28.44	26.92	27.98	30.43	27.44	28.54	29.35
n_3	26.24	26.94	24.27	28.41	32.59	34.05	28.75	29.36	26.23	30.66	26.50	28.71	31.04
p_1	23.36	25.92	24.55	28.36	27.24	29.80	26.54	25.43	26.46	27.72	-	-	-
p_2	24.74	26.02	24.81	27.70	31.98	33.80	28.18	26.56	27.64	30.33	-	-	-
p_3	28.27	29.74	25.18	31.18	31.89	33.56	29.94	30.84	28.57	30.41	-	-	-
k_1	26.98	26.57	23.27	27.14	30.80	30.88	27.61	-	-	-	-	-	-
k_2	24.65	27.39	23.43	27.55	30.53	31.79	27.56	-	-	-	-	-	-
k_3	24.74	27.72	27.84	32.56	29.78	34.29	29.49	-	-	-	-	-	-
Mean (H)	25.46	27.23	24.95	29.08	30.37	32.32	28.22						

Mean	C.D.(0.05)	S.E.
N, P or K	1.595	0.567
NP, NK or PK	2.762	0.982
H	2.256	0.801

Table 6(c). Effect of different levels of nutrients and harvest intervals on herbage yield (t/ha): pooled data for two years.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	37.22	40.65	37.99	43.51	40.70	43.70	40.62	39.41	41.63	40.85	37.30	41.19	43.39
n_2	37.23	40.12	39.47	44.41	44.86	49.70	42.63	41.30	41.59	44.99	40.93	42.86	44.11
n_3	38.31	40.40	37.42	43.49	46.97	48.94	42.59	42.74	40.74	44.29	38.41	41.96	47.40
p_1	33.85	38.13	36.46	41.65	39.54	43.57	38.88	37.50	38.95	40.20	-	-	-
p_2	37.15	38.93	37.70	41.60	47.04	49.60	42.00	40.10	41.06	44.85	-	-	-
p_3	41.77	44.04	40.71	48.15	45.96	49.16	44.97	45.65	43.95	45.08	-	-	-
k_1	39.69	39.24	35.96	41.13	44.97	45.91	41.15	-	-	-	-	-	-
k_2	36.20	40.40	37.27	43.38	43.93	46.72	41.32	-	-	-	-	-	-
k_3	36.89	41.52	41.64	46.89	43.62	49.70	43.38	-	-	-	-	-	-
Mean (H)	37.59	40.39	38.29	43.80	44.18	47.44	41.95						

Mean	C.D.(0.05)	S.E.
N, P or K	1.853	0.658
H	2.620	0.931

year and the corresponding yields for the second year were 26.54, 28.18 and 29.94 t/ha.

Effect of potassium

Increase in the levels of K_2O from 25 to 75 kg/ha did not increase the herbage yield significantly during the first year. The yields obtained at 25, 50 and 75 kg K_2O/ha were 13.44, 13.32 and 13.88 t/ha respectively.

In the second year, and in the total yield for two years, increase in the levels of K_2O increased the herbage yield significantly. Highest herbage yield in the second year was recorded with K_2O at 75 kg K_2O/ha (29.49 t/ha) and it was superior to the other two levels of K_2O (27.61 and 27.56 t/ha at 25 and 50 kg K_2O/ha respectively).

In the case of total herbage yield also, the highest level applied recorded significantly higher yield than the other two levels.

Nutrient interactions

The interaction between N and P was significant in the first year and the maximum yield was recorded by n_3p_3. The interaction of N with K was significant in the second year and the highest yield was recorded by n_3k_3.

Effect of harvest intervals

Herbage yield in the first year, second year and the total yield for the two years were influenced significantly with different intervals of harvest. Harvesting the grass at 65 day intervals recorded the maximum grass yield in both the years and the grass yield increased almost linearly with increase in the intervals of harvest.

In the first year, harvesting the grass at 65 day intervals was significantly superior to all other harvest intervals. The lowest yield was recorded in the treatment where 40 day interval was resorted to and the yield ranged between 12.14 and 15.12 t/ha.

In the second year, there was no significant difference between 65 and 60 day intervals and the lowest yield was recorded by the 50 day interval. The yield obtained with different intervals of harvest varied from 24.85 to 32.32 t/ha.

The treatment harvested at 65 day intervals was significantly superior to all other harvest treatments in the total yield for two years also and the lowest yield was recorded with 40 day intervals.

Oil yield

Data of the oil yield obtained in the first year, second year and the pooled data for both the years as influenced by the different levels of N, P, K and H are presented in Tables 7 a, b and c and in Fig. 2 and 6.

Effect of nitrogen

Effect of N on oil yield was not significant in either of the years as well as for the pooled data for the two years.

The treatment 50 kg N/ha recorded the maximum oil yield in both the years and the grass yield increased almost linearly with increase in the intervals of harvest.

In the first year, harvesting the grass at 65 day intervals was significantly superior to all other harvest intervals. The lowest yield was recorded in the treatment where 40 day interval was resorted to and the yield ranged between 12.14 and 15.12 t/ha.

In the second year, there was no significant difference between 65 and 60 day intervals and the lowest yield was recorded by the 50 day interval. The yield obtained with different intervals of harvest varied from 24.85 to 32.32 t/ha.

The treatment harvested at 65 day intervals was significantly superior to all other harvest treatments in the total yield for two years also and the lowest yield was recorded with 40 day intervals.

Oil yield

Data of the oil yield obtained in the first year, second year and the pooled data for both the years as influenced by the different levels of N, P, K and H are presented in Tables 7 a, b and c and in Fig. 2 and 6.

Effect of nitrogen

Effect of N on oil yield was not significant in either of the years as well as for the pooled data for the two years.

The treatment 50 kg N/ha recorded the maximum oil

Table 7(a). Effect of different levels of nutrients and harvest intervals on oil yield (kg/ha) in the first year: 1980-81.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	29.32	31.13	35.26	39.70	35.65	38.18	34.87	36.21	35.29	33.74	30.39	36.84	37.39
n_2	26.52	31.54	38.28	40.19	39.40	44.72	36.78	37.74	34.30	38.26	35.80	37.17	37.35
n_3	29.15	32.21	31.34	36.01	39.88	41.74	35.06	34.50	34.85	35.80	29.79	33.90	41.46
p_1	25.83	29.53	31.59	36.03	32.87	36.01	32.00	33.29	31.03	31.67	-	-	-
p_2	28.80	30.84	34.87	36.18	42.26	43.07	35.97	34.63	35.67	37.62	-	-	-
p_3	30.31	34.45	38.61	43.68	3[illegible].30	45.55	38.73	40.53	37.76	37.91	-	-	-
k_1	30.86	31.25	34.67	39.79	39.34	40.99	36.15	-	-	-	-	-	-
k_2	26.80	31.95	32.66	38.29	36.96	42.24	34.82	-	-	-	-	-	-
k_3	27.33	31.68	37.55	37.81	38.63	41.39	35.73	-	-	-	-	-	-
Mean (H)	28.33	31.63	34.96	38.63	38.31	41.55	35.57						

Mean	C.D.(0.05)	S.E.
N, P or K	2.432	0.864
NP, NK or PK	4.212	1.496
H	3.440	1.222

Table 7(b). Effect of different levels of nutrients and harvest intervals on oil yield (kg/ha) in the second year: 1981-82.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	54.76	63.70	60.72	70.68	69.40	84.97	67.37	66.94	71.38	63.79	69.76	71.14	66.22
n_2	49.47	61.79	58.70	74.54	84.80	89.27	69.76	69.34	68.36	71.59	66.37	71.02	71.90
n_3	51.71	58.58	60.97	73.00	89.01	93.08	71.06	72.07	69.20	71.91	64.54	70.97	77.67
p_1	48.73	60.82	59.96	71.20	71.86	78.74	65.22	65.58	63.54	66.56	-	-	-
p_2	51.29	58.67	61.98	69.85	89.36	95.11	71.04	68.80	72.13	72.20	-	-	-
p_3	55.92	64.57	58.42	77.17	82.00	93.48	71.93	73.98	73.28	68.52	-	-	-
k_1	54.06	61.47	57.87	68.41	85.15	89.75	69.45	-	-	-	-	-	-
k_2	53.10	61.76	58.51	70.12	85.09	89.30	69.64	-	-	-	-	-	-
k_3	48.78	60.83	64.02	79.69	72.98	88.27	69.09	-	-	-	-	-	-
Mean (H)	51.98	61.35	60.13	72.74	81.07	89.11	69.40						

Mean	C.D.(0.05)	S.E.
N, P or K	4.000	1.422
H	5.660	2.011

Table 7(c). Effect of different levels of nutrients and harvest intervals on oil yield (kg/ha): pooled data for two years.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	80.76	94.83	95.99	110.38	110.95	123.15	102.68	103.15	105.00	99.87	95.15	106.31	106.56
n_2	76.02	93.32	96.98	114.73	124.21	130.66	105.99	104.32	103.78	109.84	103.20	108.19	106.47
n_3	84.19	90.79	92.37	108.95	128.89	134.82	106.67	106.57	105.73	107.71	94.33	106.52	119.15
p_1	74.62	90.40	91.58	107.23	104.73	116.97	97.59	98.87	95.67	98.23	-	-	-
p_2	80.10	89.51	96.65	105.97	131.63	138.18	107.01	103.43	107.79	109.80	-	-	-
p_3	86.22	99.02	97.10	120.86	127.69	133.47	110.73	111.73	111.05	109.40	-	-	-
k_1	84.92	92.72	92.54	108.20	124.50	125.19	104.68	-	-	-	-	-	-
k_2	79.91	93.71	91.17	108.41	122.05	135.78	104.80	-	-	-	-	-	-
k_3	76.11	92.51	101.62	117.45	117.50	129.66	105.80	-	-	-	-	-	-
Mean (H)	80.31	92.98	95.11	111.35	121.35	129.54	105.12						

Mean	C.D.(0.05)	S.E.
N, P or K	4.973	1.769
NP, NK or PK	8.613	3.065
H	7.033	2.499
NH, PH or KH	12.181	4.330

yield of 36.78 kg/ha in the first year and the oil yields obtained at 25 and 75 kg N/ha were 34.87 and 35.06 kg/ha respectively. In the second year, the maximum oil yield was recorded with 75 kg N/ha (71.06 kg/ha) and the oil yields at 25 and 50 kg N/ha were 67.37 and 69.76 kg/ha respectively.

The maximum oil yield as per the pooled data for two years was also recorded by 75 kg N/ha.

Effect of phosphorus

Oil yield increased progressively with increasing levels of P_2O_5 and the treatment in which 75 kg P_2O_5/ha was applied recorded the highest oil yield in both the years. During the first year 75 kg P_2O_5/ha was significantly superior to the other two levels and the three levels were significantly different.

In the second year, and in the pooled data for two years also 75 kg P_2O_5/ha recorded the maximum oil yield, but there was no significant difference between 50 and 75 kg P_2O_5/ha and both of them were significantly different from 25 kg P_2O_5. The oil yields obtained at 25, 50 and 75 kg P_2O_5/ha in the first year were 32.00, 35.97 and 38.73 kg/ha respectively and that in the second year were 65.22, 71.04 and 71.93 kg/ha respectively.

Effect of potassium

Different levels of K_2O could not produce any significant effect in both the years and in the pooled data for two years also.

The oil yields obtained at 25, 50 and 75 kg K_2O/ha in the first year were 36.15, 34.82 and 35.73 kg/ha and that in the second year were 69.45, 69.64 and 69.09 kg/ha respectively.

Nutrient interactions

Interaction between N and P was significant during the first year and in the pooled data for two years. In both the years the combination n_3p_3 recorded the maximum oil yield.

Effect of harvest intervals

Oil yield was influenced significantly with different intervals of harvest in both the years. The increase in oil yield was almost linear as the intervals of harvest increased and the treatment harvested at the maximum interval viz., 65 days recorded the highest oil yield in both the years. In the first year, it was on par with 60 and 55 day intervals and the yield ranged from 28.33 to 41.55 kg/ha. In the second year, the highest yield of 89.11 kg/ha recorded with 65 day intervals was significantly superior to all other harvest intervals. The lowest yield was recorded with 40 days interval in both the years.

The treatment harvested at 65 day intervals was significantly superior to all other harvest intervals in the pooled data for two years also.

Interactions of nutrients with harvest intervals

The interaction between P and H was significant in the pooled data for two years. Highest yield was recorded by p_2h_6 followed by p_3h_6.

Oil content in the herbage on fresh weight basis

The results on the percentage of oil in the herbage on fresh weight basis (volume of oil/weight of herbage) as influenced by different levels of N, P, K and H are presented in Tables 8 a, b and c and in Fig. 2 and 6.

Effect of nitrogen

Increase in the levels of N from 25 to 75 kg/ha did not influence the oil content significantly in both the years and in the mean for the two years. The lowest level of N applied recorded the highest oil content in both the years and the mean oil contents at 25, 50 and 75 kg N/ha in the first year were 0.301, 0.290 and 0.292 per cent respectively and those in the second year were 0.276, 0.272 and 0.275 per cent respectively.

Effect of phosphorus

Increase in the levels of P_2O_5 did not influence the oil content significantly in both the years and in the mean value for two years. No definite trend was noticed in the oil content with increase in the level of P_2O_5. The mean oil contents recorded in the first year at 25, 50 and 75 kg P_2O_5/ha were 0.293, 0.292 and 0.297 per cent respectively and in the second year these were 0.274,

Table 8(a). Effect of different levels of nutrients and harvest intervals on oil content on fresh weight basis (per cent) in the first year: 1980-81.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	0.274	0.278	0.315	0.311	0.316	0.312	0.301	0.317	0.302	0.285	0.300	0.303	0.301
n_2	0.247	0.266	0.305	0.310	0.310	0.304	0.290	0.294	0.283	0.295	0.299	0.287	0.285
n_3	0.268	0.259	0.301	0.300	0.313	0.317	0.292	0.295	0.289	0.293	0.285	0.286	0.306
p_1	0.275	0.274	0.309	0.309	0.307	0.295	0.295	0.310	0.278	0.296	-	-	-
p_2	0.259	0.256	0.304	0.299	0.321	0.310	0.292	0.292	0.214	0.290	-	-	-
p_3	0.255	0.271	0.309	0.312	0.311	0.326	0.297	0.304	0.301	0.287	-	-	-
k_1	0.280	0.279	0.313	0.317	0.315	0.303	0.302	-	-	-	-	-	-
k_2	0.256	0.263	0.299	0.301	0.309	0.319	0.291	-	-	-	-	-	-
k_3	0.253	0.260	0.310	0.302	0.315	0.305	0.291	-	-	-	-	-	-
Mean (H)	0.263	0.267	0.307	0.307	0.313	0.311	0.294						

Mean	C.D.(0.05)	S.E.
N, P or K	-	0.0043
H	0.0171	0.0061

Table 8(b). Effect of different levels of nutrients and harvest intervals on oil content on

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	0.233	0.256	0.268	0.275	0.300	0.324	0.276	0.281	0.273	0.274	0.275	0.284	0.269
n_2	[illegible]	0.258	0.258	0.280	0.314	0.309	0.272	0.283	0.272	0.262	0.272	0.272	0.275
n_3	0.225	0.245	0.271	0.278	0.317	0.317	0.275	0.278	0.285	0.261	0.274	0.278	0.272
p_1	0.230	0.260	0.266	0.281	0.296	0.308	0.274	0.284	0.270	0.268	-	-	-
p_2	0.221	0.250	0.278	0.284	0.315	0.319	0.278	0.284	0.286	0.264	-	-	-
p_3	0.222	0.250	0.254	0.268	0.319	0.317	0.272	0.275	0.274	0.264	-	-	-
k_1	0.226	0.259	0.268	0.284	0.320	0.327	0.281	-	-	-	-	-	-
k_2	0.226	0.252	0.270	0.274	0.314	0.324	0.277	-	-	-	-	-	-
k_3	0.221	0.249	0.259	0.274	0.296	0.293	0.265	-	-	-	-	-	-
Mean (H)	0.224	0.253	0.266	0.278	0.310	0.315	0.274						

Mean	C.D.(0.05)	S.E.
N, P or K	0.0094	0.0033
H	0.0133	0.0047

Table 8(c). Effect of different levels of nutrients and harvest intervals on oil content on fresh weight basis (per cent): mean values for two years.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	0.264	0.267	0.292	0.294	0.308	0.317	0.291	0.304	0.288	0.280	0.288	0.298	0.285
n_2	0.231	0.262	0.287	0.295	0.312	0.317	0.284	0.294	0.280	0.278	0.291	0.280	0.281
n_3	0.246	0.252	0.286	0.287	0.315	0.314	0.283	0.287	0.287	0.277	0.280	0.282	0.289
p_1	0.252	0.267	0.288	0.295	0.302	0.313	0.286	0.302	0.274	0.282	-	-	-
p_2	0.250	0.253	0.291	0.292	0.318	0.315	0.287	0.293	0.290	0.277	-	-	-
p_3	0.238	0.260	0.286	0.290	0.314	0.321	0.285	0.290	0.290	0.275	-	-	-
k_1	0.263	0.259	0.291	0.301	0.318	0.329	0.295	-	-	-	-	-	-
k_2	0.241	0.257	0.288	0.287	0.312	0.322	0.284	-	-	-	-	-	-
k_3	0.237	0.255	0.285	0.288	0.306	0.299	0.278	-	-	-	-	-	-
Mean (H)	0.247	0.260	0.288	0.292	0.312	0.316	0.286						

Mean	C.D. (0.05)	S.E.
N, P or K	0.0081	0.0029
NP, NK or PK	0.0140	0.0049
H	0.0115	0.0041

0.278 and 0.272 per cent respectively.

Effect of potassium

Different levels of K_2O did not influence the oil content significantly during the first year, but increase in the levels of K_2O tended to decrease the oil content. Thus at 25, 50 and 75 kg K_2O/ha the oil contents were 0.302, 0.291 and 0.291 per cent respectively.

In the second year the effect of K_2O was significant and the oil content decreased as the levels of K_2O increased. The oil content at 75 kg/ha (0.265 per cent) was significantly lower than that at 50 kg (0.277 per cent) and at 25 kg K_2O/ha (0.281 per cent) and there was no significant difference between these two levels.

The mean oil content for two years also decreased with increase in the levels of K_2O and the lowest value recorded with 75 kg/ha was significantly lower than that at 25 kg K_2O/ha.

Nutrient interactions

The interaction between P and K was significant in the pooled data for two years. The highest value for oil content was recorded in the treatment p_1k_1.

Effect of harvest intervals

The oil content was influenced significantly by different intervals of harvest in both the years and it increased almost linearly with increase in the intervals between harvests. The highest value was recorded with 60 days interval (0.313 per cent) in the first year and it was on par with 65, 55 and 50 day intervals. The lowest value (0.263 per cent) was recorded with 40 days interval.

In the second year, the highest value was recorded with 65 days interval (0.315 per cent) and there was no significant difference between 65 and 60 day intervals. The lowest value (0.224 per cent) was recorded with 40 days interval in this year also.

There was no significant difference between 65 and 60 day intervals in the mean values for two years and both these were significantly higher than the other intervals of harvest.

Dry matter yield

The mean dry matter yield for different treatments obtained in the first year, second year and the pooled data for two years are presented in Tables 9 a, b and c.

Effect of nitrogen

Different levels of N influenced dry matter yield significantly in the first year. The highest yield (5.00 t/ha) was recorded at 50 kg N/ha and it was significantly more than the yields at 75 and 25 kg N/ha.

Dry matter yield increased with increase in the levels of N in the second year, though the difference between the treatments was not statistically significant. The yields obtained at 25, 50 and 75 kg N/ha were 7.66, 7.90 and 8.17 t/ha respectively.

Table 9(a). Effect of different levels of nutrients and harvest intervals on dry matter yield (t/ha) in the first year: 1980-81.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	3.80	4.14	4.43	5.34	4.17	5.97	4.64	4.55	4.61	4.76	4.16	4.88	4.89
n_2	3.91	4.45	4.81	5.24	4.75	6.85	5.00	5.01	4.79	5.20	4.74	5.04	5.24
n_3	3.84	4.49	3.95	4.86	4.67	6.17	4.66	4.56	4.61	4.83	4.15	4.58	5.27
p_1	3.34	4.14	4.05	4.84	4.01	5.71	4.35	4.23	4.40	4.41	-	-	-
p_2	3.97	4.28	4.30	4.88	4.87	6.70	4.83	4.63	4.74	5.12	-	-	-
p_3	4.25	4.66	4.84	5.73	4.71	6.59	5.13	5.26	4.88	5.25	-	-	-
k_1	4.02	4.10	4.24	5.00	4.62	6.26	4.70	-	-	-	-	-	-
k_2	3.67	4.25	4.31	5.20	4.38	6.22	4.67	-	-	-	-	-	-
k_3	3.85	4.72	4.64	5.25	4.59	6.53	4.93	-	-	-	-	-	-
Mean (H)	3.85	4.36	4.40	5.15	4.53	6.33	4.77						

Mean	C.D.(0.05)	S.E.
N, P or K	0.235	0.083
H	0.332	0.118

Table 9(b). Effect of different levels of nutrients and harvest intervals on dry matter yield (t/ha) in the second year: 1981-82.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	6.03	7.12	6.52	7.87	8.17	10.20	7.66	7.36	7.99	7.64	7.34	7.62	8.02
n_2	5.85	6.82	6.62	8.21	8.36	11.52	7.90	7.80	7.74	8.50	7.58	8.07	8.06
n_3	6.28	6.82	6.61	8.22	9.41	11.70	8.17	8.25	7.78	8.49	7.48	8.03	9.00
p_1	5.53	6.94	6.47	7.67	7.86	10.30	7.47	7.18	7.55	7.66	-	-	-
p_2	5.82	6.56	6.46	7.63	9.12	11.79	7.91	7.73	7.76	8.55	-	-	-
p_3	6.83	7.28	6.81	8.94	8.95	11.35	8.36	8.47	8.19	8.42	-	-	-
k_1	6.47	6.62	6.17	7.45	8.65	10.65	7.79	-	-	-	-	-	-
k_2	5.81	7.16	6.42	7.89	8.70	11.03	7.83	-	-	-	-	-	-
k_3	5.90	6.99	7.22	8.97	8.39	11.78	8.21	-	-	-	-	-	-
Mean (H)	6.06	6.92	6.58	8.10	8.65	11.15	7.91						

Mean	C.D.(0.05)	S.E.
N, P or K	0.431	0.153
H	0.610	0.217

Table 9(c). Effect of different levels of nutrients and harvest intervals on dry matter yield (t/ha): pooled data for two years.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	9.83	11.27	10.95	13.21	12.34	16.27	12.30	11.90	12.61	12.40	11.49	12.49	12.92
n_2	9.84	11.30	11.50	13.50	13.14	16.38	12.94	12.81	12.53	13.70	12.31	13.43	13.29
n_3	10.12	11.31	10.56	13.08	14.07	17.85	12.85	12.60	12.39	13.32	11.62	12.61	14.27
p_1	8.37	11.07	10.52	12.51	11.87	16.03	11.81	11.42	11.95	12.07	-	-	-
p_2	9.79	10.83	10.96	12.56	13.99	18.49	12.85	12.36	12.50	13.67	-	-	-
p_3	11.08	11.94	11.60	14.63	13.66	17.95	13.49	13.73	13.08	13.68	-	-	-
k_1	10.50	10.72	10.41	12.44	13.47	16.91	12.51	-	-	-	-	-	-
k_2	9.49	11.42	10.73	13.09	13.08	17.25	12.51	-	-	-	-	-	-
k_3	9.76	11.71	11.36	14.22	12.97	16.31	13.14	-	-	-	-	-	-
Mean (H)	9.91	11.28	11.00	13.25	13.18	17.49	12.71						

Mean	C.D.(0.05)	S.E.
N, P or K	0.582	0.207
H	0.823	0.292

Different levels of N showed significant influence on the total yield for two years. The maximum yield was recorded at 50 kg N/ha and it was significantly superior to the lowest level of N, but on par with 75 kg N/ha.

Effect of phosphorus

Dry matter yield in both the years and the total yield for two years were significantly increased with increased levels of P_2O_5. All the three levels were significantly different in both the years and in the total yield for two years also. The yields at 25, 50 and 75 kg P_2O_5/ha during the first year were 4.35, 4.83 and 5.13 t/ha respectively and the yields recorded in the second year corresponding to the above treatments were 7.47, 7.91 and 8.36 t/ha.

Effect of potassium

Different levels of K_2O did not significantly influence the dry matter yield in both the years and in the mean value for two years. The yields recorded at 25, 50 and 75 kg K_2O/ha in the first year were 4.70, 4.67 and 4.93 t/ha respectively and that in the second year were 7.79, 7.83 and 8.21 t/ha.

Effect of harvest intervals

Dry matter yield increased significantly with increased intervals of harvest. The maximum dry matter yield was recorded with a harvest interval of 65 days in both the years and it was significantly superior to the other harvest intervals. The lowest yield was recorded for the shortest interval tried viz., 40 days, in both the years. The dry matter yield obtained during the first year ranged from 3.85 to 6.33 t/ha while that in the second year varied from 6.06 to 11.15 t/ha.

Physico-chemical properties of the oil

Gas Liquid Chromatographic analysis of oil obtained in the first year

It may be mentioned here that the oil yield obtained per plot in the year 1980-'81 was not sufficient enough for studying the physico-chemical properties of oil by the chemical methods. Hence, the oil obtained from different harvests in a plot were pooled and analysed by GLC for its geraniol and geranyl acetate contents.

Geraniol content

Data on the geraniol content of the oil obtained in the first year and determined by the GLC are presented in Table 10.

Effect of nitrogen, phosphorus and potassium

The main effects of N, P or K or their interactions were not significant. The values recorded at 25, 50 and 75 kg N/ha were 71.5, 68.9 and 69.8 per cent respectively and the values at 25, 50 and 75 P_2O_5/ha were 69.5, 70.4 and 70.2 per cent. The geraniol contents corresponding to the different levels of K_2O were 70.9, 69.6 and 69.7 per cent respectively.

Table 10. Effect of different levels of nutrients and harvest intervals on geraniol content of the oil (per cent) determined by GLC in the first year: 1980-81.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	63.6	75.6	69.6	73.5	74.7	71.6	71.5	71.9	70.1	72.3	71.7	71.9	70.8
n_2	61.2	68.0	71.5	71.9	69.3	71.7	68.9	70.2	70.5	66.1	67.7	71.5	67.6
n_3	57.3	71.8	73.1	73.9	72.4	70.3	69.8	70.6	68.1	70.7	69.2	67.8	72.3
p_1	61.7	68.1	74.7	70.6	74.3	67.9	69.5	70.2	67.9	70.5	-	-	-
p_2	59.1	73.8	69.1	75.8	74.1	70.4	70.4	72.2	69.5	69.4	-	-	-
p_3	61.3	73.6	70.3	73.0	67.8	75.3	70.2	70.3	71.2	69.1	-	-	-
k_1	59.4	70.5	76.6	74.3	72.0	72.7	70.9	-	-	-	-	-	-
k_2	59.6	69.3	70.1	73.3	72.6	72.5	69.6	-	-	-	-	-	-
k_3	63.1	75.6	67.4	71.8	71.8	68.4	69.7	-	-	-	-	-	-
Mean (H)	60.7	71.8	71.4	73.1	72.1	71.2	70.1						

Mean	C.D.(0.05)	S.E.
N, P or K	-	0.99
H	3.94	1.40

Effect of harvest intervals

The geraniol content was influenced significantly by the different intervals of harvest. The highest value of 73.1 per cent was recorded for 55 day interval but there was no significant difference between the 45, 50, 55, 60 and 65 day intervals. The value recorded for 40 day interval was significantly lower than that of all other harvest treatments.

Geranyl acetate

The data on the geranyl acetate of the oil as determined by the GLC are furnished in Table 11.

Effect of nitrogen, phosphorus and potassium

Different levels of N, P, K or their interactions could not significantly influence the acetate content of the oil. The values recorded at 25, 50 and 75 kg N/ha were 23.1, 25.0 and 24.8 per cent respectively.

The values at 25, 50 and 75 kg P_2O_5/ha were 24.7, 24.2 and 24.1 per cent respectively and the corresponding values for the three levels of K_2O were 24.0, 24.5 and 24.4 per cent.

Effect of harvest intervals

From the data it is evident that the lowest acetate content was recorded with 65 day interval (21.8 per cent) and the highest value with 40 day interval (32.7 per cent). The acetate content decreased as the interval of harvest increased and the values recorded at 40, 45, 50, 55, 60 and

Table 11. Effect of different levels of nutrients and harvest intervals on geranyl acetate content of the oil (per cent) determined by GLC in the first year: 1980-81.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	30.6	20.8	23.7	21.8	20.6	21.4	23.1	23.0	23.9	22.5	22.8	23.2	23.5
n_2	31.7	26.1	24.1	22.4	24.6	20.9	25.0	24.5	23.3	27.1	25.5	23.2	26.2
n_3	35.9	23.9	22.4	21.9	21.7	23.1	24.8	24.5	26.3	23.6	25.8	26.1	22.5
p_1	32.4	26.6	20.4	24.6	20.5	23.8	24.7	24.3	25.7	24.1	-	-	-
p_2	34.3	22.1	25.6	19.8	21.0	22.1	24.2	23.0	24.8	24.7	-	-	-
p_3	31.4	22.2	24.2	21.8	25.3	19.4	24.1	24.7	23.0	24.5	-	-	-
k_1	34.3	25.2	19.1	21.7	22.9	21.0	24.0	-	-	-	-	-	-
k_2	34.1	25.3	24.2	21.4	21.4	20.6	24.5	-	-	-	-	-	-
k_3	29.8	20.3	27.0	23.1	22.6	23.8	24.4	-	-	-	-	-	-
Mean (H)	32.7	23.6	23.4	22.0	22.3	21.8	24.3						

Mean	C.D.(0.05)	S.E.
N, P or K	-	0.81
H	3.23	1.15

65 day intervals were 32.7, 23.6, 23.4, 22.0, 22.3 and 21.8 per cent respectively. But the difference between 45, 50, 55, 60 and 65 day intervals were not significant and all of them recorded lower acetate content than the 40 day interval treatment.

Physico-chemical properties of the oil obtained in the second year

The plotwise oil yield per harvest was not sufficient for the estimation of all the physico-chemical properties of oil. Hence the oil separately distilled plotwise were combined together for the harvests of two broad seasons viz., monsoon season (May to September) and summer season (October to February) and the physico-chemical properties of the oil were determined.

Specific gravity

The data relating to specific gravity of the oil at 30°C, obtained during the monsoon and summer seasons in the second year and the mean for the two seasons are presented in Tables 12 a, b and c.

Effect of nitrogen

The data showed that the specific gravity of the oil was not influenced significantly by the different levels of N. The values obtained at 25, 50 and 75 kg/ha in the monsoon season were 0.8937, 0.8951 and 0.8936 respectively while that in the summer season were 0.8887, 0.8890 and 0.8891 respectively.

Table 12(a). Effect of different levels of nutrients and harvest intervals on specific gravity of the oil (at 30°C) in the monsoon season: 1981-82.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	0.8951	0.8923	0.8903	0.8965	0.8954	0.8916	0.8937	0.8937	0.8949	0.8926	0.8946	0.8931	0.8935
n_2	0.8992	0.8936	0.8961	0.8957	0.8915	0.8942	0.8951	0.8966	0.8948	0.8938	0.8930	0.8978	0.8942
n_3	0.8946	0.8919	0.8938	0.8963	0.8920	0.8932	0.8936	0.8947	0.8926	0.8937	0.8962	0.8932	0.8914
p_1	0.8951	0.8931	0.8930	0.8980	0.8947	0.8938	0.8946	0.8959	0.8934	0.8946	-	-	-
p_2	0.8972	0.8923	0.8959	0.8975	0.8925	0.8929	0.8947	0.8963	0.8949	0.8929	-	-	-
p_3	0.8966	0.8928	0.8912	0.8929	0.8926	0.8924	0.8930	0.8928	0.8939	0.8927	-	-	-
k_1	0.8985	0.8952	0.8933	0.8944	0.8949	0.8936	0.8950	-	-	-	-	-	-
k_2	0.8969	0.8914	0.8924	0.8960	0.8918	0.8936	0.8941	-	-	-	-	-	-
k_3	0.8935	0.8912	0.8944	0.8961	0.8932	0.8918	0.8934	-	-	-	-	-	-
Mean (H)	0.8963	0.8927	0.8934	0.8962	0.8933	0.8930	0.8941						

Mean	C.D.(0.05)	S.E.
N, P or K	-	0.00071
NP, NK or PK	0.00357	0.00127
H	0.00292	0.00100

Table 12(b). Effect of different levels of nutrients and harvest intervals on specific gravity of the oil (at 30°C) in the summer season: 1981-82.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	0.8902	0.8897	0.8879	0.8878	0.8882	0.8884	0.8887	0.8888	0.8888	0.8885	0.8889	0.8880	0.8894
n_2	0.8906	0.8899	0.8878	0.8877	0.8892	0.8886	0.8890	0.8888	0.8899	0.8884	0.8896	0.8886	0.8888
n_3	0.8892	0.8888	0.8904	0.8891	0.8887	0.8882	0.8891	0.8889	0.8882	0.8902	0.8907	0.8886	0.8879
p_1	0.8901	0.8896	0.8897	0.8898	0.8894	0.8890	0.8897	0.8888	0.8894	0.8905	-	-	-
p_2	0.8894	0.8887	0.8884	0.8874	0.8882	0.8879	0.8883	0.8886	0.8887	0.8879	-	-	-
p_3	0.8903	0.8900	0.8879	0.8874	0.8885	0.8883	0.8887	0.8890	0.8888	0.8886	-	-	-
k_1	0.8889	0.8891	0.8885	0.8877	0.8897	0.8890	0.8888	-	-	-	-	-	-
k_2	0.8909	0.8903	0.8876	0.8880	0.8883	0.8886	0.8890	-	-	-	-	-	-
k_3	0.8902	0.8889	0.8893	0.8890	0.8881	0.8877	0.8890	-	-	-	-	-	-
Mean (H)	0.8900	0.8895	0.8887	0.8882	0.8887	0.8884	0.8889						

Mean	C.D.(0.05)	S.E.
N, P or K	0.00089	0.00031
NP, NK or PK	0.00154	0.00055
H	-	0.00045

Table 12(c). Effect of different levels of nutrients and harvest intervals on specific gravity of the oil (at 30°C): mean values for two seasons.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	0.8926	0.8911	0.8886	0.8923	0.8924	0.8901	0.8912	0.8913	0.8917	0.8905	0.8917	0.8905	0.8914
n_2	0.8949	0.8917	0.8912	0.8915	0.8902	0.8903	0.8917	0.8921	0.8921	0.8911	0.8912	0.8928	0.8912
n_3	0.8920	0.8903	0.8927	0.8928	0.8904	0.8907	0.8915	0.8918	0.8907	0.8920	0.8935	0.8912	0.8897
p_1	0.8926	0.8914	0.8914	0.8933	0.8920	0.8914	0.8921	0.8924	0.8913	0.8927	-	-	-
p_2	0.8934	0.8904	0.8920	0.8925	0.8904	0.8905	0.8915	0.8920	0.8921	0.8904	-	-	-
p_3	0.8935	0.8914	0.8890	0.8908	0.8906	0.8897	0.8908	0.8910	0.8911	0.8905	-	-	-
k_1	0.8938	0.8922	0.8901	0.8911	0.8923	0.8913	0.8918	-	-	-	-	-	-
k_2	0.8938	0.8909	0.8901	0.8930	0.8901	0.8905	0.8915	-	-	-	-	-	-
k_3	0.8920	0.8900	0.8922	0.8925	0.8908	0.8898	0.8912	-	-	-	-	-	-
Mean (H)	0.8932	0.8910	0.8903	0.8922	0.8910	0.8905	0.8915						

Mean	C.D.(0.05)	S.E.
N, P or K	-	0.00032
NP, NK or PK	0.00212	0.00075
H	0.00173	0.00062

Effect of phosphorus

Different levels of P_2O_5 did not significantly influence the specific gravity of the oil in the monsoon season. The values recorded at 25, 50 and 75 kg P_2O_5/ha were 0.8946, 0.8947 and 0.8930 respectively.

In the summer season higher levels of P_2O_5 decreased the specific gravity significantly. The lowest value was recorded with P_2O_5 at 50 kg/ha and the values recorded at 50 and 75 kg/ha were significantly lower than that at 25 kg/ha. The values recorded at 25, 50 and 75 kg P_2O_5/ha were 0.8897, 0.8883 and 0.8887 respectively. In the mean value for the two seasons the effect of P_2O_5 was not significant but there was a decrease in the specific gravity with increase in the levels of P_2O_5.

Effect of potassium

Application of different levels of K_2O showed no significant influence on the specific gravity of oil in both the seasons and in the mean value for the two seasons. The values obtained at 25, 50 and 75 kg K_2O/ha were 0.8950, 0.8941 and 0.8934 in the monsoon season and 0.8888, 0.8890 and 0.8890 in the summer season. In the mean value for the two seasons, the specific gravity of the oil decreased with increase in the levels of K_2O.

Nutrient interactions

The interaction between N and P was significant in both the seasons and in the mean value for the two seasons.

The lowest specific gravity was recorded by n_3p_3 in both the seasons. The interaction between N and K was significant in the summer season and the lowest specific gravity was recorded by n_3k_2.

Effect of harvest intervals

The effect of intervals of harvest on the specific gravity of oil was significant in the monsoon season and for the mean of the two seasons. Specific gravity was found to decrease as the interval between harvests increased. In the mean value for the two seasons the lowest value was recorded with the harvest interval of 65 days and the highest value with 40 day of harvest interval. Specific gravity of the oil in the summer season was lower than that recorded in the monsoon season and the values during the monsoon season ranged from 0.8927 to 0.8963 and these in the summer season varied from 0.8882 to 0.8900.

The mean values for the two seasons recorded for the 40, 45, 50, 55, 60 and 65 day intervals were 0.8932, 0.8910, 0.8908, 0.8922, 0.8910 and 0.8905 respectively.

Refractive index

Data relating to the refractive index of the oil at 30°C as influenced by different levels of N, P, K and H are presented in Tables 13 a, b and c.

Effect of nitrogen

The refractive index of the oil was significantly influenced by different levels of N in the monsoon season.

Table 13(a). Effect of different levels of nutrients and harvest intervals on refractive index of the oil (at 30°C) in the monsoon season: 1981-82.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	1.4677	1.4681	1.4683	1.4687	1.4687	1.4686	1.4685	1.4685	1.4682	1.4683	1.4685	1.4682	1.4683
n_2	1.4681	1.4683	1.4688	1.4691	1.4687	1.4689	1.4686	1.4688	1.4686	1.4684	1.4684	1.4688	1.4687
n_3	1.4680	1.4678	1.4684	1.4687	1.4684	1.4686	1.4684	1.4686	1.4681	1.4685	1.4685	1.4684	1.4685
p_1	1.4680	1.4681	1.4684	1.4686	1.4686	1.4688	1.4684	1.4688	1.4681	1.4684	-	-	-
p_2	1.4676	1.4680	1.4688	1.4692	1.4685	1.4687	1.4685	1.4688	1.4682	1.4683	-	-	-
p_3	1.4682	1.4681	1.4683	1.4687	1.4687	1.4686	1.4684	1.4683	1.4685	1.4684	-	-	-
k_1	1.4680	1.4684	1.4686	1.4692	1.4687	1.4688	1.4685	-	-	-	-	-	-
k_2	1.4680	1.4677	1.4682	1.4686	1.4685	1.4687	1.4683	-	-	-	-	-	-
k_3	1.4677	1.4681	1.4687	1.4688	1.4685	1.4687	1.4684	-	-	-	-	-	-
Mean (H)	1.4679	1.4681	1.4685	1.4688	1.4686	1.4681	1.4684						

Mean	C.D.(0.05)	S.E.
N, P or K	0.00025	0.00009
H	0.00036	0.00013

Table 15(b). Effect of different levels of nutrients and harvest intervals on refractive index of the oil (at 30°C) in the summer season: 1981-82.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	1.4673	1.4689	1.4692	1.4694	1.4693	1.4693	1.4689	1.4690	1.4688	1.4689	1.4691	1.4688	1.4688
n_2	1.4677	1.4691	1.4693	1.4695	1.4693	1.4694	1.4691	1.4592	1.4690	1.4689	1.4689	1.4690	1.4693
n_3	1.4675	1.4690	1.4692	1.4693	1.4695	1.4696	1.4689	1.4591	1.4689	1.4689	1.4690	1.4690	1.4689
p_1	1.4575	1.4592	1.4592	1.4592	1.4694	1.4694	1.4690	1.4692	1.4688	1.4691	-	-	-
p_2	1.4671	1.4688	1.4694	1.4695	1.4692	1.4695	1.4689	1.4691	1.4689	1.4688	-	-	-
p_3	1.4678	1.4690	1.4690	1.4692	1.4694	1.4694	1.4690	1.4690	1.4690	1.4689	-	-	-
k_1	1.4677	1.4592	1.4694	1.4693	1.4695	1.4695	1.4691	-	-	-	-	-	-
k_2	1.4672	1.4680	1.4691	1.4692	1.4695	1.4693	1.4689	-	-	-	-	-	-
k_3	1.4674	1.4698	1.4690	1.4693	1.4690	1.4695	1.46	-	-	-	-	-	-
Mean (H)	1.4675	1.4690	1.4692	1.4692	1.4693	1.4694	1.4690						

Mean	C.D.(0.05)	S.E.
	-	0.00008
H	0.00034	0.00012

Table 13(c). Effect of different levels of nutrients and harvest intervals on refractive index of the oil (at 30°C): mean values for two seasons.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	1.4675	1.4685	1.4688	1.4691	1.4690	1.4690	1.4687	1.4688	1.4685	1.4686	1.4688	1.4685	1.4685
n_2	1.4679	1.4687	1.4691	1.4693	1.4690	1.4691	1.4689	1.4690	1.4688	1.4687	1.4687	1.4689	1.4690
n_3	1.4678	1.4684	1.4686	1.4687	1.4689	1.4694	1.4687	1.4689	1.4685	1.4688	1.4688	1.4687	1.4686
p_1	1.4678	1.4687	1.4688	1.4689	1.4690	1.4692	1.4687	1.4690	1.4685	1.4688	-	-	-
p_2	1.4674	1.4684	1.4691	1.4694	1.4689	1.4691	1.4687	1.4690	1.4686	1.4686	-	-	-
p_3	1.4680	1.4686	1.4687	1.4688	1.4691	1.4690	1.4687	1.4687	1.4688	1.4687	-	-	-
k_1	1.4679	1.4688	1.4690	1.4692	1.4691	1.4692	1.4689	-	-	-	-	-	-
k_2	1.4676	1.4679	1.4687	1.4689	1.4690	1.4690	1.4685	-	-	-	-	-	-
k_3	1.4676	1.4689	1.4689	1.4690	1.4688	1.4691	1.4687	-	-	-	-	-	-
Mean (H)	1.4677	1.4686	1.4689	1.4690	1.4690	1.4691	1.4687						

Mean	C.D.(0.05)	S.E.
N, P or K	-	0.00008
H	0.00034	0.00012

Application of N at 50 kg/ha resulted in significantly higher value than at 25 kg N/ha. But there was no significant difference between 50 and 75 kg/ha and between 25 and 75 kg/ha. The values recorded at 25, 50 and 75 kg N/ha were 1.4683, 1.4686, 1.4684 respectively.

The data recorded in the summer season and the mean values for the two seasons showed that the effect of N was not significant. But N at 50 kg/ha recorded the highest value in the summer season also as in the monsoon season.

Effect of phosphorus

The refractive index of oil was not influenced by the different levels of P_2O_5 in either the season or as per the mean value for the two seasons. The values obtained at 25, 50 and 75 kg P_2O_5/ha in the monsoon season were 1.4684, 1.4685 and 1.4684 respectively and that in the summer season were 1.4690, 1.4689 and 1.4690.

Effect of potassium

The refractive index of oil was not influenced by the different levels of K_2O in either of the seasons.

Effect of harvest intervals

The refractive index of the oil increased at higher intervals of harvest in both the seasons. In the monsoon season the crop harvested at 55 day intervals recorded the highest value but it was on par with 65, 60 and 50 day intervals and these were significantly different from the results for the 45 and 40 day intervals. The values ranged from 1.4679 to 1.4688.

In the summer season 65 day intervals recorded the maximum value and it was on par with 60, 55 and 50 day intervals as in the monsoon season. The values varied from 1.4675 to 1.4694. The lowest value was recorded for the 40 day intervals and it was significantly lower than that of all other intervals of harvest. Similar results were obtained in the mean value for two seasons also.

Optical rotation

Data relating to the optical rotation of the oil obtained from the different treatments during the monsoon and summer seasons and their mean values are presented in Tables 14 a, b and c.

Effect of nitrogen, phosphorus and potassium

Optical rotation of the oil was not influenced significantly by the main effects of N, P, K or their interactions in both the seasons and in the mean values for the two seasons.

The values recorded in the monsoon season at 25, 50 and 75 kg N/ha were +1.47°, +1.58° and +1.65° and in the summer season these were +1.62°, +1.68° and +1.70° respectively.

Increasing the level of P_2O_5 from 25 to 75 kg/ha slightly increased the optical rotation of the oil in both the seasons. The values recorded at 25, 50 and 75 kg P_2O_5/ha in the monsoon season were +1.51°, +1.54° and +1.63°

Table 14(a). Effect of different levels of nutrients and harvest intervals on optical totation of the oil (degrees) in the monsoon season: 1981-82.
(All the values have a +ve sign)

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	1.17	1.59	1.48	1.46	1.54	1.57	1.47	1.59	1.38	1.44	1.37	1.56	1.48
n_2	1.36	1.51	1.46	1.54	1.52	2.09	1.58	1.47	1.54	[illegible]	1.69	1.44	1.61
n_3	1.87	1.47	1.56	1.71	1.43	1.87	1.65	1.80	1.55	1.58	1.47	1.64	1.82
p_1	1.36	1.63	1.43	1.49	1.46	1.70	1.51	1.63	1.42	1.48	-	-	-
p_2	1.18	1.39	1.52	1.74	1.43	2.00	1.54	1.58	1.42	1.63	-	-	-
p_3	1.83	1.54	1.53	1.48	1.61	1.81	1.63	1.64	1.62	1.64	-	-	-
k_1	1.71	1.67	1.38	1.69	1.53	1.73	1.62	-	-	-	-	-	-
k_2	1.21	1.37	1.56	1.43	1.51	1.87	1.49	-	-	-	-	-	-
k_3	1.46	1.53	1.56	1.59	1.46	1.92	1.59	-	-	-	-	-	-
Mean (H)	1.45	1.52	1.50	1.57	1.50	1.84	1.56						

Mean	C.D.(0.05)	S.E.
N, P or K	-	0.075
H	0.293	0.106

Table 14(b). Effect of different levels of nutrients and harvest intervals on optical rotation of the oil (degrees) in the summer season: 1981-82.
(All the values have a +ve sign)

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	1.34	1.71	1.61	1.65	1.74	1.69	1.62	1.73	1.54	1.60	1.58	1.67	1.62
n_2	1.47	1.53	1.55	1.61	1.70	2.20	1.68	1.64	1.60	1.79	1.75	1.60	1.69
n_3	1.78	1.48	1.65	1.80	1.65	1.83	1.70	1.81	1.68	1.60	1.58	1.68	1.84
p_1	1.47	1.81	1.48	1.72	1.56	1.70	1.62	1.72	1.53	1.65	-	-	-
p_2	1.30	1.39	1.70	1.79	1.65	2.07	1.65	1.70	1.59	1.66	-	-	-
p_3	1.82	1.52	1.64	1.55	1.88	1.95	1.72	1.74	1.71	1.67	-	-	-
k_1	1.71	1.77	1.51	1.72	1.77	1.89	1.73	-	-	-	-	-	-
k_2	1.39	1.43	1.67	1.67	1.63	1.85	1.61	-	-	-	-	-	-
k_3	1.50	1.51	1.65	1.66	1.69	1.97	1.66	-	-	-	-	-	-
Mean (H)	1.53	1.58	1.61	1.69	1.70	1.90	1.67						

Mean	C.D. (0.05)	S.E.
N, P or K	-	0.075
H	0.298	0.106

Table 14(c). Effect of different levels of nutrients and harvest intervals on optical rotation of the oil (degrees): mean values for two seasons.

(All the values have a +ve sign)

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	1.26	1.65	1.55	1.56	1.64	1.63	1.55	1.66	1.46	1.52	1.48	1.62	1.55
n_2	1.42	1.52	1.51	1.58	1.61	2.15	1.63	1.55	1.57	1.76	1.72	1.52	1.65
n_3	1.83	1.48	1.61	1.78	1.54	1.85	1.68	1.81	1.62	1.59	1.53	1.66	1.83
p_1	1.42	1.72	1.46	1.61	1.51	1.70	1.57	1.68	1.48	1.57	-	-	-
p_2	1.24	1.39	1.61	1.77	1.54	2.04	1.60	1.64	1.51	1.64	-	-	-
p_3	1.83	1.53	1.59	1.52	1.75	1.88	1.68	1.69	1.67	1.65	-	-	-
k_1	1.71	1.72	1.45	1.71	1.65	1.81	1.67	-	-	-	-	-	-
k_2	1.30	1.40	1.62	1.55	1.57	1.36	1.55	-	-	-	-	-	-
k_3	1.48	1.52	1.61	1.53	1.53	1.95	1.63	-	-	-	-	-	-
Mean (H)	1.50	1.55	1.56	1.63	1.60	1.87	1.62						

Mean	C.D. (0.05)	S.E.
N, P or K	-	0.078
H	0.312	0.111

respectively while these in the summer season were +1.63°, +1.65° and +1.72°.

The values of optical rotation recorded during the monsoon season at 25, 50 and 75 kg K_2O/ha were +1.62°, +1.49° and +1.59° respectively and that during the summer season were +1.73°, +1.61° and +1.66°.

Effect of harvest intervals

The optical rotation of the oil was significantly influenced by the different intervals of harvest in both the seasons and in the mean value for the two seasons. The highest and lowest values were recorded with 65 and 40 day intervals of harvest respectively in both the seasons. The values ranged from +1.45° to +1.84° in the monsoon and from +1.5[illegible]° to +1.90° in the summer season. In the mean values for the two seasons also the harvest interval of 65 days recorded the maximum value and it was on par with 60, 55 and 50 day intervals.

Solubility in 70 per cent alcohol

The values obtained in the monsoon and summer seasons for the different treatments and the mean for the two seasons are presented in Tables 15 a, b and c.

Effect of nitrogen, phosphorus and potassium

Different levels of N, P_2O_5 or K_2O showed only negligible difference with regard to the solubility of oil in 70 per cent alcohol in both the seasons. The values recorded at 25, 50 and 75 kg N/ha in the monsoon season

Table 15(a). Effect of different levels of nutrients and harvest intervals on solubility of the oil in 70 per cent alcohol in the monsoon season: 1981-82. (Volume of alcohol required for the solution of oil)

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	1.56	1.48	1.53	1.52	1.54	1.37	1.50	1.49	1.50	1.51	1.50	1.49	1.51
n_2	1.60	1.50	1.47	1.49	1.53	1.39	1.49	1.49	1.49	1.51	1.51	1.50	1.48
n_3	1.48	1.52	1.52	1.53	1.49	1.58	1.52	1.51	1.51	1.53	1.50	1.52	1.52
p_1	1.58	1.50	1.50	1.52	1.52	1.40	1.40	1.50	1.51	1.50	-	-	-
p_2	1.44	1.50	1.52	1.53	1.52	1.55	1.50	1.49	1.49	1.53	-	-	-
p_3	1.60	1.50	1.50	1.49	1.52	1.42	1.51	1.50	1.50	1.52	-	-	-
k_1	1.46	1.49	1.50	1.50	1.51	1.53	1.50	-	-	-	-	-	-
k_2	1.60	1.50	1.50	1.52	1.50	1.38	1.50	-	-	-	-	-	-
k_3	1.56	1.51	1.52	1.52	1.52	1.44	1.52	-	-	-	-	-	-
Mean (H)	1.54	1.50	1.51	1.51	1.51	1.45	1.50						

Mean	C.D.(0.05)	S.E.
N, P or K	-	0.012
H	0.046	0.016

Table 15(b). Effect of different levels of nutrients and harvest intervals on solubility of the oil in 70 per cent alcohol in the summer season: 1981-82.(volume of alcohol required for the [illegible] of oil)

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	P_1	P_2	P_3
N_1	1.56	1.57	1.47	1.47	1.46	1.41	1.49	1.49	1.47	1.49	1.49	1.51	1.46
N_2	1.54	1.54	1.43	1.42	1.48	1.47	1.48	1.48	1.48	1.47	1.50	1.47	1.48
N_3	1.51	1.56	1.42	1.42	1.51	1.46	1.48	1.48	1.49	1.46	1.47	1.49	1.48
P_1	1.52	1.54	1.43	1.43	1.51	1.47	1.48	1.47	1.50	1.48	-	-	-
P_2	1.56	1.54	1.46	1.47	1.49	1.42	1.49	1.50	1.48	1.48	-	-	-
P_3	1.54	1.57	1.43	1.42	1.44	1.44	1.47	1.49	1.46	1.47	-	-	-
K_1	1.55	1.54	1.44	1.43	1.51	1.47	1.49	-	-	-	-	-	-
K_2	1.52	1.60	1.44	1.43	1.47	1.42	1.48	-	-	-	-	-	-
K_3	1.55	1.51	1.43	1.46	1.46	1.43	1.48	-	-	-	-	-	-
Mean (H)	1.54	1.55	1.44	1.44	1.48	1.44	1.48						

Mean	C.D.(0.05)	S.E.
N, P or K	-	0.009
H	0.036	0.013

Table 15(c). Effect of different levels of nutrients and harvest intervals on solubility of the oil in 70 per cent alcohol: mean values for two seasons. (Volume of alcohol required for one volume of oil)

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	1.56	1.53	1.50	1.50	1.50	1.39	1.50	1.49	1.49	1.50	1.50	1.50	1.49
n_2	1.57	1.52	1.45	1.46	1.50	1.43	1.49	1.49	1.49	1.49	1.51	1.49	1.48
n_3	1.49	1.54	1.47	1.48	1.50	1.52	1.50	1.50	1.50	1.50	1.49	1.51	1.50
p_1	1.56	1.52	1.47	1.48	1.52	1.44	1.50	1.49	1.51	1.50	-	-	-
p_2	1.50	1.52	1.49	1.50	1.50	1.50	1.50	1.50	1.49	1.51	-	-	-
p_3	1.57	1.54	1.47	1.46	1.48	1.44	1.49	1.50	1.48	1.50	-	-	-
k_1	1.50	1.52	1.47	1.47	1.51	1.50	1.49	-	-	-	-	-	-
k_2	1.56	1.55	1.47	1.48	1.48	1.4[illegible]	1.49	-	-	-	-	-	-
k_3	1.55	1.51	1.48	1.49	1.50	1.44	1.50	-	-	-	-	-	-
Mean (H)	1.54	1.53	1.48	1.48	1.50	1.45	1.49						

Mean	C.D.(0.05)	S.E.
N, P or K	-	0.011
H	0.044	0.016

were 1.50, 1.49 and 1.52 respectively and those in the summer season were 1.49, 1.48 and 1.48.

The values recorded at 25, 50 and 75 kg P_2O_5/ha in the monsoon season were 1.50, 1.50 and 1.51 respectively and these in the summer season were 1.48, 1.49 and 1.47.

In the monsoon season, the values obtained at 25, 50 and 75 kg K_2O/ha were 1.50, 1.50 and 1.52 respectively and the corresponding figures for the summer season were 1.49, 1.48 and 1.48.

Effect of intervals of harvest

The data revealed that there was significant variation among the treatments. The highest harvest interval chosen viz., the 65 days, showed the highest solubility in both the seasons. The values recorded were 1.45 in the monsoon season and 1.44 in the summer season. It was significantly different from all other harvest treatments in both the seasons. Harvesting the crop at 40 days interval recorded the lowest solubility (1.54) in both the seasons.

Acid value

Data on the acid value of the oil obtained with different treatments during the monsoon and summer seasons and their mean values are presented in Tables 16 a, b and c.

Main effects of N, P, K and H were not significant in either of the seasons and for the mean for two seasons. The acid values recorded at 25, 50 and 75 kg N/ha in the

Table 16(a). Effect of different levels of nutrients and harvest intervals on acid value of the oil in the monsoon season: 1981-82.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	5.6	6.6	8.6	8.0	4.9	6.4	6.7	6.5	6.9	6.7	7.9	5.8	6.3
n_2	5.9	5.0	4.8	7.2	7.3	5.3	5.9	7.1	5.4	5.2	5.7	5.6	6.5
n_3	6.5	5.2	6.4	7.8	6.5	6.1	6.4	6.0	6.0	7.3	6.2	7.4	5.6
p_1	7.3	4.6	7.4	8.6	6.1	5.7	6.6	6.4	7.4	6.1	-	-	-
p_2	5.6	6.4	6.0	6.6	6.6	6.5	6.3	7.2	5.1	6.5	-	-	-
p_3	5.1	5.9	6.4	7.8	6.0	5.6	6.1	6.0	5.8	6.6	-	-	-
k_1	5.8	7.9	7.3	7.4	5.2	5.6	6.5	-	-	-	-	-	-
k_2	6.5	4.2	5.1	8.0	8.1	4.6	6.1	-	-	-	-	-	-
k_3	5.7	4.6	7.4	7.6	5.4	7.6	6.4	-	-	-	-	-	-
Mean (H)	6.0	5.6	6.6	7.7	6.2	5.9	6.4						

Mean	C.D.(0.05)	S.E.
N, P or K	-	0.42
H	-	0.59

Table 16(b). Effect of different levels of nutrients and harvest intervals on acid value of the oil in the summer season: 1981-82.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	2.2	2.8	3.0	3.2	2.5	2.2	2.6	2.1	3.3	2.3	3.2	2.0	2.5
n_2	2.7	1.9	2.1	2.8	2.5	2.4	2.4	3.0	2.2	2.1	2.3	2.4	2.6
n_3	2.9	2.3	2.8	3.4	2.6	2.9	2.8	2.9	2.4	3.1	2.9	3.0	2.4
p_1	3.2	2.1	2.9	3.3	2.7	2.8	2.8	2.9	3.2	2.3	-	-	-
p_2	2.3	2.3	2.3	2.9	2.6	2.5	2.5	2.8	2.1	2.5	-	-	-
p_3	2.4	2.5	2.6	2.8	2.4	2.2	2.5	2.3	2.5	2.7	-	-	-
k_1	2.4	2.5	3.0	3.0	2.5	2.6	2.7	-	-	-	-	-	-
k_2	3.0	2.2	2.4	3.0	2.7	2.4	2.6	-	-	-	-	-	-
k_3	2.4	2.2	2.4	3.0	2.4	2.5	2.5	-	-	-	-	-	-
Mean (H)	2.6	2.3	2.6	3.0	2.6	2.5	2.6						

Mean	C.D.(0.05)	S.E.
N, P or K	-	0.15
H	-	0.21

Table 16(e). Effect of different levels of nutrients and harvest intervals on acid value of the oil:mean values for two seasons.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	3.9	4.7	5.8	4.9	3.7	4.3	4.5	4.1	5.0	4.9	5.6	4.0	4.9
n_2	4.3	3.4	3.2	4.9	4.9	3.8	4.1	4.9	3.7	3.5	4.0	4.0	4.3
n_3	4.7	3.7	4.6	5.6	4.5	4.4	4.5	4.4	4.2	5.0	4.6	5.2	4.0
p_1	5.2	3.4	5.2	5.9	4.3	4.2	4.7	4.7	5.3	4.2	-	-	-
p_2	3.9	4.3	4.3	4.7	4.6	4.5	4.4	5.1	3.6	4.5	-	-	-
p_3	3.7	4.1	4.2	4.7	4.2	3.8	4.1	3.7	4.1	4.6	-	-	-
k_1	4.1	5.2	4.9	4.6	3.9	4.1	4.5	-	-	-	-	-	-
k_2	4.8	3.2	3.7	5.5	5.3	3.5	4.3	-	-	-	-	-	-
k_3	4.1	3.4	5.0	5.3	3.9	4.9	4.4	-	-	-	-	-	-
Mean (H)	4.3	3.9	4.5	5.1	4.4	4.2	4.4						

Mean	C.D.(0.05)	S.E.
N, P or K	-	0.30
H	-	0.42

monsoon season were 6.7, 5.9 and 6.4 and in the summer season these were 2.6, 2.4 and 2.8 respectively.

The values obtained at 25, 50 and 75 kg P_2O_5/ha in the monsoon season were 6.6, 6.3 and 6.1 respectively and in the summer season they were 2.8, 2.5 and 2.5.

Acid value recorded due to different intervals of harvest varied from 5.6 to 7.7 in the monsoon season and from 2.3 to 3.0 in the summer season.

<u>Saponification value</u>

Data obtained for the different levels of N, P, K and H for the monsoon and summer seasons and their mean values are presented in Tables 17 a, b and c.

<u>Effect of nitrogen</u>

The data reveal that there was significant difference in the saponification values in both the seasons and for the mean value for the two seasons. The values decreased at higher levels of N. The lowest value was recorded by application of N at 75 kg/ha (86.1) in the monsoon season while in the summer season the lowest value was recorded by 50 kg N/ha (81.0). In both the seasons these two treatments were on par and were significantly superior to the lowest level of N viz., 25 kg/ha (91.0 in the monsoon season and 89.2 in the summer season). The mean values for the two seasons also showed similar results and the values varied from 83.8 to 90.5.

Table 17(a). Effect of different levels of nutrients and harvest intervals on saponification value of the oil in the monsoon season: 1981-82.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	97.2	97.0	98.6	95.0	82.1	76.1	91.0	92.1	90.9	90.0	96.6	87.8	88.6
n_2	98.5	93.6	90.9	85.7	77.8	72.6	86.5	87.4	85.4	86.7	86.6	85.7	87.1
n_3	98.0	94.5	94.7	85.4	74.9	69.3	86.1	85.9	88.0	84.3	90.6	86.6	81.1
p_1	101.1	95.9	97.3	93.6	82.7	77.0	91.3	91.8	93.0	89.0	-	-	-
p_2	97.7	93.8	95.5	85.7	76.1	71.5	86.7	90.3	86.0	84.0	-	-	-
p_3	94.9	95.3	91.3	86.7	75.9	69.5	85.6	83.4	85.3	88.1	-	-	-
k_1	97.0	94.8	93.3	89.3	80.5	76.1	88.5	-	-	-	-	-	-
k_2	99.6	95.1	93.3	89.5	77.2	73.3	88.1	-	-	-	-	-	-
k_3	97.1	95.2	97.0	87.2	77.0	68.5	87.0	-	-	-	-	-	-
Mean (H)	97.9	95.0	94.7	88.7	78.2	72.7	87.9						

Mean	C.D.(0.05)	S.E.
N, P or K	2.69	0.96
NP, NK or PK	4.66	1.66
H	3.81	1.35

Table 17(b). Effect of different levels of nutrients and harvest intervals on saponification value of the oil in the summer season: 1981-82.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	95.2	103.1	101.1	94.5	75.3	65.8	89.2	89.6	87.2	90.8	94.9	83.2	89.4
n_2	89.9	95.0	88.5	82.9	73.0	57.0	81.0	82.3	80.9	79.9	79.6	78.1	85.4
n_3	91.7	92.4	92.4	84.1	73.7	62.7	82.8	86.3	79.6	82.6	85.8	86.2	76.5
p_1	95.9	96.3	93.9	91.9	77.4	65.4	86.8	87.9	86.2	86.2	-	-	-
p_2	90.8	95.5	94.9	82.7	68.0	65.1	82.5	85.8	80.6	81.1	-	-	-
p_3	90.1	98.8	93.2	86.9	76.6	57.0	83.8	84.5	80.7	86.0	-	-	-
k_1	96.6	104.7	93.1	88.3	71.6	62.1	86.1	-	-	-	-	-	-
k_2	91.5	91.8	90.7	87.1	75.9	58.1	82.5	-	-	-	-	-	-
k_3	88.8	94.0	98.0	86.1	74.5	55.2	84.4	-	-	-	-	-	-
Mean (H)	92.3	96.9	95.9	87.2	74.0	61.8	84.4						

Mean	C.D.(0.05)	S.E.
N, P or K	4.58	1.63
NP, NK or PK	7.93	2.82
H	6.47	2.30

Table 17(c). Effect of different levels of nutrients and harvest intervals on saponification value of the oil: mean values for two seasons.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	96.2	100.1	99.9	94.7	80.9	70.9	90.5	92.0	89.0	90.3	95.8	86.6	88.9
n_2	94.4	94.1	89.6	84.3	75.4	65.1	83.8	85.0	83.1	83.3	83.1	82.1	86.3
n_3	95.0	93.5	93.5	84.8	74.3	66.0	84.5	86.1	83.8	83.6	88.3	86.4	78.8
p_1	98.8	96.0	95.5	92.8	80.1	71.2	89.1	89.8	89.6	89.7	-	-	-
p_2	94.3	94.7	95.3	84.2	74.3	67.5	85.0	89.3	83.3	82.5	-	-	-
p_3	92.8	97.0	92.3	86.8	76.1	63.2	84.7	84.0	83.0	87.0	-	-	-
k_1	96.8	99.7	93.2	88.8	78.3	69.4	87.7	-	-	-	-	-	-
k_2	95.6	93.5	92.3	88.3	76.6	65.7	85.3	-	-	-	-	-	-
k_3	93.2	94.7	97.5	86.6	75.5	66.7	85.7	-	-	-	-	-	-
Mean (H)	95.2	95.9	94.3	87.9	76.8	67.3	86.3	-					

Mean	C.D.(0.05)	S.E.
N, P or K	3.24	1.15
NP, NK or PK	5.59	2.00
H	4.59	1.63

Effect of phosphorus

It was observed that the saponification value in the monsoon season and the mean value for the two seasons showed significant difference for different levels of P_2O_5. In the monsoon season, saponification value decreased with increase in the level of P_2O_5. But the values recorded at 75 and 50 kg P_2O_5/ha (85.6 and 86.7 respectively) were on par and were significantly lower than that at 25 kg P_2O_5/ha (91.3). In the summer season also though the differences were not significant, higher levels of P_2O_5 recorded lower values than at 25 kg P_2O_5/ha. The values obtained at 25, 50 and 75 kg P_2O_5/ha were 86.3, 82.5 and 83.8 respectively.

Significant effect of P_2O_5 was also reflected in the mean values for the two seasons. The lowest value was recorded with 75 kg P_2O_5/ha. There was no significant difference between the values obtained at 50 and 75 kg P_2O_5/ha and both of them were significantly lower than that at 25 kg P_2O_5/ha.

Effect of potassium

The effect of K_2O was not significant on the saponification value of the oil, but the values at 50 and 75 kg K_2O/ha were lower than those at 25 kg/ha in both the seasons.

Nutrient interactions

The interaction of N with P was significant in both the seasons and for the mean value of the two seasons. The lowest value recorded was with n_3p_3.

Effect of harvest intervals

It was observed that the saponification value in both the seasons showed high statistical significance on account of different intervals of harvest. As the interval between harvests increased the saponification value decreased in both the seasons. The lowest value was recorded for the treatment harvested at 65 day intervals in both seasons and it was significantly lower than that for all other treatments. The mean value for the two seasons also showed the same trend. The values obtained during the monsoon season varied from 72.7 to 97.9 and these in the summer season ranged from 61.8 to 96.9.

Ester value

Data relating to the ester value as influenced by the different treatments during the monsoon and summer seasons and their mean values are presented in Tables 18 a, b and c.

Effect of nitrogen

The data show that there was significant difference in the ester value in both the seasons and in the mean value for the two seasons. Application of N at 50 and 75 kg/ha have recorded significantly lower values than these at 25 kg/ha in both the seasons and in the mean value for the two seasons. There was no significant difference

Table 18(a). Effect of different levels of nutrients and harvest intervals on ester value of the oil in the monsoon season: 1981-82.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	91.6	90.4	90.0	87.0	77.2	65.7	84.3	85.6	84.0	83.7	88.7	82.0	82.3
n_2	92.6	88.6	86.1	78.5	70.5	67.3	80.6	80.3	80.0	81.5	80.9	80.1	80.6
n_3	91.5	89.3	88.3	77.6	68.4	63.2	79.7	79.9	82.0	77.0	84.4	79.2	75.5
p_1	93.4	91.3	89.9	85.0	76.6	71.3	84.7	85.4	85.6	82.9	-	-	-
p_2	92.1	87.4	89.5	79.1	69.5	65.0	80.4	83.1	80.9	77.5	-	-	-
p_3	89.8	89.4	84.9	78.9	69.9	63.9	79.5	77.4	79.5	81.5	-	-	-
k_1	91.2	86.9	86.0	81.9	75.3	70.5	82.0	-	-	-	-	-	-
k_2	93.1	90.9	88.7	81.5	69.1	68.7	82.0	-	-	-	-	-	-
k_3	91.4	90.6	89.6	79.6	71.6	60.9	80.6	-	-	-	-	-	-
Mean (H)	91.9	89.4	88.1	81.0	72.0	66.8	81.5						

Mean	C.D.(0.05)	S.E.
N, P or K	2.61	0.93
NP, NK or PK	4.51	1.60
H	3.69	1.33

Table 18(b). Effect of different levels of nutrients and harvest intervals on ester value of the oil in the summer season: 1981-82.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	93.0	100.3	98.1	91.3	72.8	63.6	86.6	87.5	83.9	88.5	91.4	81.8	86.9
n_2	87.2	93.1	86.2	80.1	70.5	54.6	78.6	79.3	78.7	77.8	77.3	75.7	82.8
n_3	88.8	90.1	89.6	80.7	71.1	59.8	80.0	83.4	77.2	79.5	82.9	83.2	74.1
p_1	93.7	94.2	91.0	88.6	74.7	63.0	84.0	85.0	83.0	83.9	-	-	-
p_2	88.5	93.2	92.6	79.8	65.4	60.6	80.0	83.0	78.5	78.6	-	-	-
p_3	87.7	96.3	90.6	84.1	74.2	54.8	81.2	82.2	78.2	83.3	-	-	-
k_1	94.2	102.2	90.1	85.3	69.1	59.5	83.4	-	-	-	-	-	-
k_2	88.5	89.6	88.3	84.1	73.0	55.7	79.9	-	-	-	-	-	-
k_3	86.4	91.8	95.6	83.1	72.1	62.7	82.0	-	-	-	-	-	-
Mean (H)	89.7	94.6	91.3	84.1	71.4	59.3	81.8						

Mean	C.D.(0.05)	S.E.
N, P or K	4.53	1.61
NP, NK or PK	7.84	2.78
H	6.40	2.27

Table 18(c). Effect of different levels of nutrients and harvest intervals on ester value of the oil: mean values for two seasons.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	92.0	95.1	93.8	89.0	76.5	66.3	85.5	87.6	83.7	85.1	89.9	82.3	83.7
n_2	89.8	90.4	86.1	79.1	70.2	61.0	79.4	79.8	79.1	79.3	78.8	77.8	81.7
n_3	90.0	89.5	88.6	73.9	69.5	61.3	79.6	81.4	79.3	78.3	83.4	80.9	74.5
p_1	93.3	92.3	90.0	86.6	75.5	66.7	84.1	84.8	84.0	83.2	-	-	-
p_2	90.0	90.1	90.7	78.7	69.4	62.7	80.4	83.9	79.4	77.7	-	-	-
p_3	88.8	92.6	87.8	81.8	71.6	59.1	80.3	80.0	78.6	82.1	-	-	-
k_1	92.4	94.2	88.0	83.9	74.1	65.0	82.9	-	-	-	-	-	-
k_2	90.5	89.9	89.1	82.5	71.0	61.9	80.7	-	-	-	-	-	-
k_3	88.8	91.0	92.2	81.0	71.1	61.5	81.0	-	-	-	-	-	-
Mean (H)	90.6	91.7	89.6	82.4	72.1	62.8	81.6						

Mean	C.D.(0.05)	S.E.
N, P or K	3.17	1.13
NP, NK or PK	5.50	1.95
H	4.49	1.60

between 50 and 75 kg N/ha. The mean values for two seasons recorded at 25, 50 and 75 kg N/ha were 85.5, 79.4 and 79.6 respectively.

Effect of phosphorus

Significant difference due to different levels of P_2O_5 was noticed in the monsoon season and in the mean value for the two seasons. Higher levels of P_2O_5 at 50 and 75 kg/ha recorded low ester value than at 25 kg/ha in both the seasons. In the monsoon season and in the mean for the two seasons the values recorded at 50 and 75 kg P_2O_5/ha were significantly lower than that at 25 kg/ha and there was no significant difference between the P_2O_5 treatments at 50 and 75 kg/ha. The mean values recorded at 25, 50 and 75 kg P_2O_5/ha were 84.1, 80.4 and 80.3 respectively.

Effect of potassium

There was no significant difference in the ester value of the oil with different levels of K_2O. The values recorded at 25, 50 and 75 kg K_2O/ha were 82.0, 82.0 and 80.6 in the monsoon season and 83.4, 79.9 and 82.0 in the summer season.

Nutrient interactions

The interaction of N with P was significant in both the seasons and in the mean value of the two seasons. Lowest value was recorded by n_3p_3 in both the seasons.

Effect of harvest intervals

Different intervals of harvest showed significant influence on the ester value in both the seasons and in the mean value for the two seasons. The ester value was found to decrease as the intervals of harvest increased. The lowest value was recorded by 65 days in both the seasons and it was significantly lower than all other harvest intervals. The mean values for two seasons for the 40, 45, 50, 55, 60 and 65 day intervals were 90.6, 91.7, 89.6, 82.4, 72.1 and 62.8 respectively.

Ester content

Data presented in Tables 19 a, b and c represent the ester content of the oil for the different treatments during both the seasons and their mean values.

Effect of nitrogen

The data indicated that the ester content of oil varied significantly with level of N in both the seasons and in their mean values. Ester content decreased as the N level increased. The lowest value was obtained at 75 kg/ha and it was on par with 50 kg/ha and both were significantly lower than that at 25 kg N/ha in both the seasons. The values recorded at 25, 50 and 75 kg N/ha during the monsoon season were 30.8, 29.4 and 29.2 per cent respectively, while those recorded in the summer season were 28.8, 26.8 and 26.4 per cent.

Effect of phosphorus

The ester content varied significantly with level of P_2O_5 in the monsoon season and in the mean value for the

Table 19(a). Effect of different levels of nutrients and harvest intervals on ester content of the oil (per cent) in the monsoon season: 1981-82.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	32.7	32.9	33.4	32.2	27.8	25.8	30.8	31.5	30.4	30.6	32.6	29.7	30.[illegible]
n_2	33.5	32.1	31.0	29.0	26.2	24.8	29.4	29.6	29.1	29.6	29.4	29.2	29.6
n_3	33.3	32.2	32.1	28.7	25.4	23.4	29.2	29.1	29.9	28.5	30.7	29.2	27.5
p_1	34.2	32.8	33.0	31.6	28.0	25.9	30.9	31.1	31.4	30.3	-	-	-
p_2	32.9	32.0	32.5	29.0	25.7	24.3	29.4	30.6	29.1	28.5	-	-	-
p_3	32.4	32.5	31.0	29.3	25.7	23.6	29.1	28.4	29.0	29.9	-	-	-
k_1	33.1	32.2	31.3	30.2	27.3	26.0	30.0	-	-	-	-	-	-
k_2	33.3	32.5	31.9	30.2	26.1	24.8	29.8	-	-	-	-	-	-
k_3	33.1	32.6	33.0	29.4	26.1	23.1	29.6	-	-	-	-	-	-
Mean (H)	33.2	32.4	32.2	30.0	26.5	24.6	29.8						

Mean	C.D.(0.05)	S.E.
N, P or K	0.93	0.33
NP, NK or PK	1.60	0.57
H	1.31	0.47

Table 19(b). Effect of different levels of nutrients and harvest intervals on ester content of the oil (per cent) in the summer season: 1981-82.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	30.4	33.7	32.7	30.3	24.8	20.6	28.8	29.3	27.7	29.2	30.1	27.1	29.0
n_2	29.8	31.6	29.9	27.0	24.1	18.1	26.8	26.9	26.6	26.7	26.6	25.8	27.8
n_3	29.8	30.6	28.4	25.7	24.0	20.0	26.4	27.2	25.6	26.4	27.9	27.6	23.8
p_1	30.6	32.1	31.1	29.5	25.4	20.5	28.2	28.7	27.5	28.3	-	-	-
p_2	29.2	31.3	31.3	26.9	22.2	20.1	26.8	27.9	26.2	26.4	-	-	-
p_3	30.2	32.5	28.7	26.5	25.2	18.2	26.9	26.7	26.2	27.7	-	-	-
k_1	32.3	33.8	29.5	27.2	24.0	20.0	27.8	-	-	-	-	-	-
k_2	29.0	30.7	30.5	27.7	23.9	18.1	26.6	-	-	-	-	-	-
k_3	28.7	31.3	31.1	28.1	25.0	20.7	27.5	-	-	-	-	-	-
Mean (H)	30.0	32.0	30.3	27.7	24.3	19.6	27.3						

Mean	C.D.(0.05)	S.E.
N, P or K	1.42	0.50
NP, NK or PK	2.46	0.87
H	2.01	0.71

Table 19(c). Effect of different levels of nutrients and harvest intervals on ester content of the oil (per cent). mean values for two seasons.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	31.6	33.3	33.1	31.2	26.3	23.2	29.8	30.4	29.0	29.9	31.4	28.4	29.6
n_2	30.6	31.8	30.4	28.0	25.1	21.5	27.9	28.2	27.3	28.2	28.0	27.0	28.7
n_3	31.6	31.4	30.2	27.2	24.7	21.7	27.8	28.1	27.8	27.5	29.3	28.4	25.7
p_1	32.5	32.4	32.2	30.6	26.6	23.2	29.6	29.9	29.4	29.3	-	-	-
p_2	30.0	31.7	31.6	27.9	23.9	22.2	27.9	29.3	27.1	27.5	-	-	-
p_3	31.3	32.5	29.8	27.9	25.5	20.9	28.0	27.6	27.6	28.8	-	-	-
k_1	32.7	33.0	30.4	28.7	25.6	23.0	28.9	-	-	-	-	-	-
k_2	30.1	31.6	31.2	29.0	24.9	21.4	28.0	-	-	-	-	-	-
k_3	30.9	31.9	32.0	28.8	25.5	21.9	28.5	-	-	-	-	-	-
Mean (H)	31.3	32.2	31.2	28.8	25.4	22.1	28.5						

Mean	C.D.(0.05)	S.E.
N, P or K	1.03	0.37
NP, NK or PK	1.79	0.63
H	1.46	0.52

two seasons. In the monsoon season the lowest value was recorded with P_2O_5 at 75 kg/ha (29.1 per cent) followed by P_2O_5 at 50 kg/ha (29.4 per cent). There was no significant difference between these two levels and both of them were significantly different from the lowest level of P_2O_5, which recorded the highest value (30.9 per cent).

In the summer season, though the effect of P_2O_5 was not significant, 50 and 75 kg levels recorded lower ester content than for 25 kg/ha, as in the monsoon season. The values recorded at 25, 50 and 75 kg P_2O_5/ha were 28.2, 26.8 and 26.9 per cent respectively.

The mean values for the two seasons also showed similar results as that in the monsoon season.

Effect of potassium

The data indicated that the ester content of the oil was not influenced significantly with level of potassium in either of the seasons. The highest value was recorded with 25 kg/ha in both the seasons, and the values decreased at higher levels of K_2O. The values recorded at 25, 50 and 75 kg K_2O/ha in the monsoon season were 30.0, 29.8 and 29.6 per cent respectively and those recorded in the summer season were 27.8, 26.6 and 27.5 per cent respectively.

Nutrient interactions

Nitrogen and phosphorus interacted significantly in both the seasons and this was reflected in the mean values for the two seasons too. The combination n_3p_3 recorded the lowest value followed by n_2p_2 in both the seasons.

Effect of harvest intervals

The ester content of the oil was found to decrease significantly as the interval of harvest increased in both the seasons. The lowest value was recorded with 65 days interval and it was significantly lower than all other harvest treatments in both the seasons and for the mean value for the two seasons. The highest value was recorded for 40 day interval in the monsoon season and for the 45 day interval in the summer season. But the treatments of 40, 45 and 50 day intervals were on par in both the seasons. The ester content of oil was lower in the summer season than in the monsoon season and the ester content with different intervals of harvest varied from 24.6 to 33.2 per cent in the monsoon season and from 19.6 to 32.0 per cent in the summer season.

Saponification value after acetylation

The data recorded for the different treatments during the monsoon and summer seasons and their mean values are presented in Tables 20 a, b and c.

Effect of nitrogen, phosphorus and potassium

Application of different levels of N, P_2O_5 or K_2O neither influenced nor showed any trend in the saponification value after acetylation of the oil with increase in the level of nutrients.

Table 20(a). Effect of different levels of nutrients and harvest intervals on saponification value after acetylation of the oil in the monsoon season: 1981-82.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	277.6	283.7	282.7	279.7	278.6	275.9	279.7	279.1	280.0	280.0	279.4	279.0	280.8
n_2	281.9	283.8	282.7	282.8	276.9	280.5	281.4	282.5	280.9	280.8	279.3	283.5	281.3
n_3	283.1	282.3	279.1	281.7	278.9	278.4	280.6	279.1	281.6	280.0	281.2	280.6	279.9
p_1	281.3	292.4	281.1	279.7	276.3	279.2	280.0	280.0	281.0	279.0	-	-	-
p_2	281.2	283.9	280.4	284.6	278.1	278.0	281.0	280.5	281.2	281.2	-	-	-
p_3	280.0	283.4	283.2	279.9	279.9	277.6	280.7	280.1	280.1	281.6	-	-	-
k_1	280.2	283.3	280.9	282.7	277.4	276.6	280.2	-	-	-	-	-	-
k_2	281.0	282.7	280.9	282.4	278.1	279.6	280.8	-	-	-	-	-	-
k_3	281.3	283.8	282.7	278.9	278.7	278.4	280.6	-	-	-	-	-	-
Mean (H)	280.8	283.3	281.5	281.4	278.1	278.3	280.6						

Mean	C.D.(0.05)	S.E.
N, P or K	-	0.79
H	3.16	1.12

Table 20(b). Effect of different levels of nutrients and harvest intervals on saponification value after acetylation of the oil in the summer season: 1981-82.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	278.6	285.4	281.8	283.2	280.6	277.5	281.2	281.4	280.0	282.1	281.5	281.2	280.8
n_2	281.1	284.2	282.6	283.2	277.7	277.3	281.0	281.7	280.6	280.8	279.5	282.4	281.2
n_3	284.2	284.2	280.3	282.4	280.7	279.4	281.7	281.6	282.1	281.5	281.8	283.2	280.1
p_1	283.0	283.0	280.9	282.1	277.3	279.2	280.9	281.7	281.0	280.1	-	-	-
p_2	282.2	284.8	281.5	285.7	280.2	279.4	282.3	283.3	281.4	282.2	-	-	-
p_3	278.8	285.8	282.4	281.0	281.6	274.5	280.7	279.7	280.3	282.1	-	-	-
k_1	280.3	285.8	282.8	286.2	279.7	274.6	281.6	-	-	-	-	-	-
k_2	280.5	283.6	280.8	282.7	279.0	278.7	280.9	-	-	-	-	-	-
k_3	283.2	284.3	281.1	280.0	280.3	279.9	281.5	-	-	-	-	-	-
Mean (H)	281.3	284.6	281.6	283.0	279.7	277.7	281.4						

Mean	C.D.(0.05)	S.E.
N, P or K	-	0.70
H	2.80	0.99

Table 20(c). Effect of different levels of nutrients and harvest intervals on saponification value after acetylation of the oil: mean values for two seasons.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	278.0	285.7	282.1	280.9	279.6	276.7	280.4	280.2	280.0	280.8	280.4	280.1	280.5
n_2	281.5	284.0	282.6	283.0	277.3	279.0	281.2	282.2	280.8	280.8	279.3	283.1	281.3
n_3	283.8	282.9	279.7	282.0	279.8	278.4	281.1	280.2	281.9	281.2	281.5	281.9	280.0
p_1	282.2	282.7	280.8	280.9	276.8	279.1	280.4	280.8	281.0	279.5	-	-	-
p_2	281.7	284.8	280.9	285.1	279.2	278.8	281.8	281.9	281.4	281.8	-	-	-
p_3	279.4	284.6	282.7	279.9	280.7	276.1	280.6	280.0	280.2	281.6	-	-	-
k_1	280.2	285.0	281.9	284.5	278.6	275.7	280.9	-	-	-	-	-	-
k_2	280.8	283.1	280.9	282.6	278.5	279.1	280.9	-	-	-	-	-	-
k_3	282.3	284.0	281.8	278.9	279.5	279.2	281.0	-	-	-	-	-	-
Mean (H)	281.1	284.0	281.5	281.9	278.9	278.0	280.9						

Mean	C.D.(0.05)	S.E.
N, P or K	-	0.69
H	2.75	0.98

Effect of harvest interval

Saponification value after acetylation was influenced significantly with different intervals of harvest in both the seasons and in the mean value for the two seasons. The saponification value after acetylation was found to increase as the interval increased from 40 to 45 days and thereafter it decreased as the growth advanced in both the seasons. This was reflected in the mean values also. In the monsoon season, the lowest value was recorded with the 60 day interval (278.1) followed by the 65 day interval (278.5). In the summer season the lowest value was recorded for the 65 day interval (277.7) followed by the 60 days interval (279.7). The highest value was recorded for the 45 day interval in both the seasons. The acetylated saponification value was higher in the summer season than in the monsoon season and the values with different intervals of harvest ranged from 278.1 to 283.3 in the monsoon season and from 277.7 to 284.6 in the summer season.

Total alcohols calculated as geraniol

The data on the percentage of total alcohol content of oil obtained for different treatments and seasons are given in Tables 21 a, b and c.

Effect of nitrogen, phosphorus and potassium

Different levels of N, P_2O_5 or K_2O did not show any significant difference with regard to the total alcohol content of the oil in both the seasons.

Table 21(a). Effect of different levels of nutrients and harvest intervals on total alcohol content of the oil (per cent) in the monsoon season: 1981-82.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	89.8	92.2	91.7	90.5	91.2	90.7	91.0	90.6	91.2	91.2	90.4	90.9	91.7
n_2	91.3	92.4	92.2	92.0	90.8	92.5	91.9	92.4	91.5	91.7	91.1	92.6	92.0
n_3	91.8	91.8	90.5	92.5	91.8	91.7	91.7	90.9	91.9	92.0	91.6	91.7	91.6
p_1	90.8	91.7	91.0	90.8	90.1	91.7	91.0	90.6	91.2	91.2	-	-	-
p_2	91.2	92.5	91.0	92.6	91.6	91.7	91.8	92.4	91.5	91.7	-	-	-
p_3	90.8	92.2	92.4	91.4	92.1	91.5	91.7	90.9	91.9	92.0	-	-	-
k_1	90.6	92.2	91.4	92.2	90.8	90.7	91.3	-	-	-	-	-	-
k_2	91.0	91.9	91.2	91.6	91.4	92.1	91.5	-	-	-	-	-	-
k_3	91.2	92.4	91.8	91.0	91.6	92.0	91.7	-	-	-	-	-	-
Mean (H)	90.9	92.1	91.5	91.5	91.3	91.6	91.5						

Mean	C.D.(0.05)	S.E.
N, P or K	-	0.32
H	-	0.46

Table 21(b). Effect of different levels of nutrients and harvest intervals on total alcohol content of the oil (per cent) in the summer season: 1981-82.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	90.6	92.6	91.3	92.8	92.4	91.9	91.9	92.2	91.6	92.1	91.6	92.5	91.8
n_2	92.0	92.7	92.7	91.9	92.0	92.6	92.3	92.7	91.8	92.3	91.7	92.7	92.5
n_3	92.7	92.9	91.5	93.1	92.6	92.5	92.6	92.3	92.8	92.6	92.6	92.9	92.2
p_1	92.2	92.1	90.8	92.8	91.2	92.7	92.0	92.3	91.9	91.8	-	-	-
p_2	92.2	93.0	92.4	92.8	92.9	92.8	92.7	93.1	92.4	92.6	-	-	-
p_3	91.0	93.2	92.3	92.2	92.9	91.5	92.2	91.8	92.2	92.5	-	-	-
k_1	91.1	92.9	92.8	94.0	92.3	91.1	92.4	-	-	-	-	-	-
k_2	91.1	92.6	91.7	92.2	92.2	93.0	92.1	-	-	-	-	-	-
k_3	93.0	92.7	91.0	91.6	92.5	93.0	92.3	-	-	-	-	-	-
Mean (H)	91.8	92.8	91.8	92.6	92.3	92.3	92.3						

Mean	C.D.(0.05)	S.E.
H, P or K	-	0.27
H	-	0.38

Table 21(c). Effect of different levels of nutrients and harvest intervals on total alcohol content of the oil (per cent): mean values for two seasons.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	90.2	92.4	91.5	91.6	91.9	91.3	91.5	91.4	91.4	91.6	91.0	91.7	91.7
n_2	91.7	92.6	92.4	91.9	91.3	92.5	92.1	92.6	91.7	92.0	91.4	92.6	92.2
n_3	92.3	92.3	91.0	92.7	92.2	92.1	92.1	91.6	92.4	92.3	92.1	92.3	91.9
p_1	91.6	91.9	90.9	91.8	90.6	92.2	91.5	91.6	91.6	91.3	-	-	-
p_2	91.7	92.7	91.7	92.7	92.2	92.2	92.2	92.2	92.1	92.4	-	-	-
p_3	90.8	92.7	92.4	91.8	92.5	91.5	91.9	91.7	91.9	92.2	-	-	-
k_1	90.9	92.6	92.1	93.1	91.6	90.9	91.9	-	-	-	-	-	-
k_2	91.1	92.3	91.4	91.9	91.8	92.6	91.8	-	-	-	-	-	-
k_3	92.1	92.4	91.4	91.3	92.0	92.5	92.0	-	-	-	-	-	-
Mean (H)	91.4	92.4	91.6	92.1	91.8	92.0	91.9						

Mean	C.D.(0.05)	S.E.
N, P or K	-	0.26
H	-	0.37

Application of N at 50 and 75 kg/ha recorded higher values than at 25 kg/ha in both the seasons. The mean values for the two seasons at 25, 50 and 75 kg N/ha were 91.5, 92.1 and 92.1 per cent respectively.

The values for P_2O_5 application at 50 and 75 kg/ha were higher than that at 25 kg/ha in both the seasons. The mean values for the two seasons at 25, 50 and 75 kg/ha were 91.5, 92.2 and 91.9 per cent respectively.

As regards K_2O, the mean values for the two seasons at 25, 50 and 75 kg/ha were 91.9, 91.8 and 92.0 per cent respectively.

Effect of harvest intervals

The total alcohol content of the oil did not show any significant difference or any definite trend with different intervals of harvest. The values obtained during the summer season were higher than those obtained in the monsoon season. The mean values for the two seasons at 40, 45, 50, 55, 60 and 65 day intervals were 91.4, 92.4, 91.6, 92.1, 91.8 and 92.0 per cent respectively.

Free alcohol

The data on the free alcohol content (per cent) for different treatments during the monsoon and summer seasons and their mean values are presented in Tables 22 a, b and c.

Effect of nitrogen

The results showed that the treatments differed significantly with regard to the free alcohol content of

Table 22(a). Effect of different levels of nutrients and harvest intervals on free alcohol content of the oil (per cent) in the monsoon season: 1981-82.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	64.0	66.2	65.2	65.0	69.0	70.2	66.6	65.9	67.1	66.8	64.7	67.3	67.8
n_2	64.9	67.0	67.7	69.0	70.0	72.9	68.6	69.0	68.5	68.3	67.8	69.3	68.7
n_3	65.6	66.3	64.8	69.4	71.7	73.7	68.6	68.2	68.4	69.5	67.4	68.6	69.9
p_1	64.0	65.8	64.9	65.8	67.9	71.2	66.6	66.5	66.5	66.8	-	-	-
p_2	65.2	67.2	65.0	69.5	71.1	72.4	68.4	67.2	68.7	69.5	-	-	-
p_3	65.2	66.5	67.9	68.0	71.3	73.2	68.8	69.4	68.7	68.2	-	-	-
k_1	64.7	66.7	66.0	68.5	69.2	70.5	67.7	-	-	-	-	-	-
k_2	64.8	66.2	66.0	67.7	70.6	72.6	68.0	-	-	-	-	-	-
k_3	64.9	66.6	65.7	67.2	71.0	73.3	68.2	-	-	-	-	-	-
Mean (H)	64.8	66.5	65.9	67.3	70.3	72.3	67.9						

Mean	C.D.(0.05)	S.E.
N, P or K	1.21	0.43
H	1.70	0.61

Table 22(b). Effect of different levels of nutrients and harvest intervals on free alcohol content of oil (per cent) in the summer season: 1981-82.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	65.8	66.2	65.5	68.9	73.4	75.7	69.3	69.0	69.5	69.2	67.7	71.1	68.9
n_2	68.8	67.8	69.5	72.2	74.0	78.3	71.8	71.9	71.6	71.9	71.2	73.5	70.6
n_3	68.6	68.5	68.9	73.2	73.9	75.8	71.5	70.9	72.3	71.2	70.4	70.2	73.8
p_1	67.8	66.4	66.4	69.7	71.6	76.6	69.8	69.2	70.2	69.8	-	-	-
p_2	68.1	68.4	68.0	73.1	76.2	75.9	71.6	71.5	71.6	71.7	-	-	-
p_3	67.4	67.7	69.5	71.5	73.4	77.3	71.1	71.1	71.5	70.8	-	-	-
k_1	65.7	66.1	69.8	72.7	74.0	75.3	70.6	-	-	-	-	-	-
k_2	67.6	68.4	67.6	71.0	73.5	78.5	71.1	-	-	-	-	-	-
k_3	69.9	68.1	66.4	70.5	73.7	76.0	70.8	-	-	-	-	-	-
Mean (H)	67.7	67.5	67.9	71.4	73.8	76.6	70.9						

Mean	C.D.(0.05)	S.E.
N, P or K	1.38	0.49
NP, NK or PK	2.39	0.95
H	1.95	0.69

Table 22(c). Effect of different levels of nutrients and harvest intervals on free alcohol content of the oil (per cent): mean values for two seasons.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	64.9	66.1	65.7	66.9	70.6	72.5	67.8	66.8	68.2	68.4	66.2	68.8	68.4
n_2	66.9	67.4	68.6	69.9	71.9	75.5	70.0	70.4	69.7	68.0	69.2	71.0	69.6
n_3	67.1	67.5	66.4	70.6	72.3	74.1	69.7	68.9	69.7	70.4	68.6	69.5	71.4
p_1	65.7	66.1	65.6	67.5	69.3	73.8	68.0	66.8	67.2	68.4	-	-	-
p_2	66.9	67.8	66.5	71.0	73.0	73.6	69.8	70.4	69.7	70.0	-	-	-
p_3	65.9	67.1	68.7	68.9	72.4	74.6	69.6	68.9	69.7	70.4	-	-	-
k_1	64.9	66.4	67.5	69.9	71.0	72.4	68.7	-	-	-	-	-	-
k_2	66.2	67.2	66.9	68.6	71.5	75.0	69.2	-	-	-	-	-	-
k_3	67.7	67.4	66.4	68.9	72.3	74.6	69.6	-	-	-	-	-	-
Mean (H)	66.3	67.0	66.9	69.1	71.6	74.0	69.1						

Mean	C.D.(0.05)	S.E.
N, P or K	1.10	0.39
H	1.55	0.55

the oil. Application of N at higher levels of 50 and 75 kg/ha recorded significantly higher free alcohol content than the lower level of 25 kg/ha in both the seasons and in the mean value for the two seasons. There was no significant difference between the free alcohol content at 50 and 75 kg N/ha. The values recorded at 25, 50 and 75 kg N/ha in the monsoon season were 66.6, 68.6 and 68.6 per cent respectively and these in the summer season were 69.3, 71.8 and 71.5 per cent.

Effect of phosphorus

The data reveal that the free alcohol content showed significant difference with different levels of P_2O_5. The highest value was recorded with P_2O_5 at 75 kg/ha in the monsoon season (68.8 per cent) and with P_2O_5 at 50 kg/ha (71.6 per cent) in the summer season. But there was no significant difference between these two treatments in either of the seasons. The lowest value was recorded with the lowest level of P_2O_5 in both the seasons, and it was significantly lower than that for the other two treatments. Similar results were noted for the mean values for the two seasons also.

Effect of potassium

Free alcohol content of the oil was not influenced by the different levels of K_2O in either of the seasons or in the mean value for the two seasons. The values recorded at 50 and 75 kg/ha were slightly higher than the value at

25 kg/ha in both the seasons. Free alcohol contents recorded at 25, 50 and 75 kg K_2O/ha in the monsoon season were 67.7, 68.0 and 68.2 per cent respectively and those in the summer season were 70.6, 71.1 and 70.8 per cent respectively.

Nutrient interactions

The interaction between N and P was significant in the summer season and n_3p_3 recorded the highest value. This treatment recorded the highest value in the monsoon season too.

Effect of harvest intervals

Significant difference was observed with different intervals of harvest. The highest value was recorded with 65 days interval and it was significantly superior to all other intervals of harvest in both the seasons and in the mean value for both the seasons. The lowest value was recorded with 40 day interval in the monsoon season and with 45 day interval in the summer season. Free alcohol content of the oil was found to increase almost linearly as the interval between the harvests increased in both the seasons. The values recorded in the summer season were higher than those recorded in the monsoon season and the values with different intervals of harvest ranged from 64.8 to 72.3 per cent in the monsoon season and from 67.5 to 76.6 per cent in the summer season.

Combined alcohol

The data relating to the combined alcohol content (per cent) as influenced by different levels of N, P, K and H are presented in Tables 23 a, b and c.

Effect of nitrogen

The effect of N was significant in both the seasons and in their mean value also.

The highest value was recorded by 25 kg N/ha in both the seasons and it was significantly higher than the other two levels. The lowest value was recorded with 75 kg N/ha in the monsoon season (23.2 per cent), while the lowest value in the summer season was recorded with 50 kg N/ha (20.6 per cent). But both those treatments were on par in both the seasons. The mean values for the two seasons also showed the same result and the values recorded at 25, 50 and 75 kg N/ha were 23.7, 22.0 and 22.2 per cent respectively.

Effect of phosphorus

The difference in the values of combined alcohol with different levels of P_2O_5 was not significant in both the seasons. But it was significant for the mean values of the two seasons. In both the seasons 50 and 75 kg/ha recorded lower values than 25 kg P_2O_5/ha.

Effect of potassium

There was no significant variation in the content of combined alcohol of oil with different levels of K_2O in any of the seasons or in their mean values. No definite

Table 23(a). Effect of different levels of nutrients and harvest intervals on combined alcohol content of the oil (per cent) in the monsoon season: 1981-82.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	25.8	26.1	27.5	25.4	22.2	20.4	24.6	24.6	24.6	24.5	25.7	23.5	24.5
n_2	26.6	25.4	24.6	22.6	21.2	20.4	23.5	23.2	23.2	24.1	23.1	23.8	23.6
n_3	25.8	25.2	24.6	22.9	21.1	19.5	23.2	22.2	24.8	22.7	24.0	22.7	22.9
p_1	26.5	25.9	26.1	24.4	22.2	20.4	24.3	23.8	25.1	23.9	-	-	-
p_2	26.0	25.3	25.0	22.7	21.0	20.0	23.3	23.6	23.2	23.2	-	-	-
p_3	25.7	25.4	25.6	23.9	21.5	19.9	23.7	22.6	24.3	24.1	-	-	-
k_1	25.5	25.2	25.3	23.3	21.1	19.6	23.3	-	-	-	-	-	-
k_2	26.7	25.8	25.2	23.9	22.3	21.2	24.2	-	-	-	-	-	-
k_3	26.0	25.6	26.3	23.7	21.2	19.6	23.7	-	-	-	-	-	-
Mean (H)	26.1	25.5	25.6	23.7	21.5	20.1	23.8						

Mean	C.D.(0.05)	S.E.
N, P or K	1.01	0.36
H	1.43	0.51

Table 23(b). Effect of different levels of nutrients and harvest intervals on combined alcohol content of the oil (per cent) in the summer season: 1981-82.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	24.8	26.4	25.9	23.9	19.1	16.2	22.7	23.2	22.2	22.8	24.0	21.4	22.8
n_2	23.2	24.9	23.2	19.8	18.1	14.5	20.6	20.9	20.4	20.5	20.6	19.3	21.8
n_3	24.1	24.4	22.6	20.0	18.6	16.7	21.1	21.4	20.5	21.4	22.1	22.7	18.5
p_1	24.4	25.7	24.5	23.3	19.5	16.0	22.3	23.1	21.6	22.0	-	-	-
p_2	24.1	24.5	24.3	19.7	16.9	17.0	21.1	21.6	20.8	20.9	-	-	-
p_3	23.6	25.5	22.9	20.8	19.5	14.2	21.0	20.7	20.7	21.8	-	-	-
k_1	25.5	26.8	23.0	21.3	18.3	15.8	21.8	-	-	-	-	-	-
k_2	23.6	24.3	24.0	21.1	18.8	14.5	21.0	-	-	-	-	-	-
k_3	23.1	24.6	24.6	21.4	18.7	17.0	21.6	-	-	-	-	-	-
Mean (H)	24.0	25.2	23.9	21.3	18.6	15.7	21.5						

Mean	C.D.(0.05)	S.E.
N, P or K	1.12	0.40
NP, NK or PK	1.94	0.67
H	1.58	0.56

Table 23(a). Effect of different levels of nutrients and harvest intervals on combined alcohol content of the oil (per cent): mean values for two seasons.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	25.3	26.2	26.7	24.7	20.7	18.5	23.7	23.9	23.4	23.6	24.8	22.5	23.7
n_2	24.9	25.1	23.9	21.1	19.7	17.4	22.0	22.0	21.7	22.3	21.9	21.5	22.7
n_3	25.0	24.9	23.6	21.5	19.9	18.4	22.2	21.9	22.7	22.3	23.0	22.7	20.7
p_1	25.5	25.8	25.3	23.9	20.8	18.2	23.2	23.4	23.3	22.9	-	-	-
p_2	25.1	24.9	24.7	21.2	19.6	18.5	22.2	22.6	22.0	22.1	-	-	-
p_3	24.6	25.6	24.2	22.2	20.5	17.5	22.4	21.6	22.5	23.2	-	-	-
k_1	25.5	26.0	24.2	22.4	19.7	17.7	22.6	-	-	-	-	-	-
k_2	25.1	25.1	24.6	22.5	20.6	17.7	22.6	-	-	-	-	-	-
k_3	24.5	25.2	25.5	22.5	20.0	18.6	22.7	-	-	-	-	-	-
Mean (H)	25.1	25.4	24.8	22.4	20.1	18.0	22.6						

Mean	C.D.(0.05)	S.E.
N, P or K	1.12	0.40
H	1.59	0.56

trend was also noticed in the combined alcohol content with the increase in the levels of K_2O.

Nutrient interactions

Interaction between N and P was significant in the summer season and n_3p_3 recorded the lowest value (18.5 per cent) followed by n_2p_2 (19.3 per cent). YThe highest value was recorded with n_1p_1 (24.0 per cent).

Effect of harvest intervals

Different intervals of harvest showed significant variation with regard to the content of combined alcohol in both the seasons and in the mean value for the two seasons. The percentage of combined alcohol was found to decrease as the interval between the harvests increased. The lowest value in both the seasons was recorded with 65 days interval and it was significantly different from all other treatments. The highest value was recorded with 40 days interval in the monsoon season and with 45 days interval in the summer season, but there was no significant variation among 40, 45 and 50 day intervals in both the seasons or for the mean values for the two seasons. Lower value of combined alcohol was recorded in the summer season compared to that in the monsoon season. The combined alcohol content with different intervals of harvest ranged from 20.1 to 26.1 per cent in the monsoon season and from 15.7 to 25.2 per cent in the summer season.

Gas Liquid Chromatographic analysis of the oil obtained in the summer season of the second year

Geraniol content

Data on the geraniol content of the oil obtained in the summer season as determined by GLC are presented in Table 24.

Effect of nitrogen

Geraniol content of the oil was not influenced significantly by the different levels of N. The values obtained at 25, 50 and 75 kg N/ha were 58.1, 58.8 and 59.3 per cent respectively.

Effect of phosphorus

Effect of different levels of P_2O_5 on the geraniol content of the oil also showed no significant difference. But P_2O_5 at 50 and 75 kg/ha recorded higher values than at 25 kg/ha and the values obtained at 25, 50 and 75 kg P_2O_5/ha were 58.1, 59.8 and 58.4 per cent respectively.

Effect of potassium

No significant difference was noticed in the geraniol content with different levels of K_2O. The values obtained at 25, 50 and 75 kg K_2O/ha were 58.5, 59.1 and 58.6 per cent respectively.

Nutrient interactions

Interaction between N and K and between P and K were significant. The highest value was recorded for the n_3k_2 level, followed by n_2k_3. Of the different PK combinations, p_2k_3 recorded the maximum value followed by p_3k_2.

Table 24. Effect of different levels of nutrients and harvest intervals on geraniol content of the oil (per cent) in the summer season: 1981-82, determined by GLC.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	61.2	56.9	52.5	54.9	59.6	63.7	58.1	59.8	56.9	57.8	55.7	60.4	58.3
n_2	57.1	54.0	60.6	56.[illegible]	58.0	66.5	58.8	56.2	59.6	60.5	59.0	60.3	56.9
n_3	58.9	60.0	56.0	55.8	61.6	63.6	59.3	59.4	60.9	57.6	59.4	58.6	59.9
p_1	57.1	59.1	55.0	52.8	60.6	63.7	58.1	57.7	57.6	58.9	-	-	-
p_2	60.1	55.1	58.0	59.7	60.0	65.8	59.8	58.7	59.1	61.6	-	-	-
p_3	59.9	56.6	56.1	54.6	58.7	64.3	58.4	59.0	60.4	55.3	-	-	-
k_1	56.1	54.5	58.4	56.2	58.9	66.8	58.5	-	-	-	-	-	-
k_2	58.7	57.8	55.6	56.7	60.8	65.1	59.1	-	-	-	-	-	-
k_3	62.4	58.6	55.1	54.1	59.6	62.0	58.6	-	-	-	-	-	-
Mean (H)	59.1	57.0	56.4	55.7	59.7	64.6	58.7						

Mean	C.D.(0.05)	S.E.
N, P or K	-	0.76
NP, NK or PK	3.71	1.32
H	3.02	1.07

Effect of harvest intervals

There was significant difference in the geraniol content of the oil for different intervals of harvest. It was found to decrease as the interval of harvest increased from 40 to 55 days and thereafter it increased. The highest value (64.6 per cent) was recorded for the 65 day interval and it was significantly more than that of all other harvest treatments. The values recorded at 40, 45, 50, 55, 60 and 65 day intervals were 59.1, 57.0, 56.4, 55.7, 59.7 and 64.6 per cent respectively.

Geranyl acetate

The data for the geranyl acetate content as influenced by the different treatments are presented in Table 25.

Effect of nitrogen

The effect of N was not significant. But with increasing levels of N the geranyl acetate content decreased. The values recorded at 25, 50 and 75 kg N/ha were 23.9, 23.4 and 22.5 per cent respectively.

Effect of phosphorus

The influence of phosphorus was also not significant for the acetate content of the oil. But the application of P_2O_5 at 50 and 75 kg/ha resulted in slightly lower acetate content than that at 25 kg/ha. The values obtained at 25, 50 and 75 kg/ha were 23.6, 22.8 and 23.3 per cent respectively.

Effect of potassium

Though the acetate content of the oil was not

Table 25. Effect of different levels of nutrients and harvest intervals on geranyl acetate content of the oil (per cent) in the summer season: 1981-82, determined by GLC.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	25.6	28.9	28.8	23.9	20.8	15.4	23.9	23.2	24.1	24.4	24.3	23.0	24.4
n_2	25.7	26.2	26.2	25.0	22.3	14.8	23.4	25.1	21.7	23.2	23.1	22.4	24.6
n_3	27.5	24.8	26.0	22.4	19.4	14.6	22.5	23.1	23.0	21.3	23.5	23.1	20.8
p_1	26.8	26.2	27.6	25.6	20.2	15.4	23.6	24.2	23.3	23.3	-	-	-
p_2	26.1	25.0	27.2	24.2	19.5	15.0	22.8	23.4	21.9	23.2	-	-	-
p_3	26.0	28.7	26.2	21.5	22.7	14.4	23.3	23.7	23.6	22.5	-	-	-
k_1	26.3	27.8	27.4	22.7	23.3	15.3	23.8	-	-	-	-	-	-
k_2	26.8	24.3	27.7	25.5	18.4	15.0	22.9	-	-	-	-	-	-
k_3	25.8	27.8	25.9	23.2	20.7	14.6	23.0	-	-	-	-	-	-
Mean (H)	26.3	26.6	27.0	23.8	20.8	14.9	23.2						

Mean	C.D.(0.05)	S.E.
N, P or K	-	0.48
NP, NK or PK	2.32	0.82
H	1.09	0.67

influenced significantly by the level of K_2O, the highest value (23.8 per cent) was recorded at the lowest level of K_2O, and the values for 50 and 75 kg K_2O/ha were 22.9 and 23.0 per cent respectively.

Nutrient interactions

The interaction of N with P and N with K were also significant. Of the various np combinations n_3p_3 recorded the lowest value (20.8 per cent) while in the nk combinations n_3k_3 (21.3 per cent) recorded the lowest value.

Effect of harvest intervals

The acetate content of the oil was significantly influenced by different intervals of harvest and the value was found to increase upto the 50 day interval with a tendency to decrease thereafter. The lowest value (14.9 per cent) was recorded by the 65 day interval and it was significantly lower than that of the other intervals. The highest value (27.0 per cent) was recorded for the 50 day harvest interval. But there was no significant difference between the intervals of 40, 45 and 50 days. The values recorded for the 40, 45, 50, 55, 60 and 65 day intervals were 26.3, 26.6, 27.0, 23.8, 20.8 and 14.9 per cent respectively.

Geraniol yield

Data on the geraniol yield obtained in the two years separately and the combined yield for both the years are presented in Tables 26 a, b and c and in Fig. 2 and 6.

Table 26(a). Effect of different levels of nutrients and harvest intervals on geraniol yield (kg/ha) in the first year: 1980-81.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	18.63	23.64	24.52	29.47	27.04	28.36	25.28	26.41	25.17	24.26	22.41	26.81	26.62
n_2	16.11	21.22	27.34	28.64	26.40	32.22	25.32	26.81	23.63	25.50	24.44	25.79	24.73
n_3	16.96	23.85	22.82	26.78	29.56	29.96	24.86	24.29	24.22	25.96	20.61	23.63	30.33
p_1	15.84	20.23	23.92	25.06	24.55	25.24	22.47	23.55	21.29	22.63	-	-	-
p_2	17.28	22.74	23.85	27.46	32.26	30.62	25.74	25.33	25.24	26.43	-	-	-
p_3	18.59	24.94	26.91	32.27	26.19	34.71	27.27	28.63	26.51	26.67	-	-	-
k_1	18.57	21.98	26.40	29.78	28.44	29.85	25.84	-	-	-	-	-	-
k_2	15.89	22.28	22.98	26.36	26.63	32.16	24.35	-	-	-	-	-	-
k_3	17.25	23.67	25.29	28.86	27.92	28.66	25.24	-	-	-	-	-	-
Mean (H)	17.24	22.64	24.89	28.30	27.66	30.19	25.15						

Mean	C.D.(0.05)	S.E.
N, P or K	2.426	0.862
H	3.432	1.220

Table 26(b). Effect of different levels of nutrients and harvest intervals on geraniol yield (kg/ha) in the second year: 1981-82.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	35.93	40.65	39.87	48.82	55.40	64.61	47.55	45.74	50.72	46.19	44.11	50.58	47.89
n_2	34.08	40.35	40.79	53.82	62.89	71.62	50.59	49.81	50.47	51.46	47.56	55.15	51.18
n_3	35.55	40.16	41.81	53.64	65.93	70.67	51.29	51.61	50.95	51.32	45.77	50.07	58.05
p_1	33.16	38.52	39.97	49.88	51.47	61.90	45.82	44.96	46.29	46.28	-	-	-
p_2	35.04	38.89	41.99	51.17	68.21	72.48	51.29	49.09	52.76	52.04	-	-	-
p_3	37.37	43.74	40.52	55.23	64.55	72.53	52.35	53.29	53.11	50.65	-	-	-
k_1	35.58	37.26	40.28	49.96	63.63	67.72	49.06	-	-	-	-	-	-
k_2	35.96	42.19	39.78	52.13	62.44	72.06	50.75	-	-	-	-	-	-
k_3	34.02	41.72	42.45	54.18	58.25	67.16	49.65	-	-	-	-	-	-
Mean (H)	35.19	40.39	40.82	52.09	61.41	69.00	49.81						

Mean	C.D.(0.05)	S.E.
N, P or K	3.837	1.363
NP, NK or PK	6.646	2.361
H	5.426	1.928

Table 26(e). Effect of different levels of nutrients and harvest intervals on geraniol yield (kg/ha): pooled data for two years.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	54.56	64.29	64.39	78.29	82.44	92.99	72.83	72.15	75.89	70.45	66.53	77.41	74.52
n_2	50.19	61.57	68.12	82.47	89.30	103.85	75.92	76.62	74.19	76.96	72.01	79.94	75.80
n_3	52.51	63.21	64.63	80.42	95.50	100.63	76.15	75.90	75.27	77.28	66.39	73.70	88.37
p_1	48.99	58.75	63.89	75.05	76.02	87.14	68.31	68.51	67.58	68.91	-	-	-
p_2	52.32	61.63	65.84	78.65	100.43	103.09	77.00	74.42	78.10	78.46	-	-	-
p_3	55.96	68.68	67.43	87.50	90.74	107.24	79.59	81.82	79.63	77.32	-	-	-
k_1	54.15	59.22	66.68	79.74	91.97	97.57	74.89	-	-	-	-	-	-
k_2	51.85	64.44	62.77	78.44	89.01	104.08	75.09	-	-	-	-	-	-
k_3	51.27	65.38	67.69	83.04	86.17	95.82	74.90	-	-	-	-	-	-
Mean (H)	52.42	63.02	65.71	80.40	89.08	99.16	74.96						

Mean	C.D.(0.05)	S.E.
N, P or K	4.697	1.668
NP, NK or PK	8.135	2.891
H	6.642	2.360

Effect of nitrogen

Geraniol yield in each of the years and the total yield for the two years combined were not influenced significantly by the levels of N. The yields recorded for 25, 50 and 75 kg N/ha in the first year were 25.28, 25.32 and 24.86 kg/ha respectively and the corresponding figures for the second year were 47.55, 50.59 and 51.29 kg/ha.

Effect of phosphorus

Increase in the level of P_2O_5 increased the geraniol yield significantly in the two years separately as well as combined. But there was no significant difference between the treatments of 50 and 75 kg P_2O_5/ha. The values recorded for 25, 50 and 75 kg P_2O_5/ha in the first year were 22.47, 25.74 and 27.27 kg/ha respectively and the corresponding yields in the second year were 45.82, 51.29 and 52.35 kg/ha.

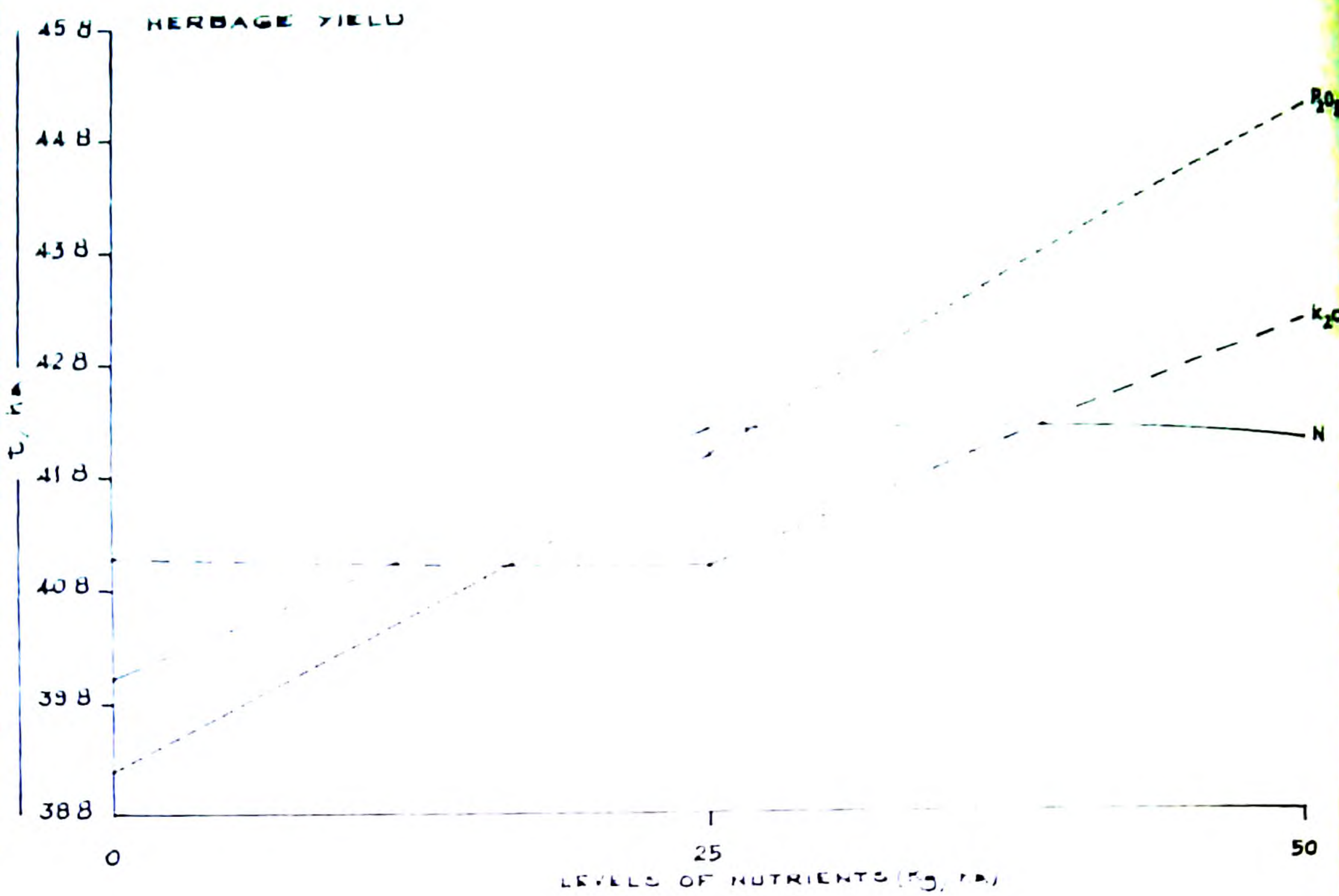
Effects of potassium

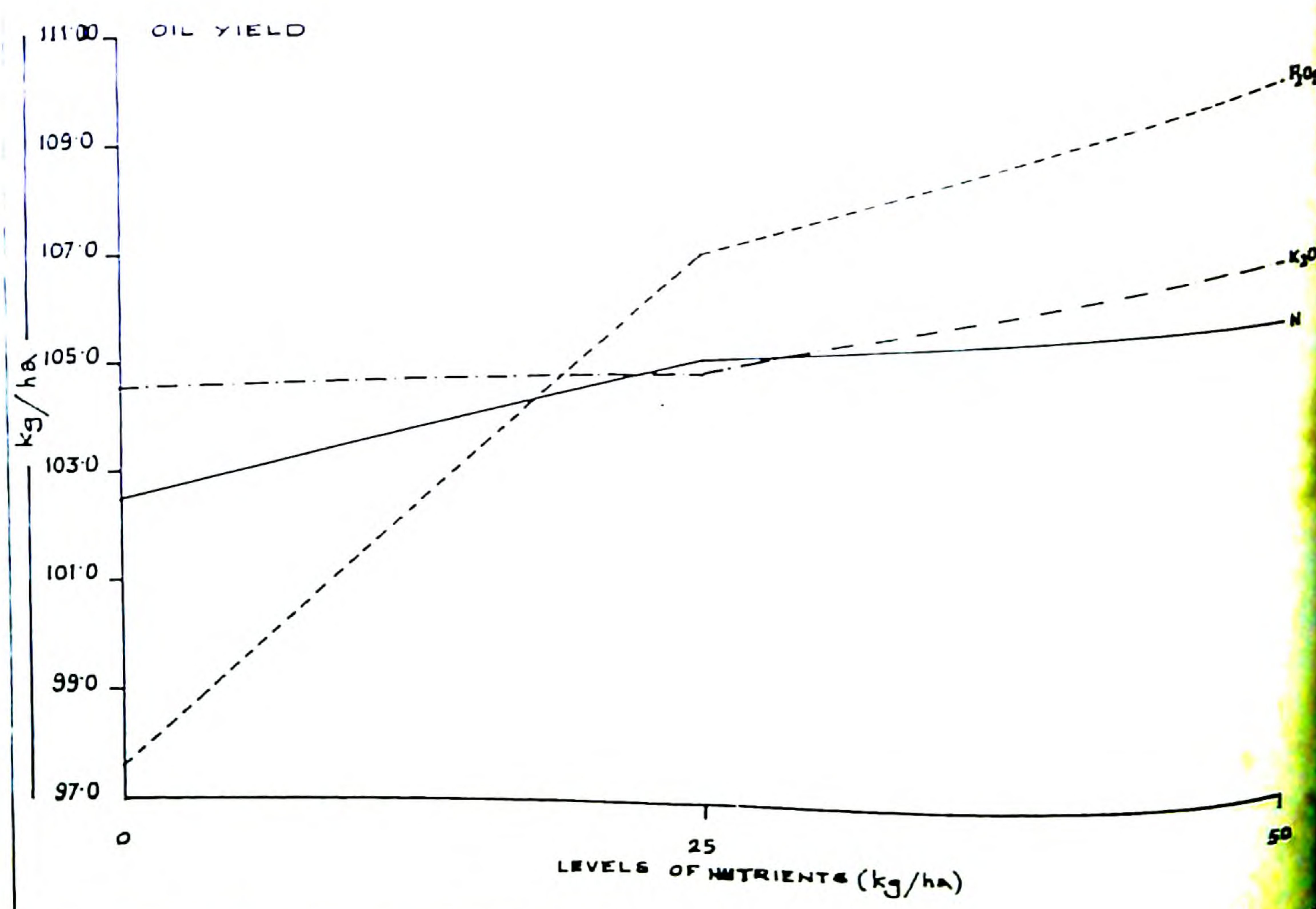
Application of different levels of K_2O did not significantly influence the geraniol yield. The yields recorded for the treatments of 25, 50 and 75 kg K_2O/ha in the first year were 25.84, 24.35 and 25.24 kg/ha respectively and those recorded in the second year were 49.06, 50.75 and 49.65 kg/ha.

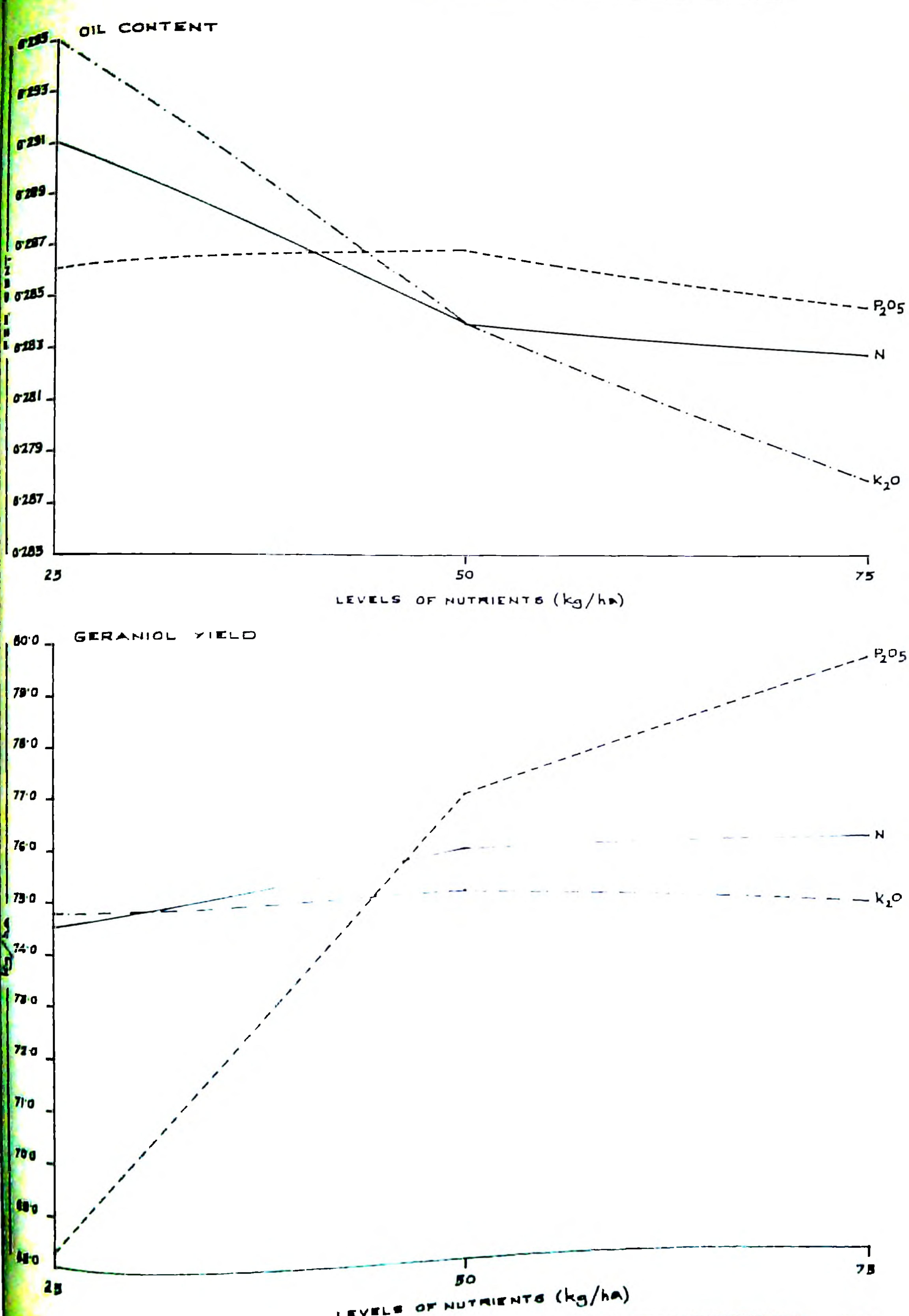
Nutrient interactions

The interaction between N and P was significant in the second year and in the pooled data for the two years. The treatment n_3p_3 gave the highest geraniol yield and it

Fig.2. Effect of different levels of nutrients on herbage yield, oil yield, oil content and geraniol yield


HERBAGE YIELD
45.8
44.8
43.8
42.8
41.8
40.8
39.8
38.8
t/ha
0
25
50
LEVELS OF NUTRIENTS (kg/ha)


OIL YIELD
111.00
109.0
107.0
105.0
103.0
101.0
99.0
97.0
kg/ha
P_2O_5
K_2O
N
0
25
50
LEVELS OF NUTRIENTS (kg/ha)



OIL CONTENT
0·295
0·293
0·291
0·289
0·287
0·285
0·283
0·281
0·279
0·277
0·275
25
50
75
LEVELS OF NUTRIENTS (kg/ha)
P_2O_5
N
K_2O
GERANIOL YIELD
80·0
79·0
78·0
77·0
76·0
75·0
74·0
73·0
72·0
71·0
70·0
69·0
68·0
25
50
75
LEVELS OF NUTRIENTS (kg/ha)
P_2O_5
N
K_2O

was significantly more than that of the other combinations. In the first year too, the above treatment resulted in the highest geraniol yield.

Effect of harvest intervals

Geraniol yield increased with increase in the intervals of harvest in both the years. The highest yield was recorded for the 65 day interval and it was significantly superior to all other harvest intervals in both the years separately and combined. The geraniol yield with different intervals of harvest varied from 17.24 to 30.19 kg/ha in the first year and from 35.19 to 69.00 kg/ha in the second year.

Nutrient composition and uptake studies

Nitrogen content

The N content of the herbage as influenced by the levels of N, P, K and H are presented in Tables 27 a, b and c.

Effect of nitrogen

Increasing the level of N from 25 to 75 kg/ha significantly increased the N content of the herbage in the first year. The highest value (1.18 per cent) was recorded with N at 75 kg/ha, but the values obtained at 50 and 75 kg/ha were on par and both were significantly more than the N content at the lowest level of N application. The values obtained at N applications of 25, 50 and 75 kg/ha were 1.08, 1.15 and 1.18 per cent respectively.

Table 27(a). Effect of different levels of nutrients and harvest intervals in nitrogen content of the plant (per cent) in the first year: 1980-81.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	1.14	1.11	1.10	1.07	1.09	1.01	1.08	1.07	1.04	1.14	1.04	1.10	1.11
n_2	1.23	1.19	1.13	1.19	1.09	1.06	1.15	1.14	1.18	1.12	1.13	1.13	1.18
n_3	1.32	1.22	1.19	1.10	1.10	1.12	1.18	1.24	1.16	1.13	1.25	1.17	1.11
p_1	1.22	1.11	1.19	1.17	1.09	1.08	1.14	1.20	1.10	1.13	-	-	-
p_2	1.23	1.16	1.11	1.14	1.09	1.07	1.13	1.14	1.13	1.13	-	-	-
p_3	1.23	1.24	1.11	1.06	1.10	1.05	1.13	1.11	1.16	1.14	-	-	-
k_1	1.26	1.21	1.14	1.14	1.09	1.05	1.15	-	-	-	-	-	-
k_2	1.20	1.13	1.15	1.11	1.10	1.09	1.13	-	-	-	-	-	-
k_3	1.23	1.17	1.11	1.11	1.10	[illegible]	1.13	-	-	-	-	-	-
Mean (H)	1.22	1.17	1.14	1.12	1.09	1.05	1.14	-	-	-	-	-	-

Mean	C.D.(0.05)	S.E.
N, P or K	0.033	0.014
NP, NK or PK	0.066	0.024
H	0.054	0.019

Table 27(b). Effect of different levels of nutrients and harvest intervals on nitrogen content of the plant (per cent) in the second year: 1981-82.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	1.16	1.13	1.14	1.12	1.06	0.97	1.10	1.08	1.14	1.07	1.07	1.10	1.13
n_2	1.18	1.16	1.15	1.16	1.07	1.06	1.13	1.09	1.10	1.20	1.15	1.15	1.10
n_3	1.23	1.22	1.11	1.07	1.12	1.00	1.13	1.10	1.14	1.14	1.22	1.08	1.08
p_1	1.23	1.16	1.18	1.13	1.06	1.09	1.14	1.17	1.16	1.11	-	-	-
p_2	1.19	1.17	1.07	1.13	1.10	0.99	1.11	1.07	1.10	1.17	-	-	-
p_3	1.15	1.13	1.15	1.09	1.10	0.94	1.10	1.03	1.14	1.13	-	-	-
k_1	1.18	1.14	1.05	1.08	1.06	1.02	1.09	-	-	-	-	-	-
k_2	1.22	1.18	1.15	1.16	1.05	1.03	1.13	-	-	-	-	-	-
k_3	1.17	1.19	1.21	1.11	1.15	0.97	1.13	-	-	-	-	-	-
Mean (H)	1.19	1.17	1.13	1.12	1.09	1.01	1.12						

Mean	C.D.(0.05)	S.E.
N, P or K	-	0.017
NP, NK or PK	0.085	0.031
H	0.070	0.025

Table 27(a). Effect of different levels of nutrients and harvest intervals on nitrogen content of the plant (per cent): mean values for two years.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	1.15	1.12	1.11	1.09	1.07	0.99	1.08	1.07	1.09	1.10	1.05	1.10	1.12
n_2	1.22	1.17	1.14	1.18	1.08	1.06	1.14	1.11	1.14	1.18	1.16	1.14	1.14
n_3	1.28	1.22	1.15	1.09	1.11	1.08	1.17	1.17	1.15	1.14	1.24	1.15	1.10
p_1	1.27	1.14	1.18	1.15	1.08	1.09	1.15	1.18	1.13	1.14	-	-	-
p_2	1.21	1.17	1.11	1.13	1.09	1.03	1.13	1.10	1.12	1.15	-	-	-
p_3	1.19	1.21	1.13	1.07	1.10	1.01	1.12	1.07	1.15	1.14	-	-	-
k_1	1.22	1.17	1.11	1.11	1.06	1.03	1.12	-	-	-	-	-	-
k_2	1.21	1.15	1.14	1.14	1.06	1.05	1.13	-	-	-	-	-	-
k_3	1.24	1.18	1.16	1.11	1.12	1.04	1.14	-	-	-	-	-	-
Mean (H)	1.22	1.17	1.14	1.12	1.09	1.04	1.13						

Mean	C.D.(0.05)	S.E.
N, P or K	0.032	0.011
NP, NK or PK	0.056	0.020
H	0.045	0.016

Though the N content was not influenced significantly by the levels of N during the second year the values recorded at 50 and 75 kg N/ha were higher than that at 25 kg/ha. The values corresponding to N application of 25, 50 and 75 kg/ha were 1.10, 1.13 and 1.13 per cent respectively.

When the pooled data were considered it is seen that the maximum value was recorded with 75 kg N/ha (1.17 per cent) and it was on par with the treatment of 50 kg N/ha (1.14 per cent). However both of them were significantly higher than that of the lowest level of N (1.08) per cent.

Effect of phosphorus

The N content of the herbage was not influenced significantly by different levels of P_2O_5 in the two years separately or combined. Nitrogen content decreased with increasing levels of P_2O_5 and the values recorded at 25, 50 and 75 kg P_2O_5/ha in the first year were 1.14, 1.14 and 1.13 per cent respectively and the corresponding figures for the second year were 1.14, 1.11 and 1.10 per cent.

Effect of potassium

Different levels of K_2O did not produce any significant effect on the N content of the herbage in the two years or as per the mean value for two years. The values recorded at 25, 50 and 75 kg K_2O/ha were 1.15, 1.13 and 1.13 per cent respectively for the first year and the corresponding figures for the second year were 1.09, 1.13 and 1.13 per cent.

Nutrient interactions

The interaction of N with P was significant in both the years and for the mean value for the two years, and n_3p_1 recorded the highest value in both the years.

The interactions between N and K and between P and K were also significant in the first year and for the mean values obtained for two years. Out of the different nk combinations, n_2k_3 recorded the maximum value and among the different pk combinations p_1k_1 recorded the highest value, when the mean data for two years were considered.

Effect of harvest intervals

Interval of harvest showed significant influence on the N content of the herbage in both the years separately and combined. As the interval between harvests increased the N content decreased significantly in both the years. The highest value was recorded for the 40 day interval and the lowest value for the 65 day interval in both the years. Nitrogen content was lower in the second year than in the first year and the values for the different levels of N ranged from 1.06 to 1.22 per cent in the first year and from 1.01 to 1.19 per cent in the second year.

Phosphorus content

The data on the P content of the herbage as affected by different levels of N, P, K and H are presented in Tables 28 a, b and c.

Table 28(a). Effect of different levels of nutrients and harvest intervals on phosphorus content of the plant (per cent) in the first year: 1980-81.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	0.161	0.170	0.169	0.153	0.158	0.128	0.157	0.154	0.158	0.158	0.136	0.165	0.168
n_2	0.161	0.154	0.159	0.147	0.149	0.156	0.154	0.147	0.147	0.169	0.142	0.170	0.152
n_3	0.157	0.162	0.157	0.144	0.139	0.138	0.150	0.150	0.152	0.146	0.156	0.142	0.150
p_1	0.147	0.145	0.158	0.148	0.140	0.131	0.145	0.132	0.152	0.150	-	-	-
p_2	0.162	0.179	0.165	0.146	0.144	0.158	0.159	0.155	0.161	0.161	-	-	-
p_3	0.171	0.161	0.164	0.149	0.162	0.133	0.157	0.164	0.143	0.163	-	-	-
k_1	0.150	0.162	0.156	0.147	0.147	0.141	0.151	-	-	-	-	-	-
k_2	0.160	0.148	0.157	0.148	0.153	0.147	0.152	-	-	-	-	-	-
k_3	0.169	0.176	0.172	0.148	0.146	0.134	0.158	-	-	-	-	-	-
Mean (H)	0.160	0.162	0.162	0.148	0.149	0.141	0.154						

Mean	C.D.(0.05)	S.E.
N, P or K	0.0101	0.0036
NP, NK or PK	0.0175	0.0062
H	0.0143	0.0051

Table [illegible](b). Effect of different levels of nutrients and harvest intervals on phosphorus content of the plant (per cent) in the second year: 1981-82.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	0.167	0.176	0.163	0.134	0.143	0.141	0.154	0.151	0.144	0.164	0.145	0.157	0.160
n_2	0.151	0.152	0.155	0.158	0.131	0.134	0.149	0.157	0.129	0.153	0.131	0.160	0.148
n_3	0.159	0.167	0.162	0.147	0.133	0.133	0.150	0.159	0.150	0.142	0.145	0.154	0.152
p_1	0.149	0.146	0.148	0.137	0.126	0.135	0.140	0.144	0.135	0.143	-	-	-
p_2	0.164	0.173	0.167	0.153	0.147	0.138	0.157	0.168	0.149	0.150	-	-	-
p_3	0.165	0.174	0.165	0.149	0.134	0.135	0.154	0.156	0.139	0.166	-	-	-
k_1	0.160	0.173	0.165	0.152	0.138	0.146	0.156	-	-	-	-	-	-
k_2	0.161	0.155	0.139	0.133	0.131	0.131	0.142	-	-	-	-	-	-
k_3	0.156	0.167	0.175	0.154	0.138	0.130	0.153	-	-	-	-	-	-
Mean (H)	0.159	0.165	0.160	0.146	0.136	0.136	0.150						

Mean	C.D.(0.05)	S.E.
N, P or K	0.0101	0.0036
NP, NK or PK	0.1750	0.0623
H	0.0143	0.0051

Table 28(c). Effect of different levels of nutrients and harvest intervals on phosphorus content of the plant (per cent): mean values for two years.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	0.164	0.173	0.168	0.143	0.151	0.134	0.156	0.152	0.152	0.166	0.140	0.161	0.16[illegible]
n_2	0.156	0.152	0.157	0.153	0.140	0.145	0.150	0.152	0.138	0.161	0.138	0.165	0.15[illegible]
n_3	0.159	0.165	0.159	0.146	0.136	0.131	0.150	0.155	0.151	0.144	0.151	0.149	0.151
p_1	0.148	0.146	0.152	0.143	0.134	0.133	0.143	0.137	0.144	0.148	-	-	-
p_2	0.164	0.176	0.156	0.149	0.145	0.148	0.158	0.162	0.156	0.157	-	-	-
p_3	0.168	0.170	0.164	0.149	0.148	0.134	0.156	0.160	0.141	0.167	-	-	-
k_1	0.156	0.157	0.161	0.149	0.142	0.143	0.153	-	-	-	-	-	-
k_2	0.161	0.151	0.148	0.141	0.142	0.139	0.147	-	-	-	-	-	-
k_3	0.163	0.174	0.174	0.151	0.142	0.134	0.157	-	-	-	-	-	-
Mean (H)	0.160	0.164	0.161	0.147	0.142	0.138	0.152						

Mean	C.D.(0.05)	S.E.
N, P or K	0.0111	0.0039
H	0.0153	0.0054

Effect of nitrogen

Application of N at different levels did not influence the P content of the herbage. Increased levels of N slightly decreased the P content of the herbage in both the years. The values with different levels of N in the first year, ranged from 0.150 to 0.157 per cent and in the second year, the variation was from 0.149 to 0.154 per cent.

Effect of phosphorus

Different levels of P_2O_5 showed significant influence on the P content of the herbage in both the years separately and in their mean value. The highest P content was recorded at 50 kg P_2O_5/ha which was on par with 75 kg N/ha and was significantly superior to 25 kg/ha in both the years. The mean value for the two years also showed the same trend. The values recorded at 25, 50 and 75 kg P_2O_5/ha in the first year were 0.145, 0.159 and 0.157 per cent and those in the second year were 0.140, 0.157 and 0.154 per cent respectively.

Effect of potassium

Different levels of K_2O did not influence the P content of the herbage in the first year. However, in the second year, the effect of K_2O was significant. But no regular trend could be noticed in the P content of the herbage in the two years separately or combined. The values for K_2O application of 25, 50 and 75 kg/ha were 0.151, 0.152 and 0.158 per cent in the first year and 0.156, 0.142 and 0.153 per cent in the second year respectively.

Nutrient interactions

The interactions between N and P and between P and K were significant in the first year and the highest values were recorded by n_1p_3 and p_3k_1 respectively. The interaction between N and K was significant in the second year and the maximum value was recorded by n_1k_3.

Effect of harvest intervals

Different intervals of harvest showed significant influence on the P content of the herbage in both the years. In the first year, the highest value was recorded with 45 and 50 day intervals (0.162 per cent) but there was no significant difference between the 40, 45, 50, 55 and 60 day intervals. The lowest value was recorded with 65 days (0.141 per cent) and it was significantly lower than that of the other harvest intervals.

In the second year also the lowest value was recorded with 65 day interval (0.136 per cent) and it was on par with 55 and 60 day intervals. All the other harvest intervals had higher values than these treatments. Similar results have been recorded for the mean values for the two years also. The P content for the different intervals of harvest ranged from 0.141 to 0.162 per cent in the first year and from 0.136 to 0.165 per cent in the second year.

Potassium content

Data relating to the K content of the herbage as influenced by different levels of N, P, K and H in both the years and their mean are given in Tables 29 a, b and c.

Effect of nitrogen

Increasing the level of N from 25 to 75 kg/ha did not influence the K content of the herbage. The values recorded with 25, 50 and 75 kg N/ha in the first year were 2.10, 2.19 and 2.10 per cent respectively.

In the second year and in the mean values obtained for two years the K content was found to decrease as the N levels increased. The K content in the second year with different levels of N ranged from 1.93 to 1.98 per cent and in the mean value for two years the values ranged from 2.01 to 2.08 per cent.

Effect of phosphorus

Different levels of P_2O_5 showed no significant influence in the K content of herbage in both the years and in the mean value for two years. The values recorded at 25, 50 and 75 kg P_2O_5/ha in the first year were 2.15, 2.08 and 2.16 per cent respectively and the corresponding figures for the second year were 1.98, 2.00 and 1.91 per cent.

Effect of potassium

The effect of K_2O on the K content of the herbage was significant in both the years and in the mean value

Table XX(a). Effect of different levels of nutrients and harvest intervals on potassium content of the plant (per cent) in the first year: 1980-81.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	2.21	2.31	2.13	2.09	1.92	1.92	2.10	2.05	2.07	2.19	2.01	2.13	2.17
n_2	2.53	2.22	2.26	2.14	1.99	2.01	2.19	1.92	2.28	2.38	2.04	2.39	2.15
n_3	2.30	2.44	1.97	2.20	1.88	1.79	2.10	2.09	2.10	2.10	2.41	1.72	2.16
p_1	2.37	2.37	2.20	2.18	1.88	1.91	2.15	2.02	2.19	2.24	-	-	-
p_2	2.19	2.26	2.07	2.16	1.92	1.88	2.08	1.94	2.12	2.18	-	-	-
p_3	2.49	2.33	2.09	2.10	1.99	1.96	2.16	2.10	2.14	2.23	-	-	-
k_1	2.31	2.26	2.02	1.96	1.68	1.90	2.02	-	-	-	-	-	-
k_2	2.16	2.27	2.16	2.28	2.07	1.98	2.15	-	-	-	-	-	-
k_3	2.58	2.44	2.18	2.20	2.04	1.87	2.22	-	-	-	-	-	-
Mean (H)	2.35	2.32	2.12	2.14	1.93	1.91	2.13						

Mean	C.D.(0.05)	S.E.
N, P or K	0.138	0.049
NP, NK or PK	0.239	0.085
H	0.195	0.069

Table 29(b). Effect of different levels of nutrients and harvest intervals on potassium content of the plant (per cent) in the second year: 1981-82.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	2.24	2.14	1.84	1.93	1.83	1.90	1.98	1.87	1.94	2.14	1.97	1.91	2.07
n_2	2.16	1.89	2.27	1.97	1.83	1.69	1.97	1.78	2.01	2.12	1.84	2.23	1.83
n_3	2.28	2.24	2.02	1.78	1.70	1.58	1.93	1.86	1.94	1.99	2.13	1.85	1.82
p_1	2.27	2.20	2.11	1.82	1.79	1.69	1.98	1.93	1.84	2.16	-	-	-
p_2	2.26	2.07	2.17	2.00	1.79	1.71	2.00	1.73	2.17	2.10	-	-	-
p_3	2.16	2.01	1.86	1.86	1.79	1.77	1.91	1.85	1.88	1.99	-	-	-
k_1	2.16	2.16	1.86	1.71	1.60	1.54	1.84	-	-	-	-	-	-
k_2	2.14	1.94	2.07	1.92	1.91	1.80	1.97	-	-	-	-	-	-
k_3	2.38	2.18	2.22	2.04	1.86	1.82	2.08	-	-	-	-	-	-
Mean (H)	2.23	2.09	2.05	1.89	1.79	1.72	1.96						

Mean	C.D.(0.05)	S.E.
N, P or K	0.119	0.043
NP, NK or PK	0.207	0.074
H	0.169	0.061
NH, PH or KH	0.292	0.105

Table 29(a). Effect of different levels of nutrients and harvest intervals on potassium content of the plant: mean values for two years.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	2.23	2.23	1.93	2.01	1.88	1.92	2.03	1.93	2.01	2.16	1.99	1.99	2.12
n_2	2.34	2.05	2.27	2.07	1.91	1.85	2.08	1.85	2.08	2.28	1.94	2.31	2.00
n_3	2.29	2.34	1.99	1.99	1.79	1.68	2.01	1.98	2.08	2.01	2.27	1.78	1.99
p_1	2.32	2.29	2.16	2.00	1.83	1.80	2.07	1.98	2.02	2.20	-	-	-
p_2	2.22	2.16	2.06	2.08	1.85	1.79	2.03	1.81	2.14	2.14	-	-	-
p_3	2.32	2.17	1.98	1.98	1.89	1.85	2.03	1.98	2.01	2.11	-	-	-
k_1	2.23	2.21	1.88	1.83	1.64	1.72	1.92	-	-	-	-	-	-
k_2	2.15	2.10	2.11	2.10	1.99	1.89	2.06	-	-	-	-	-	-
k_3	2.48	2.31	2.20	2.02	1.95	1.84	2.15	-	-	-	-	-	-
Mean (H)	2.29	2.21	2.06	2.02	1.86	1.82	2.04						

Mean	C.D.(0.05)	S.E.
N, P or K	0.104	0.036
NP, NK or PK	0.180	0.062
H	0.147	0.051

for two years. It increased with increase in the levels of K_2O. In the first year the K contents recorded at 25 and 50 kg K_2O/ha were on par and there was no significant difference between 50 and 75 kg K_2O/ha also.

In the second year, and in the mean values for the two years, 50 and 75 kg K_2O/ha were on par and they were significantly higher than the value at 25 kg K_2O/ha. The K content recorded in the first year at 25, 50 and 75 kg K_2O/ha were 2.02, 2.15 and 2.22 per cent respectively while those for the second year were 1.84, 1.97 and 2.08 per cent.

Nutrient interactions

The interaction of N with P was significant in both the years and as per the mean values for the two years. The highest value was recorded with n_3p_1 in the first year, followed by n_2p_2. In the second year, the highest value was recorded with n_2p_2. The lowest values in the first year and second year were recorded by n_3p_2 and n_3p_3 respectively. The interaction of N with K was significant in the first year and in the mean value for two years. Maximum value was recorded by n_2k_3 in the mean for two years. The interaction between P and K was significant in the second year and the highest value was recorded by p_2k_2.

Effect of harvest intervals

With increasing intervals of harvest the K content of the herbage decreased significantly in both the years. The lowest K content recorded at 65 day interval was on par with 50 day interval in both the years and in the mean for two years. The highest value in both the years was recorded with 40 day intervals. The mean values of K with different intervals of harvest ranged from 1.91 to 2.35 per cent in the first year and from 1.72 to 2.23 per cent in the second year.

Interaction between nutrients and harvest intervals

The interaction between N and H was significant in the second year and the maximum K content was recorded with n_3h_1.

Calcium content

The data relating to the Ca content as influenced by different levels of N, P, K and H in both the years and their mean values are presented in Tables 30 a, b and c.

Effect of nitrogen

The Ca content of the herbage was not influenced significantly with different levels of N in either year or as per the mean value for the two years. The highest Ca content was recorded at 75 kg N/ha in both the years and the Ca content of the herbage with N at 25, 50 and 75 kg/ha were 0.331, 0.327 and 0.340 per cent respectively in the first year and 0.333, 0.315 and 0.338 per cent respectively in the second year.

Effect of phosphorus

Phosphorus did not have any significant effect on the Ca content of the herbage in the two years either separately or combined. In the first year, Ca content

Table 30(a). Effect of different levels of nutrients and harvest intervals on calcium content of the plant (per cent) in the first year: 1980-81.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	0.360	0.326	0.336	0.321	0.332	0.292	0.331	0.355	0.303	0.335	0.306	0.352	0.336
n_2	0.360	0.330	0.346	0.307	0.312	0.317	0.327	0.320	0.331	0.330	0.323	0.324	0.335
n_3	0.329	0.355	0.351	0.324	0.340	0.336	0.340	0.327	0.339	0.358	0.334	0.336	0.351
p_1	0.301	0.316	0.339	0.317	0.332	0.322	0.321	0.328	0.290	0.347	-	-	-
p_2	0.356	0.337	0.335	0.323	0.349	0.320	0.337	0.344	0.331	0.337	-	-	-
p_3	0.393	0.350	0.362	0.307	0.325	0.290	0.341	0.331	0.353	0.339	-	-	-
k_1	0.358	0.363	0.331	0.324	0.326	0.302	0.334	-	-	-	-	-	-
k_2	0.349	0.313	0.353	0.267	0.322	0.319	0.325	-	-	-	-	-	-
k_3	0.343	0.331	0.351	0.342	0.358	0.320	0.341	-	-	-	-	-	-
Mean (H)	0.350	0.337	0.345	0.317	0.335	0.314	0.333						

Mean	C.D. (0.05)	S.E.
N, P or K	-	0.0076
NH, PH or KH	0.0362	0.0132
H	-	0.0108

Table 38(b). Effect of different levels of nutrients and harvest intervals on calcium content of the plant (per cent) in the second year: 1981-82.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	0.376	0.348	0.328	0.322	0.331	0.293	0.333	0.361	0.303	0.338	0.315	0.344	0.343
n_2	0.343	0.354	0.326	0.313	0.288	0.268	0.315	0.305	0.322	0.320	0.310	0.322	0.31[illegible]
n_3	0.335	0.321	0.329	0.302	0.323	0.419	0.338	0.330	0.353	0.332	0.329	0.351	0.33[illegible]
p_1	0.306	0.325	0.333	0.326	0.326	0.291	0.318	0.326	0.290	0.336	-	-	-
p_2	0.380	0.327	0.318	0.319	0.310	0.380	0.339	0.334	0.331	0.352	-	-	-
p_3	0.369	0.371	0.332	0.290	0.310	0.307	0.330	0.334	0.356	0.302	-	-	-
k_1	0.359	0.357	0.313	0.311	0.311	0.340	0.332	-	-	-	-	-	-
k_2	0.343	0.329	0.331	0.315	0.308	0.328	0.327	-	-	-	-	-	-
k_3	0.353	0.357	0.339	0.310	0.328	0.312	0.330	-	-	-	-	-	-
Mean (H)	0.352	0.341	0.328	0.312	0.315	0.327	0.329						

Mean	C.D.(0.05)	S.E.
N, P or K	-	0.0086
NP, NK or PK	0.0420	0.0150
H	-	0.0122

[illegible] of the plant (per cent): mean values for two years.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	P_1	P_2	P_3
n_1	0.368	0.337	0.332	0.321	0.342	0.292	0.332	0.358	0.303	0.337	0.310	0.348	0.33[illegible]
n_2	0.351	0.342	0.336	0.310	0.300	0.293	0.322	0.318	0.326	0.325	0.316	0.323	0.32[illegible]
n_3	0.332	0.338	0.390	0.313	0.351	0.370	0.338	0.329	0.349	0.345	0.332	0.344	0.34[illegible]
P_1	0.304	0.320	0.336	0.322	0.329	0.306	0.319	0.327	0.290	0.341	-	-	-
P_2	0.368	0.332	0.326	0.324	0.330	0.350	0.338	0.339	0.351	0.345	-	-	-
P_3	0.381	0.365	0.347	0.298	0.317	0.303	0.335	0.333	0.355	0.320	-	-	-
K_1	0.358	0.360	0.322	0.318	0.319	0.321	0.333	-	-	-	-	-	-
K_2	0.346	0.323	0.342	0.301	0.315	0.335	0.325	-	-	-	-	-	-
K_3	0.348	0.334	0.345	0.326	0.343	0.316	0.335	-	-	-	-	-	-
Mean (H)	0.351	0.339	0.336	0.314	0.325	0.320	0.331						

Mean	C.D.(0.05)	S.E.
N, P or K	-	0.0105
H	-	0.0149

increased with increasing levels of P_2O_5 and at 25, 50 and 75 kg P_2O_5/ha it was 0.321, 0.337, 0.341 per cent respectively. In the second year, P_2O_5 at 50 kg/ha recorded the highest value (0.339 per cent) and the values for application of P_2O_5 at 25 and 75 kg/ha were 0.318 and 0.330 per cent respectively.

Effect of potassium

Different levels of K_2O did not significantly influence the Ca content of the herbage in the two years considered separately or combined. The mean values recorded for two years for K_2O application of 25, 50 and 75 kg/ha were 0.333, 0.325 and 0.335 per cent respectively.

Nutrient interaction

The interactions of N with P, N with K and P with K were significant in the first year while in the second year only that between P and K was significant.

Effect of harvest intervals

Different intervals of harvest showed no significant influence on the calcium content of the herbage in both the years. There was no significant difference in the mean values for two years. The mean values for two years at 40, 45, 50, 55, 60 and 65 day intervals were 0.351, 0.339, 0.336, 0.314, 0.325 and 0.320 per cent respectively.

Magnesium content

The mean Mg content of the herbage during the two years and their mean values are given in Tables 31 a, b and c.

Table 39(M). Effect of different levels of nutrients and harvest intervals on magnesium content of the plant (per cent) in the first year: 1980-81.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	0.299	0.302	0.314	0.298	0.290	0.273	0.296	0.313	0.307	0.269	0.294	0.309	0.276
n_2	0.322	0.303	0.335	0.321	0.313	0.304	0.316	0.326	0.297	0.324	0.301	0.321	0.329
n_3	0.362	0.324	0.321	0.328	0.337	0.340	0.339	0.355	0.341	0.318	0.349	0.336	0.329
p_1	0.314	0.273	0.336	0.315	0.327	0.324	0.315	0.337	0.311	0.296	-	-	-
p_2	0.346	0.349	0.316	0.314	0.307	0.301	0.322	0.353	0.322	0.291	-	-	-
p_3	0.340	0.305	0.316	0.316	0.303	0.289	0.312	0.305	0.312	0.317	-	-	-
k_1	0.339	0.306	0.350	0.331	0.333	0.330	0.331	-	-	-	-	-	-
k_2	0.360	0.308	0.308	0.297	0.315	0.302	0.315	-	-	-	-	-	-
k_3	0.300	0.312	0.310	0.316	0.289	0.282	0.302	-	-	-	-	-	-
Mean (H)	0.333	0.309	0.323	0.315	0.313	0.305	0.316						

Mean	C.D.(0.05)	S.E.
N, P or K	0.0175	0.0071
NP, NK or PK	0.0303	0.0122
H	-	0.0100

Table 39(b). Effect of different levels of nutrients and harvest intervals on magnesium content of the plant (per cent) in the second year: 1981-82.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	0.318	0.274	0.309	0.288	0.305	0.287	0.297	0.298	0.329	0.264	0.309	0.303	0.279
n_2	0.341	0.279	0.349	0.317	0.317	0.314	0.320	0.323	0.311	0.325	0.306	0.316	0.338
n_3	0.368	0.350	0.336	0.308	0.327	0.311	0.333	0.309	0.339	0.352	0.342	0.332	0.326
p_1	0.335	0.288	0.324	0.324	0.340	0.303	0.319	0.313	0.327	0.316	-	-	-
p_2	0.341	0.312	0.345	0.309	0.305	0.290	0.317	0.317	0.331	0.303	-	-	-
p_3	0.352	0.303	0.325	0.281	0.304	0.319	0.314	0.298	0.321	0.323	-	-	-
k_1	0.352	0.286	0.311	0.288	0.314	0.306	0.310	-	-	-	-	-	-
k_2	0.374	0.304	0.339	0.302	0.318	0.322	0.327	-	-	-	-	-	-
k_3	0.301	0.313	0.344	0.323	0.317	0.285	0.314	-	-	-	-	-	-
Mean (H)	0.342	0.301	0.331	0.304	0.316	0.304	0.317						

Mean	C.D.(0.05)	S.E.
N, P or K	0.0171	0.0061
NP, NK or PK	0.0420	0.0105
H	0.0242	0.0081

Table 37(c). Effect of different levels of nutrients and harvest intervals on the magnesium content of the plant (per cent): mean values for two years.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	0.309	0.288	0.312	0.293	0.298	0.280	0.297	0.305	0.318	0.267	0.312	0.300	0.277
n_2	0.334	0.293	0.344	0.322	0.319	0.311	0.321	0.325	0.305	0.332	0.305	0.324	0.334
n_3	0.376	0.338	0.330	0.319	0.334	0.327	0.337	0.332	0.340	0.340	0.345	0.339	0.328
p_1	0.324	0.281	0.330	0.319	0.335	0.314	0.317	0.325	0.320	0.306	-	-	-
p_2	0.348	0.335	0.336	0.317	0.311	0.301	0.325	0.335	0.327	0.312	-	-	-
p_3	0.346	0.304	0.320	0.298	0.304	0.304	0.313	0.302	0.317	0.320	-	-	-
k_1	0.345	0.296	0.331	0.310	0.324	0.318	0.321	-	-	-	-	-	-
k_2	0.367	0.306	0.324	0.300	0.318	0.312	0.321	-	-	-	-	-	-
k_3	0.306	0.317	0.331	0.325	0.308	0.288	0.313	-	-	-	-	-	-
Mean (H)	0.340	0.306	0.329	0.311	0.317	0.306	0.318						

Mean	C.D.(0.05)	S.E.
N, P or K	0.0121	0.0043
NP, NK or PK	0.0210	0.0074
H	0.0171	0.0061

Effect of nitrogen

The Mg content of the herbage was influenced significantly by different levels of N. It increased with increasing levels of N and the maximum value was recorded at the highest level of N in both the years. In the first year, all the three levels of N were significantly different, while in the second year, N at 50 and 75 kg/ha were on par and both were significantly higher than N at 25 kg/ha. The mean values for two years showed similar trends as in the first year. The Mg content at 25, 50 and 75 kg N/ha were 0.296, 0.316 and 0.339 per cent respectively in the first year and 0.297, 0.320 and 0.333 per cent respectively in the second year.

Effect of phosphorus

Different levels of P_2O_5 showed no significant effect on the Mg content of the herbage. The values obtained at 25, 50 and 75 kg P_2O_5/ha in the first year were 0.315, 0.322 and 0.312 per cent respectively and the corresponding figures for the second year were 0.319, 0.317 and 0.314 per cent.

Effect of potassium

Different levels of K_2O did not influence significantly the Mg content of the herbage. The values obtained at 25, 50 and 75 kg K_2O/ha in the first year were 0.331, 0.315 and 0.302 per cent respectively and the corresponding figures for the second year were 0.310, 0.327 and 0.314

per cent.

Nutrient interactions

The interaction between N and K was significant in both the years and in the mean value for the two years. The maximum value was recorded by n_3k_1 in the first year and by n_3k_3 in the second year and in the mean value for two years.

The interaction of N with P was significant in the mean value for two years and the highest value was recorded by n_3p_1.

Effect of harvest intervals

The Mg content of the herbage was not influenced with different intervals of harvest in the first year. The highest value was recorded with 40 day interval (0.333 per cent) and the lowest value by 65 day interval (0.305 per cent).

In the second year and in the mean value for the two years, Mg content was influenced significantly with different intervals of harvest. The highest value in the second year was recorded with 40 day intervals (0.342 per cent). The lowest value was recorded with 65 day intervals (0.304 per cent) and it was significantly different from 40 day interval. In the mean value for the two years also similar results were obtained.

Uptake of nitrogen

The results of N uptake by herbage as influenced by different levels of N, P, K and H are presented in Tables 32 a, b and c.

Table [illegible](a). Effect of different levels of nutrients and harvest intervals on nitrogen uptake by the plant (kg/ha) in the first year: 1980-81.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	43.5	46.3	48.3	57.3	45.1	60.3	50.1	48.5	47.9	54.1	43.3	53.4	53.8
n_2	48.2	53.2	54.2	62.0	52.2	72.6	57.1	56.6	56.2	58.4	53.5	56.3	61.4
n_3	50.7	54.9	45.9	51.6	53.8	68.8	54.0	54.9	53.8	53.1	51.8	53.2	56.9
p_1	41.5	47.0	47.5	55.4	43.6	61.6	49.4	50.1	48.6	49.9	-	-	-
p_2	48.6	49.5	47.7	55.2	53.4	71.4	54.3	52.3	53.1	57.5	-	-	-
p_3	52.3	57.9	53.1	60.3	51.8	68.8	57.4	57.7	56.2	58.2	-	-	-
k_1	50.3	50.0	48.3	55.7	50.2	65.6	53.4	-	-	-	-	-	-
k_2	44.7	48.7	48.9	57.4	48.8	67.2	52.6	-	-	-	-	-	-
k_3	47.4	55.8	51.2	57.8	50.1	69.1	55.2	-	-	-	-	-	-
Mean (H)	47.5	51.5	49.5	57.0	49.7	67.3	53.7						

Mean	C.D.(0.05)	S.E.
N, P or K	3.22	1.14
H	4.55	1.62

Table 32(b). Effect of different levels of nutrients and harvest intervals on nitrogen uptake by the plant (kg/ha) in the second year: 1981-82.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	69.3	81.1	74.8	88.1	87.6	99.2	83.4	76.2	93.9	80.0	78.0	81.4	90.7
n_2	69.0	78.3	77.5	96.2	90.4	120.5	88.7	77.5	86.7	101.8	87.0	90.9	88.1
n_2	77.6	83.2	80.5	96.2	103.3	116.1	91.2	89.5	89.5	94.5	90.6	91.0	92.0
p_1	68.4	80.8	76.4	87.1	84.9	113.7	85.2	81.9	88.8	84.9	-	-	-
p_2	69.4	76.4	76.6	96.4	100.5	117.2	87.8	78.7	86.3	98.0	-	-	-
p_3	78.2	85.5	79.8	97.5	95.9	104.8	90.5	82.5	94.9	93.3	-	-	-
k_1	75.6	73.9	68.4	76.0	90.4	101.9	81.0	-	-	-	-	-	-
k_2	71.1	84.8	76.9	94.9	92.4	120.1	90.0	-	-	-	-	-	-
k_3	69.2	84.0	87.6	99.6	98.5	113.7	92.1	-	-	-	-	-	-
Mean (H)	72.0	80.9	77.6	90.2	93.8	111.9	87,8						

Mean	C.D.(0.05)	S.E.
N, P or K	5.90	2.90
NP, NK or PK	10.21	3.63
H	8.54	2.96

Table 32(c). Effect of different levels of nutrients and harvest intervals on nitrogen uptake by the plant (kg/ha): pooled data for two years.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	112.8	127.5	123.1	145.4	132.1	158.4	133.2	124.7	141.3	133.8	120.9	134.8	143.9
n_2	117.3	131.5	131.6	158.2	142.6	193.1	145.7	134.1	142.9	160.2	140.5	147.2	149.5
n_3	129.4	138.2	125.3	137.8	155.0	184.9	145.1	144.4	143.3	147.6	143.0	144.0	148.3
p_1	110.9	127.8	123.8	142.5	128.3	175.2	134.8	132.0	137.9	134.4	-	-	-
p_2	118.0	125.9	124.3	141.4	153.8	185.6	142.0	131.0	139.6	155.6	-	-	-
p_3	130.5	143.4	131.8	157.5	147.6	172.5	147.2	140.2	150.0	151.6	-	-	-
k_1	125.9	123.9	116.6	131.7	140.6	167.5	134.4	-	-	-	-	-	-
k_2	117.0	133.5	124.7	152.5	141.2	186.2	142.5	-	-	-	-	-	-
k_3	116.6	139.8	138.6	157.4	147.9	182.6	147.2	-	-	-	-	-	-
Mean (H)	119.8	132.4	126.6	147.1	143.2	178.8	141.3						

Mean	C.D.(0.05)	S.E.
N, P or K	7.85	2.79
NP, NK or PK	13.59	4.84
H	11.10	3.94

Effect of nitrogen

The uptake of N was influenced significantly by different levels of N in both the years. In the first year, the maximum uptake of 57.1 kg/ha was recorded with 50 kg N/ha and it was on par with 75 kg N/ha (54.0 kg/ha). Both of them were significantly superior to 25 kg N/ha (50.1 kg/ha).

In the second year the maximum uptake of 91.2 kg/ha was recorded with 75 kg N/ha and there was no significant difference between the N treatments of 50 and 75 kg/ha. The lowest value of 83.4 kg/ha was recorded with 25 kg N/ha and it was on par with 50 kg N/ha.

In the total uptake for two years, there was no significant difference between 50 and 75 kg N/ha and both of them were significantly higher than 25 kg N/ha.

Effect of phosphorus

Increase in the levels of P_2O_5 from 25 to 75 kg/ha significantly increased the N uptake in the first year. The highest uptake (57.4 kg/ha) was obtained with 75 kg P_2O_5/ha and it was on par with 50 kg P_2O_5/ha (54.3 kg/ha). Both of them were significantly higher than the lowest level of P_2O_5 (49.4 kg/ha).

In the second year, the difference in the uptake of N for different levels of P_2O_5 was not significant. But it increased with increasing levels of P_2O_5 and the uptake recorded at 25, 50 and 75 kg P_2O_5/ha were 85.2, 87.8 and

90.3 kg/ha respectively.

The total uptake for the two years was significantly increased with increasing levels of P_2O_5. The highest uptake was recorded with 75 kg P_2O_5/ha (147.2 kg/ha) and it was on par with 50 kg P_2O_5/ha (142.0 kg/ha) and significantly superior to 25 kg P_2O_5/ha (134.8 kg/ha).

Effect of potassium

The influence of potassium on the uptake of N was not significant in the first year. The N uptake at 25, 50 and 75 kg K_2O/ha were 53.4, 52.6 and 55.2 kg/ha respectively.

In the second year the uptake of N increased significantly with increase in the levels of K_2O. The highest uptake of 92.1 kg/ha was recorded for K_2O at 75 kg/ha and it was on par with K_2O at 50 kg/ha (90.0 kg/ha) and both of them were significantly higher than 25 kg K_2O/ha (81.0 kg/ha). The effect of K_2O was significant on the total uptake also and the results obtained were similar to those obtained in the second year.

Nutrient interactions

The interaction between N and K was significant in the second year and in the total uptake for two years and the highest value was recorded by n_2k_3 in both the years.

Effect of harvest intervals

There was significant difference in the uptake of N with different intervals of harvest. The maximum uptake was recorded with 65 day intervals and it was significantly higher than all other treatments in both the years and in the total yield for the two years. The lowest value was obtained with 40 day intervals. The uptake of N with different intervals of harvest varied from 47.5 to 67.3 kg/ha in the first year and from 72.0 to 111.9 kg/ha in the second year.

Uptake of phosphorus

The data relating to P uptake as influenced by the different treatments are presented in Tables 33 a, b and c.

Effect of nitrogen

Phosphorus uptake was significantly influenced with different levels of N in the first year. The uptake of P_2O_5 increased as the levels of N increased from 25 to 50 kg/ha and on further increase to 75 kg/ha it decreased. The maximum uptake of 7.7 kg/ha was recorded with 50 kg/N/ha, but there was no significant difference between 50 and 25 kg N/ha (7.3 kg/ha). The uptake of P at 75 kg N/ha (6.9 kg/ha) was significantly lower than that at 50 kg N/ha.

There was no significant difference in the uptake recorded in the second year and in the total uptake for the two years. The values obtained with 25, 50 and 75 kg N/ha in the second year were 11.6, 11.5 and 12.2 kg/ha respectively.

Effect of phosphorus

Phosphorus uptake increased significantly with increase in the levels of P_2O_5 in both the years and in the

Table 33(a). Effect of different levels of nutrients and harvest intervals on phosphorus uptake by the plant (kg/ha) in the first year: 1980-81.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	6.3	7.1	7.7	8.3	6.5	7.7	7.3	7.0	7.3	7.8	5.5	8.0	8.2
n_2	6.2	6.9	7.6	7.6	7.1	10.7	7.7	7.4	7.0	8.7	6.8	8.4	8.0
n_3	6.1	7.2	6.2	7.0	6.5	8.3	6.9	6.8	7.0	6.8	6.5	6.5	7.7
p_1	5.0	6.1	6.3	7.2	5.6	7.3	6.3	5.5	6.7	6.5	-	-	-
p_2	6.2	7.7	7.1	7.0	7.1	10.7	7.5	7.2	7.5	8.2	-	-	-
p_3	7.3	7.5	8.1	5.6	7.5	8.7	8.0	8.5	7.0	8.3	-	-	-
k_1	6.3	6.7	6.6	7.4	6.8	8.8	7.1	-	-	-	-	-	-
k_2	5.7	6.4	6.8	7.7	6.7	9.2	7.1	-	-	-	-	-	-
k_3	6.5	8.2	8.1	7.8	6.7	8.7	7.7	-	-	-	-	-	-
Mean (H)	6.2	7.1	7.2	7.6	6.7	8.9	7.3						

Mean	C.D.(0.05)	S.E.
N, P or K	0.54	0.19
NP, NK or PK	0.94	0.33
H	0.77	0.27
NH, PH or KH	1.33	0.47

Table 55(b). Effect of different levels of nutrients and harvest intervals on phosphorus uptake by the plant (kg/ha) in the second year: 1981-82.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	10.3	12.3	10.7	10.6	11.7	14.0	11.6	11.0	11.6	12.2	10.7	11.4	12.7
n_2	8.9	10.4	10.3	13.0	11.2	15.3	11.5	11.8	9.9	13.0	9.9	12.8	11.9
n_3	9.9	11.6	10.8	12.5	12.6	15.8	12.2	13.2	11.5	11.8	10.8	12.2	13.4
p_1	8.3	10.4	9.6	10.7	10.1	15.3	10.5	10.4	10.3	10.8	-	-	-
p_2	9.5	11.3	10.8	11.9	13.4	15.9	12.1	12.4	11.4	12.7	-	-	-
p_3	11.3	12.6	11.4	13.4	12.1	15.3	12.7	13.1	11.3	13.6	-	-	-
k_1	10.5	11.5	10.5	11.4	12.5	15.7	12.0	-	-	-	-	-	-
k_2	9.4	11.1	8.8	10.4	11.5	14.5	11.0	-	-	-	-	-	-
k_3	9.3	11.7	12.7	14.1	11.6	14.7	12.4	-	-	-	-	-	-
Mean (H)	9.7	11.4	10.6	12.0	11.8	15.0	11.8						

Mean	C.D.(0.05)	S.E.
N, P or K	1.01	0.36
NP, PK or NK	1.74	0.62
H	1.42	0.51

Table 33(c). Effect of different levels of nutrients and harvest intervals on phosphorus uptake by the plant (kg/ha) pooled data for two years.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	16.6	19.5	18.6	18.7	18.2	22.2	19.0	18.0	18.9	20.0	16.2	19.8	21.0
n_2	15.1	17.5	18.0	20.0	18.4	26.1	19.3	19.2	16.9	21.8	16.8	21.2	19.8
n_3	16.0	18.7	17.0	19.3	19.1	25.0	19.2	20.0	18.9	18.6	17.8	18.7	21.1
p_1	13.3	16.6	15.9	17.9	15.7	22.2	16.9	16.0	17.4	17.4	-	-	-
p_2	15.8	19.0	17.9	18.8	20.5	27.2	19.9	19.6	18.9	21.1	-	-	-
p_3	18.6	20.1	19.5	22.0	19.6	24.0	20.6	21.6	18.3	21.9	-	-	-
k_1	16.7	18.1	16.9	18.8	19.2	24.7	18.1	-	-	-	-	-	-
k_2	15.2	17.5	15.7	18.0	18.3	24.7	18.2	-	-	-	-	-	-
k_3	15.8	20.1	20.7	21.9	18.3	24.0	20.1	-	-	-	-	-	-
Mean (H)	15.9	18.6	17.8	19.6	18.6	24.5	19.1						

Mean	C.D.(0.05)	S.E.
N, P or K	1.37	0.49
NP, NK or PK	2.36	0.84
H	1.95	0.69

mean value for two years. Application of P_2O_5 at 75 kg/ha recorded the maximum uptake and it was significantly higher than that at 25 kg/ha. There was no significant difference between 50 and 75 kg P_2O_5/ha in either year or in the total uptake for two years also. The uptake of P with P_2O_5 at 25, 50 and 75 kg/ha were 6.3, 7.6 and 8.0 kg/ha in the first year and 10.5, 12.1 and 12.7 kg/ha respectively in the second year.

Effect of potassium

Potassium significantly influenced the uptake of P. The highest level of K_2O (75 kg/ha) recorded the maximum uptake of P in both the years. The values recorded at 25, 50 and 75 kg K_2O/ha in the first year were 7.1, 7.1 and 7.7 kg/ha respectively and the corresponding figures for the second year were 12.0, 11.0 and 12.4 kg/ha.

Nutrient interactions

The interaction between N and P was significant in the first year and the maximum uptake was recorded by n_2p_2. The interaction between N and K was significant in the second year as well as in the pooled data for the two years. In the pooled data for two years maximum uptake was recorded by n_2k_3.

Effect of harvest intervals

Uptake of P increased with increasing intervals of harvest and the highest uptake was recorded with 65 day harvest and it was significantly superior to all other intervals and it was significantly superior to all other intervals in both the years and in the total uptake for two years also. The lowest value was recorded with 40 day intervals in both the years. The uptake of P with different intervals of harvest ranged from 6.2 to 8.9 kg/ha and from 9.7 to 15.0 kg/ha in the first and second year respectively.

Interaction of nutrients with harvest intervals

Harvest intervals interacted significantly with levels of P in the first year. Out of different combinations of harvest intervals with levels of P, p_2h_6 recorded maximum uptake of P.

Harvest intervals interacted significantly with levels of N also in the first year. Out of the different combinations of harvest intervals with levels of N, n_2h_6 recorded the maximum uptake of P.

Uptake of potassium

The data relating to the uptake of potassium for the different treatments are presented in Table 34 a, b and c.

Effect of nitrogen

Different levels of N influenced the uptake of K significantly only in the first year. The maximum uptake was recorded with 50 kg N/ha and it was significantly higher than the other levels and there was no difference between the uptake at 75 and 25 kg N/ha. In the second year and in the total uptake for two years there was no significant difference with different levels of N. The uptake of K at 25, 50 and 75 kg N/ha were 96.5, 109.4 and 93.9 kg/ha in

Table 34(a). Effect of different levels of nutrients and harvest intervals on the potassium uptake by the plant (kg/ha) in the first year: 1980-81.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	84.2	95.8	95.4	111.2	76.3	115.8	96.5	93.0	93.8	102.6	82.5	102.3	104.6
n_2	103.1	110.1	105.8	111.6	84.4	131.2	109.4	97.1	106.4	125.3	96.9	113.1	118.8
n_3	84.5	99.5	75.7	107.2	87.1	109.2	93.9	94.2	97.4	90.1	96.3	79.0	106.4
p_1	76.4	100.1	86.4	105.7	74.2	108.5	91.9	84.1	96.4	95.2	-	-	-
p_2	86.9	96.9	88.0	104.9	90.9	121.2	98.1	90.2	95.8	108.4	-	-	-
p_3	108.6	108.9	102.6	120.0	92.8	126.4	109.9	109.9	105.5	114.4	-	-	-
k_1	96.5	93.2	83.5	97.4	78.9	118.9	94.7	-	-	-	-	-	-
k_2	80.1	97.2	94.4	118.2	87.0	118.4	99.2	-	-	-	-	-	-
k_3	95.3	114.9	99.8	114.4	92.0	118.8	106.0	-	-	-	-	-	-
Mean (H)	90.6	101.8	92.4	110.0	86.0	118.7	99.9						

Mean	C.D.(0.05)	S.E.
N, P or K	8.46	3.00
NP, NK or PK	14.65	5.21
H	12.00	4.25

Table 34(b). Effect of different levels of nutrients and harvest intervals on potassium uptake by the plant (kg/ha) in the second year: 1981-82.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	136.2	151.4	119.1	151.7	149.9	192.0	150.1	135.3	154.0	161.2	143.0	142.4	164.7
n_2	127.7	128.8	152.8	161.2	153.6	197.5	153.6	129.5	155.3	176.0	139.3	176.2	145.3
n_3	142.8	154.0	133.8	148.2	157.8	183.8	153.4	148.6	149.5	162.1	156.1	146.1	157.9
p_1	127.3	154.3	138.2	140.0	141.8	175.3	146.2	137.1	138.9	162.4	-	-	-
p_2	131.5	135.0	140.3	153.9	164.9	204.0	154.9	124.9	165.8	174.0	-	-	-
p_3	148.0	144.8	127.2	167.3	154.7	193.9	156.0	151.9	154.0	162.7	-	-	-
k_1	140.7	142.0	112.5	127.9	140.7	162.8	137.8	-	-	-	-	-	-
k_2	125.9	139.4	133.8	151.2	167.3	199.8	152.9	-	-	-	-	-	-
k_3	140.1	152.7	159.3	182.0	153.3	210.7	166.4	-	-	-	-	-	-
Mean (H)	135.6	144.7	135.2	153.7	153.7	191.1	152.3						

Mean	C.D.(0.05)	S.E.
N, P or K	16.70	5.93
H	23.62	8.39

Table 34(e). Effect of different levels of nutrients and harvest intervals on the potassium uptake by the plant (kg/ha): pooled data for two years.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	219.8	247.0	214.5	263.0	229.6	307.8	246.9	228.2	249.2	263.4	225.5	246.3	269.1
n_2	230.0	238.8	260.1	275.8	248.1	328.5	263.4	226.6	263.0	301.3	236.2	287.6	265.6
n_3	227.4	253.5	209.4	255.4	244.9	292.9	247.3	242.7	246.8	252.3	252.4	225.1	264.3
p_1	203.7	253.6	226.1	248.4	216.0	283.9	238.6	221.2	235.3	257.6	-	-	-
p_2	218.4	231.8	228.3	258.8	257.0	325.1	253.0	214.5	263.2	282.4	-	-	-
p_3	256.6	254.1	229.7	287.3	248.5	320.2	266.0	261.3	260.7	277.0	-	-	-
k_1	237.2	235.3	196.1	225.5	219.6	231.8	232.6	-	-	-	-	-	-
k_2	205.5	236.6	228.2	272.4	257.6	313.2	253.0	-	-	-	-	-	-
k_3	235.4	267.6	259.8	296.4	245.3	329.4	272.6	-	-	-	-	-	-
Mean (H)	226.0	246.5	228.0	264.[illegible]	240.8	309.8	252.6						

Mean	C.D.(0.05)	S.E.
N, P or K	17.47	6.21
NP, NK or PK	30.27	10.77
H	24.71	8.78

the first year and 150.1, 153.6 and 153.4 kg/ha in the second year.

Effect of phosphorus

Different levels of P_2O_5 showed significant difference on the uptake of K in the first year and on the total value for the two years. In the first year, P_2O_5 at 75 kg/ha recorded the highest value and it was significantly higher than the other two levels. In the second year also the maximum uptake was recorded with P_2O_5 at 75 kg/ha, though the difference due to different levels of P_2O_5 were not significant.

The maximum uptake for the two years was also recorded with 75 kg P_2O_5/ha (266.0/ha) and it was significantly higher than P_2O_5 at 25 kg/ha. There was no significant difference between P_2O_5 at 75 and 50 kg/ha and between 50 and 25 kg/ha. The uptake of K at 25, 50 and 75 kg P_2O_5/ha were 91.9, 98.1 and 109.9 kg/ha respectively in the first year and 146.2, 154.9 and 156.0 kg/ha respectively in the second year.

Effect of potassium

Increase in the level of K_2O from 25 to 75 kg/ha significantly increased the K uptake in both the years and the total uptake for two years. The highest value was recorded with 75 kg K_2O/ha and the lowest value with 25 kg K_2O/ha in both the years. In the first year K_2O at 75 kg/ha was on par with K_2O at 50 kg/ha and significantly higher than K_2O at 25 kg/ha. Similar results were obtained in the second year also. In the total uptake for two years all the three levels were significantly different. The uptake of K with application of K_2O, at 25, 50 and 75 kg/ha were 94.7, 99.2 and 106.0 kg/ha respectively in the first year and 137.8, 152.9 and 166.4 kg/ha respectively in the second year.

Nutrient interactions

The interaction between N and P was significant in the first year and in the total for two years. The maximum uptake was recorded with n_2p_3 in the first year and with n_2p_2 in the total for two years.

Effect of harvest intervals

Increase in the intervals of harvests increased the uptake of K and the maximum uptake was recorded with 65 day intervals in both the years. In the first year it was significantly higher than all other harvest treatments except for the 55 day interval. In the second year and in the total for two years it was significantly superior to all other harvest intervals. The uptake of K with different intervals of harvest ranged from 86.0 to 118.7 kg/ha in the first year and from 135.2 to 191.1 kg/ha in the second year.

Uptake of calcium

The results obtained in the uptake of calcium for the different treatments are presented in Tables 35 a, b and c.

Table 35(a). Effect of different levels of nutrients and harvest intervals on calcium uptake by the plant (kg/ha) in the first year: 1980-81.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	13.8	13.5	14.9	17.9	13.9	17.6	15.3	15.8	14.3	16.0	12.5	16.7	16.6
n_2	14.0	14.5	16.0	15.2	14.5	20.5	15.7	15.3	14.5	17.5	14.3	15.9	17.0
n_3	19.7	16.7	14.8	16.6	16.8	22.5	17.9	15.3	17.1	21.0	14.9	18.1	20.4
p_1	9.9	13.4	13.8	15.2	13.0	17.9	13.9	13.8	12.6	15.4	-	-	-
p_2	20.4	13.8	13.8	15.5	16.0	21.6	16.9	15.5	14.6	20.7	-	-	-
p_3	17.1	17.6	17.9	18.9	16.0	20.7	18.0	17.2	18.4	18.5	-	-	-
k_1	14.5	15.3	13.9	16.2	14.7	13.4	15.5	-	-	-	-	-	-
k_2	13.1	13.5	15.0	15.3	14.2	20.1	15.2	-	-	-	-	-	-
k_3	19.9	16.0	16.7	18.0	16.7	21.9	18.2	-	-	-	-	-	-
Mean (H)	15.8	14.9	15.2	16.5	15.2	20.2	16.3						

Mean	C.D.(0.05)	S.E.
N, P or K	2.28	0.81
H	3.22	1.15

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Table 35(b). Effect of different levels of nutrients and harvest intervals on calcium uptake by the plant (kg/ha) in the second year: 1981-82.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	23.0	24.2	21.3	25.1	27.6	30.3	25.5	26.5	23.4	25.9	23.0	25.8	27.0
n_2	20.2	24.4	21.9	25.8	24.4	30.8	24.6	22.3	24.6	26.9	23.2	25.2	25.3
n_3	22.9	24.1	23.8	27.1	33.2	45.5	29.4	29.2	27.9	31.2	24.9	29.7	33.7
p_1	16.9	22.5	21.7	25.2	25.6	30.1	23.7	23.4	21.7	25.8	-	-	-
p_2	23.1	22.5	21.7	25.7	29.4	39.3	27.0	26.1	25.2	29.5	-	-	-
p_3	26.1	27.7	23.5	27.7	30.2	37.2	28.7	28.5	29.0	28.5	-	-	-
k_1	24.6	25.1	20.5	24.9	29.3	31.4	26.0	-	-	-	-	-	-
k_2	20.0	22.9	20.9	24.5	26.9	36.6	25.4	-	-	-	-	-	-
k_3	21.5	24.6	25.5	28.6	28.9	38.8	28.0	-	-	-	-	-	-
Mean (H)	22.0	24.2	22.3	26.0	28.4	35.5	26.4						

Mean	C.D.(0.05)	S.E.
N, P or K	2.51	0.89
H	3.55	1.26
NH, PH or KH	4.35	1.55

Table 35(e). Effect of different levels of nutrients and harvest intervals on calcium uptake by the plant (kg/ha): pooled data for two years.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	36.9	38.2	36.2	42.9	41.5	48.0	40.6	42.3	37.7	41.9	35.3	42.9	43.9
n_2	33.7	39.0	38.3	41.6	38.7	50.7	40.3	37.4	39.6	44.0	37.6	40.9	42.9
n_3	42.6	41.6	38.6	43.7	48.9	67.9	47.2	44.6	45.1	52.2	39.3	47.8	54.2
p_1	27.0	35.9	35.6	40.4	37.6	48.0	37.4	36.4	34.3	41.2	-	-	-
p_2	43.0	37.4	36.6	41.2	45.4	60.6	44.0	41.8	39.9	50.2	-	-	-
p_3	43.3	45.8	41.9	46.6	46.2	58.0	47.0	45.7	48.2	47.1	-	-	-
k_1	38.7	41.5	34.5	41.1	42.7	49.9	41.4	-	-	-	-	-	-
k_2	33.1	36.9	36.4	40.4	41.2	56.8	40.8	-	-	-	-	-	-
k_3	41.4	40.7	42.2	46.7	45.3	59.8	46.0	-	-	-	-	-	-
Mean (H)	37.7	39.7	37.7	42.7	43.1	55.5	42.7						

Mean	C.D.(0.05)	S.E.
N, P or K	3.46	1.23
H	4.90	1.74

Effect of nitrogen

The highest uptake was recorded with 75 kg N/ha in both the years. In the first year it was on par with 50 kg N/ha but significantly superior to 25 kg N/ha. In the second year and in the total for two years application of N at 75 kg/ha was significantly superior to the other two levels. The uptake of Ca at 25, 50 and 75 kg N/ha were 15.3, 15.7 and 17.9 kg/ha in the first year and 25.3, 24.6 and 29.4 kg/ha respectively in the second year.

Effect of phosphorus

Different levels of P_2O_5 also significantly influenced the uptake of Ca. The maximum uptake was recorded with P_2O_5 at 75 kg/ha. It was on par with 50 kg P_2O_5/ha and significantly superior to 25 kg P_2O_5/ha in both the years. The total uptake for two years also showed identical results and the values obtained at 25, 50 and 75 kg P_2O_5/ha were 37.4, 44.0 and 47.0 kg/ha respectively.

Effect of potassium

The influence of K_2O was significant in the first year. Application of K_2O at 75 kg/ha recorded the maximum value of 18.2 kg/ha and it was significantly higher than those at 25 and 50 kg K_2O/ha. Though the differences were not significant in the second year the maximum uptake was recorded with 75 kg K_2O/ha. The total uptake for two years also showed significant difference with different levels of K_2O and 75 kg/ha recorded significantly higher value than the other two levels. The values recorded at 25, 50 and 75 kg K_2O/ha were 41.4, 40.8 and 46.0 kg/ha respectively.

Effect of harvest intervals

Uptake of Ca was influenced significantly by different intervals of harvest. The highest value was recorded with 55 day interval and it was significantly superior to all other intervals of harvest in both the years. In the first year no definite trend was noticed in the uptake of Ca with increasing intervals of harvest, while in the second year and in the total for two years the uptake increased almost linearly with increasing intervals. The values with different intervals of harvest ranged from 14.9 to 20.2 kg/ha in the first year and from 22.0 to 35.5 kg/ha in the second year.

Interaction of nutrients with harvest intervals

The interaction between N and H was significant in the second year and the maximum uptake was recorded by n_3h_6.

Uptake of magnesium

The data relating to the uptake of Mg influenced by different treatments are presented in Tables 36 a, b and c.

Effect of nitrogen

The uptake of Mg was increased significantly with increasing levels of N in both the years and in the total uptake for two years also. The maximum uptake was recorded with N at 50 kg/ha (15.9 kg/ha) in the first year and it was on par with 75 kg N/ha (15.7 kg/ha). Both these were

Table 36(a). Effect of different levels of nutrients and harvest intervals on magnesium uptake by the plant (kg/ha) in the first year: 1980-81.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	11.7	12.8	13.9	15.8	12.2	17.0	13.9	14.5	13.8	13.2	12.5	15.6	13.5
n_2	12.7	14.2	16.3	15.8	15.1	21.2	15.9	16.3	14.4	17.0	14.4	16.6	16.7
n_3	14.6	14.4	12.6	16.2	15.3	21.1	15.7	15.7	15.6	15.8	14.5	15.1	17.5
p_1	11.5	11.0	13.5	15.2	13.2	18.5	13.8	14.6	13.8	13.0	-	-	-
p_2	13.7	15.4	14.0	15.9	15.0	20.9	15.8	15.7	15.0	16.5	-	-	-
p_3	14.1	14.6	15.3	16.7	14.4	20.0	15.9	16.2	15.0	16.5	-	-	-
k_1	13.6	12.5	14.9	16.2	14.9	20.9	15.5	-	-	-	-	-	-
k_2	13.2	13.3	13.3	15.2	13.9	18.7	14.6	-	-	-	-	-	-
k_3	12.2	15.6	14.6	16.4	13.8	19.8	15.3	-	-	-	-	-	-
Mean (H)	13.0	13.8	14.3	15.9	14.2	19.8	15.1						

Mean	C.D.(0.05)	S.E.
N, P or K	1.24	0.44
H	1.75	0.62

Table 36(b). Effect of different levels of nutrients and harvest intervals on magnesium uptake by the plant (kg/ha) in the second year: 1981-82.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	19.1	19.6	20.2	22.2	25.5	29.5	22.7	21.8	26.1	20.1	22.7	22.9	22.6
n_2	20.3	19.2	23.2	26.1	26.5	36.8	25.4	24.5	24.0	27.8	23.2	25.6	27.4
n_3	25.2	23.7	22.8	25.2	30.7	36.6	27.0	25.4	26.1	29.5	25.8	26.1	29.2
p_1	18.6	20.3	21.1	24.8	26.8	31.2	23.8	23.0	24.4	24.1	-	-	-
p_2	19.9	20.3	22.8	23.5	27.9	34.3	24.8	23.2	25.2	26.1	-	-	-
p_3	24.1	21.9	22.5	25.2	27.4	37.2	26.5	25.5	26.6	27.2	-	-	-
k_1	23.0	19.0	19.2	21.5	27.7	33.0	23.9	-	-	-	-	-	-
k_2	21.8	21.8	21.8	23.1	28.1	35.5	25.4	-	-	-	-	-	-
k_3	17.8	21.7	25.2	29.1	26.7	34.2	25.8	-	-	-	-	-	-
Mean (H)	20.9	20.8	22.1	24.5	27.5	34.3	25.0						

Mean	C.D. (0.05)	S.E.
N, P or K	2.05	0.73
NP, NK or PK	3.55	1.26
H	2.90	1.03

Table 36(c). Effect of different levels of nutrients and harvest intervals on magnesium uptake by the plant (kg/ha): pooled data for two years.

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	30.9	32.4	34.1	38.1	37.6	46.6	36.6	36.4	40.0	33.4	35.2	38.5	36.1
n_2	33.0	33.5	39.5	42.0	41.8	57.9	41.3	40.8	38.4	44.7	37.6	42.2	44.1
n_3	37.8	38.2	35.4	41.4	46.0	57.7	42.8	41.2	41.7	45.4	40.3	41.2	46.7
p_1	29.6	32.0	34.7	40.1	40.3	49.6	37.7	37.6	38.2	37.2	-	-	-
p_2	33.7	35.7	36.8	39.4	43.0	55.4	40.7	39.0	40.3	42.6	-	-	-
p_3	38.5	36.5	37.6	41.9	42.1	57.2	42.3	41.7	41.5	43.7	-	-	-
k_1	36.6	31.6	34.0	37.6	42.7	54.3	39.5	-	-	-	-	-	-
k_2	35.1	35.2	35.1	38.3	42.1	54.3	40.0	-	-	-	-	-	-
k_3	30.0	37.4	39.8	45.6	40.6	53.7	41.2	-	-	-	-	-	-
Mean (H)	33.9	34.7	36.3	40.5	41.8	54.1	40.2						

Mean	C.D.(0.05)	S.E.
N, P or K	2.85	1.01
NP, NK or PK	4.94	1.76
H	4.03	1.43

significantly superior to 25 kg N/ha (13.9 kg/ha).

There was no significant difference between 50 and 75 kg N/ha in the second year and in the total uptake for the two years also. Both of them were superior to 25 kg N/ha. The total uptake of Mg for two years at 25, 50 and 75 kg N/ha were 36.6, 41.3 and 42.8 kg/ha respectively.

Effect of phosphorus

Different levels of P_2O_5 influenced the uptake of Mg significantly. The highest value was recorded with 75 kg P_2O_5/ha and it was on par with 50.0 kg P_2O_5/ha. The minimum value was obtained for P_2O_5 at 25 kg/ha in both the years. The total uptake of Mg for two years at 25, 50 and 75 kg P_2O_5/ha were 37.7, 40.7 and 42.3 kg/ha respectively.

Effect of potassium

Uptake of Mg was not influenced by different levels of K_2O. The total uptake for two years at 25, 50 and 75 kg K_2O/ha were 39.5, 40.0 and 41.2 kg/ha respectively.

Nutrient interactions

The interaction of N with K was significant in the second year and in the total uptake for two years. The maximum uptake was recorded by n_3k_3.

Effect of harvest intervals

The uptake of Mg was influenced significantly by different intervals of harvest and the uptake increased linearly with increasing intervals of harvest. The highest value recorded for 65 day interval was significantly higher than the values obtained in all other intervals in both the years and in the total uptake for two years. The uptake of Mg at different intervals of harvest ranged from 13.0 to 19.8 kg/ha in the first year and from 20.8 to 34.3 kg/ha in the second year.

Soil analysis

The soil sample taken from each plot after the experiment were analysed for total N, available P_2O_5 and available K_2O.

Total nitrogen

Data related to the total nitrogen content of the soil are presented in Table 37.

Application of different levels of N, P and K showed no significant influence in the total N content of the soil. Increasing levels of N resulted in an increase in the N content of the soil from 1730.4 kg/ha at 25 kg N/ha to 1742.6 kg/ha at 75 kg N/ha. The N content of the soil did not show any definite trend with increasing levels of P_2O_5 or K_2O and the values recorded at 25, 50 and 75 kg P_2O_5/ha were 1738.5, 1731.1 and 1743.7 kg/ha respectively and the values recorded for 25, 50 and 75 kg K_2O/ha were 1733.7, 1741.9 and 1737.8 kg/ha.

Increasing the intervals of harvest showed a significant decrease in the N content of the soil. The lowest value of 1654.1 kg/ha was recorded with 65 day interval and it was on par with 55 and 60 day intervals and

Table 37. Effect of different levels of nutrients and harvest intervals on the total nitrogen content of the soil after two years of the experiment (kg/ha).

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	1792.6	1896.7	1825.6	1654.4	1750.0	1617.3	1730.4	1698.4	1726.7	1765.6	1788.7	1698.9	1704.4
n_2	1835.6	1762.2	1822.2	1630.0	1646.7	1695.6	1740.4	1728.9	1716.0	1776.9	1748.9	1686.7	1785.5
n_3	1788.8	1775.6	1764.4	1668.9	1624.4	1683.3	1742.6	1793.4	1783.3	1671.1	1678.9	1807.8	1741.1
p_1	1843.3	1787.8	1737.8	1670.0	1681.1	1661.1	1738.5	1690.0	1760.0	1765.6	-	-	-
p_2	1794.4	1765.6	1818.9	1695.7	1627.8	1683.3	1731.1	1736.7	1713.3	1743.3	-	-	-
p_3	1778.9	1881.1	1805.6	1636.7	1712.2	1647.8	1743.7	1774.4	1752.2	1704.4	-	-	-
k_1	1771.1	1806.7	1868.9	1628.9	1628.9	1697.8	1733.7	-	-	-	-	-	-
k_2	1882.2	1746.7	1771.1	1740.1	1653.3	1657.8	1741.9	-	-	-	-	-	-
k_3	1763.3	1881.1	1772.2	1654.4	1758.9	1656.7	1737.8	-	-	-	-	-	-
Mean (H)	1805.5	1811.5	1804.1	1657.8	1673.7	1664.1	1737.8						

Mean	C.D.(0.05)	S.E.
N, P or K	-	7.23
H	28.28	10.23

significantly different from other shorter intervals of harvest.

Available P_2O_5

The data relating to the available P_2O_5 content of the soil are presented in Table 38.

The influence of different levels of N and K_2O were not significant for the P_2O_5 content of the soil. The values recorded at 25, 50 and 75 kg N/ha were 51.60, 47.02 and 51.46 kg/ha and the corresponding values for 25, 50 and 75 kg K_2O/ha were 46.03, 5[illegible].04 and 55.91 kg/ha. The available P_2O_5 content of the soil increased with increasing levels of P_2O_5 and all the three levels were significantly different. The values obtained at 25, 50 and 75 kg P_2O_5/ha were 35.26, 49.79 and 65.02 kg/ha respectively.

No significant difference was noticed for the P_2O_5 content of the soil due to different intervals of harvest. The values varied from 45.96 kg/ha at 65 day interval to 52.33 kg/ha at 40 day interval.

Available K_2O

The data on available K_2O content of the soil for different treatments are presented in Table 39.

Different levels of N, P, K or H did not show any significant difference with regard to the K_2O content of the soil. The values for the different levels of N, P and K ranged from 193.84 to 199.96, 191.46 to 201.06 and

Table 38. Effect of different levels of nutrients and harvest intervals on the available P_2O_5 content of the soil after two years of the experiment (kg/ha).

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	51.79	52.19	51.94	48.82	55.14	50.15	51.60	47.15	52.65	55.01	33.31	53.13	68.20
n_2	54.56	50.65	47.38	43.24	45.39	40.74	47.02	42.87	42.46	55.63	35.18	46.35	59.41
n_3	50.87	47.67	57.57	51.89	53.61	46.97	51.46	48.25	55.01	51.09	37.01	49.90	67.47
p_1	33.99	33.34	41.17	36.14	35.22	31.42	35.20	35.52	36.00	34.12	-	-	-
p_2	52.20	51.89	49.94	46.12	51.55	47.11	49.79	42.53	47.52	59.31	-	-	-
p_3	70.82	65.24	65.72	61.67	67.37	59.40	65.02	60.12	66.67	68.20	-	-	-
k_1	50.82	47.54	46.24	42.80	46.99	42.11	46.08	-	-	-	-	-	-
k_2	48.85	47.88	55.10	49.19	51.65	47.56	50.04	-	-	-	-	-	-
k_3	57.24	55.03	55.58	51.96	55.23	48.43	53.91	-	-	-	-	-	-
Mean (H)	52.33	50.15	52.30	47.98	51.39	45.95	50.02						

Mean	C.D.(0.05)	S.E.
N, P or K	6.662	2.368
H	-	3.349

Table 39. Effect of different levels of nutrients and harvest intervals on the available K_2O content of the soil after two years of the experiment (kg/ha).

	h_1	h_2	h_3	h_4	h_5	h_6	Mean	k_1	k_2	k_3	p_1	p_2	p_3
n_1	197.12	195.96	197.84	185.64	211.76	211.41	199.96	198.96	188.32	212.48	179.20	211.48	209.20
n_2	211.76	197.40	200.84	198.48	193.28	189.12	198.48	195.00	199.48	201.20	199.84	200.56	195.40
n_3	201.08	194.04	201.20	201.72	190.88	174.12	193.84	189.36	192.40	199.28	195.40	186.88	198.64
p_1	203.84	202.44	191.96	183.60	188.12	178.80	191.46	185.64	192.16	195.52	-	-	-
p_2	210.8[illegible]	205.20	192.68	192.12	201.20	195.96	199.65	193.44	198.40	207.20	-	-	-
p_3	195.20	180.60	214.16	210.00	206.48	199.92	201.06	204.24	189.64	209.36	-	-	-
k_1	191.80	191.12	204.04	192.56	198.64	188.60	194.46	-	-	-	-	-	-
k_2	204.20	204.48	192.92	187.92	189.08	131.92	193.40	-	-	-	-	-	-
k_3	213.96	192.64	201.72	205.36	208.08	204.16	204.32	-	-	-	-	-	-
Mean (H)	203.36	196.08	199.64	195.24	198.60	191.52	197.41						

Mean	C.D.(0.05)	S.E.
N, P or K	-	3.549
H	-	5.019

from 193.40 to 204.32 kg/ha respectively. The values due to different intervals of harvest varied from 191.52 kg/ha at 65 day interval to 203.36 kg/ha at the lowest interval of 40 days.

Path analysis for yield of herbage oil and geraniol

Yield of herbage and related characters

Table 40(a) presents the correlation coefficients showing direct and indirect effects in path analysis of yield of herbage as influenced by number of tillers (x_3), height of the plant (x_6) and length of inflorescence (x_7). The results of the path analysis are presented diagramatically in Fig. 3.

Table 40(a). [illegible] indirect effects of yield components on herbage yield

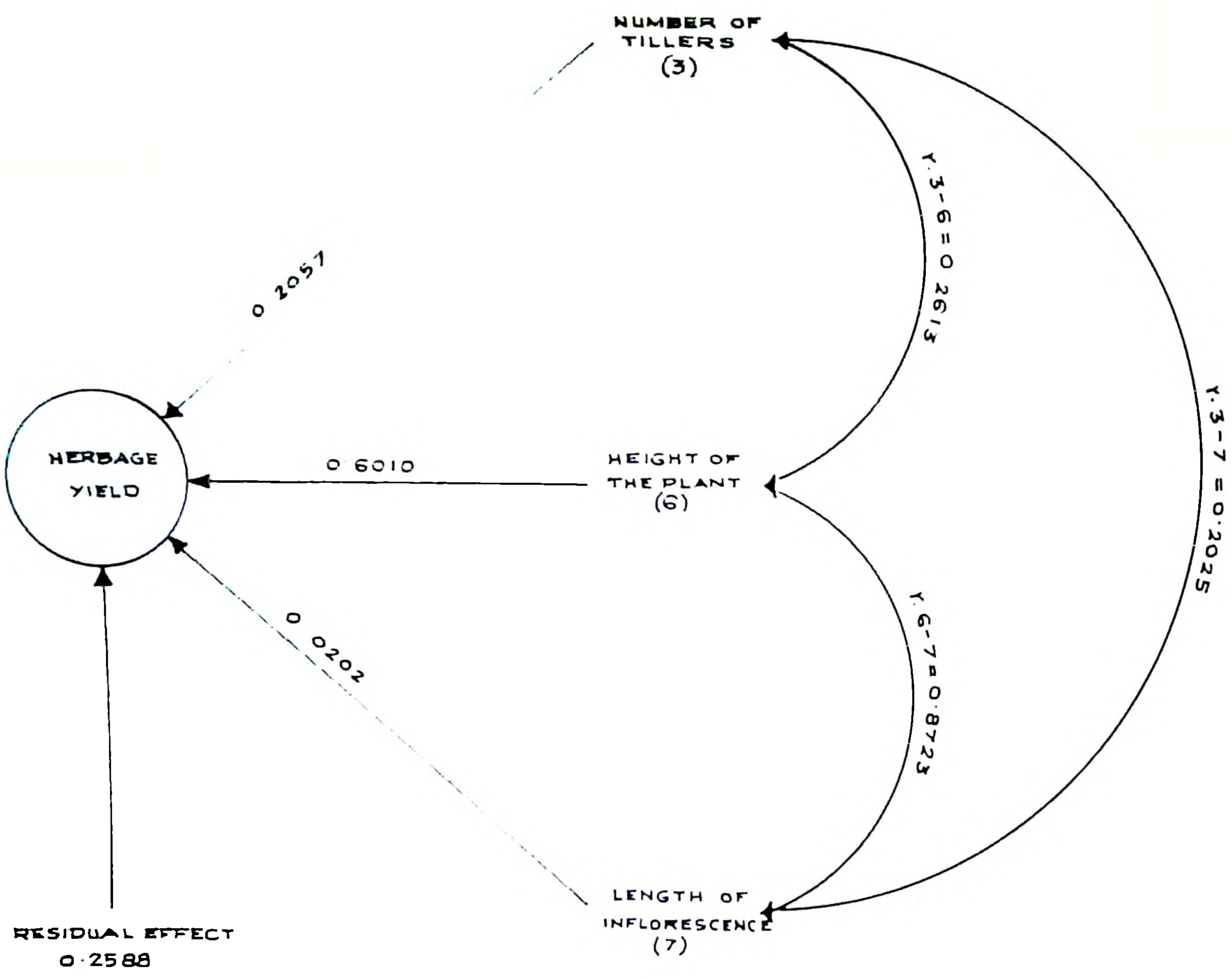
	Number of tillers x_3	Height of the plant x_6	Length of inflore-scence x_7	Total corre-lation
x_3	<u>0.2057</u>	0.1569	0.0042	0.3668
x_6	0.0537	<u>0.6010</u>	0.0176	0.6723
x_7	0.0417	0.5230	<u>0.0202</u>	0.5849
Residual effect		0.2558		

The underlined figures are the direct effects

The maximum direct effect on the yield of the herbage was through height of the plant (0.6010). The

Fig.3. Path diagram showing herbage yield as related to yield components

FIG 3. HERBAGE YIELD RELATED TO YIELD COMPONENTS.



correlation between the height of the plant and herbage yield was 67 per cent. The remaining 7 per cent was accounted for as due to the indirect effects via tiller number and length of inflorescence. The correlation between tiller number and herbage yield was 37 per cent of which 21 per cent was contributed by the direct effects of tiller number and 16 per cent by the indirect effect via height of plant. The indirect effect through the length of inflorescence was negligible. So too was the direct effect of the length of inflorescence (0.0202). However, the correlation between length of inflorescence and herbage yield was high (0.5849). This high degree of correlation can be mainly attributed to the indirect effect of length of inflorescence via height of the plant. The indirect effect via tiller number (0.04) was slightly more than that due to the direct effect of length of inflorescence. Thus from the path analysis it became very clear that height of plant is the most important yield attribute which influenced directly the yield of herbage.

<u>Yield of oil and related characters</u>

Table 40(b) presents the correlation coefficients showing direct and indirect effects in the path analysis of yield of oil as influenced by herbage yield (x_1), tillers with inflorescence (x_4), tillers without inflorescence (x_5), height of plant (x_6) and length of inflorescence (x_7). The results obtained from the path analysis are presented diagrammatically in Fig. 4.

Table 40(b). Direct and indirect effects of yield components on oil yield

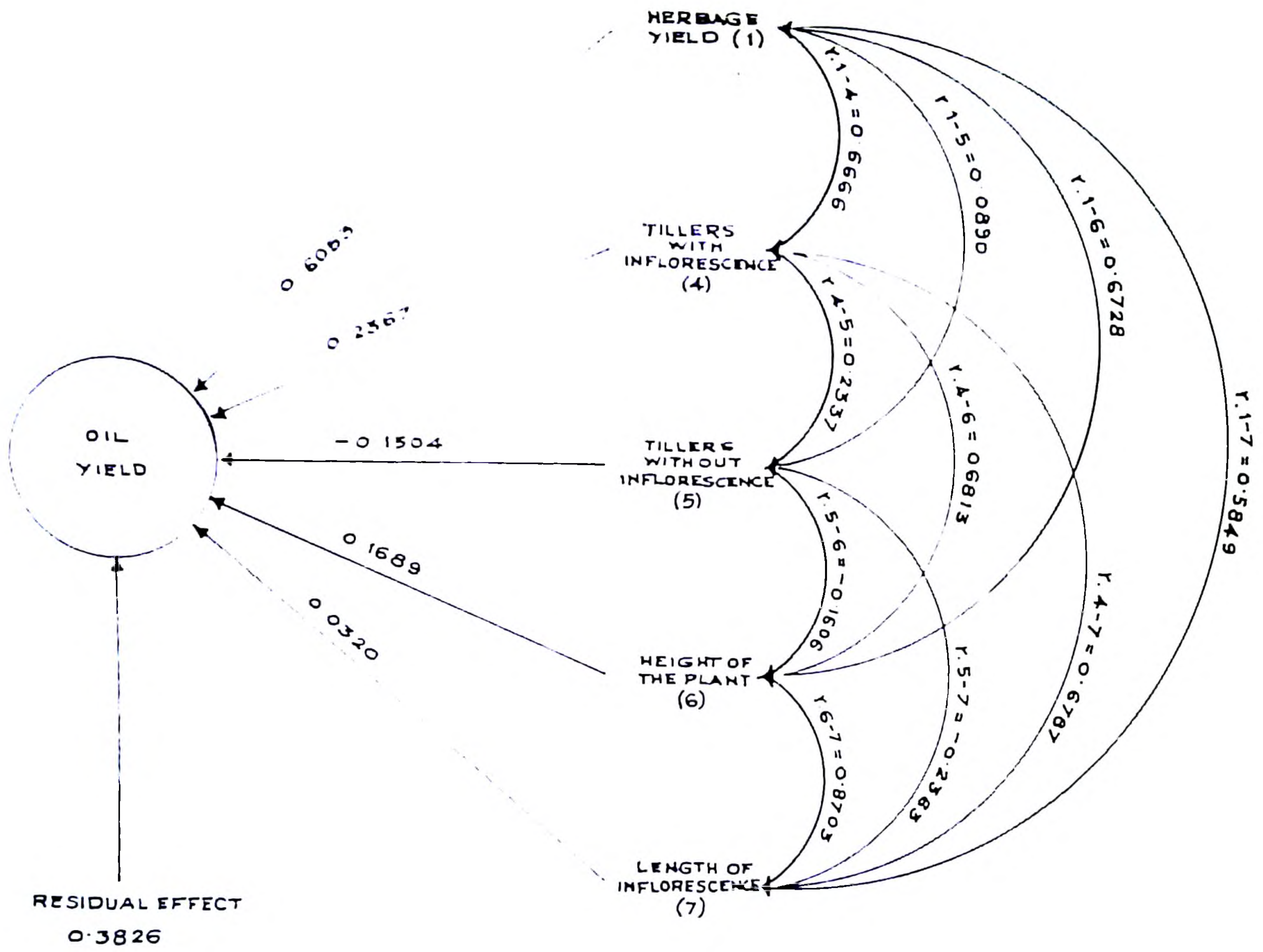
	Herbage yield x_1	Tillers with inflorescence x_4	Tillers without inflorescence x_5	Height of plant x_6	Length of inflorescence x_7	Total correlation
x_1	0.6053	0.1104	-0.0134	0.1135	-0.0187	0.8347
x_4	0.2824	0.2367	0.0351	0.1150	0.0217	0.6911
x_5	0.0538	-0.0553	-0.1504	-0.0270	-0.0075	-0.1864
x_6	0.4069	0.1613	0.0241	0.1689	0.0279	0.7890
x_7	0.3541	0.1606	0.0355	0.1469	0.0320	0.7293
	Residual effect		0.3826			

The underlined figures are the direct effects

The cause-effect relationship of oil yield with related characters is explained by the path diagram wherein it is seen that 62 per cent of the oil yield is accounted by the factors considered. The maximum direct effect on oil yield was through herbage yield 0.6053, its correlation with oil yield being 0.8347. The indirect effects via tillers with inflorescence, height of the plant and length of inflorescence, enhanced the correlation to 83 per cent though a reduction of one per cent was made by tillers without inflorescence. Tillers with inflorescence contributed 24 per cent to oil yield, but its correlation with oil yield was

Fig. 4. Path diagram showing oil yield as related to yield components

FIG 4 OIL YIELD RELATED TO YIELD COMPONENTS.



69 per cent. Thus apart from herbage yield which is known to be the major contributing factor to total oil yield, one of the significant factors influencing oil yield appeared to be tillers with inflorescence. This effect of tillers with inflorescence was seen to be as a result of the indirect contribution via herbage yield 28 per cent, height of the plant 11.5 per cent and also via tillers without inflorescence and length of inflorescence. The direct and indirect influence of number of tillers without inflorescence through all factors except herbage yield was negative resulting in a negative correlation of 0.1864 which was found to be insignificant. The correlation of the height of the plant with oil yield was found to be 79 per cent, though its direct effect was only 17 per cent. The maximum indirect effect was via herbage yield and it was 41 per cent, tillers with inflorescence contributed 16 per cent indirectly while the other two factors together contributed 5.1 per cent.

The direct influence of length of inflorescence was negligible though significant correlation of 0.7293 was observed. This was due to maximum indirect influence via herbage yield (0.3541) and indirect effects via tillers with and without inflorescence and height of the plant. From the above results it could be observed that oil yield was mainly dependent upon herbage yield. The most significant direct effects by yield attributes are found to be in the decreasing order of number of tillers with inflorescence, height of plants and length of inflorescence. Maximum indirect effect via grass yield was expressed by the height of the plant (41 per cent), length of inflorescence (35 per cent) and number of tillers with inflorescence (28 per cent).

<u>Geraniol yield and related characters</u>

Table 40 (c) presents the correlation coefficients showing direct and indirect effects in path analysis of yield of geraniol with related characters (Oil yield x_2, tillers with inflorescence x_4, tillers without inflorescence x_5, height of plant x_6, length of inflorescence x_7 and dry matter yield x_9). The results of the path analysis are presented diagramatically in Fig. 5.

The cause and effect relationship of geraniol yield with oil yield and other growth characters was explained about 76 per cent by path diagram. The maximum direct effect was brought about by oil yield (0.7849). The correlation of geraniol yield with oil yield was 0.9653. This enhanced correlation was accounted by the additional influence of indirect effects via the other factors. The correlation between tillers with inflorescence and geraniol yield was 0.7030 which was mainly due to the indirect effect of tillers with inflorescence, via oil yield (0.5425). Direct effect of tillers with inflorescence was negligible (0.0427). The other factors also contributed little to this correlation. The direct and indirect effect of tillers without inflorescence were negative, resulting in a

Table 40(e) Direct and indirect effects of yield components on geraniol yield.

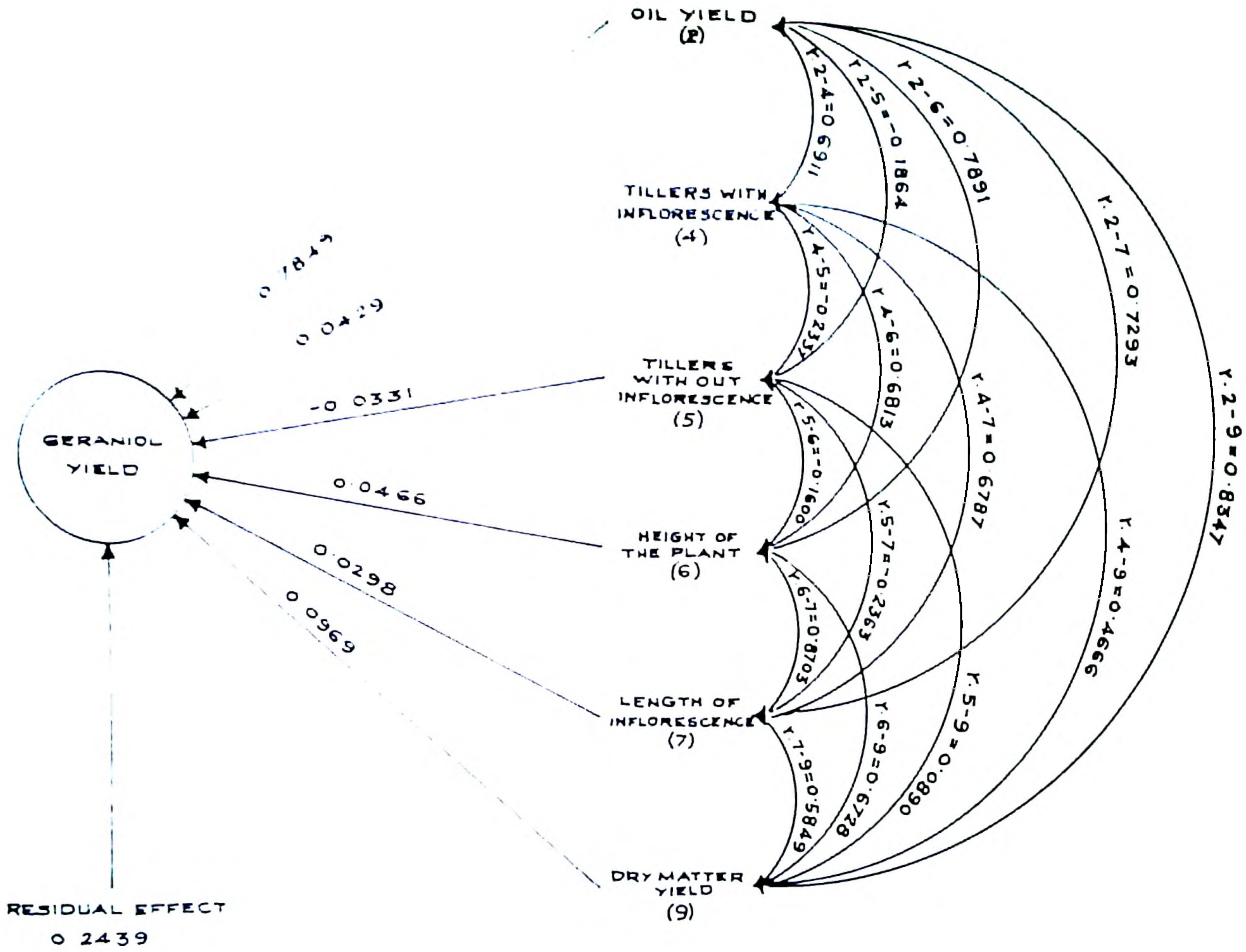
	Oil yield x_2	Tillers with infloresence x_4	Tillers without infloresence x_5	Height of the plant x_6	Length of infloresence x_7	Dry matter yield x_9	Total correlation
x_2	<u>0.7849</u>	0.0295	0.0062	0.0368	0.0217	0.0861	0.9653
x_4	0.5425	<u>0.0427</u>	0.0077	0.0317	0.0202	0.0581	0.7030
x_5	-0.1463	-0.0099	<u>-0.0331</u>	-0.0074	-0.0070	-0.0148	-0.2188
x_6	0.6194	0.0291	0.0053	<u>0.0466</u>	0.0259	0.0780	0.8044
x_7	0.5725	0.0289	0.0078	0.0406	<u>0.0298</u>	0.0694	0.7492
x_9	0.6975	0.0256	0.0051	0.0375	0.0213	<u>0.0969</u>	0.8840

Residual effect = 0.2439

The underlined figures are the direct effects

Fig.5. Path diagram showing geraniol yield related to yield components

FIG 5 GERANIOL YIELD RELATED TO YIELD COMPONENTS.



correlation of -0.2188, which was significant. In this case also the maximum contribution was through the indirect effect via oil yield. The correlation between geraniol yield and height was 0.8044 which was mainly due to the indirect effect of height of the plants via oil yield. The direct effect of height was very small 0.0466. The other factors also contributed indirectly to increase the correlation by 80 per cent.

Length of inflorescence was also found to be significantly correlated with geraniol yield (0.7492). The main cause of this correlation was due to the indirect effect of the length of inflorescence via oil yield (0.5725). The direct effect of length of inflorescence was small 0.0298. This along with the other indirect effects was responsible for this correlation. A similar result was also observed for geraniol yield and dry matter yield, the main contribution being the indirect effect via oil yield (0.6?75).

Main experiment continued for the third and fourth year

Effect of different harvest intervals on the herbage yield, oil yield and oil content

The pooled data for different intervals of harvest obtained in the third and fourth year of the experiment are presented in Table 41.

The data showed that the herbage yield increased almost linearly from 40 to 60 day intervals (60.76 t/ha) and at 65 day interval, it showed a slight decrease (57.18 t/ha). The highest oil yield was also recorded at

Table 41. Effect of different harvest intervals on herbage yield, oil yield and oil content: pooled data for the third and fourth year of the main experiment.

Harvest intervals	Herbage yield (t/ha)	Oil yield (kg/ha)	Oil content on fresh weight basis (%)
40 days	47.97	107.50	0.248
45 days	54.55	132.79	0.270
50 days	55.72	149.83	0.298
55 days	53.54	141.53	0.293
60 days	60.76	186.82	0.342
65 days	57.18	180.49	0.351

60 day interval (186.92 kg/ha) followed by 65 days (180.49 kg/ha). The oil content was found to increase as the interval increased upto 65 days.

Observation trial conducted with wider harvest intervals

Effect of harvest intervals on herbage yield, oil yield, oil content and geraniol yield

The data collected for the different intervals of harvest on herbage yield, oil yield, oil content and geraniol yield are presented in Table 42(a) and in Fig.6.

The maximum herbage and oil yields were recorded at 65 day interval and on further increase in the intervals of harvest the yields were found to decrease. The oil content was found to increase upto 65 days (0.412 per cent) and thereafter it decreased progressively as the interval increased to 135 days. The geraniol yield increased upto 85 day interval, but there was only slight difference in the yields recorded at 65, 75 and 85 day intervals. As the interval increased above 85 days the geraniol yield decreased.

Effect of harvest intervals on physico-chemical properties of oil

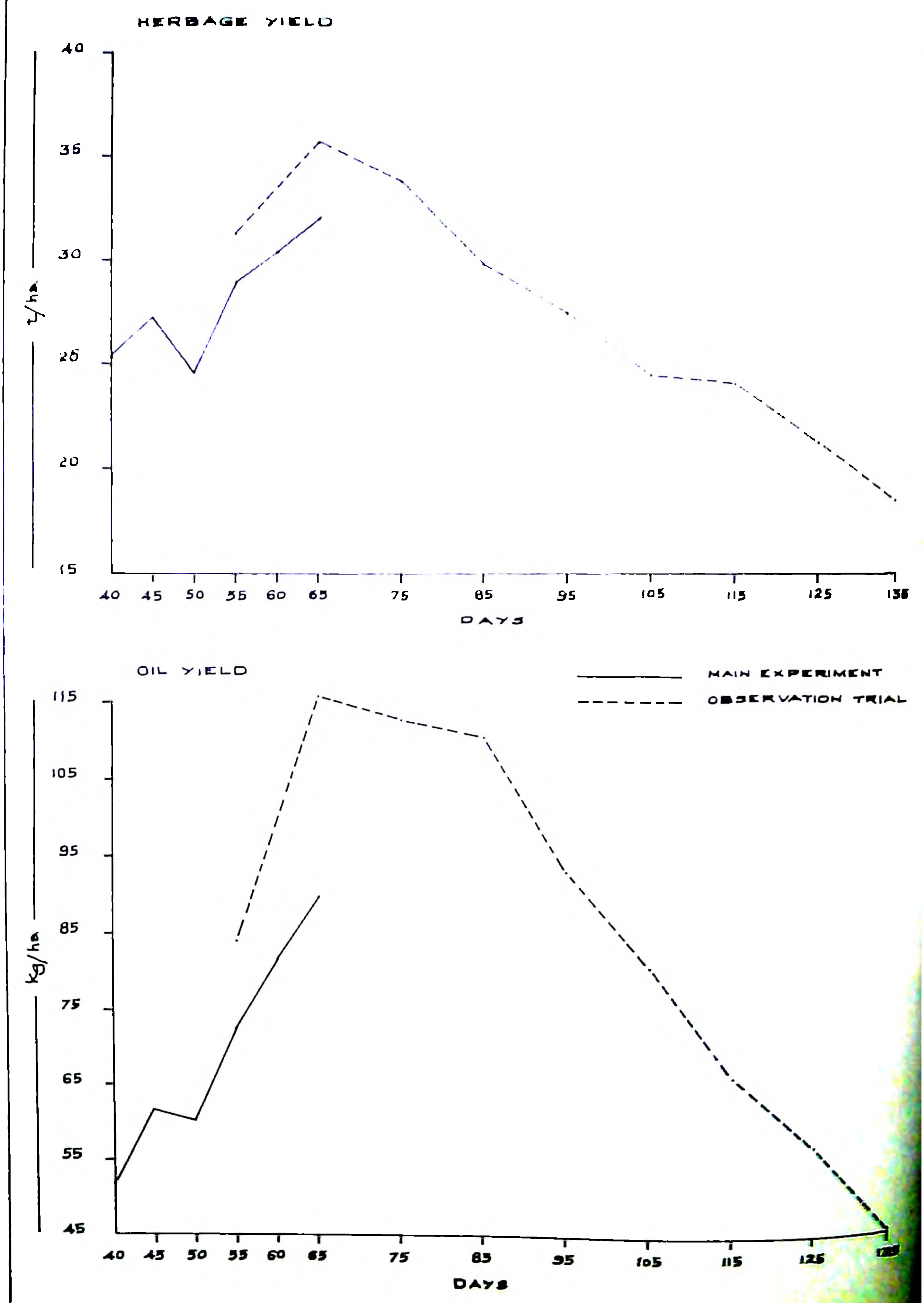
The data relating to the physico-chemical properties of oil, for the different harvest intervals are presented in Table 42(b).

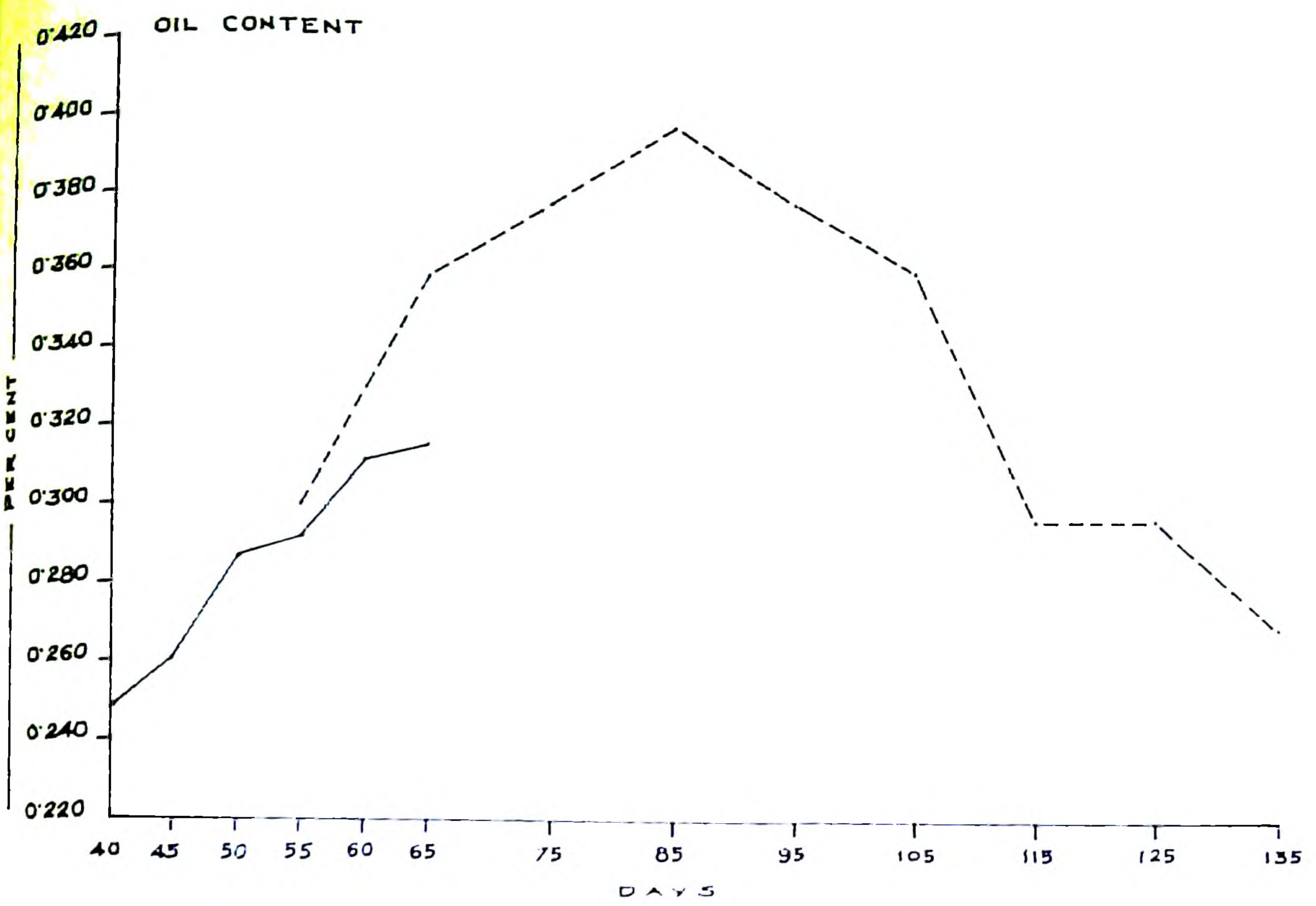
The specific gravity of the oil was found to decrease as the interval increased from 55 (0.8890) to 105 days (0.8770), remained without change at 115 days and

Table 42(a). Effect of different harvest intervals on herbage yield, oil yield, oil content and geraniol yield (based on the observation trial).

Harvest intervals	Herbage yield (t/ha)	Oil yield (kg/ha)	Oil content on fresh weight basis (%)	Geraniol yield (kg/ha)
55 days	31.29	84.20	0.301	58.80
65 days	35.91	115.62	0.360	84.40
75 days	33.76	114.10	0.380	84.00
85 days	29.93	110.12	0.412	84.50
95 days	27.40	93.14	0.382	77.10
105 days	24.50	80.33	0.366	67.10
115 days	24.04	66.21	0.305	56.40
125 days	21.23	57.00	0.301	47.40
135 days	18.63	45.23	0.274	37.50

Fig. 6. Effect of different intervals of harvest on herbage yield, oil yield, oil content and geraniol yield.


HERBAGE YIELD
t/ha
40
35
30
25
20
15
40 45 50 55 60 65 75 85 95 105 115 125 135
DAYS
OIL YIELD
MAIN EXPERIMENT
OBSERVATION TRIAL
kg/ha
115
105
95
85
75
65
55
45
40 45 50 55 60 65 75 85 95 105 115 125 135
DAYS


OIL CONTENT
PER CENT
0.420
0.400
0.380
0.360
0.340
0.320
0.300
0.280
0.260
0.240
0.220
40 45 50 55 60 65 75 85 95 105 115 125 135
DAYS

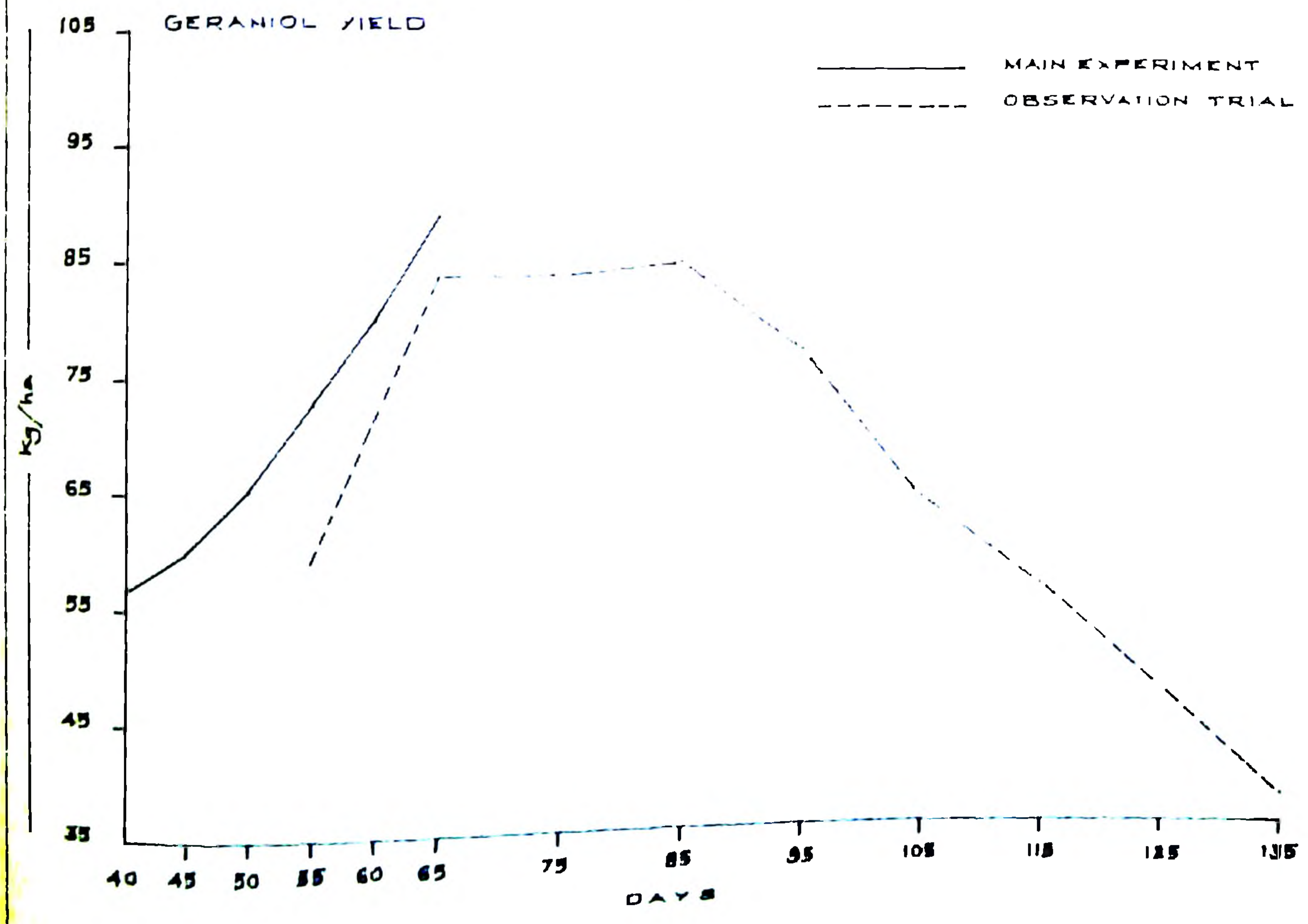

GERANIOL YIELD
MAIN EXPERIMENT
OBSERVATION TRIAL
Kg/ha
105
95
85
75
65
55
45
35
40 45 50 55 60 65 75 85 95 105 115 125 135
DAYS

Table 42(b). Effect of different harvest intervals on the physico-chemical properties of the oil (based on observation trial).

Treatment (Harvest interval)	Specific gravity at 30°C	Refractive index at 30°C	Optical rotation (degrees)	Solubility in 70% alcohol	Acid value	Saponification value	Ester value	Ester content (%)	Saponification value after acetylation	Total alcohol content (%)	Free alcohol content (%)	Combined alcohol content (%)	Odour
55 days	0.8890	1.4698	+1.7	1.8	4.5	83.9	79.4	27.8	281.2	92.0	69.8	22.4	Terpenic
65 days	0.8873	1.4705	+1.7	1.8	3.5	69.5	66.0	23.1	276.4	91.1	73.0	18.3	,,
75 days	0.8841	1.4703	+1.3	1.8	4.0	64.3	60.3	21.1	273.3	90.3	73.6	16.7	,,
85 days	0.8827	1.4710	+1.6	1.7	3.3	54.1	50.8	17.8	273.0	90.9	76.8	14.0	,,
95 days	0.8790	1.4710	+1.6	1.7	3.0	35.8	32.8	11.5	272.4	91.4	82.8	9.0	Rosaceous
105 days	0.8770	1.4701	+1.7	1.7	1.7	33.6	31.9	11.2	272.9	92.2	83.5	8.9	,,
115 days	0.8770	1.4700	+1.6	1.6	1.4	29.2	27.8	9.7	274.1	92.7	85.2	7.5	,,
125 days	0.8795	1.4702	+1.6	1.7	2.2	34.7	32.5	11.4	273.3	91.9	83.2	8.7	,,
135 days	0.8790	1.4690	+1.7	1.6	2.0	36.7	34.4	12.0	273.5	92.0	82.7	9.4	,,

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thereafter it showed a slight increase.

The refractive index of oil was found to increase as the interval increased from 55 (1.4698) to 85 days (1.4710) and remained without change at 95 days. The values recorded at all the intervals higher than 95 days showed a slightly lower value.

Optical rotation of the oil remained without much change as the harvest intervals increased from 55 to 135 days. The values for optical rotation ranged from +1.6° to +1.8°. Solubility of oil in 70 per cent alcohol showed a tendency to increase with increase in the intervals of harvest upto 115 days.

Acid value of the oil was found to decrease progressively as the interval increased upto 115 days (1.4) and it showed a slight increase as the harvest intervals increased further. Saponification value, ester value and geranyl acetate content also showed similar trends. The values decreased as the intervals of harvest increased from 55 to 115 days. At the harvest interval of 115 days the values recorded for saponification value and ester value were 29.2 and 27.8 respectively. The acetate content at this interval was 9.7 per cent. As the intervals increased above 115 days, these values showed a slight increase. Saponification value after acetylation was found to decrease upto 95 days (272.4) and thereafter it showed a slight increase as the harvest intervals increased further.

Total alcohol calculated as geraniol was maximum (92.7 per cent) at 115 days. But no definite trend either to increase or decrease were noticed with changes in the harvest intervals.

Free alcohol content also increased progressively upto 115 days (85.2 per cent) and it showed a tendency to decrease as the intervals increased further.

Combined alcohol decreased progressively as the interval increased upto 115 days (7.5 per cent) and it showed an increase as the harvest interval increased further.

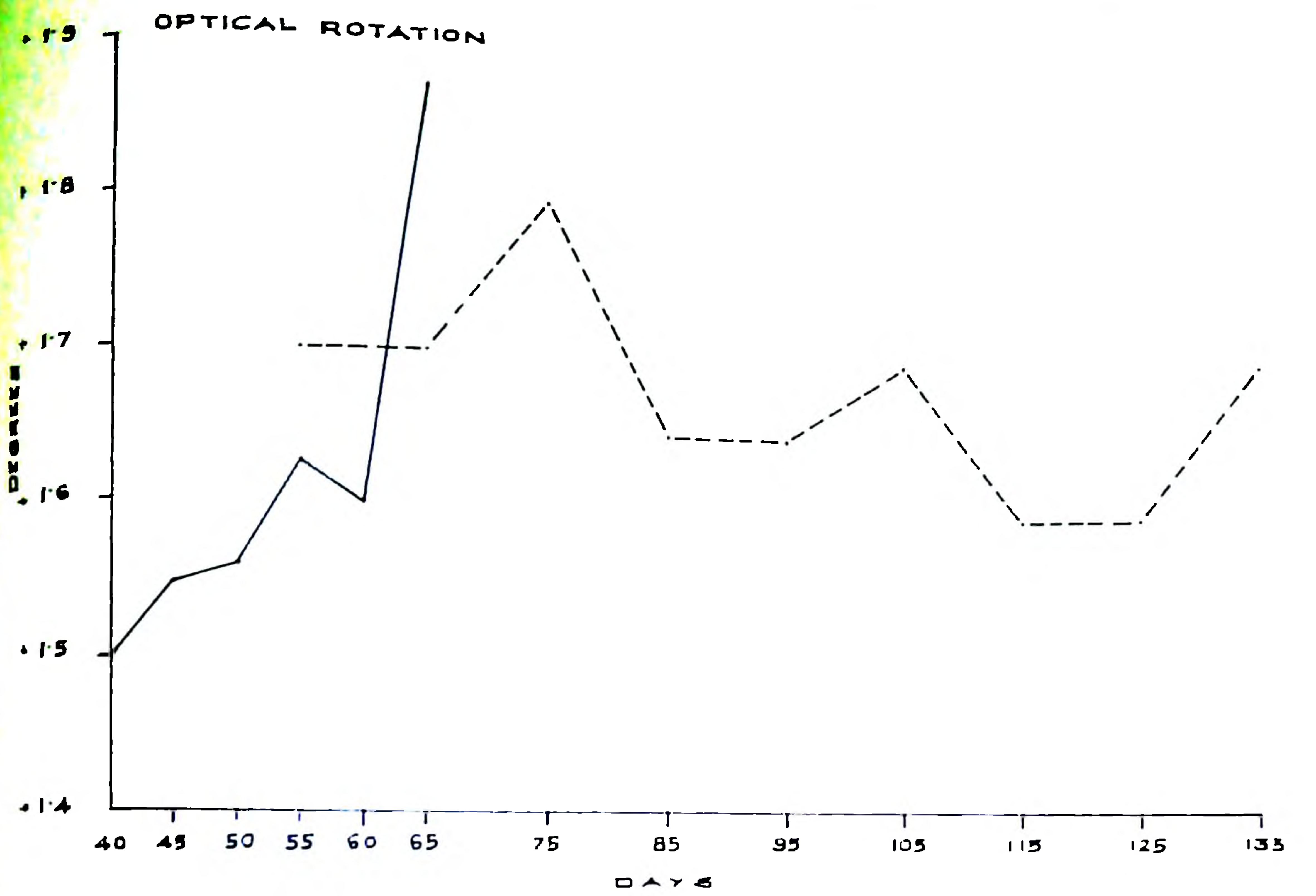
With regard to the odour of the oil, a sweet rosaceous odour was noticed for the oils obtained at intervals of 95 days and above. The oil obtained at lower intervals of harvest showed a terpenic note.

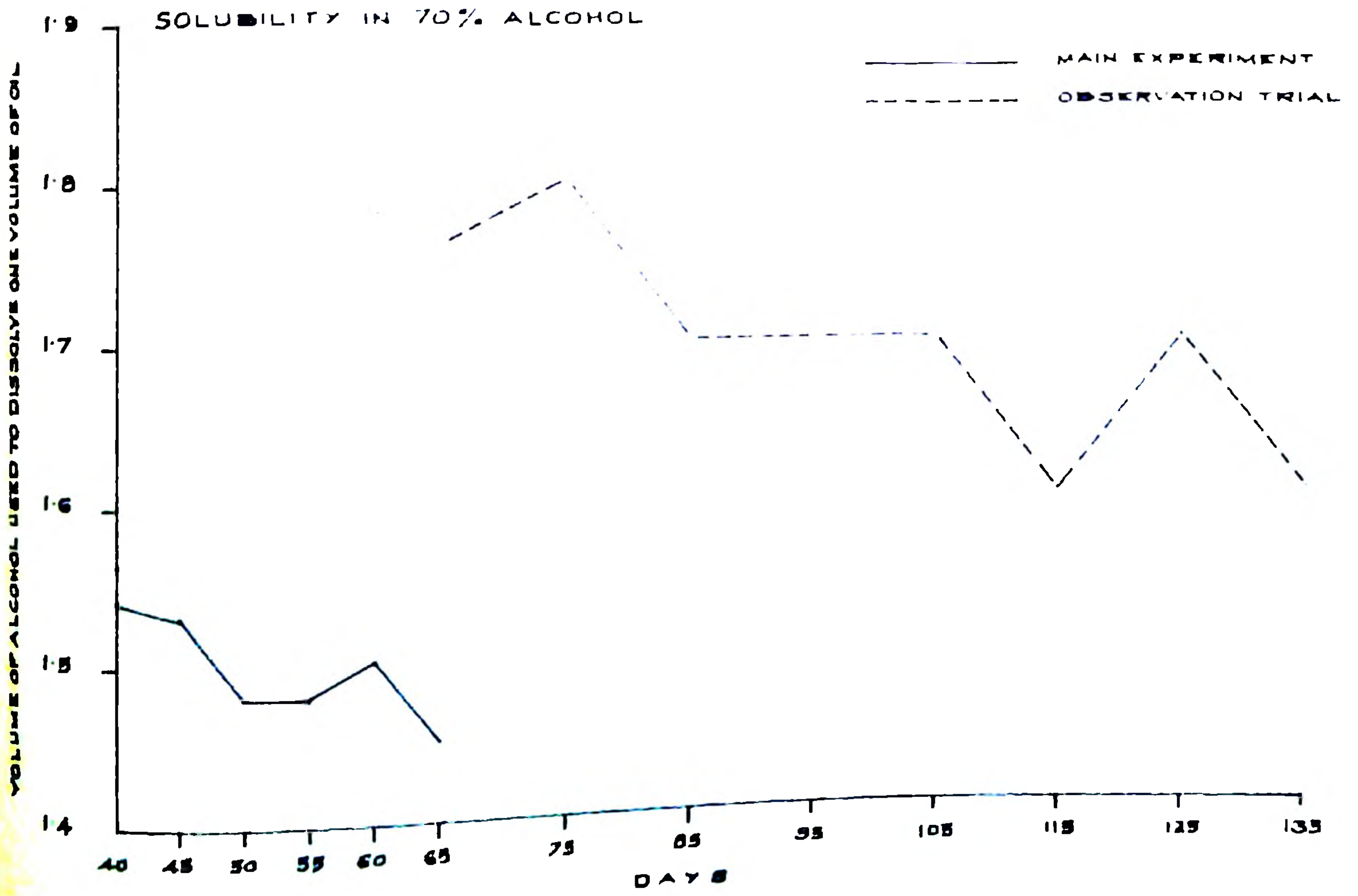
The data obtained for the physico-chemical properties of oil in this trial along with the data obtained in the main experiment for the first two years are presented in Fig. 7 and 8.

Geraniol and geranyl acetate content of the oil, determined by GLC

The data obtained are presented in Table 42(c). The results showed that the geraniol content increased and geranyl acetate content decreased, as the harvest intervals increased from 55 to 115 days. With further increase in the intervals of harvests the geraniol content decreased and the geranyl acetate content increased.

Fig.7. Effect of different intervals of harvest on the physical properties of the oil.


OPTICAL ROTATION
DEGREES
+1·9
+1·8
+1·7
+1·6
+1·5
+1·4
40 45 50 55 60 65 75 85 95 105 115 125 135
DAYS


SOLUBILITY IN 70% ALCOHOL
MAIN EXPERIMENT
OBSERVATION TRIAL
VOLUME OF ALCOHOL USED TO DISSOLVE ONE VOLUME OF OIL
1·9
1·8
1·7
1·6
1·5
1·4
40 45 50 55 60 65 75 85 95 105 115 125 135
DAYS

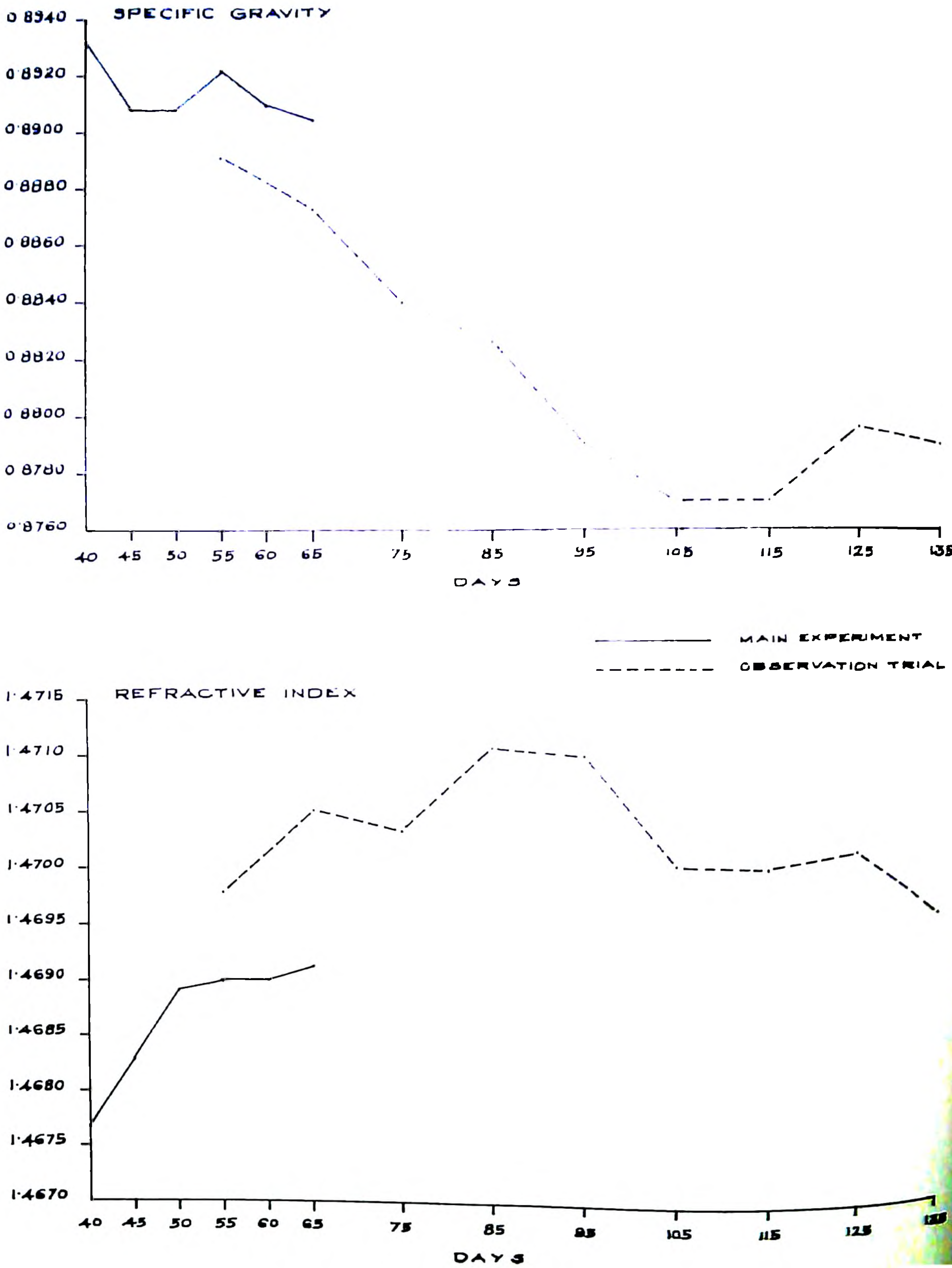
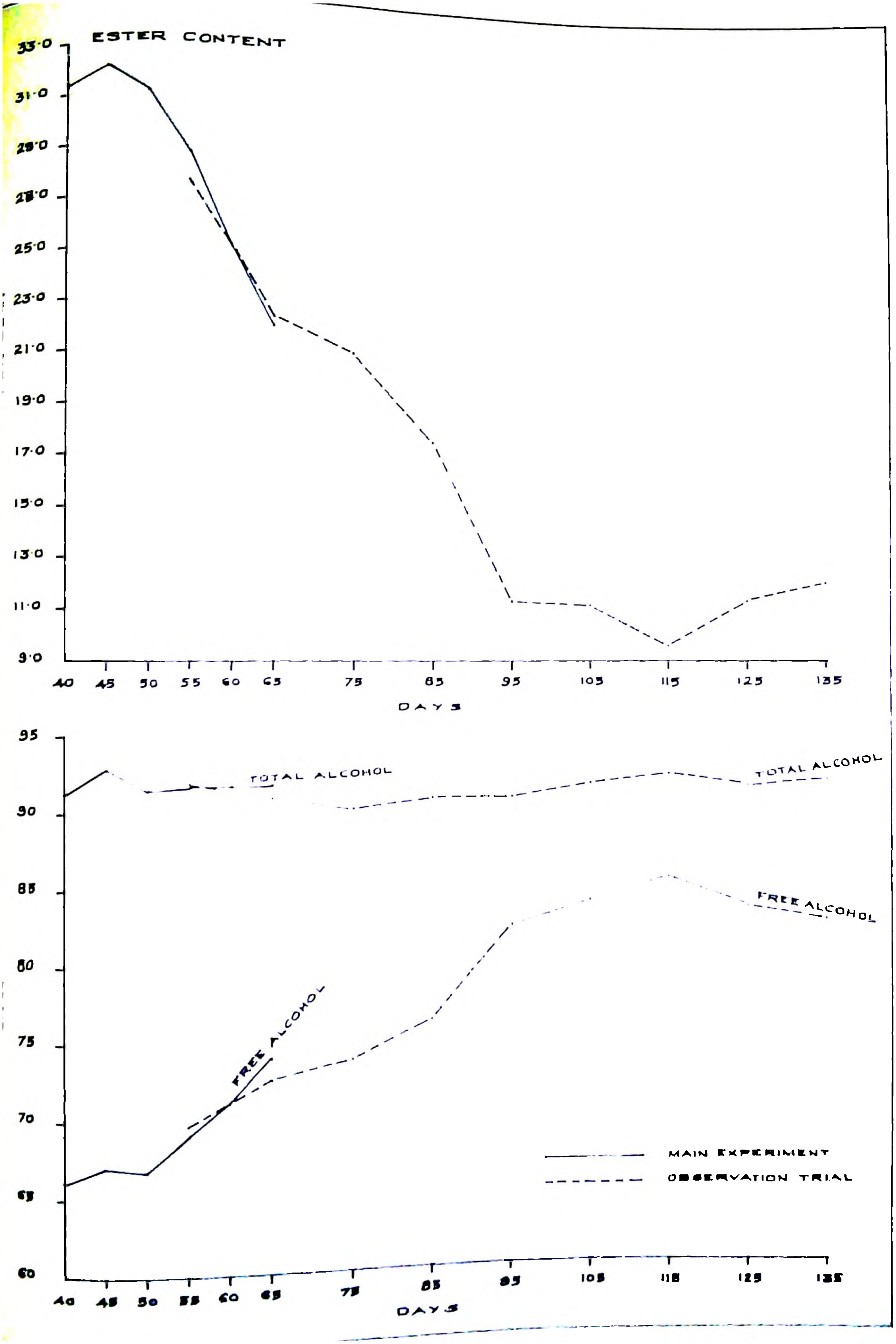
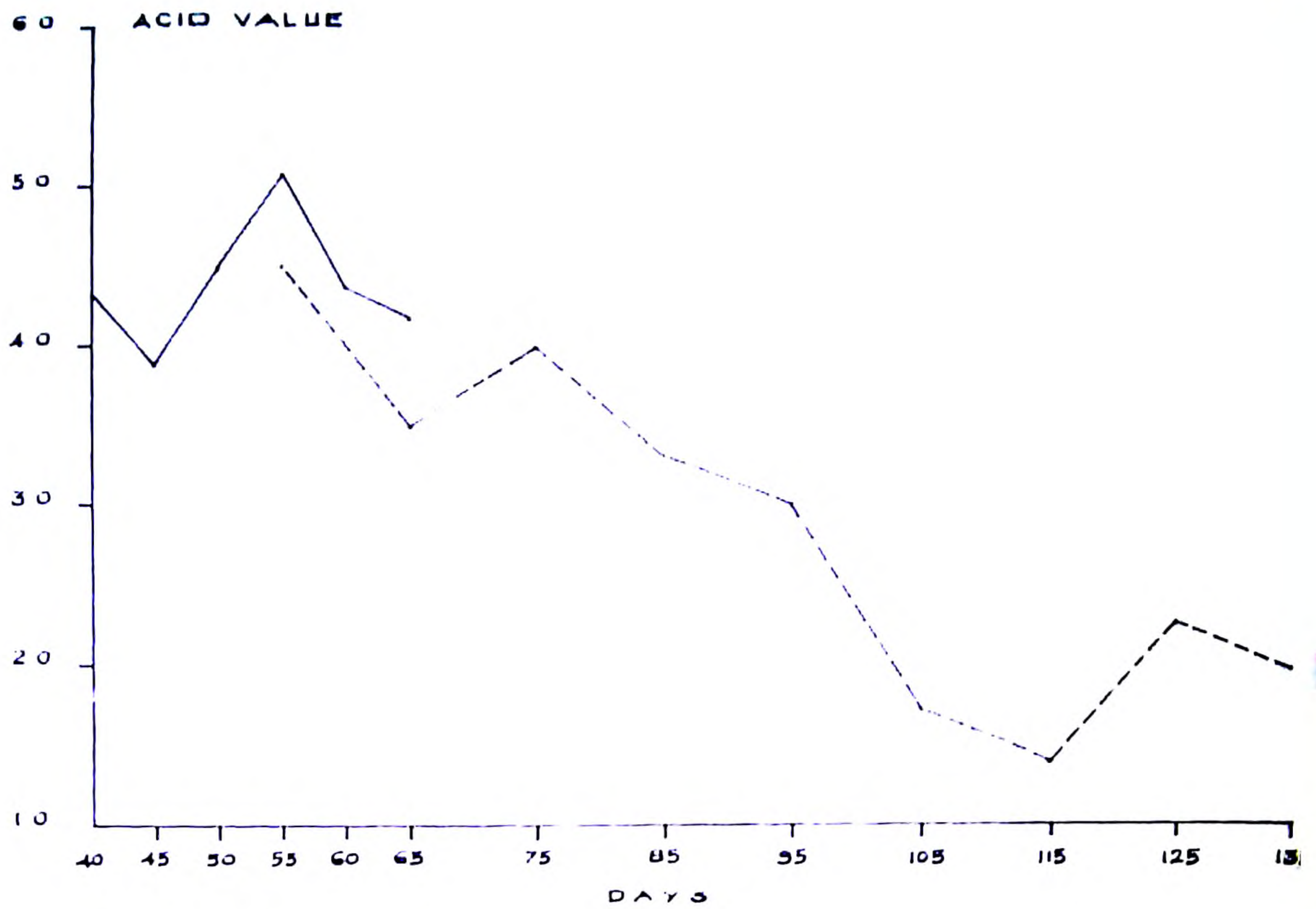
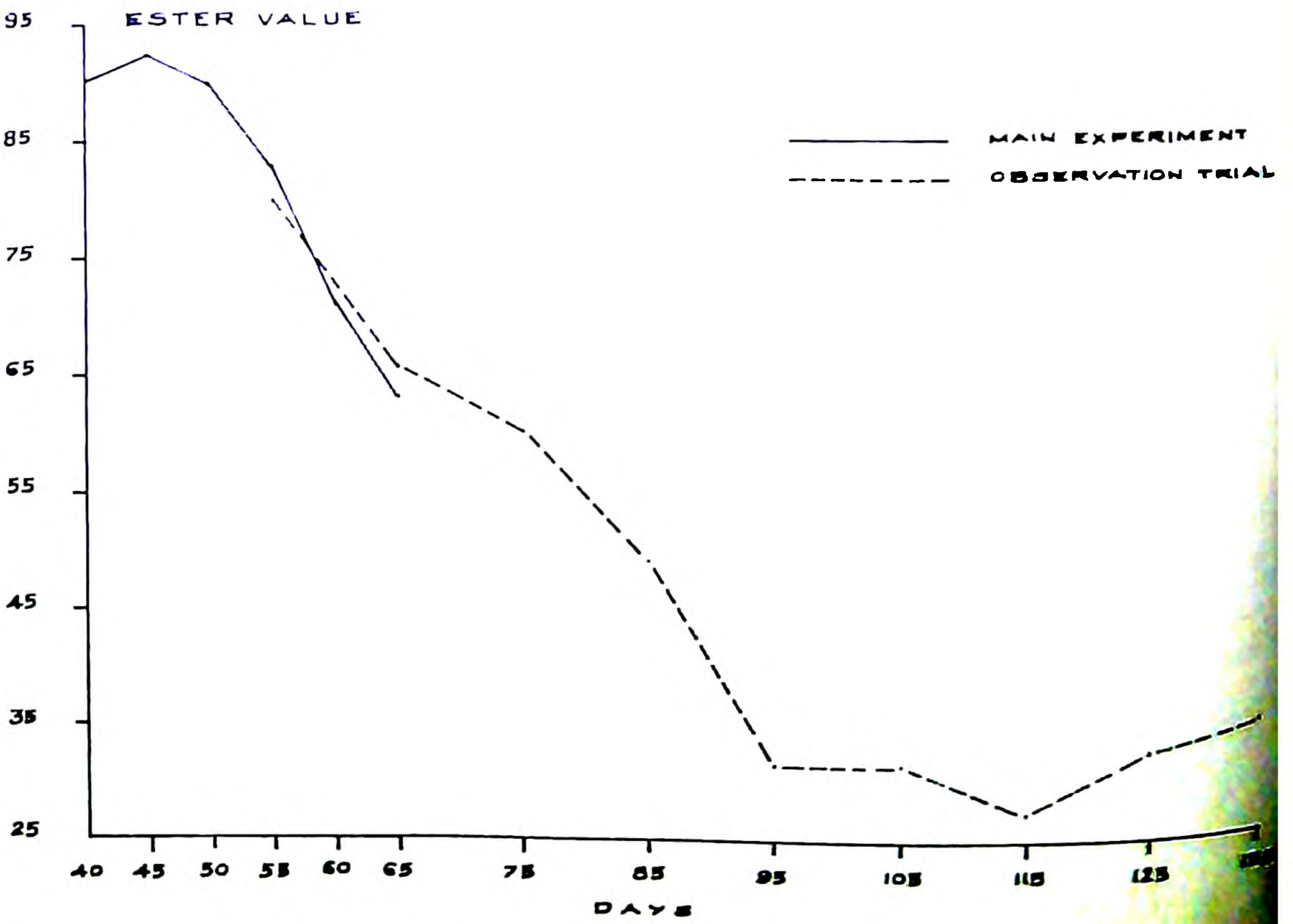

SPECIFIC GRAVITY
0·8940
0·8920
0·8900
0·8880
0·8860
0·8840
0·8820
0·8800
0·8780
0·8760
40
45
50
55
60
65
75
85
95
105
115
125
135
DAYS
MAIN EXPERIMENT
OBSERVATION TRIAL
REFRACTIVE INDEX
1·4715
1·4710
1·4705
1·4700
1·4695
1·4690
1·4685
1·4680
1·4675
1·4670
40
45
50
55
60
65
75
85
95
105
115
125
DAYS

Fig. 8. Effect of different intervals of harvest on the chemical properties of oil.


ESTER CONTENT
33·0
31·0
29·0
27·0
25·0
23·0
21·0
19·0
17·0
15·0
13·0
11·0
9·0
40 45 50 55 60 65 75 85 95 105 115 125 135
DAYS
95
90
85
80
75
70
65
60
TOTAL ALCOHOL
TOTAL ALCOHOL
FREE ALCOHOL
FREE ALCOHOL
MAIN EXPERIMENT
OBSERVATION TRIAL
40 45 50 55 60 65 75 85 95 105 115 125 135
DAYS



ACID VALUE
60
50
40
30
20
10
40
45
50
55
60
65
75
85
95
105
115
125
DAYS



ESTER VALUE
95
85
75
65
55
45
35
25
MAIN EXPERIMENT
OBSERVATION TRIAL
40
45
50
55
60
65
75
85
95
105
115
125
DAYS

Table 42(c). Effect of different harvest intervals on the geraniol and geranyl acetate content of the oil (per cent) determined by GLC (based on the observation trial).

Harvest intervals	Geraniol (%)	Geranyl acetate (%)
55 days	59.0	22.7
65 days	67.0	20.5
75 days	70.4	14.0
85 days	73.7	13.5
95 days	76.2	12.0
105 days	79.6	10.4
115 days	80.0	8.2
125 days	74.9	9.1
135 days	76.1	9.5

The geraniol and geranyl acetate contents recorded in the GLC analysis were slightly lower than that obtained in the chemical analysis.

DISCUSSION

DISCUSSION

The present investigation has thrown considerable light on the nutritional requirements of palmarosa grass and the effect of graded levels of nutrients on the quantity and quality of oil at different harvest intervals during a cropping year. The stabilisation of the crop since planting takes about one year in view of which the results for the first year especially in terms of total yield are generally less though the effect of treatments can well be discerned in them. The pooled data for two years for many of the parameters studied however, follow the trend observed in the second year.

The results obtained from the major experiment during the third and fourth year on herbage and oil yields and the results obtained from the observational trial are also discussed.

Biometric characters

The results obtained for various biometric characters are individually discussed since there is a general lack of published data on these aspects of this essential oil crop. However, many of the biometric characters, which are both yield attributes and quality attributes have been related to the yield of herbage, yield of oil and yield of geraniol by path analysis. These results have also been discussed.

Number of tillers per clump

Number of tillers per clump are not influenced significantly by different levels of N, P_2O_5 or K_2O. From studies conducted at IARI Gupta et al. (1978) reported that the number of tillers increased upto 80 kg N and P_2O_5 per ha, but the tiller number decreased as the levels of K_2O increased from 40 to 80 kg K_2O/ha. Pareek et al. (1981 a) reported that the tiller number increased with increase in the levels of N upto 80 kg/ha, but there was no effect for P and K application.

Different intervals of harvest significantly influenced the total number of tillers in both the years and the mean data for two years. The palmarosa crop when harvested normally gives forth fresh tillers from the base. The harvested stump of each tiller dries up unlike lemongrass, where each harvested tiller further elongates to give herbage yield in subsequent harvests. Thus in the case of palmarosa, from the present study, it has to be understood that after each harvest fresh tillers are put forth and the number of fresh tiller put forth is very much dependent upon the harvest interval. The highest number of tillers is produced when the crop is harvested at 55 day intervals in both the years. As the interval of harvest increased over 55 days the number of tillers decreased.

However, these results are at variance with the findings of Pareek et al. (1981 b) who reported that harvesting the crop at different stages viz., vegetative phase, commencement of flowering, bloom period with most flower open stage, early seeding and late seeding stages had not affected the subsequent tiller number. Thus the results of the present study indicate that harvest interval of 55 days has a stimulatory effect on subsequent tillering. Both lower and higher intervals have a depressing effect. This appears to be the result of the ratooning habit of the crop as a result of which the plant tries to overcome the harvest interference with a further vegetative phase.

Height of the plant

The results of the study have shown that different levels of N have not influenced significantly the height of the plants in both the years. Height of the plants decreased slightly with increase in the levels of N as revealed by the mean data for two years. While the results of Singh et al. (1981) are generally in agreement, those of Gupta et al. (1978) and Pareek et al. (1981 a) are at variance with the results of the present study.

Lack of response to higher levels of N especially in the plant height indicates higher levels of available N in soil. The analytical data of the soils of the experimental field show that they are fairly well supplied with available N.

Increase in the levels of P_2O_5 increased the height of the plants in both the years. The difference is significant in the second year and in the mean value for two years. Maximum height is recorded by P_2O_5 application at 75 kg/ha in both the years. Significant increase in the height of the plants with increase in the levels of P_2O_5 has been reported by Gupta et al. (1978), while Pareek et al. (1981 a) and Singh et al. (1981) reported non-significant response to application of P_2O_5. Such variation in results are indicative of differences in soil situations under which the experiments have been conducted. However, application of P is known to increase root growth and correspondingly the uptake of many other major as well as minor nutrients, resulting in enhanced performance by the plant in biometric parameters.

The results indicate that application of K_2O at 50 and 75 kg/ha has slightly increased the height of the plants in both the years. But the difference is not significant. This may be attributed to a medium level of available K in the experimental soil. Similar results have been reported by Gupta et al. (1978), Pareek et al. (1981 a) and Singh et al. (1981).

The interaction between N and P is significant in the present study and the maximum height in both the years is recorded by the application of N and P_2O_5 each at 75 kg/ha. Gupta et al. (1978) also reported that the plant height was increased by a balanced dose each of 80 kg N, P_2O_5 and K_2O.

Different intervals of harvest have significantly influenced the height of the plant. The maximum harvest interval tried viz., 65 days has recorded the highest value in both the years. Pareek et al. (1981 b) also reported that increase in age progressively increased height of plants significantly from vegetative phase to most flower open stage.

Length of inflorescence

Of the different levels of N, P and K tried, only the level of P has influenced the length of inflorescence significantly.

Length of inflorescence appears to be increased with increasing levels of phosphorus in both the years. The maximum length is recorded by 75 kg P_2O_5/ha. This result is not in agreement with the findings of Gupta et al. (1978) who have reported that the length of inflorescence increased only upto 40 kg N/ha and that P and K application had no significant effect on length of inflorescence. Pareek et al. (1981 a) reported that length of inflorescence increased with increase in the levels of N, P_2O_5 and K_2O upto 40 kg/ha.

Gupta et al. (1978) reported that increase in plant height did not correspondingly increase the length of flowering shoots. On the contrary a slight reduction in the size of the floral shoots was noticed in taller plants particularly in the autumn crop. However, in the present study application of P increased the height of the plants as well as the length of inflorescence in both the years. Phosphorus is known to stimulate earliness in flowering, reduce protracted flowering and increase the number of flowers per panicle in many cereal grasses. The present observation of increased length of inflorescence under phosphorus treatments may be due to these effects.

Different intervals of harvest influence significantly the length of inflorescence. The length increased almost linearly with increasing intervals of harvest. The maximum length is recorded by the harvest treatment of 65 day interval in both the years. But Pareek et al. (1981 b) reported that increase in age from commencement of flowering to late seeding stage did not significantly influence the length of inflorescence.

Number of tillers with inflorescence

The results indicate lack of significant difference in the number of tillers with inflorescence due to different levels of N application in both the years.

Though the effect of P is also non-significant in increasing the number of tillers with inflorescence during the first year, the number of tillers at 50 and 75 kg P_2O_5/ha are found to be higher than that at 25 kg/ha. In the second year and in the mean value for the two years the number of tillers with inflorescence increase significantly with increase in the levels of P_2O_5. The effect of phosphorus in increasing the flowering is well known.

Application of K_2O at different levels has also not influenced the number of flowered tillers significantly in both the years.

Different intervals of harvest have influenced significantly the number of flowered tillers and, in general, the flowered tillers increase with increase in the intervals of harvest. This observation is in line with what could be expected since increase in the harvest interval ensures enough time for both vegetative growth of new tillers and putting forth of the inflorescence for completion of the physiological growth phase. Maximum number of inflorescence is recorded with the harvest interval of 65 days which is on par with the number of inflorescences for shorter harvest intervals of 60 and 55 days in both the years. From this observation it appears that 55 days would be sufficient for completion of vegetative growth and nearly 50 per cent flowering of the newly put forth tillers. Between the two harvest intervals of 55 and 65 days there has been no significant increase in the percentage of flowered tillers. The percentage of tillers with inflorescence recorded at 55, 65, 75, 85, 95, 105, 115, 125 and 135 day intervals were 53.2, 55.4, 58.7, 62.1, 59.2, 65.9, 67.9, 65.4 and 64.8. Though Gupta et al. (1978) have recorded more than 90 per cent flowering at harvest stage of maximum flowering, from the trend of the results such a high percentage of flowered tillers cannot be attained under Odakkaly conditions. It appears, therefore, that high percentage of tillers with inflorescence is better guided by climatic factors such as day length etc. rather than by harvest interval.

Number of tillers without inflorescence

Different levels of N, P, K or their combinations did not significantly influence the number of tillers without inflorescence.

Differences in the interval between harvests significantly influenced the number of tillers without inflorescence. As the interval between harvests increased the number of tillers without inflorescence decreased and the treatment harvested at 65 day intervals has recorded the lowest number in both the years. Further it is significantly lower than all other harvest treatments for physiological reasons already discussed under tillers with inflorescence. Moreover, it has to be pointed out that the total tiller number is maximum at 55 day harvest interval and the number of tillers with inflorescence is maximum for harvest interval of 65 days with no significant difference for shorter intervals of 60 and 55 days. Evidently this leads to a significant reduction in tillers without inflorescence for harvest interval of 65 days.

Herbage yield

In the first year the herbage yield is influenced significantly by different levels of N. Herbage yield increased as the N level increased from 25 kg to 50 kg/ha, but as the level increased further to 75 kg/ha, the yield decreased. In the second year, and in the total yield for two years, there is no significant difference with different levels of N.

In the first year, in general, the herbage yield at every harvest and in every plot is less than that in the second year at the corresponding harvests. This is mainly due to the time taken during the first year for the crop to establish itself in the field. Further, while N levels especially the middle level of 50 kg/ha is able to show an improvement in herbage yield in the first year, this slight difference is seen to be masked by the better or equally good performance in all N treatments by the second year. This again may partly be due to the better available N status of the soils in general, which has rendered the difference between N treatments not large enough to cause a response. Increase in the herbage yield with application of N fertilizers has been reported by many workers (Dutta and Paul, 1976; Hazarika and Bora, 1977; Sarma et al. 1977; Gupta et al. 1978; Sharma et al. 1980; Pareek et al. 1981 a and Munsi and Mukherjee, 1982). However, Singh et al. (1981) found that application of N at 0, 50 and 100 kg/ha had no influence in the herbage yield under the agroclimatic conditions of Jorhat.

Significant response to application of P has been obtained in both the years and in the total yield for two years. Herbage yield increases linearly with increase in the levels of P_2O_5 from 25 to 75 kg/ha. The reasons for such a linear response has to be mainly attributed to the low available P content of the soil which resulted in an alround increase in the yield attributing characters such as total number of tillers with inflorescence, height of the plant, length of inflorescence etc. with increase in the levels of P.

The influence of the various yield attributes have been discussed after a path coefficient analysis in a later section of this chapter. Response to P_2O_5 upto 100 kg/ha was reported by Dutta and Paul (1976) while response upto 80 kg/ha was reported by Gupta et al. (1978), Singh et al. (1981) and by Munsi and Mukherjee (1982). Sharma et al. (1980) obtained response upto 50 kg P_2O_5/ha. Contradictory to this Sarma et al. (1977) and Pareek et al. (1981 a) obtained no response to application of P. The response pattern of the crop to application of P reported in literature thus appears to be at variance to one another obviously due to variations in the available P status. The low available P status of the experimental soils in the present study explains the response obtained for P application.

The herbage yield in the first year is not influenced significantly by increase in the levels of K. But the highest yield recorded is under the treatment with 75 kg K_2O/ha. In the second year and in the total for two years, a significant influence with different levels of K_2O can be observed. The highest yield has been recorded at 75 kg K_2O/ha and it is significantly higher than that of the other two levels. The yield attributing characters such as tiller number, height of the plant, length of inflorescence etc. individually have not been increased significantly by K_2O application. However, the small increases in these yield attributes at higher levels of K together might have contributed to increase the yield of herbage. Varying responses to application of K_2O have been reported by workers such as Dutta and Paul (1976), Hazarika and Bora (1977) and by Gupta et al. (1978). But Sharma et al. (1980), Pareek et al. (1981 a) and Singh et al. (1981) have reported non-response to K.

Increasing intervals between harvests increased herbage yield in both the years. Of the various harvest intervals tried the maximum interval of 65 days recorded the highest yield. Most of the yield contributing characters such as height of plant, length of inflorescence, number of tillers with inflorescence, are found to be the highest at this interval. The higher herbage yield at this harvest interval has to be attributed to these contributions. The yield recorded by this treatment in the first year and second year are respectively 15.12 and 32.32 t/ha. The low herbage yield in the first year is mainly on account of the lower tiller number and number of harvests. Gupta and Jain (1978) reported that the yield of herbage was lowest in the first year and highest in the second and third years after planting. The observation trial conducted with higher intervals of harvest showed that the herbage yield increased upto 65 days and then decreased as the interval increased above 65 days. Pareek et al. (1981 b) reported that the maximum herbage yield was obtained at Issapur Farm, Delhi for two years of experiment at the bloom period with most flowers open stage and the yield was 94.3 t/ha.

Oil yield

No significant effect could be discerned in the oil yield in the first and second year with different levels of N. This showed that 25 kg N/ha is sufficient under Odakkaly condition where the available soil N level was found to be medium. In the first year herbage yield is increased significantly with increasing levels of N but the difference in oil yield is not significant because oil contents at 50 and 75 kg N/ha are lower than that at 25 kg N/ha. Varying responses to application of N have been reported by workers such as Hazarika and Bora (1977), Sarma et al. (1977), Gupta et al. (1978), Sharma et al. (1980), Pareek et al. (1981 a) and by Munsi and Mukherjee (1982). Singh et al. (1981), however, reported non-response to application of N for oil yield.

Oil yield increased significantly with increase in the level of P in both the years. Higher herbage yield recorded at higher levels of P might have contributed towards higher oil yield as there is no significant difference in the percentage recovery of oil with different levels of P. In the first year, P_2O_5 at 75 kg/ha has recorded the maximum oil yield (38.73 kg/ha) which is significantly superior to the other two levels. But in the second year and in the total for two years the maximum oil yield is recorded at 75 kg P_2O_5/ha which itself is on par with 50 kg P_2O_5/ha. Therefore, 50 kg P_2O_5/ha may be sufficient for obtaining higher oil yield under the agroclimatic situations of Odakkaly.

Varying responses to application of P have been reported by many workers (Hazarika and Bora, 1977; Sarma et al. 1980; Singh et al. 1981 and Munsi and Mukherjee, 1982). On the contrary Sarma et al. (1977) and Pareek et al. (1981 a) reported that there was no response to P in the experiments conducted at the Punjab Agricultural University, Ludhiana and Issapur Farm, Delhi respectively.

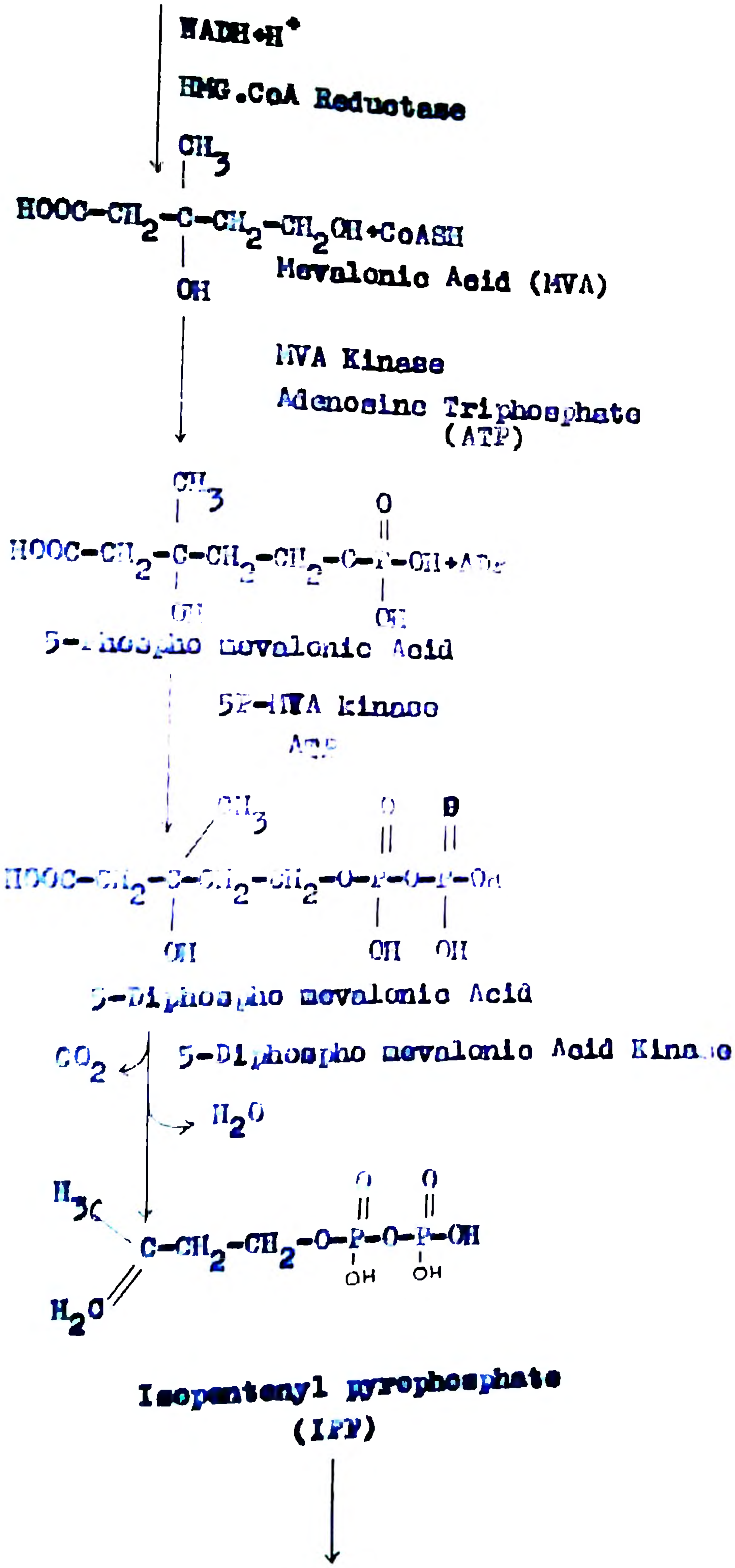
Phosphorus which is one of the important macro-nutrients does not occur in the living cell in its acid form. Instead in the constant biological reactions phosphorus plays its cardinal role in the forms of esters of phosphoric acid and pyrophosphoric acid. Thus, in a wide spectrum of biological reactions that are occurring in the plant cell, animal cell or in the cells of lower organisms, phosphorus exerts its role in the form of energy containing esters such as adenosine triphosphate (ATP), creatine phosphate (CP) and phosphoenol pyruvate (PEP). In the biosynthetic formation of monoterpenes, cholesterol, amino acids, proteins etc. Geranyl pyrophosphate is however an intermediate in the pathway. The pathway of synthesis of monoterpenes is briefly depicted as follows.

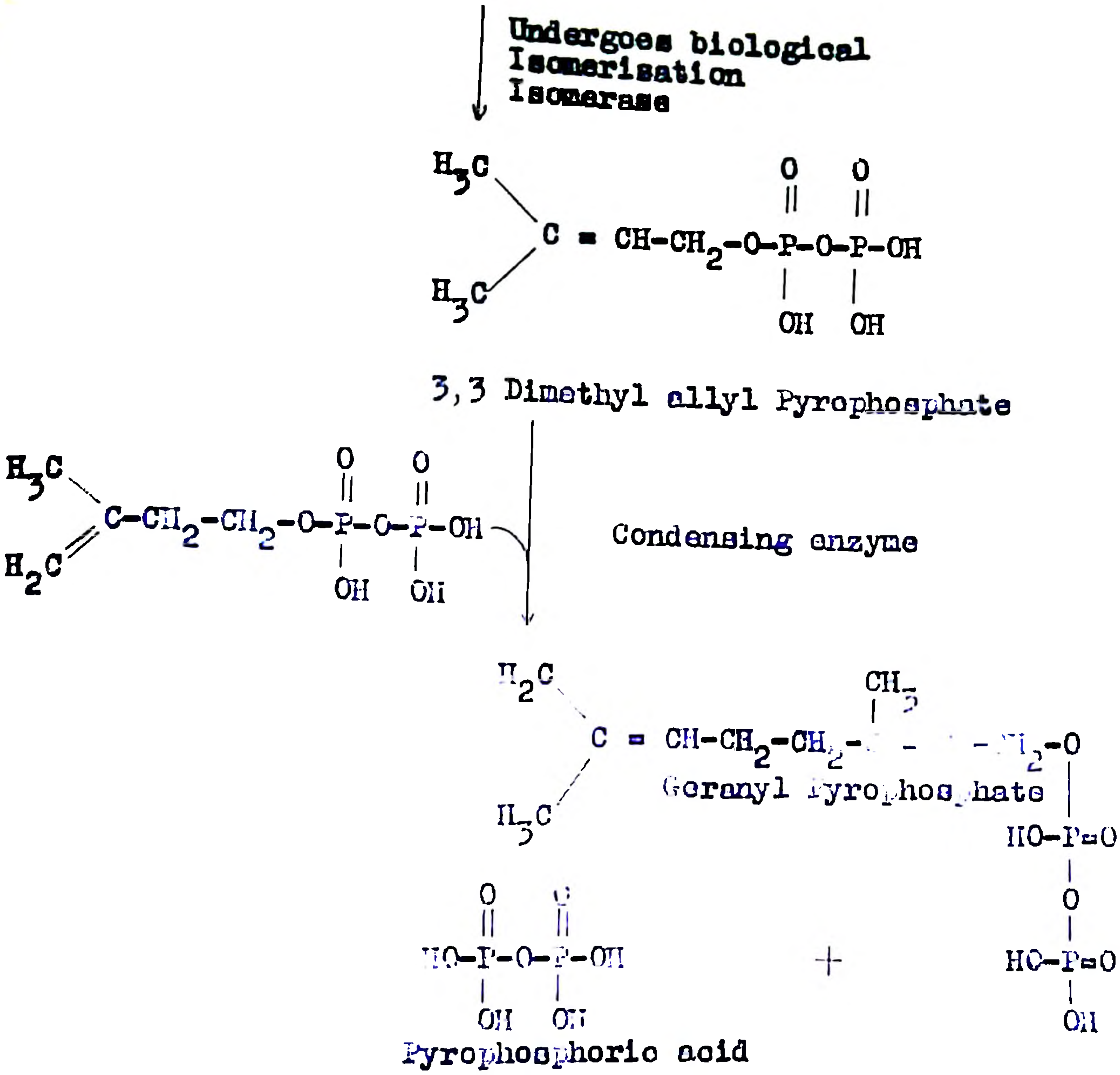
$$\underset{\text{aceto acetyl CoA}}{CH_3COCH_2COSCoA} + \underset{\text{Acetyl CoA}}{CH_3COSCoA} \longrightarrow$$

$$HOOC-CH_2-\underset{CH_3}{\overset{OH}{\underset{|}{\overset{|}{C}}}}-CH_2-CO-SCoA + CoASH$$

β-Hydroxy- β-methyl glutaryl CoA
(HMGCoA)

$$\downarrow$$


NADH+H+
HMG.CoA Reductase
Mevalonic Acid (MVA)
MVA Kinase
Adenosine Triphosphate (ATP)
5-Phospho mevalonic Acid
5P-MVA kinase
5-Diphospho mevalonic Acid
5-Diphospho mevalonic Acid Kinase
Isopentenyl pyrophosphate (IPP)



The scheme clearly tells that during the reductive processes and phosphorylation, energy is consumed directly or indirectly in the form of ATP, the formation of which evidently depends upon the continuous release of ATP by the cell. The finding in the present study that soil application of phosphorus leads to considerable increase in oil yield of palmarosa plants is substantiated by the involvement of high energy phosphate compounds in the biosynthetic pathway, which possibly gets stimulated by the P fertilisation.

The results indicate that there is a lack of response in oil yields to application of K_2O at different levels in the laterite soils of Odakkaly which is found to have medium level of available K_2O. However, application of K_2O has recorded significantly higher herbage yield in the second year and in the total yield for two years. In spite of this, the lack of response when oil yield is taken as the criterion has to be attributed to the observed lower oil content in herbage at higher levels of K_2O. The oil content decreased from 0.281 per cent at 25 kg K_2O/ha to 0.265 per cent at 75 kg K_2O/ha in the second year. In the first year also higher levels of K_2O application showed a similar trend. This consistent tendency of K_2O to reduce the oil content in palmarosa needs further study.

Non response of K_2O for oil production has been reported by Sharma et al. (1980), Pareek et al. (1981 a) and by Singh et al. (1981). On the contrary the optimum level of K_2O/ha/year was found to be 40 kg by Hazarika and Bora (1977) and by Gupta et al. (1978).

Oil yield increased significantly as the interval between harvests increased in both the years. Maximum oil yield has been recorded by the harvest treatment with an interval of 65 days in both the years. The observation trial conducted with longer intervals showed that harvest intervals greater than 65 days do not significantly increase oil yield. In fact there is a tendency for oil yields to decrease beyond 65 day interval of harvest. The oil yield obtained for 65 days harvest interval during the first year is 41.55 kg/ha and in the second year it is 89.11 kg/ha. The low oil yield in the first year is largely due to the lower herbage yield obtained. Increasing the interval of harvest resulted in increased vegetative growth and allowed maximum flowering. The inflorescence generally contains the highest content of oil compared to other portions of the grass. Enhanced vegetative growth and a greater proportion of inflorescence to stem and leaves in the herbage has contributed towards the higher oil yield at longer harvest intervals.

Lal (1935) and Rao et al. (1949) had reported that the maximum yield of oil was obtained when the crop was harvested one week after flowering. Nair and Marian (1978) were of the opinion that the sixth or seventh day after the full flowering of the crop was the optimum stage of harvest for obtaining maximum oil yield. Many workers have reported that maximum yield of oil was obtained when the plants were harvested at full flowering stage (Virmani et al., 1977; Gupta and Jain, 1978 and Pareek et al., 1981 b). On the other hand Singh (1958) reported that maximum yield of oil was obtained during budding to flowering time with a decrease in yield with the onset of seeding.

The total oil yield obtained in the study is in conformity with the findings of Hazarika and Bora (1977), Singh et al. (1981) and Munsi and Mukherjee (1982), but disagree with the yields reported by Sarma et al. (1977), and Pareek et al. (1981 a and b). Sarma et al. (1977) reported higher oil yield (161.6 to 222.9 kg/ha) in the first year than in the second year (84 to 102.3 kg/ha). But Gupta and Jain (1978) have reported that in all the species of Cymbopogans the yield of the herbage was the lowest in the first year and highest in the second and third year after planting. Pareek et al. (1981 a) reported a oil yield as high as 463.4 kg/ha in two years. Oil yield as high as 345.3 l/ha was recorded for two years in another study conducted at Issapur Farm, Delhi (Pareek et al., 1981 b).

Such high yields reported in literature, however could not be obtained in the present study under Kerala situation. In this respect one of the observations worthy to be emphasised is that the present recommended spacing of 30 x 30 cm adopted in the present study is too high as it permits weed growth in between both plants and between rows. If the population density per hectare is increased with shorter spacing it may be possible to attain higher yields. However this agronomic aspect needs further study.

Oil content

Different levels of N application tried have not significantly influenced the oil content of the plants. But higher levels of N application slightly reduced the oil content. Decrease in the oil content of plants with increased application of N has been reported in Java citronella by Bommegowda (1978). But Sarma et al. (1977) reported that the percentage recovery of oil increased with increase in the levels of N and according to Pareek et al. (1981 a), Singh et al. (1981) and Pareek et al. (1983), there was no significant difference in the oil content due to different levels of N at 0, 50 and 100 kg/ha.

Different levels of P_2O_5 also have not influenced the oil content significantly nor have they shown any definite trend to either increase or decrease in both the years. Many workers such as Dutta and Paul (1976), Sarma et al. (1977), Pareek et al. (1981 a), Singh et al. (1981) and Pareek et al. (1983) also reported non-significant response to application of P in the oil content.

Application of K_2O at higher levels decreased the oil content in the first and second year and this is significant in the second year. The decrease in oil content obtained with increase in the level of K_2O in this study may be due to the fact that the minimum level of concentration to be maintained in the soil solution as well as in the plant cell sap might have been met from the available K supply from the soil itself besides through the additions of K fertilizers at different levels.

Moisture content at higher levels of K_2O is observed to be high as the proportion of dry matter to fresh weight of the herbage is low at higher levels of K_2O. This may be one of the reasons for the observed low oil content at higher levels of K_2O. Dutta and Paul (1976), Pareek et al. (1981 a), Singh et al. (1981) and Pareek et al. (1983) reported non-significant response in oil content due to application of K_2O.

In the present study none of the combinations of NPK has a significant influence in the oil content. But Hazarika et al. (1978) observed that out of 16 NPK combinations, the combination N_{120} P_{40} K_0 and N_{60} P_{40} K_{40} yielded maximum percentage of oil and these two combinations were highly significant compared to other combinations.

Percentage of recovery of oil is influenced significantly by differences in harvest intervals. Oil content increased almost linearly as the interval between harvests increased in both the years. The highest value of (0.316 per cent) is recorded by 65 days and the lowest value (0.247 per cent) is for 40 days in the means for the two years.

The increase in oil content with increase in the interval of harvest may be due to the increase in the number of inflorescence and length of inflorescence as inflorescence contains much higher oil content than the leaves and stems (Rakshit and Dutt, 1947; Naridn and Das Gupta, 1948; Rao et al., 1949; Karira and Beri, 1966; Virmani et al., 1967; Dutta and Sahoo, 1977; Gupta et al., 1978; Alice, 1982 and Naresh et al. (1982). Many workers have reported that maximum oil content was obtained during the full bloom stage and the oil content was low at the early and late flowering stages (Karira and Beri, 1966; Ghosh and Chatterjee, 1976 and Pareek et al., 1981 b). According to Naresh et al. (1982) the oil content of plants at anthesis was appreciably higher than before or at full flowering stage. Kerala Agricultural University has recommended that the crop should be harvested one week after flowering when the essential oil content reaches its maximum (Anon., 1982). In the present study, it is observed that the crop harvested at 65 days interval has not attained the late flowering stage and hence the oil content linearly increased upto 65 days. This further posed the question whether the maximum harvest interval of 65 days tried would be sufficient for realising maximum oil content. The observation trial conducted with intervals varying from 55 to 135 days has shown that the oil content increased upto 85 days and thereafter it showed a downward trend. This shows that the optimum interval for obtaining maximum oil content is around 85 days. It is thus possible that the model for optimising the yield by harvest intervals may be between 65 and 85 days.

The oil content recorded in this study is in agreement with the findings of Dutta and Paul (1976), Virmani et al. (1967) and Alice (1982). Many reports with regard to the essential oil recovery by Lal (1935), Narian and Gupta (1948), Karira and Beri (1966), Sarma et al. (1977), Gupta et al. (1978), Hazarika et al. (1978), Pareek et al. (1981 b), Singh et al. (1981) and by Naresh et al. (1982) varied widely and are not in agreement with the results obtained in the present study. This variation in oil recovery may be attributed to the variation in agro-climatic conditions of the cultivation sites and the proportion of flower, leaf and stalk in the herbage. The flower top has the maximum oil content and the leaves and stem have lesser oil content. In view of this the height at which the herbage is harvested is sure to influence the oil recovery percentage. The lower the height at which the grass is harvested the lesser will be the recovery.

Dry matter yield

Different levels of N have produced significant difference in the dry matter yield of herbage in the first year. In the second year, however, the dry herbage yield has not been influenced by different levels of N. Similar results are obtained in the case of fresh weight of herbage also, indirectly indicating that the moisture content of the herbage is unaffected by the level of N.

As in the case of fresh weight of herbage the dry matter yield also showed significant difference with different levels of P in both the years. Similar trends have been noticed for dry and fresh weights of herbage. This indicates that as in the case of N the moisture content of the herbage is unaffected by different levels of P in both the years.

No significant difference in the dry weight of the herbage with different levels of K_2O could be observed in both the years and in the total yield for two years. The fresh weight of the herbage in the second year and the total yield for the two years are influenced significantly by different levels of K_2O. The treatment in which K_2O is applied at the rate of 75 kg/ha recorded significantly higher fresh weight of herbage than the other two levels. But there is no significant difference in the dry weight of the herbage indicating that the moisture content of the herbage may be high at higher levels of K_2O.

The dry matter yield increased with increase in the interval of harvest in both the years. The high dry matter yield at longer intervals of harvest is due to the high fresh weight of herbage and low moisture content with increasing intervals of harvest. The moisture content of the herbage decreased as the intervals increased and the mean moisture percentage recorded in two years at 40, 45, 50, 55, 60 and 65 days intervals are 71.7, 70.3, 70.0, 68.0, 66.7 and 62.5 respectively.

Number of harvests obtained in a year

In the present study the number of harvests obtained for the different harvest interval treatments varied from three to four in the first year and from five to nine in the second year. This is not in agreement with the findings from other locations reported in literature. Generally one, two or at times a maximum of three harvests only are generally taken in an year (Burger, 1958; Singh, 1958; Karira and Beri, 1966; Gupta, 1972; Ghosh and Chatterjee, 1976; Hazarika and Bora, 1977; Virmani, et al. 1977; Gupta et al., 1980; Kanjilal et al., 1981; Singh et al., 1981; Munsi and Mukherjee, 1982). But under Kerala conditions Rao et al. (1949) have reported that they obtained seven cuttings in two years in an experiment conducted in North Malabar (Kerala). Nair et al. (1980 a) reported from a study conducted at AMPRS, Odakkaly that they obtained four harvests in the first year for ODP-2, the same variety used in the present experiment. From another study on the influence of spacing of a late flowering variety ODP-1, Nair et al. (1980 b) reported two harvests in the first year four in the second, three in the third year and four in the fourth year . It appears that comparatively more number of harvests are possible under Kerala conditions because the crop comes to flowering more frequently under the agro-climatic conditions of the State. This may be because palmarosa possesses the characteristics of long day plants and long days hasten flowering and increase the reproductive growth (Ghosh and Chatterjee, 1977).

<u>Physico-chemical properties of the oil</u>

<u>Gas Liquid Chromatographic analysis of the oil obtained in the first year</u>

GLC analysis of oil samples collected during the first year showed that geraniol content of the oil is not affected by NPK application. However different intervals of harvest have a definite influence on the geraniol content. Thus maximum geraniol content (73.1 per cent) could be obtained with a harvest interval of 55 days, the minimum being for the shortest interval of 40 days (60.7 per cent). For periods shorter than 65 and longer than 45 days the geraniol content is more or less the same.

Geranyl acetate also is unaffected by NPK fertilization. However, geranyl acetate decreased as the interval increased attaining the minimum value at 65 days (21.8 per cent) harvest interval. The maximum value is recorded by 40 days interval (32.7 per cent). The result of the study thus shows that harvest intervals greater than 65 days may be required to bring down the acetate content to ISI specification of 3.1 to 12.5 per cent. However it appears that the industry has methods for decreasing the acetate content and thus increasing the geraniol content to ISI specification. These methods though specially guarded secrets cannot be anything other than simple techniques for hydrolysing the geranyl acetate and washing out the acetic acid as sodium acetate.

<u>Physico-chemical properties of the oil obtained in the second year</u>

<u>Specific gravity at 30°C</u>

The specific gravity of the oil recorded in both the seasons are not influenced significantly by different levels of N, P_2O_5 or K_2O except in the summer season where the effect of P_2O_5 is significant. The NP interaction is significant in both the seasons. The lowest specific gravity is recorded by the combination n_3p_3. This shows that the specific gravity of the palmarosa oil decreased as the fertility of the soil on which the crop has been grown increased.

Specific gravity of the oil is influenced by different intervals of harvest in the monsoon season and in the mean value for both the seasons. It is found to decrease as the interval between the harvests increased. Specific gravity recorded during the summer season is lower than that in the monsoon season. The values with different intervals of harvest has been found to vary from 0.8927 to 0.8963 in the monsoon season and from 0.8882 to 0.8900 in the summer. These values are higher than the specification fixed by the ISI. As per the ISI specifications, the specific gravity of palmarosa oil should be within the range of 0.8740 to 0.8860 at 30°C. The decrease in the specific gravity of the oil with increase in the interval of harvest may be explained by the higher content of alcohol and lower content of esters in the later stages of growth. Geraniol has a low specific gravity of 0.8812 compared to geranyl acetate, 0.9163 (Guenther, 1950). Many workers have reported that the specific gravity of oil from the leaves to be lower than that of the oil from the flower top (Gupta et al., 1978; Alice, 1982). But in the present study it has been found that though the proportion of tillers with inflorescence increased with increasing intervals between harvests, the specific gravity of oil decreased as the interval increased. The results thus show that not only the proportion of leaves and inflorescence, but the interval of harvest is also an important factor in determining the specific gravity of the oil. The results reported by Pareek et al. (1981 b) is in agreement with the results obtained in the study. According to him, the specific gravity of oil showed a downward trend from commencement of flowering to the late seeding stage. But Karira and Beri (1966) reported that there was not much difference in the specific gravity of oil at the flowering and late flowering stages. The specific gravity of the oil obtained in the summer season is lower than that of the oil obtained in the monsoon season.

The specific gravity of the oil decreased as the harvest interval increased upto 65 days. However the oil with the maximum harvest interval still has a higher specific gravity than that required by ISI specification. The observation trial conducted with longer intervals during 1983-'84 has shown that the specific gravity decreased further as the intervals increased above 65 days. The specific gravity of oil obtained after 75 days is within the ISI specifications. The harvest interval of 75 days is found to be sufficient to attain ISI specification. Thus, the harvest interval for attaining ISI specification is highly influenced by the time at which it is harvested and the period at which the oil is synthesised in the plant.

Refractive index

Refractive index of the oil is influenced by different levels of N only in the monsoon season, while P and K showed no influence in both the seasons and in the mean value for both the seasons. At higher levels of N, P and K geraniol content of the oil is found to increase and the acetate content is found to decrease though the differences are not significant. In fact pure geraniol and geraniol acetate have significantly different refractive indices. However, this has not been reflected in the refractive indices of the oil.

Refractive index of the oil is found to increase significantly as the interval between the harvests increased. The increase in the values with increase in the intervals of harvest may be attributed to the higher geraniol content and the lower acetate content in the oil as the interval between the harvests increased. Geranyl acetate has a lower refractive index 1.4655 compared to geraniol 1.4766 (Guenther, 1950). The highest value of 1.4688 in the monsoon season is recorded by 55 day interval but it is on par with harvest intervals of 65, 60 and 50 days, all of which are significantly different from 45 and 40 days. In the summer season, the highest value of 1.4694 is recorded by 65 days harvest interval and it is on par with 60, 55 and 50 day intervals. The values recorded by all the harvest treatments during the monsoon season are below the ISI limits as the ISI specification for refractive index at 30°C is 1.4690 to 1.4735. In the summer season the values recorded at 65, 60, 55 and 50 day intervals are within the ISI units. Higher refractive index of the oil obtained in the summer season may be due to the higher geraniol content and lower acetate content in the oil obtained in the summer season. The results obtained in this study are thus generally in agreement with the findings of Pareek et al. (1981 b) who have reported an increase in the refractive index of oil from the vegetative phase (1.4676) to full bloom stage (1.4731) and thereafter it remained without much change. Virmani et al. (1967) have reported that the refractive index of oil decreased as the duration of harvest increased from 12 to 14 weeks to 60 weeks. The refractive index of oil of the flower tops was reported to be lower than that of the oil obtained from leaves and stem (Karira and Bori, 1966; Alice, 1982). Gupta et al. (1978 and 1981) have reported that the refractive index of oil of leaves was higher than that of the inflorescence. But in the present study the refractive index of oil is found to increase as the interval between harvests increased and as the proportion of flowered tillers increased. This also shows that as in the case of specific gravity of oil, refractive index is also determined not only by the proportion of the leaves and inflorescence but also by the stage of harvest. The observation trial has indicated that the refractive index increased as the intervals increased upto 85 days and that the refractive index of all the samples harvested at and above 55 days interval have passed the ISI specification. The refractive index showed a tendency to decrease as the harvest interval increased above 95 days.

Optical rotation

Optical rotation of the oil is not influenced significantly by the main effects of N, P, K or their interactions. The optical activity of the oil is found to increase as the interval between the harvests increased. The difference between the treatments is found to be significant in both the seasons and in the mean value for the two seasons. Maximum optical activity is recorded by 65 days interval in both the seasons and there is no significant difference between 55, 60 and 65 days in the mean value for the two seasons. The values obtained for the treatments varied from +1.45° to +1.84° in the monsoon season and from +1.53° to +1.90° in the summer season and all these values are within the ISI limits as the range fixed is from -2° to +3°. Pure geraniol, geranyl acetate and allied substances have no optical activity because of the absence of asymmetric carbon atoms in them. Therefore, the increase in activity obtained at higher intervals may be due to the increased concentration of some minor components with optical activity.

In the observation trial conducted with intervals from 55 to 135 days, it is noticed that there is not much difference in the optical activity of the oil as the intervals increased. Pareek et al. (1981 b) also obtained similar results, that the optical rotation of the oil increased from vegetative phase to the commencement of flowering and thereafter it decreased.

Solubility in 70 per cent alcohol

No significant difference or any definite trend is noted in the solubility with different levels of N, P_2O_5 and K_2O. Both from chemical analysis and from the GLC studies higher levels of N and P have been found to give a higher geraniol content and a lower content of geranyl acetate. But the difference in the contents of geraniol and geranyl acetate has not been reflected in the solubility of oil in 70 per cent alcohol. This may partly be due to the differential effects produced on other minor terpene alcohol constituents.

Different intervals of harvest have influenced the solubility of the oil in both the seasons and the solubility is found to increase almost linearly with increase in the intervals of harvest. Highest solubility is recorded with 65 day interval in both the seasons, 1.45 in the monsoon season and 1.44 in the summer season. Geraniol, being more polar than geranyl acetate will have a higher solubility in a polar solvent like alcohol. Hence the increase in solubility in alcohol at higher intervals may be attributed to the higher geraniol content in the oil at later stages of growth. It could also be due to an increase in other minor terpenes. The solubility recorded by all the treatments confirm to the ISI specification of solubility in one to two volumes of 70 per cent alcohol.

The higher solubility of the oil obtained in the summer season may probably due to the higher geraniol content.

The solubility of the soil in 70 per cent alcohol showed a tendency to increase as the intervals of harvest increased upto 115 days in the observation trial.

Acid value

Main effects of N, P, K or intervals of harvest are not significant and no definite trend has also been noticed in the acid value of the oil with different treatments. The maximum value fixed by ISI for this character is 3. The oil obtained during the monsoon season has recorded higher value than in the summer season. The values obtained in the monsoon season are higher than the ISI specifications, but the values recorded with all the treatments during summer season are below 3.0 which satisfied the ISI requirement.

As the interval between harvests increased above 65 days in the observation trial the acid value correspondingly decreased upto 115 days. The values obtained for harvest intervals of 95 days and more are within the ISI specifications. This also shows that for obtaining oil of better quality the interval has to be increased upto 95 days.

Pareek et al. (1981 b) also reported higher acid value than the ISI specification for the oil obtained in all the growth stages (from vegetative phase to the seeding stage) that he studied and the absence of a definite trend in his studies for the acid number at different stages of harvest. Karira and Beri (1966) reported that the acid value of the oil of the 1/3rd top portion of the plant was higher than that of the 2/3rd bottom portion. Gupta et al. (1981) found that the oil of the leaves had a low acid value compared to that of the inflorescence. Alice (1982) also observed that the acid value of the flower tops to be higher to the oil obtained from the bottom portions of the plant. But in the present study, the acid value of the oil is found to decrease as the proportion of inflorescence is increased with increasing intervals of harvest. This also shows that as in the specific gravity and refractive index of oil, not only the proportion of the leaves and inflorescence but the stage of harvest of the crop is also important in determining the acid value of the oil.

Saponification value of unacetylated oil, ester value and ester content

The saponification value is an indicator of the ester value and ester content of the oil. There is significant difference in the saponification value for different levels of N and P. All these values are significantly low at higher levels of N and P.

The effect of K is not significant in these values.

The effect of N and P in decreasing the ester content of the oil may be due to the changes in the enzymatic activity at higher levels of N, and P_2O_5.

As the interval between harvests increased, these values decreased significantly. The lowest value for ester content is recorded with the treatment harvested at 65 day interval in both the seasons (24.6 per cent in the monsoon season and 19.6 per cent in the summer season). The ester content obtained in the monsoon season is higher than that in the summer season. The values with different intervals of harvest ranged from 24.60 to 33.15 per cent in the monsoon season and from 19.58 to 31.96 per cent in the summer season. The ISI requirement for the ester content of palmarosa oil is within the range of 5.1 to 12.5 per cent. A high ester content in the oil of palmarosa is not a desirable character and such oils are given a lower rank for perfumery purpose. Several workers have reported that the oil of leaves and stem had a lower ester content compared to the oil in the inflorescence (Gupta et al., 1978 and Alice, 1982). Nair et al. (19[illegible] a) reported a high ester content for the oil and they were of the opinion that the high ester content has to be attributed to the higher proportion of inflorescence when harvested at full flowering stage. In fact this was one of the reasons why the longest interval was fixed at 65 days in the present major experiment. Contrary to this expectation, in the present study the ester content is found to decrease as the interval between harvests increased, when the length of inflorescence and the number of tillers with inflorescence increased.

The observation trial has shown that the ester content decreased progressively with increasing intervals of harvest upto 115 days. The results indicate that for obtaining oil with a low geranyl acetate content so as to satisfy the ISI specifications, the crop has to be harvested at longer intervals of around 95 days. The results obtained in the present study thus conform the findings of Karira and Beri (1966) and Pareek et al. (1981 b). Karira and Beri reported that the ester value recorded at the flowering stage was higher than that in the late flowering stage. These stages probably correspond to the 65 day and 95 day harvest intervals respectively of the observation trial of the present study. Pareek et al. (1981 b) reported that geranyl ester was highest at the commencement of flowering (21.5 per cent) and that it decreased progressively to 6.5 per cent at the late seeding stage.

The acetate content obtained during the summer season is comparatively lower than that in the monsoon season. The low ester content in the summer season may be due to the triggering of physiological maturity by the water stress of the summer season.

Guenther (1950) reported that the oil produced in India had a low ester content, while the oil produced in Java with the material introduced from India had a relatively higher content of ester. He has attributed this to the crude methods of distillation followed in India which results in the hydrolysis of the ester with a consequent decrease in the acetate content. In Java the methods of distillation are more refined and the oil has a higher ester content. But in the present study it has been found that the stage of maturity of the crop at the time of harvest is probably more important in determining the ester content of the oil because results obtained from the steam distillation process adopted in this study shows that the maturity of the crop decides the extent of ester content of the oil.

Saponification value after acetylation

Saponification value after acetylation can be taken as an indirect measure of total alcohols (as geraniol) present in the oil. These values are not influenced significantly with different levels of N, P, K or their combinations. No definite trend has also been noticed with different levels of N, P, K or their combinations. Geraniol and geranyl acetate have shown a definite trend to increase and decrease respectively with increase in the levels of N, P and K. However, a similar trend has not been noticed in the saponification value after acetylation. This possibly indicates that total alcohol as indicated by saponification value after acetylation is unaffected by NPK levels. However geraniol is seen affected by NP & K. Contrary to this Hunsi and Mukherjee (1982) reported that the total alcohol content of oil was influenced by N & P.

Saponification value after acetylation is influenced significantly with different intervals of harvest in both seasons. The ISI requirements for this character ranges from 266 to 280. The values increased as the interval between harvests increased from 40 to 45 days and on further increase in the interval, the saponification value after acetylation decreased. The values obtained varies from 278.1 to 283.3 in the monsoon season and from 277.7 to 284.6 in the summer season. There is no significant difference in the values obtained by the harvesting intervals of 60 and 65 days. Further they are unaffected by the season at which harvests have been done, viz., the summer or monsoon season.

The values recorded for the oil obtained at the shorter intervals of harvest do not conform to the ISI specifications. However the values recorded with 60 and 65 day intervals are in agreement with the ISI requirements in both the seasons.

As the interval increased from 65 days in the observation trial the saponification value of acetylated oil is found to decrease further and the values recorded by all the intervals of harvest at and above 65 days are within the ISI limits.

Total alcohol

Total alcohol calculated as geraniol has not shown significant difference with different levels of N, P_2O_5, K_2O

or intervals of harvest in both the seasons. No definite trend has also been noted with different treatments. Though there is significant difference in the ester content, free alcohol and combined alcohol with different treatments, no significant difference in total alcohol content could be observed. This indicates that the capacity of plants to synthesis total terpene alcohols appear to be unaffected by the manurial and harvest treatments.

Munsi and Mukherjee (1982) reported that a gradual increase in total alcohol content has been observed with increasing levels of N and P_2O_5. Application of N and P at 60 kg/ha has recorded the highest geraniol content of 90.5 per cent as against 90.3 per cent in the control n_0p_0. Karira and Beri (1966) reported that the total alcohol content was higher in the flowering stage than in the late flowering stage. They have also reported that the total alcohol in the 1/3rd top (mainly inflorescence) was higher than that in the 2/3rd bottom portion (leaf and stem). But many other workers have reported that the flowers had a low total alcohol content than the leaves (Gupta et al., 1978; Gupta et al., 1981; Alice, 1982).

The ISI specification for total alcohol is a minimum of 90 per cent. The values obtained for all the treatments are well above the ISI specification. When the interval increased from 65 to 135 days in the observation trial the total alcohol showed no definite trend with increase in the intervals of harvest and the values varies from 90.3 to 92.7 per cent. This further strengthens the view that total alcohol content is unaffected by the stage of harvest.

Free alcohol

Free alcohol content during both the seasons are influenced by N and P levels. As the N levels increased, free alcohol content increased and the values at 75 and 50 kg N/ha are on par and are higher than the value at 25 kg N/ha. This observation is further corroborated by the low saponification value and acetate content at higher levels of N. Higher geraniol content with increasing levels of N was reported by Hazarika et al. (1978). Non-significant response to different levels of N on geraniol content had been reported by Singh et al. (1981).

Free alcohol content is increased with increase in levels of P in both the seasons and the alcohol content at 75 and 50 kg P_2O_5/ha are on par and higher than that at the lower level of P_2O_5 in both the seasons. Increase in the geraniol content with increasing levels of P has been reported by Singh et al. (1981).

Higher alcohol content at higher levels of N and P may be due to increase in some enzymatic activity.

Free alcohol is not influenced with different levels of K_2O. But free alcohol content at higher levels of K_2O are slightly higher than that at 25 kg K_2O/ha. On the other hand, Singh et al. (1981) reported that application of K brought about a positive significant increase in geraniol over control.

Non-significant response to application of N, P and K when applied singly or in combination has been reported by Pareek et al. (1981 a).

The np interaction is significant in the summer season and the highest value is recorded by n_3p_3 in both the seasons. Gupta et al. (1980) observed from the analysis conducted with oils obtained from different tracts in Maharashtra and Madhya Pradesh that the palmarosa grass with superior quality of oil occur in the forest ranges where the soil was more fertile.

Free alcohol content of oil is found to increase as the interval between the harvests increased. The 65 day harvest interval ranked first in both the seasons. The increase in the geraniol content with increase in the interval of harvest may be due to the increased synthesis of geraniol, due to the breakdown of geranyl acetate with the liberation of geraniol and utilisation of acetate for energy release or for synthesis of more geraniol.

The analysis of the oil derived from the observation trial shows that free alcohol content increased further with increase in the intervals upto 115 days and thereafter it decreased slightly.

The high content of geranyl acetate during the earlier periods of growth might be probably due to the esterification of free alcohol (geraniol) to ensure safe storage of the product in the form of acetate. But as the plant starts ageing, the acetate gets hydrolysed spontaneously with a corresponding increase in the content of free alcohol.

The result obtained in the present study is in agreement with the findings of Pareek et al. (1981 b) who reported that the geraniol content increased progressively from commencement of flowering (70.6 per cent) to late seeding stage (87.5 per cent).

But Karira and Beri (1966) reported that the geraniol content in the late flowering stage was lower than that in the flowering stage. Virmani et al. (1967) reported that the free alcohol content increased as the interval increased from 12-14 weeks (71.6 per cent) to 20 weeks (81.3 per cent) and with further increase in the interval to 36 weeks (73.7 per cent) and 50 weeks (74.9 per cent) the free alcohol content decreased.

The free alcohol content in the summer season is comparatively higher than that in the monsoon season. The difference in the alcohol content in the summer and monsoon seasons indicates that separate intervals have to be fixed in monsoon and summer season for obtaining ISI specified geraniol content in the oil. Thus in the monsoon season longer intervals may be required to achieve this, compared to the summer season.

Combined alcohol

The percentage of alcohol which occurs in oil in combined form as ester is referred to as combined alcohol. It followed the same trend as that of the ester content. Combined alcohol is indicative of the ester content of the oil.

The combined alcohol at 50 and 75 kg N/ha is lower than that at 25 kg N/ha in both the seasons. Similar results have been obtained for different levels of P_2O_5 also. Different levels of K_2O have no significant influence on the combined alcohol and no definite trend has also been noticed with increase in the levels of K_2O. The interaction between N and P is significant in the summer season and the lowest value is recorded by n_3p_3 in both the seasons.

Combined alcohol in the oil decreased significantly as the interval between the harvests increased upto 65 days in both the seasons. The observation trial conducted showed that the values decreased progressively upto 115 days and thereafter it showed a trend to increase.

Gas Liquid Chromatographic analysis of the oil obtained in the summer season of the second year

Geraniol content

Analysis of the oil samples obtained in the summer season in the second year has shown that different levels of N, P_2O_5 or K_2O have not influenced the geraniol content significantly. But increased levels of N, P_2O_5 and K_2O at 50 and 75 kg/ha have recorded higher values than at 25 kg/ha. This is in conformity with the trend observed in the chemical analysis.

Geraniol content is significantly influenced by different intervals of Harvest. The highest value (64.6 per cent) is recorded with the 65 day interval and it is significantly superior to all other stages. Similar results have been obtained in the chemical analysis also. The lowest value is recorded with 55 day interval (55.6 per cent) and there is no significant difference between 45, 50 and 55 day intervals. The shortest interval tried viz., 40 days, has recorded higher value than these treatments. In the chemical analysis, geraniol content increased progressively with increase in the intervals of harvest and in the GLC analysis, geraniol content decreased when the interval increased from 40 days to 55 days and thereafter it increased.

GLC analysis of the oil samples collected from the observation trial with higher intervals has shown that the geraniol content increased upto 115 days and with further increase in the intervals of harvest it showed a tendency to decrease. The results obtained are in agreement with the results of the chemical analysis.

The values obtained in the GLC analysis are lower than that obtained for free alcohol content in the chemical analysis. Similar results have been reported by Alice (1982). This may perhaps be due to the hydrolysis of esters taking place during the chemical estimation of free alcohol.

<u>Geranyl acetate determined by GLC</u>

In the case of geranyl acetate also the main effects of N, P_2O_5 and K_2O are not significant. But at higher levels of N, P_2O_5 and K_2O the values recorded are lower than that at the lowest levels. Similar trends have been noticed in the chemical analysis too.

Interactions between N and P and N and K are significant. The lowest value of geranyl acetate is recorded at n_3p_3 and n_3k_3 levels.

The acetate content of the oil is significantly influenced by different intervals of harvest and the acetate content is found to decrease as the intervals of harvest increased. The lowest acetate content is recorded at the maximum interval of 65 days (14.9 per cent). The oil obtained at all other lower intervals recorded significantly higher levels of acetate. This is in agreement with the results obtained in the chemical analysis. GLC analysis of the oil samples collected in the observation trial also show that the acetate content decreased further as the interval increased and the lowest value is recorded at 115 days. This also shows that as in the chemical analysis, for obtaining oil within the ISI specifications the interval of harvest has to be increased to 95 days.

The acetate content recorded in the GLC analysis however is lower than that in chemical methods. Similar results have been reported by Alice (1982). Higher values of geranyl acetate recorded in chemical analysis may perhaps be due to the presence of esters other than geranyl acetate in the palmarosa oil.

Geraniol yield

Influence of N and K are not significant in the geraniol yield in both the years and in the total yield for two years. There is no significant difference in oil yield due to different levels of N and K and that may be one of the reasons for the non significant difference in geraniol yield due to different levels of N and K. As regards the geraniol content, the effect of N is significant in the second year and geraniol content increased with increase in the level of N. But this is not reflected in the geraniol yield. Different levels of K_2O has no significant influence on the geraniol content of the oil also. Therefore, the non significant difference in geraniol yield due to different levels of K_2O could be expected.

Geraniol yield increased with increase in the levels of P_2O_5 and the difference is significant in both the years and in the total yield for two years. There is significant increase in the oil yield at higher levels of P_2O_5 in both the years. This increased oil yield at higher levels of P along with the higher geraniol content of the oil is the reason for the significant increase in the geraniol yield at higher levels of P.

Increase in the interval of harvest increased the geraniol yield significantly, the maximum yield is recorded at 65 day interval. Increased oil yield, as well as increased geraniol content at higher intervals of harvest, have obviously contributed for the increased geraniol yield.

The observation trial conducted with intervals of harvest varying from 55 to 135 days has shown that the geraniol yield showed not much difference as the interval between harvests increased from 65 to 85 days and thereafter it showed a decreasing trend.

Nutrient composition and uptake

Nitrogen content of plants

Increase in the level of N application from 25 to 75 kg/ha increased the N content of the herbage significantly in the first year. In the second year also, though the effect is not significant, increase in the level of N showed a trend to increase the N content of the plants. This is in agreement with the findings of Munsi and Mukherjee (1982) and of Pareek et al. (1983) who have reported, increase in the N content of palmarosa plants with increasing levels of N application. Similar results in Java citronella and lemongrass have been reported by Bommegowda (1978) and Rajan (1982) respectively.

The N content of the herbage in the first year is higher than that in the second year. This may be due to the fact that the yield per hectare in the first year is very low compared to that in the second year and the low N content in the second year may be due to the dilution effect.

Different levels of P_2O_5 have no significant influence on the N content of the plants. The N content decreased with increasing levels of P_2O_5. Similar results have been reported in palmarosa by Pareek et al. (1983). Dry matter yield increased significantly with increasing levels of P_2O_5 and the consequent dilution effect might account for the low N content. However this result is not in agreement with the findings of Munsi and Mukherjee (1982) who have reported that increased levels of P_2O_5 increased the N content of palmarosa.

Different levels of K_2O have not influenced the N content in both the years and the mean value for two years. Pareek et al. (1983) also reported that application of K_2O did not bring about any significant change in the N content of palmarosa crop. Similar results in lemongrass have been reported by Rajan (1982).

The interaction between N and P is significant in both the years and n_3p_1 has recorded the highest value.

As the interval between the harvests increased the N content decreased significantly in both the years. This is in agreement with the observation of Anjali (1982) who has reported that the N content in palmarosa was high at young and immature stages and decreased with increasing maturity. The N content for the different intervals of harvest ranged from 1.065 to 1.228 per cent in the first year and from 1.010 to 1.190 per cent in the second year. The decrease in N content of grasses with increase in cutting interval has been reported by many workers (Vicente Chandler, 1959; Thomas, 1978 and Kanodia et al. 1981).

Phosphorus content

The P content of the herbage is not significantly influenced by different levels of N in any of the years. Increased levels of N showed a tendency to decrease the P content in both the years. Similar results were reported in palmarosa by Pareek et al. (1983) and in lemongrass by Rajan (1982). On the other hand Munsi and Mukherjee (1982) reported that P content of palmarosa increased progressively with increase in the levels of N.

The concentration of P in plants is increased significantly by P_2O_5 supply in both the years and the P content at 50 and 75 kg P_2O_5/ha are higher than that at 25 kg/ha. Similar results were reported by Munsi and Mukherjee (1982) for palmarosa. Increased application of P_2O_5 increased the rate of absorption of the element which resulted in higher concentration of P in the herbage. On the contrary, Pareek et al. (1983) reported that increased levels of P_2O_5 had no significant influence on the P content of palmarosa.

Different levels of K_2O have no significant influence on the P content of plants. Similar results were obtained in palmarosa by Pareek et al. (1983) and in Java citronella by Bommegowda (1978).

In both the years the P content decreased as the interval of harvest increased. At the young and immature stages it is reported to be high in the plants with a tendency to decrease with increasing maturity (Anjali, 1982).

The result obtained in the present study is in agreement with the findings of Vicente Chandler (1959), Vilaipol (1967), Kothandaraman et al. (1973) and of Thomas (1978) for fodder grasses such as napier and guinea.

Potassium content

Increasing levels of N from 25 to 75 kg/ha has not influenced the K content of the plants significantly. Similar results have been reported by Pareek et al. (1983). In the mean value for two years the K content is found to decrease as the level of N increased. This is not in conformity with the findings of Munsi and Mukherjee (1982) who have reported that the K content of palmarosa plants increased with increase in the level of N. On the other hand Bommegowda (1978) reported that increase in the level of N application has not increased the K content of Java citronella.

Different levels of P_2O_5 have neither shown any significant influence nor any definite trend on the K content of the plants in both the years. Similar results in palmarosa have been reported by Pareek et al. (1983). On the other hand Munsi and Mukherjee (1982) reported that the K content of palmarosa plants increased with increasing levels of P_2O_5.

Increase in the level of K_2O has increased the K content of the plants in both the years. This is contradictory to the findings of Pareek et al. (1983) and Bommegowda (1978) in their studies with palmarosa and Java citronella respectively.

With increasing intervals of harvest the K content has been decreased significantly in both the years. Similar decrease in the K content of the herbage with increasing intervals of harvest in fodder grasses has been reported by many workers (Vicente Chandler, 1959; Kothandaraman et al., 1973 and Thomas, 1978). The K content of the plants in the second year is low compared to that in the first year. This is to a large extent due to the greater biomass production and consequent dilution effect.

Calcium content

Calcium content of the plants is not significantly influenced with different levels of N in both the years. Similar results have been reported by Pareek et al. (1983) in palmarosa.

Higher levels of P_2O_5 have recorded higher values of Ca than for the lowest level of P_2O_5, viz., 25 kg/ha in both the years, but the differences are not significant. Similar results have been reported in palmarosa by Pareek et al. (1983).

Different levels of K_2O have no significant influence on the Ca content of the plants in both the years. Pareek et al. (1983) have reported that Ca content of palmarosa plants showed a trend to increase, though not significantly, with increase in the levels of K_2O.

Different intervals of harvest have no significant influence on the Ca content of the crop in both the years. But there is no significant difference in the mean values for the two years and in general it tended to decrease as the interval increased. Almost the same trend is noticed in both the years. Decrease in Ca content with increasing intervals of harvest in guinea and hybrid napier grasses has been reported by Vicen... Chandler, 1959 and Vilaipol, 1967. But Kothandaraman (1973) has reported an increase in Ca content with increase in the cutting interval in guinea grass.

Magnesium content

Different levels of N influenced the Mg content significantly in both the years. Magnesium content increased as the levels of N increased. Significant increase in the Mg content of palmarosa by the application of N has been reported by Pareek et al. (1983).

Different levels of P_2O_5 have no significant effect on the Mg content of the plants. No definite trend has also been shown in the Mg content of the plants with different levels of P_2O_5. Similar results have been reported by Pareek et al. (1983).

The Mg content is not significantly influenced by the level of K_2O. This is in accordance with the findings of Pareek et al. (1983).

There is no significant difference in the Mg content with different intervals of harvest in the first year. But the trend is for the Mg content to decrease with increase in the intervals of harvest. In the second year and in the mean values for two years also the same trend is observed and the differences are significant. Similar results in fodder grasses have been reported by Vicente Chandler (1959). However an increase in Mg content with increase in cutting interval was observed in guinea grass by Kothandaraman et al. (1973).

Uptake of nitrogen

Application of N at 50 and 75 kg/ha has recorded significantly higher uptake than at 25 kg N/ha in both the years and there is no significant difference between application of N at 50 and 75 kg/ha. This increase in the uptake at higher levels of N is directly related to the higher per cent composition of N in the herbage and due to an increase in the dry matter yield at higher levels of N. Increased uptake of N in palmarosa with application of N has been reported by Pareek et al. (1983). Similar results in Java citronella were reported by Bommegowda (1978).

With increasing levels of P_2O_5 the uptake of N increased in both the years but the difference is significant only in the first year. This increased uptake is mainly due to the increased dry matter yield through P nutrition as the increase in the levels of P_2O_5 has slightly decreased the N content. Similar results were reported in

Java citronella by Bommegowda (1978). On the contrary, no significant change in the uptake of N by application of P_2O_5 on palmarosa has been reported by Pareek et al. (1983).

The influence of K_2O on the uptake of N is not significant in the first year. In the second year and in the total for two years, uptake of N increased with increasing levels of K_2O and the differences are significant. This increased uptake at higher levels of K_2O is due to increased dry matter yield and higher per cent composition of N in the herbage at higher levels of K_2O. Contrary to this, Pareek et al. (1983) and Bommegowda (1978) obtained no significant difference in the uptake of N in palmarosa and Java citronella respectively with increasing levels of K_2O.

As the interval between harvests increased, the N uptake increased in both the years. Maximum uptake is recorded by the longest interval tried in both the years and it is significantly higher than that of the other intervals. Though the N content of the herbage decreased as the intervals increased, the uptake, increased mainly due to an increase in the dry matter yield with increased intervals of harvest.

Uptake of phosphorus

Phosphorus uptake is influenced significantly by the level of N in the first year. Maximum uptake is recorded at 50 kg N/ha, but it is on par with 25 kg N/ha. The high uptake at 50 kg N/ha is due to increased dry matter production at this level, as the P content showed a tendency to decrease though not significantly, with increase in the levels of N. Uptake is low at 75 kg N/ha as the dry matter yield is also low at this level. In the second year and in the total for two years there is no significant difference in the uptake of P. Contrary to this Bommegowda (1978) and Pareek et al. (1983) reported that there was significant increase in the uptake of P at higher levels of N in Java citronella and palmarosa respectively.

Increased levels of P_2O_5 increased the uptake of P in both the years. Application of P_2O_5 at 75 kg/ha has recorded the maximum uptake and it is significantly higher than that of the lowest level of P_2O_5 in both the years. But there is no significant difference between 50 and 75 kg P_2O_5/ha. Increased dry matter production, as well as increased P content at higher levels of P_2O_5 have contributed for the increased uptake. On the other hand, no significant change in the uptake of P with increased levels of P_2O_5 has been reported by Pareek et al. (1983).

Influence of K_2O is also significant in the uptake of P. The highest level of K_2O, viz., 75 kg/ha recorded the maximum uptake in both the years. Application of K_2O at 50 kg/ha has recorded the lowest uptake. The highest uptake of P is at 75 kg K_2O/ha and this is due to the increased dry matter production as well as high P content at this level, as compared to that at the other two levels.

Non significant change in the P uptake, with application of K_2O was reported by Pareek et al. (1983).

The uptake of P is increased with increasing intervals of harvest. Though the P content of the plants decreased with increase in the interval of harvest, the uptake increased as the interval between harvests increased and this is due to the increased dry matter production at higher intervals of harvest.

Uptake of potassium

The uptake of K is influenced by different levels of N only in the first year and N at 50 kg/ha has recorded the highest uptake (10).61 kg/ha). The high dry matter production along with the high K content at this level might have contributed for the observed higher uptake.

In the second year, the uptake is not influenced significantly with different levels of N, though higher levels of N has recorded a slightly higher uptake.. In the dry matter production, as well as in the K content of the herbage, there is no significant difference with different levels of N. Contrary to this, significant increase in the K uptake with increasing levels of N has been reported in palmarosa and in Java citronella by Pareek et al. (1983) and by Bommegowda (1978).

Uptake of K is influenced significantly with different levels of P_2O_5 in the first year and in the total for two years. The maximum uptake is recorded at 75 kg P_2O_5/ha and the lowest value is recorded at 25 kg/ha in both the years. The increased uptake at higher levels of P_2O_5 in the first year is mainly due to the higher dry matter yield at higher levels. Though the application of P_2O_5 at 75 kg/ha registered the highest dry matter yield in the second year the K content is so low that the uptake of K is also rather low during this year. This might be the reason for the lack of significant difference in uptake of K between treatments of P_2O_5 in the second year. On the contrary Pareek et al. (1983) reported that there was no significant difference in the uptake of K with application of P_2O_5.

Uptake of K is increased significantly with increase in the level of K_2O in both the years. This is mainly due to the increase in the K content of the plants at higher levels of K_2O. Total uptake for two years increased from 232.00 kg/ha to 272.32 kg/ha as the level of K_2O increased from 25 to 75 kg/ha. Contrary to this Pareek et al. (1983) and Bommegowda (1978) reported that there was no significant variation in the uptake of K by palmarosa and Java citronella respectively with increased levels of K_2O.

Uptake of K is also increased almost progressively with increase in the intervals of harvest from 40 to 65 days. The maximum uptake for two years is recorded by 65 days (337.70 kg/ha) and it is significantly superior to all other treatments. The lowest value is recorded by 40 day intervals (225.20 kg/ha). Though the K content of the herbage decreased with increase in the interval of harvest, the uptake increased due to increase in the dry matter yield with increasing intervals of harvest.

Uptake of calcium

Increased levels of N increased the uptake of Ca and the maximum uptake is recorded by 75 kg N/ha in both the years (46.2 kg/ha). Increase in the Ca content of the plants is mainly responsible for the highest uptake at this level. Increased uptake of Ca with application of N in palmarosa has been reported by Pareek et al. (1983).

Calcium uptake is increased significantly with increasing levels of P_2O_5 in both the years. The maximum uptake of 47.0 kg/ha for two years is recorded by 75 kg P_2O_5/ha and it is significantly superior to the lower levels. Calcium content of the herbage at higher levels of P_2O_5 is higher than that at 25 kg P_2O_5/ha. The increased Ca content along with the increased herbage yield at higher levels of P_2O_5 have contributed for the increased uptake of Ca.

Contrary to this Pareek et al. (1983) observed no significant change in the uptake of Ca by palmarosa, with higher levels of P_2O_5.

Uptake of Ca is influenced significantly with different levels of K_2O in the first year and in the pooled data for two years and the maximum uptake is recorded at 75 kg K_2O/ha. Though the dry matter yield and Ca content of the plants are not influenced significantly with different levels of K_2O, the dry matter production and Ca content at 75 kg K_2O/ha are higher than that at the lower levels suggesting thereby that increased uptake of Ca occurred at 75 kg K_2O/ha. Pareek et al. (1983) observed no significant change in the uptake of Ca with increased levels of K_2O.

Calcium uptake is influenced significantly with different intervals of harvest in both the years. Maximum uptake is recorded with the treatment harvested at 65 day interval in both the years. Though the dry matter production is increased with increase in the intervals of harvest in both the years, uptake of Ca has not shown any definite trend in the first year, due to lack of any definite trend in the Ca content of the herbage with increase in the intervals of harvest. While in the second year and in the total for two years, uptake of Ca increased with increase in the intervals of harvest and this is mainly due to the increased dry matter production at higher intervals of harvest as the Ca content decreased with increasing intervals.

Uptake of magnesium

Magnesium uptake is influenced significantly with different levels of N and the uptake at 50 and 75 kg N/ha are significantly higher than that at 25 kg/ha in both the years. Magnesium content of the plants increased with increase in the levels of N and this may be the reason for the increased uptake of Mg at higher levels of N. Increased uptake of Mg with increased levels of N was reported by Pareek et al. (1983).

Application of P_2O_5 at 50 and 75 kg/ha has significantly increased uptake of Mg as compared to that at 25 kg/ha in both the years. This increased uptake at higher levels of P_2O_5 is mainly due to the increased dry matter production at higher levels of P_2O_5 as the Mg content is neither influenced significantly nor did it show any definite trend with increase in the levels of P_2O_5. No significant change in the uptake of Mg with application of P has been observed by Pareek et al. (1983).

Different levels of K_2O have no influence on the uptake of Mg. This could be expected since application of K_2O has no effect on either the dry matter yield or on the content of magnesium in the herbage. Similar results have been reported by Pareek et al. (1983).

Magnesium uptake is influenced significantly with different stages of harvest in both the years. In general, the uptake increased as the interval increased in both the years and the uptake at 65 day interval is significantly higher than that at the other intervals in both the years. The increased uptake at higher intervals of harvest is mainly due to the increased dry matter production as the Mg content is low at higher intervals.

Pareek et al. (1983) reported that the uptake of K is sizeable compared with the uptake of other nutrients and the uptake/ha/year of N, P, K, Ca and Mg is 94.8, 22.2, 225.0, 104.4 and 71.8 kg respectively. The corresponding uptake obtained in the present study in the second year are 87.8, 11.8, 152.3, 26.4 and 25.0 kg/ha.

Soil analysis

No significant difference in the total N content of the soil with the application of N, P_2O_5 or K_2O at different levels could be observed. However, plant uptake of N has been observed to increase with increasing levels of N, P_2O_5 and K_2O. This has to be attributed to the direct effect of increased application of N, and due to the indirect effect of P and K application on N uptake. Phosphorus and potash application are known to profoundly affect root growth and consequently the uptake of N from the soil.

Different intervals of harvest have been observed to influence significantly the N content of the soil. Nitrogen content of the soil at higher intervals of harvest namely 55, 60 and 65 day intervals is lower than that at the shorter intervals of 40, 45 and 50 days. This may partly be due to the senescence and death of the harvested stumps which probably by mineralisation adds to the soil N. This happens more frequently for shorter periods of harvest. Further, the total uptake of N for vegetative parts increase with increasing intervals of harvest due to higher herbage production. This removal impoverishes the soil in the treatments with longer harvest intervals.

Different levels of N and K_2O have not significantly influenced the P_2O_5 content of the soil. Increased levels of P application significantly increased the available P_2O_5 content of the soil.

Harvest intervals could not significantly alter the P_2O_5 content of the soil.

Available K_2O content of the soil has not shown any difference with different levels of N, P, K or different intervals of harvest.

Path analysis for yields-herbage, oil and geraniol

Yield of herbage and yield of oil being the two major quantitative parameters expressing economic yield of the crop are subjected to path analysis to identify the direct and indirect effects of the factors which are significantly associated with them. Geraniol yield, however is a quantitative as well as a qualitative parameter. The attributes that control geraniol yield automatically control the quality of oil also. In view of these, factors correlated with geraniol yield are also subjected to path analysis.

Herbage yield

From Table 40 (a) presented in the Chapter IV it is clear that the maximum direct effect on yield of herbage is through the height of the plant (0.6010) indicating that herbage yield is maximum influenced by the height of the plant. The correlation between the height of the plant and herbage yield is 67 per cent. From the results on the influence of nutrients on this single factor viz., the height of plant (Table No.2) it is seen that P_2O_5 at 50 kg/ha has the maximum and significant effect in enhancing the height of the plant. Increasing the interval of harvest has significant effect as increasing the height of the plant and it is maximum at the maximum interval of 65 days tried in the two year experiment. The response models fitted to the four year data on herbage and oil yield showed that the optimum harvest interval is 62 days for herbage yield and 63 days for oil yield. So it can be concluded that optimum yield is obtained between 60-65 day intervals of harvest which synchronise with the attainment of maximum height.

Seven per cent of the correlation is accounted to the indirect effects via tiller number and length of inflorescence. As the number of tillers increase the total length of plants contributed by the enhanced number of tillers is obviously high. Further, in general, as the tillers increase, the number of tillers with inflorescence will also increase. Again the total length of inflorescence contributed by tillers with inflorescence happens to be higher. The observed indirect effects of tiller number and length of inflorescence are possibly due to these effects.

The correlation between tiller number and the herbage yield is 37 per cent of which 21 per cent is contributed by the direct effect of tiller number and 16 per cent by the indirect effect via height of the plant. The indirect effect due to the length of inflorescence is negligible. The significant contribution made by tiller number on herbage yield is much relevant and understandable.

The direct effect of the length of inflorescence is low (0.0202) though the correlation between length of inflorescence and the herbage yield is high. This high degree of correlation has to be attributed mainly to the indirect effect of the length of inflorescence via height of the plant. It is only too obvious in the case of flowered tillers that the greater the height of the plant the greater will be the length of the inflorescence. This is revealed in the results obtained for the length of inflorescence and height of plants in Table 2 and 3. Further, P_2O_5 application at 50 kg/ha has been shown to increase the height of the plant, as well as the length of the inflorescence, the two major factors that contribute directly and indirectly towards herbage yield.

The indirect effect via tiller number (0.04) is more than the direct effect due to the length of inflorescence, which significantly shows that it is the total herbage bio mass devoid of the inflorescence that has greater yield contribution than the biomass of the inflorescence *per se*.

In short, the path analysis strongly indicated the contribution of the height of the plant towards higher herbage yield. This is indirectly influenced by tiller number, as well as the length of inflorescence. In fact, the two factors which contribute to increase the height and influence the indirectly operating factors are adequate phosphate nutrition at 50 kg P_2O_5/ha and the greater harvest interval of around 60 to 65 days as worked out in the fitted response model (Table 44).

<u>Oil yield</u>

Results of path analysis presented in Table 40(b) and path diagram between oil yield and various oil yield contributing factors show that 62 per cent of the yield are accounted for by the factors considered. The maximum direct effect on oil yield is through the herbage yield. Besides, this result which is quite obvious, the indirect effect on herbage yield via tillers with inflorescence, height of plant and the length of the inflorescence are responsible for enhancing the correlation to 0.8347. The significant direct effects on yield are to be attributed to the number of tillers with inflorescence (24 per cent), height of plants (17 per cent) and length of inflorescence (3 per cent).

Results presented in Tables 2, 3 and 4 on the effect of P_2O_5 indicate that height of plant, length of inflorescence and tillers with inflorescence are influenced by higher levels of P_2O_5 application. An increase in the harvest interval also

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increased the height of the plant and number of tillers with inflorescence, as well as the length of the inflorescence. The results for two years indicate that 65 days, the maximum interval tried, has the maximum effect. A subsequent observation trial with increased intervals of harvest however, indicated that these characters are not substantially enhanced with further increase in the interval of harvest. Thus putting the results on path analysis against the results on influence of harvest intervals indicate that the maximum yield is obtained as a result of the contribution of various yield attributes around 65 day harvest interval and 50 kg P_2O_5/ha.

Tillers with inflorescence, though it contributed to 24 per cent in oil yield gave a correlation of 69 per cent with oil yield. This is mainly due to the contribution throhgh herbage yield (28 per cent) via height of the plant (12 per cent), and tillers without inflorescence (4 per cent) and length of inflorescence (2 per cent). All these indirect effects clearly show that the height of plant, number of tillers without inflorescence, length of inflorescence etc. also contribute to yield of oil via herbage yield.

The maximum indirect effect of height of plant on oil yield is via herbage yield (41 per cent). The indirect effects via tillers with inflorescence (16 per cent) and tillers without infloresscence and length of infloresscence together (5 per cent) contribute to oil yield. Length of infloresscence has a negligible direct contribution as already stated (3 per cent) but a significant correlation of 0.7293 exists between oil yield and length of inflorescence. This is mainly due to the indirect influence on herbage yield (0.3541). From all these results one significant point that emerges is the role of height of plant, tiller number with infloresscence, and length of infloresscence in increasing the oil yield. It is significant that these very same yield attributes are significantly affected by the optimum harvest interval of 65 days and higher levels of P_2O_5 application.

Geraniol yield

The results on path analysis presented in Table 40(c) and Fig. 5 show that the cause and effect relationship of geraniol yield with oil yield and other quantitative and qualitative attributes may be explained by about 76 per cent by the characters studied. The maximum direct effect is brought about by oil yield (0.7849). This is to be expected since geraniol yield itself is depended upon the oil yield, the high degree of correlation between geraniol yield and oil yield being (0.9653). This enhanced correlation is accounted for by the additional influence of the indirect effects through the other factors.

The correlation between the number of tillers with inflorescence and geraniol yield is 0.7030. As the direct effect of the tillers with inflorescence on geraniol yield is negligible (0.0427) this high correlation is mainly due to its indirect effect on oil yield. Various workers (Gupta et al. 1978, Alice, 1983) have shown that the inflorescence produces oil which contains a higher content of geranyl acetate comparison to geraniol. The low direct effect of tillers with inflorescence on geraniol yield has to be attributed mainly to this reason. On the other hand, there are quite a number of evidences to show that the inflorescence contains a higher concentration of oil than the herbage without inflorescence. Thus the presence of the inflorescence has an indirect effect on increasing the oil yield and thereby increasing the total geraniol yield.

The direct and indirect effects of tillers without inflorescence are negative with a correlation of -0.2188. This negative correlation is mainly due to the fact that grass without inflorescence contribute less to oil yield and consequently to the total geraniol yield.

The correlation between geraniol yield and height of plants is 0.8044 which is mainly due to the indirect effect of the height of plants through oil yield. In the separate path analysis of oil yield the direct effect of height of plant is found to be about 17 per cent (Table 40 (b)).

However the direct effect of height has been reduced to 4.6 per cent in this analysis, though it is very clear that height of plant has an indirect effect on geraniol yield through oil yield.

Length of inflorescence has also been correlated with the geraniol yield (0.7492). The main factor contributing to this correlation is the indirect effect of the length of inflorescence through oil yield. The direct effect of length of inflorescence is very small. Similar results have been obtained for herbage yield and oil yield also.

From various results on the factors contributing to geraniol yield it seems that, the yield attributes which decide geraniol are the height of the plant, and number of tillers with inflorescence. From other aspects of the study both these factors are seen to be affected by harvest intervals as well as by phosphorus treatment viz., 50 kg P_2O_5/ha. Thus from various results of the present study a brief analysis can be made on the factors controlling herbage yield, oil yield and geraniol yield.

<u>Relationship between harvest interval and yield of herbage and oil</u>

The yield of herbage and oil for two years of the experiment followed the pattern of Cobb-Douglus function ($Y = a\, x^b$) which is usually used to express factors in econometrics

Y = yield

a = constant

b = rate of change in yield increase

x = harvest interval

The high value of coefficients of determination (r^2) confirm that the fitted relationship holds good.

Fitted function	Cobb-Douglus function		
Yield		r	r^2
Herbage	Y = 6.9125 x 0.4559	0.909	0.826
Oil	Y = 1.4114 x 1.0870	0.988	0.976

The observed and expected yields are given below for comparison.

Table 43. Observed and expected yields for various harvest intervals based on the data obtained during 1980-81 and 81-82.

Intervals of harvest (days)	Herbage yield (t/ha) Observed value	Expected value	Oil yield (kg/ha) Observed value	Expected value
40	37.59	37.16	76.27	77.82
45	40.39	39.21	92.98	88.44
50	38.29	41.14	95.11	99.18
55	43.80	42.96	111.35	110.00
60	44.18	44.70	121.35	120.91
65	47.44	46.36	131.39	131.90

The 'b' value being > 1.0 in the case of the relationship for oil yield a diminishing return in yield with increase in the interval of harvest is not derivable. But it stands to reason that we cannot expect increase in yield when the harvest interval is increased without limit. In view of this the data for the yield of herbage and oil obtained in the third and fourth year as a continuation of the study conducted at AMPRS, Odakkaly has also been taken for working out the yield trends. The data obtained in the third and fourth year however, showed a quadratic nature of response for the last three harvest intervals, (55, 60 and 65 days) as the yield declined after 60 days of harvest. This is evident from the yield data given below.

Table 44. Pooled data of herbage and oil yield for four years from 1980-81 to 1983-84.

Intervals of harvest (days)	Yield in the first and second year		Yield in the second and third year		Total for four years	
	Herbage (t/ha)	Oil kg/ha	Herbage (t/ha)	Oil kg/ha	Herbage (t/ha)	Oil kg/ha
40	37.59	76.27	47.97	107.50	85.56	183.78
45	40.39	92.98	54.55	132.79	94.94	225.75
50	38.29	95.11	55.72	149.85	94.01	244.96
55	43.80	111.35	53.54	141.53	99.81	252.88
60	44.18	121.35	60.76	186.92	104.95	308.27
65	47.44	131.39	57.18	180.49	104.62	311.88

Hence by taking the data on total yield for the four years with respect to the last three treatments namely 55, 60 and 65 days, the possibility of fitting a quadratic response function was explored. This gave the following results.

<u>Herbage yield for 4 years</u>

$Y = 104.95 + 2.405\ h - 2.73\ h^2$

h opt = 0.4405

Days optimum = 62.20

<u>62 days</u>

<u>Oil yield for 4 years</u>

$Y = 308.27 + 29.5\ h - 25.89\ h^2$

h opt = 0.5697

Days optimum = 62.95

<u>63 days</u>

These results thus show that the yield of herbage and oil reach an optimum at 60-65 days harvest interval.

However, several of the physical parameters on quality of oil such as specific gravity, refractive index, optical rotation etc. and chemical parameters especially geraniol and geranyl acetate content as affected by harvest intervals indicate that 60-65 days is often insufficient in attaining the ISI specifications for quality of oil. The results from the observation study show that the yield of geraniol increases consistently and crosses ISI limit at intervals of harvest greater than 95 days. However, this increase in geraniol content leads to a substantial decrease in oil yield from 115.62 kg at 65 days interval to 93.14 kg at 95 days harvest interval. In view of the fact that the perfumery industry has techniques available with it for increasing the geraniol content and decreasing the acetate content, the question is open whether we should decrease the yield by increasing the harvest interval to attain the ISI specification. Further work is required from organic/perfumery chemists in the use of cheap chemical treatments and methods for improving the quality of oil to ISI specification. This would ensure the application of such methods to utilise the highest oil yields obtained to be converted into oil yield of high geraniol content. The cheap methods are only one for partial hydrolysis of the geranyl acetate to geraniol and acetic acid to ensure the decrease of geranyl acetate and increase in geraniol content. The methods employed should also remove the acetic acid liberated without removing or denaturing other odorific principles.

Economics of different intervals of harvest and different levels of P_2O_5 application in the cultivation of palmarosa

Based on the cost of cultivation of palmarosa in the AMPRS, Odakkaly, and cost estimates for fuel charges and labour charges for distillation of a tonne of herbage, computations have been made on total cost of production of oil yield from harvest intervals ranging from 55 days to 135 days at 10 days interval, based on the data obtained from the observation trial. The prices of oil passing above ISI specification has been taken as Rs. 240/- per kg and that below the ISI specification as Rs. 220/- per kg (the oil from 55 to 85 day harvest intervals) and using the usual sale value of spent grass in AMPRS as Rs. 50/- per tonne, total receipts obtainable for various harvest intervals have been worked out. The net profit as well as net profit per rupee investment for each of the harvest interval treatments, has been computed. These results presented in Table 45(a) show that maximum net profit is obtained in the treatment with the harvest interval of 75 days. The harvest interval of 65 days duration gives a net profit of only Rs. 40/- less than that of the 75 day harvest interval. The return per Rupee investment indicates that maximum return of Rs. 2.60 is obtained for a harvest interval of 85 day duration. The harvest interval of 65 day duration, though gives a slightly lesser net return of Rs. 2.43 per rupee invested, entails an earlier return of profit in view of the shorter interval of harvest, thus offsetting the slight decrease in the net return.

The economics of different levels of P_2O_5 application, which has given significant results from the field experiment have been worked out and presented in Table 45 (b) and (c). The economics of P_2O_5 application has been worked out separately for the two years of experiment.

From the result it is clear that maximum net profit and net return per rupee investment is obtained for the stabilised crop (second year) by the application of P_2O_5 at 50 kg/ha. This is due to several reasons.

Table 45(a). Economics of harvesting the grass at different intervals based on the observation trial.

Treatment (Harvest intervals)	Cost of cultivation excluding harvest and distillation (Rs)	Additional cost for the harvest and distillation (Rs)	Total cost of production (Rs)	Yield		Value		Total receipts (Rs)	Net profit (Rs)	Return per rupee invested (Rs)
				Oil in kg/ha	Spent grass in t/ha	Oil*	Spent grass @ Rs.50/- per tonne			
55 days	3269/-	7540/-	10809/-	84.20	31.30	18524.00	1565.00	20089.00	9280.00	1.86
65 days	3269/-	7944/-	11213/-	115.62	35.90	25436.40	1795.00	27231.40	16018.40	2.43
75 days	3269/-	7460/-	10729/-	114.10	33.70	25102.00	1685.00	26787.00	16058.00	2.50
85 days	3269/-	6618/-	9887/-	110.12	29.90	24226.40	1495.00	25721.40	15834.40	2.60
95 days	3269/-	6078/-	9347/-	93.14	27.40	22353.60	1370.00	23723.60	14736.60	2.54
105 days	3269/-	5439/-	8708/-	80.33	24.50	19279.20	1225.00	20504.20	11796.20	2.35
115 days	3269/-	5304/-	8573/-	66.21	24.00	15890.40	1200.00	17090.40	8517.40	1.99
125 days	3269/-	4673/-	7942/-	57.00	21.20	13860.00	1060.00	14920.00	6978.00	1.88
135 days	3269/-	4101/-	7370/-	45.28	18.60	10867.20	930.00	11797.20	4427.20	1.60

* At the rate of Rs. 220/- per kg for oil obtained from 65, 75 and 85 days interval and at Rs. 240/- per kg for oil obtained from intervals of 95 days and above.

Table 45(b). Economics of application of different levels of phosphorus in the first year 1980-'81.

Treatment (Levels of P_2O_5)	Cost of production excluding the treatment (Rs)	Additional cost for the treatment (Rs)	Total cost of production (Rs)	Yield		Value		Total receipts (Rs)	Net profit (Rs)	Return per rupee invested (Rs)
				Oil in kg/ha	Spent grass t/ha	Oil at the rate of Rs.220/- per kg	Spent grass at the rate of Rs.50/- per tonne			
25 kg/ha	8978.50	111.00	9089.50	36.00	13.70	7920.00	685.00	8605.00	-484.50	0.95
50 kg/ha	8978.50	563.00	9541.50	43.00	15.80	9460.00	790.00	10250.00	+708.50	1.07
75 kg/ha	8978.50	761.00	9739.50	46.00	15.90	10120.00	795.00	10915.00	+1175.50	1.12

Table 45(c). Economics of application of different levels of phosphorus in the second year 1981-'82.

Treatment (Levels of P_2O_5)	Cost of production excluding the treatment (Rs)	Additional cost for the treatment (Rs)	Total cost of production (Rs)	Yield		Value		Total receipts (Rs)	Net profit (Rs)	Return per rupee invested (Rs)
				Oil in kg/ha	Spent grass t/ha	Oil at the rate of Rs.220/- per kg	Spent grass at the rate of Rs.50/- per tonne			
25 kg/ha	9528.60	111.00	9639.60	79.00	30.00	17380.00	1500.00	18880.00	9240.40	1.96
50 kg/ha	9528.60	1000.00	10528.60	95.00	34.00	20900.00	1700.00	22600.00	12071.40	2.15
75 kg/ha	9528.60	885.00	10413.60	94.00	33.00	20680.00	1650.00	22330.00	11916.40	2.14

The expenditure in the first year is more on account of preparatory cultivation, and planting while in the second year only ratoon harvesting is followed. Secondly the herbage yield in the second year is approximately twice as much as that obtained in the first year. It is also possible that the superimposed application of P_2O_5 at the rate of 50 kg each per year has also optimised the net return in the second year.

Taking the response pattern for harvest intervals in terms of herbage yield, oil yield, geraniol yield, net profit and net return per rupee invested, it appears that 65 days could be fixed as the harvest interval for palmarosa. Under conditions existing in and around Odakkaly and for soil situations reportedly low in phosphorus an application of 50 kg P_2O_5/ha appears to enhance the net return.

SUMMARY

SUMMARY AND CONCLUSIONS

An investigation was conducted at the AMPRS, Odakkaly to study the effect of three levels of N, P_2O_5 and K_2O, each at 25, 50 and 75 kg/ha along with six intervals of harvest at 40, 45, 50, 55, 60 and 65 days on the yield and quality of palmarosa oil. The field experiment was conducted in a $3^3 \times 6$ confounded asymmetrical factorial design during 1980-'81 and 1981-'82. The experiment was continued for another two years (1982-'84) limiting the observations to yield of herbage and oil. In addition to this harvest intervals longer than 65 days were tried in 1983-'84 in an observation trial. This was necessitated since the oil distilled at the longest harvest interval of 65 days in the main experiment did not conform strictly to the ISI specifications. The results of the investigations are summarised below.

Yield attributes

Different levels of N and K showed no significant influence on any of the yield attributes of the crop such as number of tillers, number of tillers with inflorescence, number of tillers without inflorescence, height of the plant and length of inflorescence. Increasing levels of P_2O_5 significantly increased the number of tillers with inflorescence, height of plants and length of inflorescence. Total number of tillers and tillers without inflorescence were not influenced significantly by P application.

Intervals of harvest influenced significantly all the yield attributes. Maximum tiller number per clump was recorded by 55 days. The crop harvested at 65 day intervals recorded the maximum height of plant, length of inflorescence and number of flowered tillers. The minimum number of non-flowered tillers was also recorded by this harvest interval.

Yield of herbage, yield of oil, oil content and dry matter yield

Different levels of N did not significantly influence the herbage yield, oil yield or oil content. But there was significant difference in the total dry matter yield due to different levels of N.

Phosphorus application significantly enhanced herbage yield, oil yield and dry matter yield. Maximum oil yield was recorded at 75 kg P_2O_5/ha but 50 and 75 kg P_2O_5/ha were on par. No significant effect was produced on oil content due to different levels of P application. Potash significantly increased the herbage yield and decreased the oil content. However, the oil yield and dry matter yield were not significantly influenced by the different levels of K_2O.

Harvest intervals showed significant influence on herbage yield, oil yield, oil content and dry matter yield and the maximum value was recorded by the 65 day interval. In the third and fourth year of the experiment the highest herbage and oil yields were recorded by the 60 day interval followed by the interval of 65 days. In the observation trial the herbage yield and oil yield showed a decreasing trend as the interval increased above 65 days. The oil content increased progressively upto 85 days and thereafter it showed a decreasing trend.

Physical properties of oil

Different levels of N, P or K did not significantly affect any of the physical properties such as the specific gravity, refractive index, optical rotation or solubility of oil in 70 per cent alcohol.

Harvest intervals significantly influenced all the physical properties. Increasing the intervals of harvest from 40 to 65 days decreased the specific gravity and increased the refractive index, optical rotation and solubility in 70 per cent alcohol.

In the observation trial, the specific gravity of the oil decreased further as the interval increased upto 105 days and refractive index increased upto 85 days. Optical rotation of oil remained without much change with increasing intervals of harvest. Solubility of the oil in 70 per cent alcohol showed a tendency to increase with increase in the intervals of harvest upto 115 days.

Chemical properties of oil

None of the nutrients tried showed any effect on the acid value of the oil. But saponification value, ester value and hence the ester content were significantly decreased at higher levels of N and P_2O_5. Potash application showed no significant influence on these values.

Different intervals of harvest showed no significant effect on the acid value of the oil. The saponification value, ester value and ester content significantly decreased with increasing intervals of harvest and the lowest value was recorded by the 65 day interval.

In the observation trial, acid value, saponification value and ester value decreased as the interval increased upto 115 days. The lowest ester content was also recorded at this harvest interval.

Different levels of N, P or K did not show any significant effect on the saponification value after acetylation and on the total alcohol content.

Saponification value after acetylation was influenced by different intervals of harvest and the value decreased as the harvest interval increased beyond 45 days. Different intervals of harvest showed no significant influence on the total alcohol content of the oil.

In the observation trial also, the saponification value after acetylation showed a tendency to decrease as the intervals increased upto 95 days. The total alcohol content remained without much change with increasing intervals of harvest.

Application of N and P_2O_5 at higher levels significantly increased the free alcohol content and decreased the combined alcohol content. Different levels of potassium produced no significant difference on the free and combined alcohol contents.

The highest value for free alcohol and the lowest value for combined alcohol were recorded by 65 day interval and it was significantly different from all other harvest intervals.

The free alcohol content increased and combined alcohol content decreased as the interval increased upto 115 days in the observation trial.

The oil obtained at harvest intervals less than 95 days showed a terpenic note, while the oil collected at intervals of 95 days and above had a sweet rosaceous odour.

Analysis of the oil by the GLC showed that geraniol and geranyl acetate contents of the oil were not influenced significantly by different levels of N, P or K. The highest value for geraniol content and the lowest value for geranyl acetate were recorded by 65 days interval and it was significantly superior to all other harvest intervals. GLC analysis of the oil samples collected from the observation trial showed that the geraniol content increased and the geranyl acetate content decreased upto 115 days.

Geraniol yield

Geraniol yield was not significantly influenced by the different levels of N and K, but increase in the levels of P significantly increased the geraniol yield. Harvest interval of 65 days gave the maximum value in both the years and it was significantly superior to all other intervals of harvest. Results obtained from the observation trial showed that there was not much difference in geraniol yield as the interval increased from 65 to 85 days.

Nutrient contents and uptake

Increasing the levels of N significantly increased the N and Mg content of the herbage, while it showed no significant influence on the P, K and Ca contents of the plants.

Application of different levels of P_2O_5 and K_2O significantly influenced the P and K contents of the herbage respectively. No significant difference in the concentration of the other nutrients resulted by the application of P and K.

As the intervals of harvest increased the N, P, K, and Mg contents of the herbage decreased significantly.

The total uptake of N, Ca and Mg for two years were significantly increased with increase in the application of N. No significant difference in the P and K uptake resulted due to different levels of N.

Increasing the levels of P_2O_5 significantly increased the uptake of all the nutrients viz., N, P, K, Ca and Mg.

Uptake of N, P, K and Ca was significantly influenced, but there was no significant difference in the uptake of Mg by the different levels of K_2O.

Different intervals of harvest significantly influenced the uptake of all the nutrients and the maximum uptake was recorded for the 65th day interval.

Effect of different treatments on the N, P_2O_5 and K_2O contents of the soil

Total N content of the soil was not influenced significantly by the different levels of N, P_2O_5 or K_2O. Increasing the intervals of harvest showed a significant decrease in the N content of the soil.

Available P_2O_5 content of the soil showed significant difference only with different levels of P application.

Different levels of N, P, K or the intervals of harvest did not produce any significant effect on the available K_2O content of the soil.

Path analysis

A path analysis of the herbage yield with related characters has shown that the height of the plant is the most important yield attribute influencing directly the yield of herbage.

Path analysis of oil yield showed that oil yield is mainly dependent upon herbage yield. The direct effects on oil yield by yield attributes are found to be in the decreasing order of number of tillers with inflorescence, height of the plants and length of inflorescence. Maximum indirect effect via herbage yield is expressed by the height of the plant and length of inflorescence. All these directly and indirectly contributing factors are seen to be markedly influenced by the application of phosphorus and intervals of harvest.

Path analysis of geraniol yield showed that geraniol yield is mainly dependent upon oil yield. The yield attributes which decide geraniol yield are the height of the plant and number of tillers with inflorescence.

Relationship between harvest interval and yield of herbage and oil

Relationship between the harvest interval and yield of herbage and oil (based on the data for four years from 1979-'80 to 1983-'84) showed that the optimum herbage and oil yield were obtained when the harvest was done at 62 and 63 days interval respectively (the yield reaches the optimum at 60 to 65 day interval). However, intervals of 60 to 65 days were insufficient to produce the quality specification for the oil stipulated by the ISI. The oil obtained at intervals of 90 days and above satisfied the ISI specifications with respect to all the physico-chemical properties.

The yield of oil decreases considerably as the interval increase above 65 days. The improvement in quality and the consequent increase in returns is offset by the decrease in yield beyond 85 days.

The economics worked out for different levels of P application showed that the maximum net profit is obtained for the stabilised crop (second year) with the application of P_2O_5 at 50 kg per hectare.

The return per rupee investment is maximum for a harvest interval of 85 days (Rs. 2.60). The harvest interval of 65 days gave a slightly lesser return (Rs.2.43) per rupee invested. However, it entails an earlier return of profit in view of the shorter interval of harvest, thus offsetting the slight decrease in the net return.

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*Originals not seen

APPENDICES

APPENDIX I

Meteorological observations during the years from 1980-1984

Month	Mean maximum temperature °C				Mean minimum temperature °C				Rain fall in mm				Relative humidity (%)			
	1980-81	1981-82	1982-83	1983-84	1980-81	1981-82	1982-83	1983-84	1980-81	1981-82	1982-83	1983-84	1980-81	1981-82	1982-83	1983-84
April	33.2	33.4	33.9	34.3	23.9	23.9	25.3	24.3	157.3	149.7	94.7	51.9	88.2	77.4	75.5	70.9
May	32.4	32.1	32.1	31.6	24.0	23.5	24.1	24.4	149.0	249.7	335.9	141.0	89.1	77.5	79.6	76.9
June	27.0	26.9	27.8	29.6	22.7	22.1	22.5	23.1	1004.7	1055.8	697.3	408.7	88.4	85.4	84.4	80.3
July	26.9	26.7	27.9	27.6	21.8	22.1	22.2	22.3	1278.1	624.2	651.4	857.4	89.7	87.7	85.6	84.3
August	27.2	27.1	27.0	26.6	22.0	22.1	21.9	22.2	620.3	524.2	537.6	734.5	89.6	90.9	88.7	83.4
September	29.3	27.8	29.3	27.6	22.6	22.4	21.7	22.3	147.0	645.4	77.5	419.5	90.0	88.6	87.9	83.2
October	30.4	29.4	30.6	29.6	22.1	22.4	21.9	22.2	565.9	273.1	339.6	205.8	89.8	88.7	88.6	87.4
November	30.4	29.9	30.9	30.0	22.4	21.8	22.0	21.4	280.8	171.0	132.0	263.4	89.1	91.2	88.7	86.9
December	31.3	31.6	32.2	31.3	21.1	20.5	18.2	21.7	11.0	44.0	4.2	94.1	85.0	87.0	86.3	85.2
January	32.2	33.2	33.5	31.2	20.3	19.9	18.0	20.8	0.0	0.0	0.0	69.4	85.0	84.9	83.9	82.7
February	33.5	33.7	34.0	32.2	20.4	20.9	21.8	21.7	0.0	34.0	0.0	135.2	84.2	78.9	80.6	82.3
March	35.2	35.1	35.2	35.2	22.3	22.4	22.4	22.9	78.8	43.8	12.7	0.0	84.1	81.9	78.9	81.1

APPENDIX II

Analysis of variance for total number of tillers and height of the plant

Source	df	Mean squares					
		Total number of tillers			Height of the plant		
		1980-81	1981-82	Mean for two years	1980-81	1981-82	Mean for years
Block	8	79.4**	20.1	28.9	1313.6**	552.4**	852.0**
N	2	11.1	5.5	7.5	39.6	67.6	47.7
P	2	[illegible].0	40.4	34.7	253.4	489.4**	374.5**
K	2	2.8	18.7	7.0	271.0	242.9	212.0
NP	4	27.3	13.2	15.1	332.8*	333.8**	311.1**
NK	4	10.4	19.0	14.3	152.7	158.00	146.4
PK	4	32.0	27.6	25.0	162.3	58.80	89.9
H	5	34.6*	66.0*	55.7*	2176.3**	13162.1**	5820.9**
NH	10	16.7	9.9	12.2	160.3	156.9	101.2
PH	10	15.1	22.6	17.9	169.9	157.3	128.1
KH	10	12.3	13.6	6.7	48.7	84.8	51.7
NPK	2	10.5	9.0	5.2	240.5	5.3	44.4
NP^2K	2	2.2	1.6	0.1	232.3	44.9	32.1
NP^2K^2	2	37.2	20.0	25.8	158.7	91.8	5.0
Error	94	13.9	24.2	12.7	115.8	83.1	71.1

*Significant at 5 per cent level

**Significant at 1 per cent level

APPENDIX III

Analysis of variance for length of inflorescence, number of tillers with inflorescence and number of tillers without inflorescence

Source	df	Mean squares								
		Length of inflorescence			Number of tillers with inflorescence			Number of tillers without inflorescence		
		1980-81	1981-82	Mean for two years	1980-81	1981-82	Mean for two years	1980-81	1981-82	Mean for two years
Block	8	99.1**	12.6	54.7**	10.6**	1.4	2.3	81.0**	23.8	35.0**
N	2	0.2	13.7	1.2	5.3	9.2	5.6	8.9	20.0	11.1
P	2	74.9**	10.7	53.3**	5.7	28.2*	15.2**	22.4	5.5	5.4
K	2	25.5	0.2	4.2	1.2	1.2	0.9	2.9	31.1	11.2
NP	4	46.2	4.6	19.6	8.3	11.8	6.6	27.9	11.9	12.9
NK	4	18.0	22.4	19.5	1.4	5.7	1.3	6.9	13.5	6.3
PK	4	21.6	15.5	5.0	7.9	3.7	2.3	20.2	30.1	23.5
H	5	259.6**	924.0	451.1	92.6**	154.8**	115.8**	50.4**	227.2**	103.0**
NH	10	25.4	28.7	13.5	2.4	2.9	1.3	9.5	6.3	5.6
PH	10	19.0	7.7	9.0	6.5	10.1	3.5	11.5	20.2	13.4
KH	10	14.1	19.1	10.7	5.6	1.5	1.6	8.3	13.8	6.3
NPK	2	9.5	2.4	3.8	4.4	1.0	0.2	13.1	31.8	2.0
NP^2K	2	53.3	0.3	8.0	5.4	4.6	0.6	6.1	8.1	2.7
NP^2K^2	2	11.2	1.1	2.7	2.1	5.7	0.2	24.2	36.9	26.5
Error	94	17.3	12.4	9.5	3.8	6.0	2.8	12.8	17.7	8.2

*Significant at 5 per cent level

**Significant at 1 per cent level

APPENDIX IV

Analysis of variance for herbage yield and oil yield

Source	df	Mean squares					
		Herbage yield			Oil yield		
		1980-81	1981-82	Total for two years	1980-81	1981-82	Total for two years
Block	8	100.84**	205.61**	561.8**	676.68**	897.37**	2359.95**
N	2	15.15**	24.51	70.8	59.38	188.85	246.4
P	2	70.98**	156.16**	500.2**	619.92**	716.06**	2476.2**
K	2	4.68	65.30*	82.8**	24.98	4.26	20.2
NP	4	7.36*	8.48	43.1	148.29**	209.39	586.6*
NK	4	1.36	51.50*	36.4	55.60	176.63	161.2
PK	4	4.66	26.16	40.2	42.22	132.64	123.7
H	5	27.93**	227.97**	396.3**	652.93**	5345.50**	9513.8**
NH	10	4.67	17.16	26.7	53.20	217.81	234.5
PH	10	3.27	17.16	30.7	40.17	215.06	357.7*
KH	10	1.77	25.33	31.1	20.21	190.33	196.1
NPK	2	4.27	43.78	45.7	9.67	85.23	77.0
NP^2K	2	4.35	24.50	23.8	26.55	10.35	0.66
NP^2K^2	2	10.57	0.06	22.2	30.82	126.64	104.20
Error	94	3.10	17.34	23.4	40.33	109.22	168.60

*Significant at 5 per cent level

**Significant at 1 per cent level

APPENDIX V

Analysis of variance for oil content and dry matter yield

Source	df	Mean squares: Oil content 1980-81	Oil content 1981-82	Oil content Mean for two years	Dry matter yield 1980-81	Dry matter yield 1981-82	Dry matter yield Total for two years
Block	8	4.430×10^{-3}**	6.905×10^{-3}**	4.695×10^{-3}**	10.890**	10.321**	41.813**
N	2	1.831×10^{-3}	2.020×10^{-4}	8.056×10^{-4}	2.219**	3.548	7.412*
P	2	3.978×10^{-4}	6.161×10^{-4}	2.249×10^{-5}	8.490**	10.877**	38.914**
K	2	2.193×10^{-3}	3.475×10^{-3}	39.28×10^{-4}**	1.040	3.860	7.153
NP	4	1.541×10^{-3}	2.546×10^{-4}	9.642×10^{-4}	0.793	1.707	4.784
NK	4	1.603×10^{-3}	8.525×10^{-4}	4.650×10^{-4}	0.141	2.708	2.875
PK	4	2.002×10^{-3}	5.332×10^{-4}	12.520×10^{-4}*	0.592	1.838	3.286
H	5	14.230×10^{-3}	32.260×10^{-3}	20.640×10^{-3}	20.517**	93.179**	191.713**
NH	10	5.091×10^{-4}	5.973×10^{-4}	5.137×10^{-4}	0.642	1.431	3.433
PH	10	8.685×10^{-4}	7.214×10^{-4}	3.800×10^{-4}	0.493	1.806	3.797
KH	10	5.269×10^{-4}	4.338×10^{-4}	3.016×10^{-4}	0.227	1.999	2.683
NPK	2	4.734×10^{-4}	1.539×10^{-4}	2.697×10^{-4}	0.574	1.827	2.171
NP^2K	2	5.662×10^{-4}	7.861×10^{-4}	5.663×10^{-4}	0.712	1.642	2.379
NP^2K^2	2	3.828×10^{-4}	2.020×10^{-3}	14.120×10^{-4}	1.179	0.419	2.514
Error	94	1.001×10^{-3}	5.999×10^{-4}	4.477×10^{-4}	0.376	1.268	2.309

*Significant at 5 per cent level

**Significant at 1 per cent level

APPENDIX VI

Analysis of variance for geraniol and geranyl acetate content in the oil (1981-82) determined by GLC

Source	df	Mean squares: Geraniol content in the first year	Mean squares: Geranyl acetate content in the first year
Block	8	50.80	34.46
N	2	89.62	55.44
P	2	10.79	6.51
K	2	29.57	3.53
NP	4	68.45	55.62
NK	4	71.13	52.85
PK	4	35.37	21.26
H	5	379.92**	474.26**
NH	10	49.08	27.91
PH	10	99.99	59.35
KH	10	76.82	63.40
NPK	2	19.03	2.14
NP^2K	2	173.83	100.84
NP^2K^2	2	15.29	12.19
Error	94	52.91	35.64

**Significant at 1 per cent level

APPENDIX VII

Analysis of variance for specific gravity and refractive index of oil, 1981-82

Source	df	Mean squares					
		Specific gravity at 30°C			Refractive index at 30°C		
		Monsoon season 1981-82	Summer season 1981-82	Mean for two seasons	Monsoon season 1981-82	Summer season 1981-82	Mean for two seasons
Block	8	2.800×10^{-5}	1.980×10^{-6}	1.651×10^{-1}	4.18×10^{-6}**	1.300×10^{-6}**	3.100×10^{-6}**
M	2	3.370×10^{-5}	2.097×10^{-5}*	4.862×10^{-6}	1.52×10^{-6}*	2.690×10^{-7}	7.100×10^{-7}
P	2	4.442×10^{-5}	2.278×10^{-5}*	2.504×10^{-5}	2.50×10^{-9}	2.300×10^{-8}	1.600×10^{-8}
K	2	3.556×10^{-5}	6.205×10^{-7}	4.665×10^{-6}	4.57×10^{-7}	8.460×10^{-7}	8.200×10^{-7}
MP	4	8.824×10^{-5}*	1.363×10^{-5}*	2.853×10^{-5}*	7.34×10^{-7}	3.615×10^{-7}	6.300×10^{-7}
MK	4	2.323×10^{-5}	1.405×10^{-5}*	9.248×10^{-6}	4.92×10^{-7}	8.000×10^{-8}	4.400×10^{-7}
PK	4	2.717×10^{-5}	1.117×10^{-5}	1.147×10^{-5}	1.01×10^{-6}	3.138×10^{-7}	8.900×10^{-7}
H	5	7.378×10^{-5}*	1.229×10^{-5}	2.824×10^{-5}*	3.53×10^{-6}**	15.016×10^{-6}**	1.290×10^{-5}**
MH	10	3.858×10^{-5}	6.777×10^{-6}	1.460×10^{-5}	2.60×10^{-7}	1.302×10^{-7}	2.000×10^{-7}
PH	10	2.146×10^{-5}	2.130×10^{-6}	8.709×10^{-6}	5.04×10^{-7}	4.312×10^{-7}	5.200×10^{-7}
KH	10	2.725×10^{-5}	7.761×10^{-6}	1.127×10^{-5}	2.84×10^{-7}	1.901×10^{-7}	2.900×10^{-7}
MPK	2	6.572×10^{-5}	8.052×10^{-6}	1.403×10^{-5}	1.08×10^{-6}	9.150×10^{-8}	2.200×10^{-7}
MP^2K	2	2.211×10^{-5}	2.236×10^{-6}	4.975×10^{-6}	2.54×10^{-7}	2.700×10^{-8}	4.300×10^{-8}
MP^2K^2	2	1.328×10^{-5}	5.080×10^{-6}	6.393×10^{-6}	6.95×10^{-7}	5.900×10^{-7}	7.100×10^{-7}
Error	94	2.899×10^{-5}	5.419×10^{-6}	10.205×10^{-6}	4.39×10^{-7}	3.829×10^{-7}	4.000×10^{-7}

*Significant at 5 per cent level

**Significant at 1 per cent level

APPENDIX VIII

Analysis of variance for optical rotation and solubility in 70% alcohol of the oil, 1981-82

Source	df	Mean squares					
		Optical rotation			Solubility in 70% alcohol		
		Monsoon season	Summer season	Mean for two seasons	Monsoon season	Summer season	Mean for two seasons
Block	8	1.748**	1.426**	1.461**	$7.9x10^{-3}$	$8.3x10^{-3}$	$9.2x10^{-3}$
N	2	0.417	0.164	0.581	$6.0x10^{-3}$	$8.0x10^{-4}$	$5.4x10^{-3}$
P	2	0.221	00207	0.263	$2.5x10^{-3}$	$1.9x10^{-3}$	$1.4x10^{-3}$
K	2	0.245	0.404	0.388	$7.7x10^{-3}$	$1.2x10^{-3}$	$6.1x10^{-3}$
NP	4	0.379	0.358	0.331	$6.2x10^{-3}$	$6.0x10^{-3}$	$7.1x10^{-3}$
NK	4	0.312	0.340	0.335	$2.5x10^{-4}$	$3.6x10^{-3}$	$1.2x10^{-3}$
PK	4	0.096	0.066	0.017	$1.7x10^{-3}$	$3.6x10^{-3}$	$2.7x10^{-3}$
H	5	1.019*	0.950*	1.248**	$9.7x10^{-2}$**	$6.9x10^{-2}$**	$7.9x10^{-2}$**
NH	10	0.285	0.508	0.444	$7.2x10^{-3}$	$6.7x10^{-3}$	$8.2x10^{-3}$
PH	10	0.290	0.687	0.405	$3.5x10^{-3}$	$4.4x10^{-3}$	$7.6x10^{-3}$
KH	10	0.173	0.187	0.262	$4.7x10^{-3}$	$6.8x10^{-3}$	$4.1x10^{-3}$
NPK	2	0.054	0.266	0.162	$1.7x10^{-2}$	$4.0x10^{-4}$	$1.0x10^{-2}$
NP^2K	2	0.053	0.696	0.291	$1.3x10^{-2}$	$1.2x10^{-3}$	$4.1x10^{-3}$
NP^2K^2	2	0.151	0.077	0.121	$7.5x10^{-3}$	$9.1x10^{-3}$	$8.2x10^{-3}$
Error	94	0.303	0.302	0.332	$7.3x10^{-3}$	$4.3x10^{-3}$	$6.7x10^{-3}$

*Significant at 5 per cent level
**Significant at 1 per cent level

APPENDIX IX

Analysis of variance for acid value and saponification value of the oil, 1981-82

Source	df	Mean squares					
		Acid value			Saponification value		
		Monsoon season 81-82	Summer season 81-82	Mean for two seasons	Monsoon season 81-82	Summer season 81-82	Mean for two seasons
Block	8	24.23*	2.99*	12.66*	253.4**	437.0**	360.8**
N	2	8.62	1.71	4.07	395.7**	989.4**	708.4**
P	2	3.36	1.97	4.55	486.5**	259.7	321.2*
K	2	2.93	0.49	0.22	31.3	169.9	76.9
NP	4	18.93	1.94	8.71	178.7*	586.4**	315.2**
NK	4	13.43	1.88	8.97	33.0	61.5	29.1
PK	4	15.94	2.27	9.23	66.4	64.6	130.7
H	5	14.46	1.35	4.41	2828.9**	5044.4**	3721.6**
NH	10	9.96	1.08	4.36	51.5	59.9	32.7
PH	10	6.36	0.57	2.36	27.2	94.3	41.8
KH	10	19.35	0.54	5.06	41.3	138.9	34.3
NPK	2	18.45	1.61	0.21	25.9	57.7	34.0
NP^2K	2	0.87	0.54	0.09	83.2	30.2	48.7
NP^2K^2	2	15.03	1.78	0.33	178.7	7.1	26.8
Error	94	9.39	1.22	4.87	49.4	142.9	71.7

*Significant at 5 per cent level

**Significant at 1 per cent level

APPENDIX X

Analysis of variance for ester value and ester content of oil, 1981-82

Source	df	Mean squares					
		Ester value			Ester content		
		Monsoon season 81-82	Summer season 81-82	Mean for two seasons	Monsoon season 81-82	Summer season 81-82	Mean for two seasons
Block	8	215.6**	426.0**	350.4**	26.12**	24.34	24.21**
N	2	345.3**	969.4**	696.4**	43.15**	85.88**	67.69**
P	2	454.2**	237.4	301.3	52.32**	32.58	46.50**
K	2	28.1	159.8	69.4	3.33	18.92	10.25
NP	4	169.4**	584.2**	298.6**	18.85*	60.24**	35.32**
NK	4	32.1	58.3	44.2	6.86	3.16	2.42
PK	4	67.6	49.6	120.7	17.16	6.57	12.36
H	5	2634.2**	4876.7**	3621.4**	333.87**	578.54**	429.16**
NH	10	48.3	90.3	28.6	7.40	9.66	4.49
PH	10	24.7	127.8	50.6	2.85	11.89	6.49
KH	10	39.4	56.3	30.7	5.49	13.22	4.73
NPK	2	24.3	27.4	32.1	2.45	11.33	2.92
NP^2K	2	80.6	5.2	45.6	10.35	8.23	7.81
NP^2K^2	2	74.6	136.7	25.4	17.50	21.45	4.03
Error	94	46.3	139.7	68.7	5.85	13.74	7.25

*Significant at 5 per cent level

**Significant at 1 per cent level

APPENDIX XI

Analysis of variance for saponification value after acetylation and total alcohol content of oil, 1981-82

Source	df	Mean squares: Saponification value after acetylation – Monsoon season 81-82	Saponification value after acetylation – Summer season 81-82	Saponification value after acetylation – Mean for two seasons	Total alcohol – Monsoon season 81-82	Total alcohol – Summer season 81-82	Total alcohol – Mean for two season
Block	8	99.42**	92.37**	64.74**	6.2	11.6**	8.4
N	2	38.29	6.70	13.20	11.0	5.0	6.9
P	2	16.30	39.86	25.20	9.0	7.5	7.1
K	2	4.74	6.85	0.13	1.6	0.9	0.2
NP	4	44.55	23.37	26.80	4.1	1.5	1.7
NK	4	22.61	10.90	11.60	5.9	2.2	3.4
PK	4	15.00	24.87	13.80	2.1	2.8	1.2
H	5	108.34*	155.00**	133.40**	4.2	4.2	3.5
NH	10	31.86	22.49	25.40	5.1	3.3	3.3
PH	10	23.39	37.33	28.70	3.3	4.6	3.0
KH	10	14.41	39.92	26.00	2.2	8.5	4.4
NPK	2	20.59	5.37	8.10	5.9	1.9	3.5
NP^2K	2	1.10	64.37	15.90	0.1	5.3	1.7
NP^2K^2	2	47.30	19.24	27.90	8.1	1.9	2.5
Error	94	34.04	26.69	25.70	5.6	4.0	3.6

*Significant at 5 per cent level

**Significant at 1 per cent level

APPENDIX XII

Analysis of variance for free alcohol and combined alcohol content of oil, 1981-82

Source	df	Mean squares: Free alcohol			Combined alcohol		
		Monsoon season 81-82	Summer season 81-82	Mean for two seasons	Monsoon season 81-82	Summer season 81-82	Mean for two seasons
Block	8	29.2**	37.6*	51.0**	19.7**	13.8	19.5*
N	2	73.2**	104.6**	77.4**	28.1*	67.6**	56.1**
P	2	71.7**	49.8*	51.9**	11.7	23.0	28.4 *
K	2	3.5	3.5	10.8	9.7	8.9	5.2
NP	4	9.5	59.7**	12.9	10.4	63.3**	12.4
NK	4	7.5	3.5	7.7	15.2	0.9	10.8
PK	4	14.2	1.7	6.6	8.4	6.9	4.7
H	5	215.1**	332.9**	237.0**	163.2**	366.0**	231.8**
NH	10	11.2	8.9	4.6	5.7	8.2	12.5
PH	10	7.6	12.0	9.0	0.9	11.5	5.6
KH	10	7.3	23.1	7.8	2.1	9.3	8.7
NPK	2	17,1	7.3	8.4	3.6	6.2	3.3
NP^2K	2	6.0	8.0	9.5	0.9	1.2	7.1
NP^2K^2	2	43.3	18.0	3.0	20.4	12.4	4.7
Error	94	9.9	15.0	8.2	7.0	8.5	8.6

*Significant at 5 per cent level

**Significant at 1 per cent level

APPENDIX XIII

Analysis of variance for geraniol and geranyl acetate content of oil, 1981-82, determined by GLC and geraniol yield

Source	df	Mean squares				
		Geraniol	Geranyl acetate	Geraniol yield 1980-81	Geraniol yield 1981-82	Geraniol yield Total
Block	8	70.06*	26.18*	473.60**	629.62**	1648.22**
N	2	17.96	29.14	41.57	112.20	162.25
P	2	45.96	8.67	412.21**	680.92**	1659.41**
K	2	6.39	12.41	15.92	3.16	18.12
NP	4	58.16	31.48*	82.89	255.41*	396.41*
NK	4	86.78*	32.45*	40.41	112.61	110.23
PK	4	90.77*	6.50	25.21	96.46	86.41
H	5	289.68**	595.45**	420.16**	4149.61**	6216.44**
NH	10	61.55	15.47	50.16	200.81	221.42
PH	10	34.14	19.37	30.16	150.15	257.61
KH	10	46.52	22.12	25.42	200.67	400.21
NPK	2	12.01	13.47	15.61	16.21	12.47
NP^2K	2	28.37	2.46	18.45	14.31	9.11
NP^2K^2	2	46.74	27.53	40.31	100.46	99.47
Error	94	31.18	12.25	40.16	100.37	150.41

*Significant at 5 per cent level

**Significant at 1 per cent level

APPENDIX XIV

Analysis of variance for nitrogen, phosphorus and potassium content of the plant

Source	df	Mean squares: Nitrogen content 1980-81	Nitrogen content 1981-82	Nitrogen content Mean for two years	Phosphorus content 1980-81	Phosphorus content 1981-82	Phosphorus content Mean for two years	Potassium content 1980-81	Potassium content 1981-82	Potassium content Mean for two years
Block	8	0.122**	0.153**	0.013**	1.3×10^{-3}	2.0×10^{-3}*	7.4×10^{-3}**	1.15**	0.23*	0.10
N	2	0.115**	0.019	0.080**	0.7×10^{-3}	0.6×10^{-3}	1.0×10^{-3}	0.34	0.04	0.16
P	2	0.002	0.028	0.013	3.4×10^{-3}**	4.0×10^{-3}**	3.6×10^{-3}**	0.19	0.12	0.02
K	2	0.007	0.041	0.020	0.8×10^{-3}	4.0×10^{-3}**	2.0×10^{-3}	0.55*	0.82**	0.71**
NP	4	0.068**	0.057*	0.047**	3.3×10^{-3}**	0.6×10^{-3}	2.1×10^{-3}	1.36**	0.74**	0.93**
NK	4	0.056**	0.036	0.019*	1.2×10^{-3}	2.0×10^{-3}	1.8×10^{-3}	0.56**	0.08	0.24*
PK	4	0.025*	0.035	0.018*	2.1×10^{-3}*	1.0×10^{-3}*	1.4×10^{-3}	0.03	0.38**	0.14
H	5	0.089**	0.112**	0.108**	2.1×10^{-3}*	4.0×10^{-3}**	3.1×10^{-3}**	0.93**	1.01**	0.93**
NH	10	0.014	0.013	0.010	0.6×10^{-3}	0.7×10^{-3}	0.6×10^{-3}	0.06	0.22*	0.07
PH	10	0.019	0.016	0.010	0.8×10^{-3}	0.2×10^{-3}	0.7×10^{-3}	0.05	0.06	0.04
KH	10	0.005	0.022	0.005	0.5×10^{-3}	0.6×10^{-3}	0.6×10^{-3}	0.15	0.10	0.10
NPK	2	0.011	0.097	0.013	0.2×10^{-3}	0.9×10^{-3}	0.7×10^{-3}	0.10	0.22	0.11
NP^2K	2	0.034	0.019	0.027	0.2×10^{-3}	0.3×10^{-3}	0.5×10^{-3}	0.02	0.20	0.04
NP^2K^2	2	0.034	0.056	0.023	0.3×10^{-3}	3.0×10^{-3}	1.5×10^{-3}	0.26	0.08	0.10
Error	94	0.010	0.017	0.007	0.7×10^{-3}	0.7×10^{-3}	0.8×10^{-3}	0.13	0.10	0.07

*Significant at 5 per cent level

**Significant at 1 per cent level

APPENDIX XV

Analysis of variance for calcium and magnesium content of the plant

Source	df	Mean squares: Calcium content 1980-81	Calcium content 1981-82	Calcium content Mean for two years	Magnesium content 1980-81	Magnesium content 1981-82	Magnesium content Mean for two years
Block	8	14.84×10^{-3}**	0.36×10^{-2}	1.38×10^{-2}	7.82×10^{-3}	8.0×10^{-3}	73.0×10^{-3}**
N	2	6.18×10^{-3}	0.92×10^{-2}	0.18×10^{-2}	27.80×10^{-3}**	18.0×10^{-3}**	23.0×10^{-3}**
P	2	7.32×10^{-3}	1.01×10^{-2}	0.18×10^{-2}	6.04×10^{-3}	0.2×10^{-3}	2.0×10^{-3}
K	2	3.53×10^{-3}	0.9×10^{-2}	0.8×10^{-2}	6.32×10^{-3}	4.0×10^{-3}	1.0×10^{-3}
NP	4	9.40×10^{-3}*	0.4×10^{-2}	0.3×10^{-2}	4.46×10^{-3}	5.0×10^{-3}	5.0×10^{-3}**
NK	4	7.94×10^{-3}*	0.7×10^{-2}	0.9×10^{-2}	7.91×10^{-3}**	10.0×10^{-3}**	8.0×10^{-3}**
PK	4	12.41×10^{-3}*	1.2×10^{-2}*	0.9×10^{-2}	4.06×10^{-3}	2.0×10^{-3}	2.0×10^{-3}
H	5	5.72×10^{-3}	0.6×10^{-2}	1.2×10^{-2}	2.90×10^{-3}	8.0×10^{-3}**	5.0×10^{-3}**
NH	10	2.76×10^{-3}	0.8×10^{-2}	0.6×10^{-2}	2.37×10^{-3}	2.0×10^{-3}	1.0×10^{-3}
PH	10	4.61×10^{-3}	0.8×10^{-2}	0.8×10^{-2}	3.96×10^{-3}	3.0×10^{-3}	2.0×10^{-3}
KH	10	2.90×10^{-3}	0.1×10^{-2}	0.3×10^{-2}	2.75×10^{-3}	4.0×10^{-3}	3.0×10^{-3}
NPK	2	3.24×10^{-3}	0.6×10^{-2}	1.4×10^{-2}	22.89×10^{-3}**	25.0×10^{-3}**	23.0×10^{-3}**
NP^2K	2	1.70×10^{-3}	0.9×10^{-2}	0.7×10^{-2}	9.44×10^{-3}	5.0×10^{-3}	4.0×10^{-3}
NP^2K^2	2	10.78×10^{-3}	0.8×10^{-2}	1.4×10^{-2}	0.75×10^{-3}	1.0×10^{-3}	0.2×10^{-3}
Error	94	3.15×10^{-3}	0.4×10^{-2}	0.6×10^{-2}	2.69×10^{-3}	2.0×10^{-3}	1.0×10^{-3}

*Significant at 5 per cent level

**Significant at 1 per cent level

APPENDIX XVI

Analysis of variance for uptake of nitrogen, phosphorus and potassium by the plant

Source	df	Mean squares: Nitrogen uptake 1980-81	Nitrogen uptake 1981-82	Nitrogen uptake Pooled data for two years	Phosphorus uptake 1980-81	Phosphorus uptake 1981-82	Phosphorus uptake Pooled data for two years	Potassium uptake 1980-81	Potassium uptake 1981-82	Potassium uptake Pooled data for two years
Block	8	1416.2**	1516.4**	5019.4**	31.3**	51.0**	154.3**	4864.8**	5543.1	19114.2**
N	2	649.6**	856.5*	2682.8**	9.30**	6.1	1.2	3837.7**	215.54	4623.1
P	2	847.7**	340.5	2116.3**	42.7**	70.6**	205.1**	4532.3**	1574.88	10820.0**
K	2	95.9	1864.2**	2257.7**	6.4*	27.1*	50.3*	1732.4*	11013.72**	21954.0**
NP	4	105.1	256.4	421.5	9.1**	8.5	22.7	1335.6**	4553.18	8499.5**
NK	4	78.9	1285.6**	1117.2*	4.5	19.5*	43.5*	1358.1	1461.74	5127.3
PK	4	58.3	439.6	689.3	4.3	4.5	27.7	509.3	2817.89	4199.7
H	5	1470.8**	5531.5**	11874.9**	23.0**	88.2**	222.4**	4267.6**	11545.67**	26779.8**
NH	10	112.5	300.1	703.8	5.3**	6.5	12.6	389.0	1117.24	1552.5
PH	10	58.8	284.1	556.0	4.8*	4.1	14.6	260.7	1118.13	2285.4
KH	10	33.6	344.8	477.9	2.2	10.1	15.6	477.8	1172.01	2687.3
NPK	2	11.6	107.2	44.3	0.1	17.7	16.6	645.0	3791.63	5218.3
NP^2K	2	106.0	218.1	429.5	2.9	9.5	14.2	490.4	196.28	241.0
NP^2K^2	2	507.3	272.8	1131.5	5.3	14.6	25.7	526.7	889.52	1844.5
Error	94	70.5	236.9	419.7	2.0	6.9	12.7	487.4	1901.91	2081.8

*Significant at 5 per cent level

**Significant at 1 per cent level

APPENDIX XVII

Analysis of variance for uptake of calcium and magnesium by the plant

Source	df	Mean squares					
		Calcium uptake			Magnesium uptake		
		1980-81	1981-82	Pooled data for two years	1980-81	1981-82	Pooled data for two years
Block	3	281.0**	281.6**	1037.1**	157.9**	249.7**	769.5**
N	2	100.4**	370.3**	5[illegible]6.3**	66.0**	260.3**	559.2**
P	2	247.9**	350.9**	1241.1**	76.4**	86.1**	293.0**
K	2	144.6*	100.6	270.1*	12.7	53.1	40.6
NP	4	16.6	55.1	145.6	22.4	30.6	89.6
NK	4	34.7	43.5	76.7	13.8	138.1**	215.7**
PK	4	48.9	35.0	94.9	9.6	4.8	25.6
H	5	107.3*	690.8**	1343.9**	163.7**	730.2**	1512.2**
NH	10	23.4	104.6*	159.8	14.4	23.2	58.2
PH	10	41.1	43.4	83.6	4.6	18.5	26.4
KH	10	12.6	42.1	77.1	8.6	56.9	82.7
NPK	2	42.1	22.9	14.0	70.8**	255.0**	581.8**
NP^2K	2	1.7	27.7	112.8	40.9	105.3	195.1
NP^2K^2	2	16.6	95.9	64.4	9.2	37.7	82.3
Error	94	35.4	42.9	81.8	10.4	28.6	55.4

*Significant at 5 per cent level

**Significant at 1 per cent level

APPENDIX XVIII

Analysis of variance for total nitrogen, available P_2O_5 and available K_2O content of the soil after two years of the experiment

Source	df	Mean squares Total N	Available P_2O_5	Available K_2O
Block	8	21313.61**	470.42	288.60
N	2	3816.94	18.96	72.42
P	2	2514.64	1052.63*	36.94
K	2	2619.75	2042	272.73
NP	4	1916.48	48.61	150.15
NK	4	1012.63	40.23	130.46
PK	4	846.20	52.41	250.20
H	5	6819.74**	60.36	120.21
NH	10	1246.61	26.24	57.05
PH	10	1216.46	52.31	150.92
KH	10	842.65	34.73	62.47
NPK	2	1512.62	22.21	110.13
NP^2K	2	2032.43	18.47	52.41
NP^2K^2	2	1942.17	36.23	20.60
Error	94	2824.12	302.85	680.25

*Significant at 5 per cent level

**Significant at 1 per cent level

INFLUENCE OF APPLIED NUTRIENTS AND STAGE OF HARVEST ON THE YIELD AND PHYSICO-CHEMICAL PROPERTIES OF ESSENTIAL OIL OF PALMAROSA (*Cymbopogon martini* Stapf var. motia)

By

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ABSTRACT OF THE THESIS

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ABSTRACT

Palmarosa, an essential oil crop introduced in Kerala from Maharashtra, nearly two decades ago, is spreading steadily in the plains and midland regions of North Kerala. Several agro-techniques have yet to be standardised for the commercial cultivation of this crop in the State. The present studies were undertaken at the Aromatic and Medicinal Plants Research Station, Odakkaly during 1980-'84 to obtain information on the nutrition of palmarosa, optimum harvest intervals to ensure maximum herbage and oil yields and the factors influencing the quality of oil.

The treatments in the major field experiment (1980-'82) consisted of three levels of N, P_2O_5 and K_2O, each at 25, 50 and 75 kg/ha along with six intervals of harvest at 40, 45, 50, 55, 60 and 65 days. The total number of treatment combinations were 162 in a 3^3 x 6 confounded asymmetrical factorial design. The main experiment was continued for another two years limiting the observations, to the yield of herbage and oil. This was then followed by an observation trial with intervals of harvest longer than the maximum of 65 days tried in the main experiment.

In the main experiment the herbage yield was significantly increased by application of P_2O_5 and K_2O. Nitrogen did not have any significant effect on herbage yield possibly due to the medium level status of soil N in the

experimental plots. The oil yield was significantly enhanced by P_2O_5 application at 50 kg/ha. Different levels of N and K showed no significant influence on the yield of oil.

Harvest intervals showed significant influence on herbage yield, oil yield and oil content and the maximum value was recorded by the 65 day interval.

A path analysis of the herbage yield with related characters has shown that the height of the plant is the most important yield attribute influencing directly the yield of herbage.

Path analysis of oil yield showed that oil yield is mainly dependent upon herbage yield. The direct effects on oil yield by yield attributes are found to be in the decreasing order of number of tillers with inflorescence, height of the plants and length of inflorescence. Maximum indirect effect via herbage yield is expressed by the height of the plant and length of inflorescence. All these directly and indirectly contributing factors are seen to be markedly influenced by the application of phosphorus and intervals of harvest.

Herbage yield and oil yield for various harvest intervals obtained in the first two years were fitted in a Cobb-Doughlus response function and the expected values calculated were found to be very close to the actual observed values.

In the third and fourth year of the experiment, the highest herbage and oil yields were recorded by 60 day interval followed by the interval of 65 days. A quadratic function for the data pooled over for four years was fitted to see if the data show a diminishing return with an increase in harvest interval and it was found that the optimum herbage yield and oil yield were obtained when the harvest was done at 62 and 63 days interval respectively. The final observational trial also indicated that the herbage and oil yields were maximum for a harvest interval of 65 days beyond which it decreases.

Increase in the levels of both N and P tended to increase the content of geraniol and to decrease the content of geranyl acetate which are the price determining quality attributes of the essential oil. But the maximum interval of harvest viz., 65 days tried in the main experiment was not sufficient for most of the physico-chemical properties of oil such as specific gravity, refractive index, geraniol content, geranyl acetate content etc. to reach the minimum limit prescribed by ISI. The observational trial showed that the oil obtained at intervals of 95 days and above satisfied the ISI specification with respect to all the physico-chemical properties of the oil. However, at this harvest interval the yield itself was considerably depressed as compared to the yield at 65 day interval.

The economics worked out for different intervals of harvest based on the current market price of the oil passing above the ISI limits as Rs. 240/- per kg (oil from harvest intervals at and above 95 days) and those below them at Rs.220/- per kg (oil from harvest intervals of 55, 65, 75 and 85 days) it has been found that a wider cost benefit ratio and net return per rupee investment are obtainable for harvest intervals ranging from 65 to 85 days. However, 65 day interval has the advantage of early returns from the investment. Application of 50 kg P_2O_5/ha in view of its significant effect on herbage yield, oil yield and oil quality increase the net profit per rupee invested for the harvest interval of 65 days.

The average removal of N, P, K, Ca and Mg from the soil by palmarosa per hectare per year has also been worked out. The optimum fertilizer level for palmarosa is 25 kg N, 50 kg P_2O_5 and 25 kg K_2O per hectare over an application of spent grass at 5 tonnes per hectare per year. The optimum harvest interval is 65 days. This would give maximum herbage yield, oil yield and early return from investments.