

**EFFECT OF NITROGEN, PHOSPHORUS, POTASSIUM AND
HERBICIDE APPLICATIONS ON PRODUCTION AND
OIL QUALITY OF CITRONELLA JAVA**

(Cymbopogon winterianus Jowitt)

THESIS
SUBMITTED TO THE
BIDHAN CHANDRA KRISHI VISWAVIDYALAYA
FOR THE AWARD OF THE DEGREE OF DOCTOR OF PHILOSOPHY
IN
AGRICULTURAL CHEMISTRY AND SOIL SCIENCE

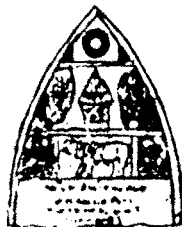
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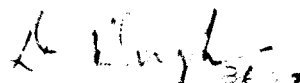
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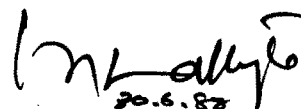
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CERTIFICATE

This is to certify that the work recorded in the Thesis entitled "Effect of nitrogen, phosphorus, potassium and herbicide applications on production and oil quality of citronella Java (Cymbopogon winterianus Jowitt)" submitted by Sri Kambod Singh for the award of the degree of Doctor of Philosophy in Agricultural Chemistry and Soil Science of the Bidhan Chandra Krishi Viswavidyalaya, is a bonafied research work carried out under our supervision and guidance. The results of the investigation represented in the thesis have not so far been submitted for any other degree or diploma. The assistance and help received during the course of investigation have been duly acknowledged.


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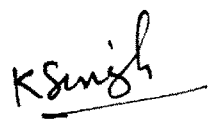
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ABSTRACT

Three field experiments were conducted during 1983-86 on sandy loam soil of research farm, of the Central Institute of Medicinal and Aromatic Plants, Lucknow to study the effect of different weed control measures, levels of N, levels of P_2O_5 and K_2O (along with methods of K applications) at 250 kg N / ha, on growth, oil yield and quality of citronella Java (Cymbopogon winterianus Jowitt.).

Fresh herbage yields were in general, maximum at fourth cutting (Apr-Jun) and minimum in second cutting (Oct-Dec); the low amount of growth was recorded during first three cuttings in first harvest year.

Oil yield increased significantly upto the application of 200 kg N / ha in both the years. The quality and oil content were not affected due to weed control measures and levels of nitrogen.

The optimum economic doses (kg N / ha) and yields (kg / ha) in first harvest year were 160 & 256, 156 & 190 and 137 & 224 in weed free, weedy and Diuron treated plots; in second harvest year the respective values were 176 & 341, 158 & 272 and 122 & 307. The net return was maximum (Rs.3,840/-) in weed free followed by diuron (Rs.3,588/-)

treated plots in first harvest year, whereas in second harvest year, the respective values were Rs.4,023/- and Rs.4,024/-.

The net return per rupee investment on N- fertilizer application at the optimum dose of nitrogen were Rs.4.80, Rs.2.80 and Rs.5.20 in the weed free, weedy and diuron treated plots in first harvest year and the corresponding values in second harvest year were Rs.4.60, Rs.5.10 and Rs.6.60.

Growth of herbage and oil yields of citronella grass were also significantly influenced by phosphatic fertilization; at 50 kg P_2O_5 / ha it significantly caused 18.7 and 12.4 percentage increases in oil yield in first and second harvest years. From the response curve the optimum dose was found to be 80.2 and 81.2 kg P_2O_5 / ha during the first and second harvest years, respectively. The returns for only rupee investment on phosphatic fertilizer applied at optimum doses in the first and second harvest years were Rs.3.70 and Rs.6.80, respectively.

Optimum dose of K for maximum crop growth and yield differed with the methods of application, when K was applied basally, the optimum dose was found to be about 75 kg K_2O /ha.

while it was 100 kg / ha with split application. The optimum economic doses (K_2O kg / ha) and yields (kg / ha) deducted from response curves in the first harvest year, were 159 & 234; 253 & 298; 87 & 247 in basal two, three and four split application whereas in second harvest year, the corresponding values were 100 & 302, 262 & 422, 108 & 377 and 71 & 393, respectively. The net returns per rupee invested on K fertilizer only were high in four splits, Rs.37.40 and Rs.51.03 during first and second harvest years, respectively. With basal application of K_2O net return values per rupee investment were Rs.10.63 and Rs.16.21 during first and second harvest years.

N : K ratio was slightly higher than one at 4th cutting (Oct-Nov) and slightly lower than one in first cutting, when crops received 250 kg N and 50 to 100 kg K_2O / ha.

The oil content and quality of oil were not influenced due to applications of N, P and K. The maximum concentration of citronellal and geraniol was observed in first cutting (Jul-Sep) whereas the citronellol content was high at third cutting (Jan-Mar). Maintenance of the crop under weed free conditions, resulted in maximum crop

growth, oil yield and nutrient uptake followed by Diuron and weedy treatments.

The oil content and quality of oil were not affected due to the weed control measures. The reductions in oil yield as compared to those recorded in weed free plots were high in weedy plots and medium in Diuron treated plots. The net returns per rupee investment on Diuron treatment were Rs.13.30 and Rs.14.50 in first and second harvest year. The corresponding values in hand weeding were Rs.1.32 and Rs.1.50, because of high cost of manual labour.

It was concluded that under weed free environment citronella grass should be fertilized with 160 kg N, 80 kg P_2O_5 and 75 kg K_2O / ha in the first harvest year and the corresponding figures in second harvest year would be 176 kg N, 81 kg P_2O_5 and 75 kg K_2O / ha, N and K are to be applied in 3 to 4 split doses.

1. INTRODUCTION

In India, Cymbopogon winterianus Jowitt was introduced in 1959 by National Botanical Research Institute, Lucknow, from Indonesia (Chandra, 1973). Now it is cultivated in the country on a fairly large scale with the production of its oil to the extent of about 800 tonnes per year. Its major production in India comes from tea gardens of Assam, Uttar Pradesh, Maharashtra, West Bengal, Karnataka, Gujarat, Arunachal Pradesh, Manipur, Mizoram, Meghalaya, Nagaland and Tripura (Gupta, 1973; Narayana, ^{et al} 1976 and Virmani et al., 1979). Besides, India, it is also cultivated in South Sumatra, Sri Lanka, Java and Formosa, Guatemala, Honduras, Argentina and Ecuador (Guenther, 1950; CSIR, 1950; Singh and Ganguly, 1972; Virmani et al., 1979).

Citronella Java, a cultivar of Cymbopogon winterianus Jowitt) is a foliage rich grass and on steam distillation of the leaves it yields essential oil, which is a natural source of citronellal, geraniol, citronellol, etc. The oil is widely used for perfuming of soap and other household cleaners, detergents etc. (Jagdish Chandra, 1975a; Virmani et al., 1979).

In spite of high domestic and international demand, the crop has not received its due share of research in evolving appropriate agro-technologies for its cultivation and enhanced productivity. One of the major aspects of improved agro-

technology is the nutritional requirement particularly the major nutrients (N, P and K). The crop itself is unique for having essential oil, a secondary metabolic product, as the economic yield. As the crop is perennial, it requires special attention for the efficient utilization of NPK fertilizers. Moreover, the herbage of the crop is frequently harvested for the extraction of essential oil which creates a situation of continuous nutrient depletion.

Being herbaceous crop where leaves are the economic product, nitrogen is expected to promote the growth and yield of crop. On account of its long duration and frequent herbage removal, supply of N in large quantities may be beneficial to obtain high yields. Research work carried out so far on this aspect in this crop is sketchy ~~extractions~~. The added N in this crop may also be subjected to variety of losses as the crop passes through heavy rains and hot summer seasons.

The crop also require a fair amount of phosphatic and potassic fertilizers for nutritional balance and better growth. Hitherto research information on P and K requirement under high N- levels in this crop is inadequate and it needs special attention. The nutrients, therefore, call for efficient management techniques in a long duration crop like citronella Java.

Application of nitrogenous fertilizer to the crop simultaneously provide congenial conditions for weed growth.

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Added, to this, in North India, a major portion of the yield is harvested during rainy season (Jul - Oct) which is also equally favourable for weed growth. Thus, the crop has to face tough competition from weed. The depletion of nutrients is directly related with degree of weed infestation.

To meet the increasing demand of perfumery and flavouring industries in the country and to create export potential, it is necessary to evolve the appropriate agro-technology particularly fertilizer management for enhancing the production and quality of citronella Java oil domestically. Keeping this in the back ground and the necessity for efficient management of N, P, K fertilizers in view, the present investigation entitled, "Effect of Nitrogen, phosphorus, potassium and herbicide applications on ~~growth~~ production and oil quality of citronella Java (Cymbopogon winterianus Jovitt.) was undertaken with the following objectives :

(i) to work out the optimum nitrogen requirement of citronella Java,

(ii) to study the effect of graded levels of N on yield and quality of citronella oil,

(iii) to find out the optimum phosphorus and potassium requirement of citronella Java at higher levels of N,

(iv) to study the effect of split application of K on growth and productivity of the crop, and

(v) to work out the strategies for weed management in relation to N fertilizer application for maximising the productivity of the crop.

2. REVIEW OF LITERATURE

Citronella Java (*Cymbopogon winterianus* Jowitt) an essential oil bearing grass, is a natural source of citrone-llal, citronellol and geraniol which are widely used in high grade perfume, soap and cosmetic industries. Although the crop was introduced in India during 1959 systematic studies on agro-technology especially nutritional requirements of this new crop remained inadequate. Due to frequent defoliations for the recovery of essential oil during the crop cycle, large requirement of major plant nutrients N, P and K can be expected. In the present investigation, an attempt has been made to find out the N, P and K requirements and management in this crop. The influence of graded levels of N on weed flora and weed management using herbicide has also been investigated. The literature relevant to the above aspects have been reviewed under the following heads :

2.1 Effect of nitrogen on growth and herbage yield

Nitrogen is vital for the various physiological function in plant metabolism. The deficiency of this element is widely prevalent in Indian soils under the cover of tropical climate. Application of N is absolutely essential for improving the growth and yield of the crop.

Chandra et al. (1970) and Chandra (1973) working at Lucknow reported that addition of N is responsible for more

number of tillers and herbage. Ghosh and Chatterjee (1978) noticed maximum number of tillers per plant and growth at the highest level of nitrogen (300 kg N / ha) application. However, at Bangalore, Bommegowda et al. (1983) observed that addition of N upto 150 kg / ha / harvest significantly increased the number of tillers with increasing levels of N. Similarly, Prakasa Rao et al. (1983) from the same place reported that with increasing levels of nitrogen from 0 to 200 kg / ha / yr increased, significantly the total number of tillers / sq.m except in the second and fourth harvest seasons.

Application of 0, 250 and 400 kg N / ha / yr increased the herbage yield significantly 17, 35 and 44 t / ha / yr, respectively under the conditions of Bangalore (Marayana et al., 1975). Similarly, an increase of 50 per cent in herbage yield was recorded with increase in the N rates from 75 to 150 kg N / ha / harvest (Bommegowda et al., 1980). According to Khan and Marayana (1972), Citronella is heavy feeder of N application. They observed that addition of 112.5 kg N / ha along with 15 tonnes of FYM was most profitable for this crop in Bangalore conditions. Singh and Ganguly (1972) advocated that increase in level of N (0, 60, 90 and 120 kg N / ha / yr) significantly increased the herbage yield, but between 90 & 120 kg N / ha there was no significant change in Assam conditions. Ng (1972) observed in soils of Sarawak in East Malaysia 120 kg N / ha as optimum rate which gave 30 t / ha fresh herbage yield. At Lucknow, Chandra (1972) found 200 kg N / ha as optimum

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dose for herbage production. Somnagowda and Krishnamurthy (1979) found application of 150 kg N / ha / harvest to the soil and foliage, as optimum for high production. Saxena and Bardolet (1982) recorded maximum herbage production with application of 200 kg N / ha at Assam. However, Munsi and Mukherjee (1982) observed linear increase in herbage production only up to 120 kg N application. Yadav et al. (1984) found significant increase in herbage production up to 180 kg N / ha / yr at Lucknow. Prakash Rao et al. (1985) noticed that with increasing levels of N up to 400 kg / ha, caused significant increase in herbage yield.

On the basis of literature reviewed, it may be stated that addition of N from 150 to 200 kg / ha was sufficient in producing optimum tiller production and herbage yield of the crop under Lucknow conditions. However, information on the annual dose of N and total N requirement of the crop cycle is not available for many regions of citronella. In addition, information is also lacking regarding the effects of N on different growth parameters that directly influence the herbage yield.

2.2 Effect of nitrogen on oil content, oil yield and oil quality

In the previous para it was observed that N has a positive role in herbage yield of citronella Java. It may possibly exert similar influence on oil yield as oil yield

is a product of oil content in leaves and herbage yield of the crop.

My (1972) working at East Malaysia reported that application of N fertilizers decreased the oil content significantly from 1.28 to 1.14 per cent. Marayana et al. (1975) observed a similar trend in essential oil contents on fresh weight basis; 1.29 to 1.26 per cent decrease was also observed by Singh et al. (1976) with the increasing N levels from 0 to 80 kg N / ha. On the other hand, at Regional Research Laboratory, Jorhat, oil content was not appreciably influenced due to level of N (Anonymous, 1968).

At Bardham (West Bengal), Ganguly and Thyagarajan (1976) noticed that application of N increased the oil content at 200 kg N / ha. However, at the same place, Saha and Bordelei (1982) did not find any change in oil content with different rates of N. Under terai condition of Minalai, Singh et al. (1983) reported that application of N caused slight reduction over control. Kommegowda et al. (1983) observed that oil percentage in the herbage significantly decreased (0.814 to 0.718) with N application. While Prakasa Rao et al. (1985) did not observe any effect on change in oil content with N application.

The increase in oil yield under N- fertilization takes place due to increase in herbage yield as has been reported by many workers. The oil yield as influenced by N application

varied depending on the agro-climatic conditions. On red sandy loam soils of Bangalore, positive increase in oil yield with graded levels on N was observed and the optimum dose for maximum oil yield ranged from 150 to 200 kg N / ha (Marayana et al., 1975; Bannegowda et al., 1979 and 1983). Prakasa Rao (et al. (1985) from the same location found the optimum annual requirement of N as 400 kg / ha. Dimari et al. (1973) obtained optimum oil yield with the same dose of N in combinations with FYM @ 30 tonnes / ha. On high fertile alluvial soils of Pantnagar having subtropical climate, relatively low dose of N (120 kg / ha), was found optimum for high yield (Singh et al., 1983).

However, on sandy loam soils of Lucknow region application of a slightly high dose of N (180 kg / ha) produced optimum oil yield (Yadav et al., 1984). In Assam, which is one of the main citronella Java, producing area addition of 200 kg N / ha was found optimum for improvement in oil yield. Investigations on N conducted in other countries (Sri Lanka, Taiwan and Malaysia) also showed significant increase in oil yield with graded levels of N (Joachim and Pandittasekera, 1953; Shye and Yang, 1973 and Ng, 1972).

As per Marayana and Rao (1969) quality of citronella oil, is dependent on aldehyde (calculated as citronellal) and total alcohols (calculated as geraniol and citronellol). According to Dev Kumar et al. (1977) the constituents of citronella oil differed largely under the influence of seasonal

variations. They reported that maximum accumulation of citronellal, citronellol and geraniol occurred during August to October. The percentage of geraniol according to Chandra et al. (1970) increased with rise in temperature, while citronellal content declined under high temperature. Cool temperature was found necessary for maximum synthesis of citronellal.

Nitrogen seems to have no direct influence on the constituents of citronella oil, as concluded by Reitzema (1958) from his investigation on biosynthetic pathway on other essential oil in crops like mint species. Prabhase Rao et al. (1985) did not notice changes in oil quality due to different rates of N application. They however, found high citronellal, citronellol and geraniol contents during low temperature period. Several other workers also reported that through application of N did not cause any change in the quality of oil (Singh et al., 1976; Ganguly, 1978).

However, some workers noticed changes in particular constituents of the oil with addition of N. Chandra (1973) reported higher citronellal and geraniol content with increase in N levels. While Marayana et al. (1975) found the influence of N on total aldehyde only. Many other workers also made similar observations on quality of oil (Bonnagowda and Krishnamurthy, 1979; Ghosh and Chatterjee, 1976).

2.3 Effect of nitrogen on nutrient concentration and uptake

Addition of N is reported to enhance the tissue concentration of N in many crops. It may also favour more herbage production leading to higher uptake in plots treated with higher levels of N. The concentration and uptake of N by the crop gives an index of the efficiency with which the crop utilizes the applied N.

Bonnagowda et al. (1980) observed that application of N @ 75 to 150 kg / ha significantly increased the N concentration ranging from 0.928 to 1.099 per cent. Munsli and Mukherjee (1982) reported higher N concentration in plant application at the rate of 120 kg N / ha.

According to Prakasa Rao et al. (1983), application of 200 kg N / ha significantly increased the N uptake at Bangalore. Similarly, at Lucknow, Yadav et al. (1984) reported maximum increase in N uptake at 180 kg N / ha. They further, observed lower N content at the early stage of harvest as compared to later stages.

It is apparent from the report that N application has enhanced the tissue N concentration and uptake but no information is available on distribution of N in different plant parts.

Just after establishment, N content in plants was reported to be 2.0 per cent thereafter N concentration in

get reduced to 1.4 per cent in winter and 0.51 per cent in summer. According to Yadav et al. (1982 and 1984) in monsoon season, the N concentration in leaves was low (0.68 %) under Lucknow conditions.

2.4 Effect of phosphorus on growth and herbage yield

It is very well known that P application plays a great role in growth and development of plants. It also maintains balance between other nutrients. Responses to added P grown on soils particularly low in available P or otherwise problematic soils, are usually observed. Chandra (1973) reported that application of P increased the number of tillers / plant and the optimum dose was 100 kg P_2O_5 / ha. Greater number of tillers were recorded with P application by Ganguly and Thyagarajan (1976). At Burdwan, Ghosh and Chatterjee (19) observed maximum plant height. Number of tillers / plant and dry matter yield due to application of 75 kg P_2O_5 / ha.

Herbage yield of citronella Java was significantly influenced with addition of 40 kg P_2O_5 / ha at Sarawak, Malaysia (Ng, 1972). At Sri Lanka, Joachem and Pandittesera (1953) reported that P fertilization produced the maximum herbage yield. From Bangalore Khan and Marayana (1972) reported maximum herbage yield with addition of 49.6 kg P_2O_5 / ha. Similarly, Chandra (1973) obtained the optimum herbage yield only at 50 kg P_2O_5 / ha. From Taiwan, Shyu

and Yange (1973) reported that application of P increased the herbage yield significantly upto 60 kg P_2O_5 / ha. At Bangalore, Narayana et al. (1975) working on red sandy loam soils, observed increase in herbage yield upto 100 kg P_2O_5 / ha. However, Sa and Bordelei (1982) did not observe increase in herbage^{yield} due to P application at Assam hills. Munsi and Mukherjee (1982) noticed a linear increase in herbage yield upto 60 kg P_2O_5 / ha which was the economic optimum level of P. Singh et al. (1983) recorded the significant response in herbage yield upto 40 kg P_2O_5 / ha under tarai conditions of U.P.

2.5 Effect of phosphorus on oil content, oil yield and oil quality.

No effect on oil content due to P application was recorded at Regional Research Laboratory Farm, Jorhat (Anonymous, 1968). Narayana et al. (1975) noticed decrease in oil content with increase in P level at Bangalore, while P application did not show any influence on oil content at Assam (Singh et al., 1976). At Bardwan, Ghosh and Chatterjee (1978) found increase in oil content with the application of P fertilizers which reached maximum percent at 75 kg P_2O_5 / ha. However, Singh et al. (1983) marked no variations in oil content due to increased levels of P.

Joachim and Pandittesekera (1953) from Sri Lanka reported high oil yield due to application of P fertilizers in Ceylon citronella.

Increasing levels of phosphorus up to 40 kg P_2O_5 / ha significantly increased the oil yield but further increase in P caused a decline in the oil yield in East Malaysia (Ng, 1972). In Taiwan Shyu and Yang (1973) observed significant increase in oil yield up to 30 kg P_2O_5 / ha.

At Bangalore, Dimri et al. (1973) obtained maximum oil yield with 100 kg P_2O_5 / ha. However, Narayana et al. (1975) at the same place noticed increase in oil yield up to 200 kg P_2O_5 / ha. Ghosh and Chatterjee (1978) also recorded an increase in oil yield at 75 kg P_2O_5 / ha at Burdwan.

Chandra (1973) advocated that application of P increased both geraniol and citronellal in citronella oil and he recommended 100 kg P_2O_5 / ha, to obtain the best quality of oil under agro-climatic condition of Lucknow. Narayana et al. (1975) studied the effect of different levels of P on the quality of citronella oil. They reported that total alcohol contents decreased but total aldehydes increased with increase in levels of added P. The changes in aldehyde were 36.8, 37.5 and 37.1 per cent while in alcohol they were 91.0, 90.6 and 90.2 per cent at 0, 100 and 200 kg P_2O_5 / ha respectively. In contrast, Singh et al. (1976) did not find any change in the quality of oil due to differential rates of P (Ghosh and Chatterjee, 1978).

2.6 Effect of phosphorus on nutrient concentration and uptake

Munsi and Mukherjee (1982) reported that with increasing level of P up to 60 kg P_2O_5 / ha there was corresponding increase in the P content of whole plant. No further information is available so far on this aspect.

2.7 Effect of potassium on growth and herbage yield

Very little work has been carried out so far with respect to the influence of K on growth parameters in citronella Java. Ghosh and Chatterjee (1978) observed optimum growth at 60 kg K_2O / ha at Burdwan (W.B) while at Lucknow, Chandra (1973) recommended application of 50 kg K_2O / ha for optimum growth of the citronella Java.

Khan and Narayana (1972) advocated that Java citronella is heavy feeder of K and recorded the maximum return at 75.6 kg K_2O / ha in Bangalore soil. In East Malaysia Ng (1972) recommended 80 kg K_2O / ha for optimum herbage yield. From field experiments at Bangalore, Dimri et al. (1973) obtained the maximum herbage yield at 125 kg K_2O / ha.

Dutta and Mishra (1973) working at Bhubaneswar (Orissa) suggested that citronella Java requires 20 kg K_2O / ha at the time of planting in first year and 40 kg K_2O / ha for second and subsequent years. Narayanan et al. (1975) observed that application of K slightly influenced the herbage yield and obtained yields of 17, 38 and 43 t / ha at 0, 125 and 225 kg K_2O / ha, respectively. Application of 60 kg K_2O produced the optimum herbage yield at Burdwan (Ghosh and Chatterjee, 1978). At Taiwan, significant increase in herbage yield was observed upto 60 kg K_2O / ha (Shyu and Yang, 1973). Ganguly and Thyagarajan (1976) did not observe significant difference in herbage yield due to

graded levels of K. Singh et al. (1983) working on alluvial soils of Pantnagar did not find the significant increase in herbage yield with increased levels of K.

2.8 Effect of potassium on oil content, oil yield and oil quality.

Ghosh and Chatterjee (1978) recorded maximum oil content with addition of 60 kg K_2O / ha at Burdwan (W.B.). However, Munsi and Mukherjee (1983) and Samal and Bordoloi (1982) did not find any marked differences in oil content due to different levels of K. Anmegowda et al. (1983) and Singh et al. (1983) could not find any definite trend of variation in oil contents due to K application.

At Bangalore maximum oil yield was obtained with an application of 125 kg K_2O / ha (Khan and Marayana, 1972; Dimri et al., 1973). Application of K up to 80 kg K_2O / ha increased the oil yield significantly (Ng, 1972). However, Dutta and Mishra (1973) obtained maximum oil yield only at 20 kg K_2O added in first year and 40 kg K_2O addition each in second and subsequent years. Shyu and Yang (1973) in Taiwan observed significant increase in oil yield upto 60 kg K_2O / ha. Marayana et al. (1975) observed that application of K increased the oil yield in order of 143, 313 and 331 kg / ha at 0, 125 and 250 kg K_2O / ha. Thyagarajan (1976) did not find appreciable increase in oil yield. Whereas Ghosh and Chatterjee (1978) suggested application of 60 kg K_2O / ha for citronella Java to get optimum oil yield. However, on loamy soils of

Pantnagar. Singh et al., (1983) could not find significant increase in oil yield due to application of K.

Chandra (1973) reported that application of K up to 50 kg / ha increased the citronellal and geraniol contents at Lucknow. Marayana et al. (1975) observed that total alcohols decreased by 91.0, 90.3 and 90.4 per cent and aldehydes increased 36.8, 37.5 and 37.1 per cent at 0, 125 and 225 kg K_2O / ha respectively. However, Singh et al. (1976) did not find appreciable difference due to K application.

2.9 Effect of phosphorus and potassium at high levels of nitrogen on crop growth and yield

Among the different essential plant nutrients, P and K occupy important place. In fact, judged by the criterion of crop removal alone, the quantity of K taken up by crops equals, and in some cases exceeds, that of nitrogen. However, phosphorus removal was lower than N and K. Most striking responses were observed when K was applied in conjunction with higher levels of N (Roy et al., 1981; Singh et al., 1974). Leptanik (1972) working on N and K fertilization of various crops inferred that better utilization of K takes place in association with high level of N. Singh and Dubey (1976) reported that K did not exhibit significant crop response when applied alone, but when it was applied with P the response was found to be significant.

Kemmler and Malicornet (1976) pointed out that results obtained in first year gave response only to N, while the response of P and K become visible in second and third year of experimentation due to exhaustion of soil fertility.

Mitt (1971) reported from a five year experiment on grass land that the optimum application rate of P was 60 kg P_2O_5 at higher N and K levels. Further, the field response to 60 kg P_2O_5 was three times higher than that was recorded in earlier period. Further increasing the rates of application did not produce an additional yield increase. In case of K an increase of the rates to 160 kg / ha K_2O resulted in additional production of 1.1 tonnes in the first and 1.5 tonnes / ha in second year and both were highly profitable. He concluded from the studies that large response of P and K were obtained when plant growth was promoted following an increase in the rates of N addition.

2.10 Effect of split application of potassium on crop growth and yield

Potassium is not only essential in the nutrition of the plant, but plays vital indirect roles in the physiology of plant and its presence is necessary to bring out nutritional balance in the plant. Behaviour of K studied over long period remained difficult to understand due to the tricky nature of the nutrient in different soil types. On soils having sufficient available K, crop responses to added K was reported, while in soils having low K status, crops

failed to show response to application of K. Inconsistent response to K are mainly attributed to variation in soil types, mineral composition and nature of crop. Potassium is normally applied at the time of planting in many crops.

Recent reports advocated that K application in splits specially in maize crop for efficient nutrient utilization and better crop response. Mandal *et al.* (1982) observed that at high level of N, K increased the yield. Split application of K resulted higher yield than their basal application. The number of panicles / m², percentage filled grain were significantly increased by potassium.

Although, investigation on these lines are in progress with respect to field crops, such investigations have so far not been made in aromatic grasses such as citronella Java. Therefore, research work carried out in other crops have also been reviewed, where necessary.

In India, the effect of split application was investigated in cereals and other crops. Singh and Dubey (1976) noted that application of full dose of K at sowing produced lower yield than split application of K in wheat.

singh et al. (1976) reported that large response to K was obtained by split application (33 % each as basal, tillering and at panicle initiation over complete basal application).

Singh and Singh (1978) observed that split application of K favourably influenced both the grain yield and the yield contributing characters and was better than basal application. Applying half of the K as basal dressing and spraying the remainder in two splits, one at active tillering and another before heading was the best method of split application. However, it was also observed that at high levels of N and K produced maximum yield in rice. Singh and Singh (1979) found K application during active growth period in addition to basal application increased the grain yield of wheat, through increasing in number of tillers and test weight of grain. Singh et al. (1981) observed significant increase in grain and straw yields of wheat due to split application of K over basal application at the time of planting.

To obtain high wheat yields on alluvial soils of Kanpur, Pathak and Tiwari (1978) recommended three equal splits of potassium each at basal, tillering and panicle initiation stages. In sugarcane, Srivastava and Hunsigi (1978) observed that split application of K was somewhat more beneficial than its basal application in South India. On

Raychaudhuri (1976) reported that application of K in two or three split doses may be superior to single basal application depending on the texture of the soil. Singh (1978) pointed out that potash should be applied at the time of sowing and the rest should be top dressed with nitrogen to get maximum yield. Agrawal (1979) reported that split application of K was equally effective as its basal application.

2.11 Studies on weed control

2.11.1 Weed species

Duhan and Galati (1973) reported that Cyperus rotundus, Amaranthus viridis, Echinochloa colona, Phyllanthus niruri, Cynodon dactylon, Euphorbia hirta, Pigosa arvensis, Portulaca oleracea and Calceas argentea are the main weeds in the stands Java citronella in tarai region of Pantnagar. Yadav et al. (1981 a and b) working at CIMAP, Lucknow noted Dactyloctenium aegyptium, Digitaria sanguinalis and rotundus as the main weeds in Java citronella. Singh and Mawet (1978) found that amongst the grasses, Imperata cylindrica, Digitaria sanguinalis, Paspalum conjugatum, Cynodon dactylon, Echinochloa colona and Elyusine indica were important species while predominant broad leaf weeds were Rottaria hispida, Mihania micrantha, Commelina benghalensis, Ageratum conyzoides, Oxalis acetosella and Polygonum chinense.

2.11.2 Losses caused by weeds

Presence of weeds in crop community influence the crop growth and productivity by competing for light, nutrient and

moisture. The extent of crop loss is dependent on variety of factors like weed population.

Guenther (1950) reported that weeds caused significant reduction in herbage production of citronella Java and solubility of the oil in 80 per cent alcohol. If the weeds were not checked they affected the oil quality besides lowering the herbage yield (Chandra, 1973).

Duhan and Gulati (1973) reported reduction in the oil yield from 78 kg oil / ha in weed free crop to 30 kg oil / ha in weedy due to weed growth.

Yadav et al. (1981 a and b) reported that weeds caused severe reduction in shoot formation, leaf growth, which in turn reduced fresh herbage and oil yield by 78 % . In other study by the same author at Lucknow revealed that Cyperus rotundus, B. acgyptium, Echinochloa sp., D. arvensis and A. viridis were reported as major weeds with dry matter production as high as of 4.6 and 14.7 q / ha at 30 and 60 days, respectively after citronella planting reduction of 59 per cent herbage yield. He further observed that weeds reduce the shoots / plant by 50 % in first cutting and 40 % in second cutting. The workers from the same place reported that weeds reduction was 50.0 and 17.3 per cent in herbage during first and second year, respectively (Anonymous, 1983-84).

2.11.3 Effect of herbicides

Duhan and Gulati (1973) suggested that Java citronella crop needs to be kept free of weeds initially three to four months for good crop establishment and early vigour. 2, 4-D and paraquat were two herbicides recommended for weed control in citronella Java. They controlled weeds only for few days. The herbicides effectively checked most of dicotyledonous weeds but showed no effect on C. rotundus and P. oleracea (Duhan and Gulati, 1973 and Khosla, 1979). Singh and Rawat (1978) also recommended post-emergence application of 2, 4-D @ 0.5 kg ai / ha for effective control of dicot weeds. Yadav et al. (1981b) tested six herbicides (feroxin, Lasso, Diuron, Simazine, Atrazine and nitrofen) for weed control in citronella Java and found diuron and simazine to be most effective. At same place it was found that use of organic mulch (3 t / ha), oxyfluorfen (0.5 kg ai / ha) and Diuron (1.5 kg ai / ha) were also promising for controlling weeds in this crop (Anonymous, 1984-85).

2.11.4 Crop weed competition for nitrogen

Weeds remove considerable amount of nitrogen from the soil depending upon species, intensity and time and duration of infestation, uptake of N by weeds alone and the extent of competition with Java citronella or other *Cymbopogon* spp.

The nutrient removal has not been investigated. The nitrogen uptake in citronella crop at Lucknow (Yadav et al., 1984) has been found to be 119 to 198 kg / ha. Maide (1976) found that Colosium indicum, Sanguinalis and C. dactylon removed 8.2, 26.3 and 32.7 kg N / ha while Eclipta alba, P. minima, P. niruri and C. argente removed 5.9, 16.0 and 26.5 kg N / ha at 30, 45 and 60 days after planting.

2.11.5 Effect of diuron on weeds in other crops

Effect of diuron application for weed control has not yet been investigated in citronella Java. Information available with other crops has been reviewed. Levy term application of herbicides on cotton for two years, with application of Diuron @ 0.80 to 1.0 kg in cotton was effective against weeds and had no adverse effect on growth development (Lozovetskaya 1976). Contrary to above Marwal and Malik (1982) working with autumn planted sugarcane found, diuron showed limited effect in depressing grassy weed population due to kills ^mperennial grassy weeds, shorter period of persistence in soil.

2.11.6 Interaction effect of N-fertilizer and herbicides

Application of N creates favourable nutrient environment per crop as well as weed. The situation further complicate the understanding of weed growth and to evolve practices for weed management in recent times, many reports are appearing in different crops, but investigation on these lines are yet to begin in citronella Java. Mody (1978) observed more

nutrient absorption by weeds than rice crop plants. He further reported that weed free situation in rice yield with N addition while in weedy crop nitrogen addition caused reduction in crop yield as the exp. of weed growth. Studies conducted at International Institute of tropical Agriculture in Nigeria, revealed that crop yield was increased by 29 % only with fertilizer addition if weed were checked while fertilizer addition to weed free, resulted in additional yield increased to the extent of 20 % yield was increased due to weed control. However, cost benefit ratio was 1 : 1.66 for fertilizer alone and 1 : 2.62 for combined fertilizer and weed control (I.I.T.A. 1973). Nathi and Tiwari (1981) working at Kanpur reported that grain production at 80 kg N / ha in the absence of weed (Manual or chemical weeding) as compared with 120 kg N / ha in the weedy check.

2.12 Summary and scope of work

The optimum dose of N for citronella Java varied widely from 100 to 400 kg N / ha. Further, there is very little information on the annual requirement of N and its timings of applications. Research work has not yet been initiated an efficient management of the important nutrient through cultural and management practices, modified forms of fertiliser and its application techniques. Similarly, investigation on improving^N use efficiency remain untouched.

In case of phosphorus also the optimum dose varied widely and no efforts were made to find out the optimum dose

in specific soil and agro-climatic situation. Effect of different fertilizer sources and efficient management methods of this nutrient and to provide ideas of soil P use efficiency have not been attempted in field or control conditions.

Research information on K nutrition is rather meagre in this crop. Timing of K application, an important and relevant aspects in this perennial crop has not been taken up so far.

Integration of N with other input such as P, K, weed control methods and moisture regime is lacking in this crop.

3. MATERIALS AND METHODS

The present investigation entitled "Effect of nitrogen and herbicide applications on production of *Citronella Java* (*Cymbopogon winterianus* Jovitt)" was conducted at Agricultural Research Farm of the Central Institute of Medicinal and Aromatic Plants, Lucknow, during 1983-86. Details of the experiments, materials used and methods employed are described in this chapter.

3.1 Experimental site

The Agricultural Research Farm of Central Institute of Medicinal and Aromatic Plants, Lucknow, is situated at 26.5°N latitude and 80.50°E longitude and at 120 m altitude above mean sea level.

3.2 Climate

Climatologically, Lucknow is included in semi-arid sub-tropical zones with severe hot summers and fairly cool winters. In this region, monsoon normally commences from last week of June and continues till end of September. About 88 per cent rainfall is received during July and August. The area occasionally experience few showers of rains during December to February. During summer the temperature is very high while during winter it remains fairly low.

3.2.1 Weather conditions

The weather data were collected from meteorological observatory of Awadh Forest, Picnic Spot, Lucknow, situated very close to CIMAP research farm. The details of the weather condition that prevailed during the course of this present investigation are depicted in Fig. 1.

The minimum temperatures fluctuated from 3.5°C to 24.5°C while the maximum temperature varied from 24.8°C to 45.0°C during the entire period of crop growth. The minimum - maximum temperatures ranged from 3.8 to 43.5°C , 4.4 to 45.0°C and 3.5 to 44.8°C during 1983-84, 1984-85 and 1985-86, respectively. On an average the weather during 1984-85 was hotter than the remaining years of experimentation.

The minimum relative humidity varied from 20.8 to 94.4 per cent while the maximum fluctuated between 22.3 to 96 per cent during the entire period of crop growth. The lowest relative humidity 20.8 per cent, was noted in February 1984. However, the maximum of 96 % humidity was recorded in September 1983. Wide fluctuation in humidity was observed in 1983-84.

The major portion of the rainfall was received during July and August. The total amount of rainfall received were 1331.2, 685.4 and 1710.7 mm during 1983-84, 1984-85 and 1985-86, respectively.

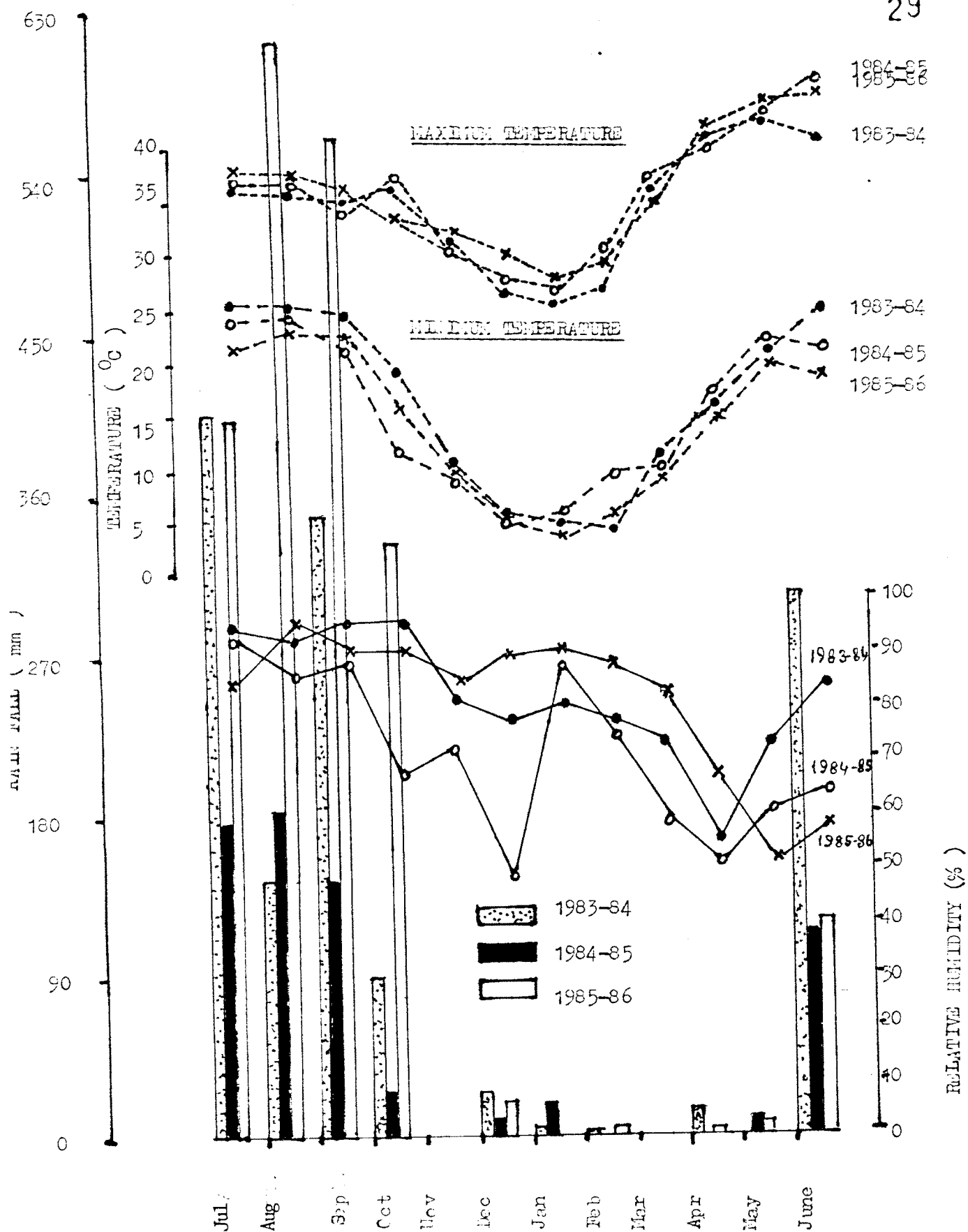


FIG.1: WEATHER PARAMETERS DURING THE PERIOD OF EXPERIMENTATION

3.3 Soil characteristics

Surface soil samples (0 - 30 cm) from experimental sites were collected before planting the experiments. The samples were processed and analysed for different physical and chemical properties by following standard procedures. The result of the analysis and the methods of estimation are given in Table 3.1.

The soils of the experimental sites were sandy loam in texture, low in organic carbon, nitrogen, available phosphorus and potassium.

3.4 Cropping history

The Agricultural Research Farm of Central Institute of Medicinal and Aromatic Plants, Kikrail, Lucknow, was acquired from the Forest Department of Uttar Pradesh Government in 1976. Cultivation of aromatic and medicinal plants was started, in 1977 after development of farm land in 1976. The details of cropping history of the experimental sites for three years before experiment are presented in Table 3.2. One year before the experimentation maize was grown in kharif followed by Mustard in rabi without addition of fertilizers in order to minimise the soil fertility variation.

Table 3.1 Physico-chemical characteristics of the experimental soils

Particulars	Analytical values		Methods employed
	Site I	Site II	
	(1983-85)	(1984-86)	
1. Physical characteristics			
Mechanical composition			International Pipette Method (Piper, 1950)
Sand %	68.0	66.0	
Silt %	23.2	24.0	
Clay %	8.8	10.0	
Bulk Density	1.3	1.3	Dustane, 1972.
Field capacity (%)	16.8	17.0	Dustane, 1972.
Permanent Wilting point (%)	5.3	5.3	Richards, 1956
2. Chemical characteristics			
pH (1 : 2 soil :water)	8.0	7.6	Jackson, 1973
Cation Exchange Capacity (me/100 g)	10.	10.0	Schollenberger and Simon, 1945
EC	0.8	0.8	Jackson, 1973
Organic Carbon (%)	0.20	0.22	Walkley Black's Rapid Titration Methods (Jackson, 1973)
Total N (%)	0.04	0.04	Modified Kjeldahl Method (Jackson, 1973)
Available N (kg N/ha)	92.5	98.0	Alkaline Permanganate Methods (Subbiah and Asija, 1956)
Available P (kg P ₂ O ₅ / ha)	6.5	9.0	Olson's Extractant (Jackson, 1973)
Available K (kg K ₂ O / ha)	85.8	95.0	By Flame Photometer (Mohr et al., 1965)

Table 3.2 Previous cropping history of the experimental field

Year	Season	Crop grown	Remarks
1980-81	Rabi	Coriander	Commercial crop was grown with 100 kg N, 60 kg of each P_2O_5 and K_2O / ha
1981-82	Kharif	Fallow	Harrowing for control of weed establishment
1981-82	Rabi	Rye	With 100 kg N, 60 kg P_2O_5 and K_2O / ha
1982-83	Kharif	Maize	Grown without fertilizers
1982-83	Rabi	Mustard	Grown without fertilizers

3.5 Experimental details

Three field experiments were conducted in the present series of investigation as detailed below.

3.5.1 Experiment 1a

Title : Effect of nitrogen and weed control treatments on yield and quality of citronella Java.

Objectives :

- (1) To work out the optimum dose of N and efficient weed management practices for increasing the productivity and oil quality of citronella Java,

- (ii) To study the interaction effect of N application in relation to weed management practices on the productivity and oil quality of citronella Java,

Treatments :

(A) Main plot treatments:

- (i) Weed free (About 8 weeding / year)
- (ii) Weedy (No weeding except once at the end of first harvest year)
- (iii) Application of Diuron @ 1.5 kg ai / ha;
Diuron was sprayed at pre-emergence and then at 6 months interval,

(B) Sub plot treatments :

Levels of N (kg / ha) 0, 50, 100, 150, 200 and 250.

Design : Split plot : Replication - Three

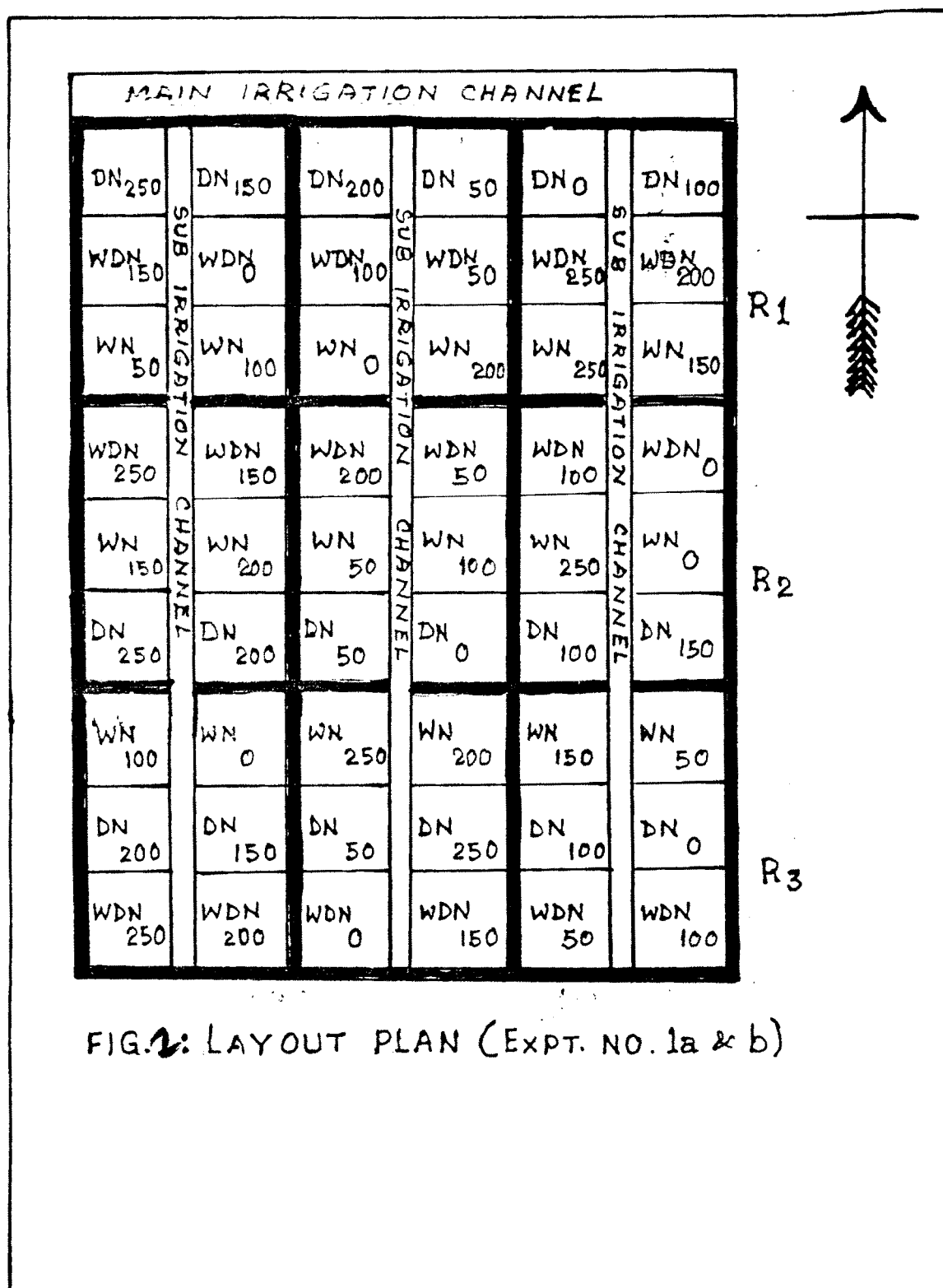
Gross plot size : 8.8 sq m (3.20 m x 2.70 m)

Net plot size : 6.1 sq m (2.70 m x 2.25 m)

The experiment was carried out in two consecutive years 1983-84 and 1984-85.

3.5.2 Experiment No.1(b):

The experimental details are same as in Experiment No.1(a). This was laid out separately in a contiguous plot of Experiment No.1(b). This was carried out in 1984-85 and 1985-86.



3.5.3 Experiment 2a

Title : Effect of phosphorus and potassium at high level of application on yield and oil quality of citronella Java

Objectives : To work out phosphorus and potassium requirement at high level of nitrogen on oil yield and oil quality.

Treatments (Fertilizer doses in kg P_2O_5 or K_2O / ha) :

- (1) $P_0 K_0$
- (2) $P_{50} K_0$
- (3) $P_{100} K_0$
- (4) $P_0 K_{50}$
- (5) $P_{50} K_{50}$
- (6) $P_{100} K_{50}$
- (7) $P_0 K_{100}$
- (8) $P_{50} K_{100}$
- (9) $P_{100} K_{100}$

P and K were applied in the form of single super phosphate and potassium chloride as basal and N was applied @ 250 kg N / ha in 4 splits (basal, I, II and III harvest)

Design : Randomised Block Design in 3 replications.

Gross plot size : 8.8 sq m (3.20 m x 2.75 m)

Net plot size : 6.1 sq m (2.70 m x 2.25 m)

The experiment was carried out in two consecutive years 1983-84 and 1984-85.

3.5.4 Experiment No. 2(b)

The experimental details are same as in Experiment No. 2(a). This was laid out separately in a contiguous plot of Experiment No.2 (b). This was carried out in 1984-85 and 1985-86.

3.5.5 Experiment 3(a)

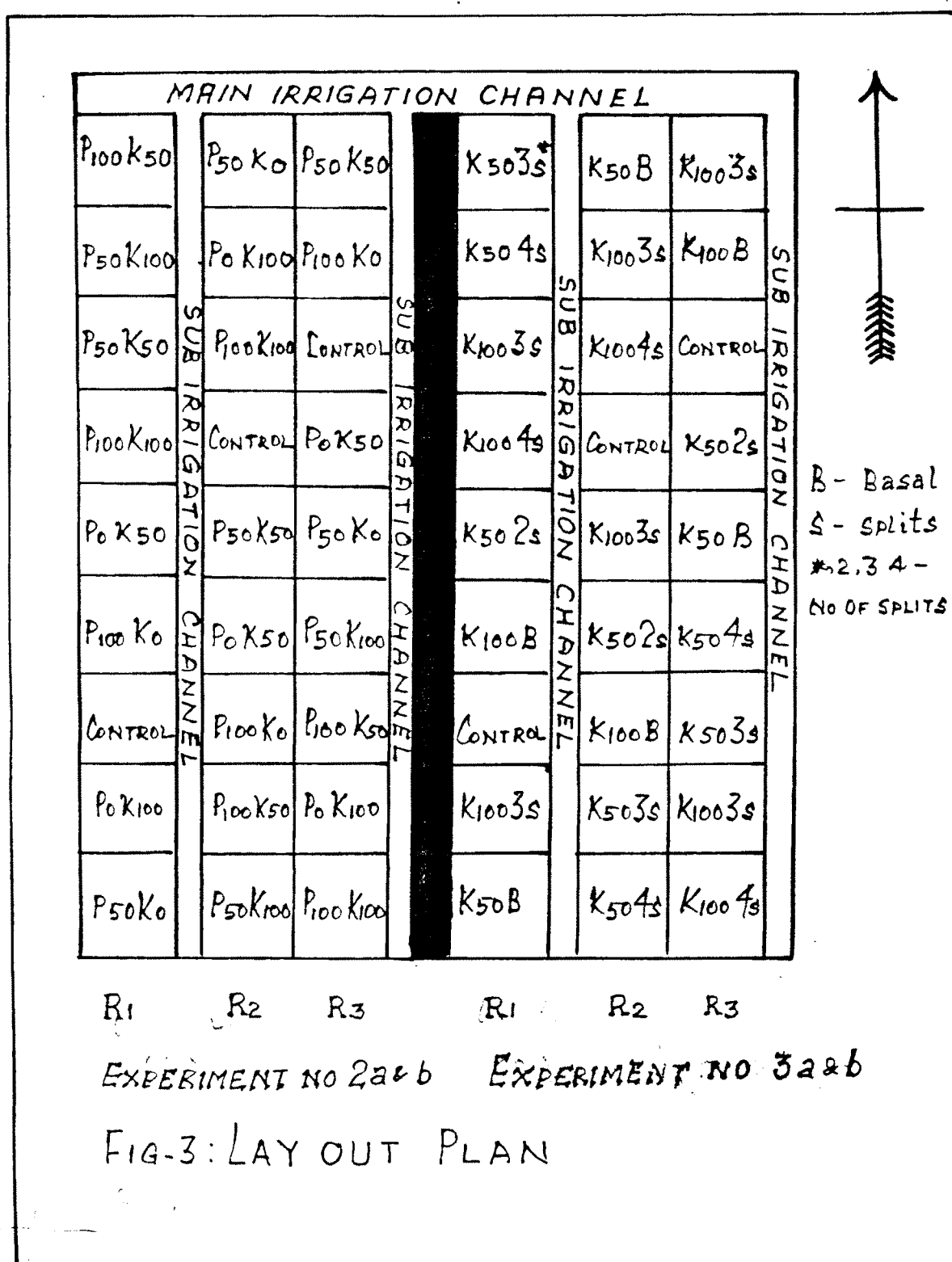
Title : Effect of split application of potassium at high level of N application on yield and oil quality of citronella Java.

Objectives :

- (i) To work out K requirement of citronella Java at high level of N fertilization.
- (ii) To study the effect of split application of K on yield and oil quality of citronella Java.

Treatments :

1. Control
2. Basal application of K @ 50 kg K_2O / ha
3. Basal application of K @ 100 kg K_2O / ha
4. 50 kg K_2O / ha - split doses (2 splits) after I & II harvest



5. 100 kg K_2O / ha - split doses (2 splits) after I & II harvest
6. 50 kg K_2O / ha - split doses (3 splits) after I, II & III harvest
7. 100 kg K_2O / ha - split doses (3 splits) after I, II & III harvest
8. 50 kg K_2O / ha - split doses (4 splits) Basal, I, II & III harvest
9. 100 kg K_2O / ha - split doses (4 splits) Basal, I, II & III harvest

Nitrogen @ 250 kg / ha as urea was applied 4 splits (basal, I, II and III harvest). K was applied as potassium chloride.

Design : Randomised Block Design in 3 replications

Gross plot size : 8.85 sq m (3.20 m x 2.75 m)

6.1 sq m (2.70 m x 2.25 m)

The experiment was carried out in two consecutive years 1983-84 and 1984-85.

3.5.6 Experiment No.3(b)

The experimental details are same as in Experiment No.3(a). This was laid out separately in a contiguous plot of Experiment No.3(b). This was carried out in 1984-85 and 1985-86.

3.6 Field operations

The details of field operations performed are given below :

Table 3.3 Calendar of cultural operations

Operations	Dates		Remarks
	First crop (1983-85) Exp. No. 1a, 2a, 3a	Second crop (1984-86) Exp. No. 1b, 2b, 3b	
1. <u>Pre-planting</u>			
Ploughing	Jun 5, 1983	Jun 1, 1984	
Harrowing	Jun 7, 1983	Jun 10, 1984	
Ploughing	Jun 14, 1983	Jun 10, 1984	
Harrowing	Jun 14, 1983	Jun 12, 1984	
Planking	Jun 14, 1983	Jun 12, 1984	
Layout	Jun 28, 1983	Jul 2, 1984	
Fertilizer application	Jun 5, 1983	Jul 2, 1984	
Planting	Jul 8, 1983	Jul 9, 1984	
2. <u>Post planting</u>			
2.1 Irrigation	Jul 8, 1983	Nov 11, 1984	
	Aug 20, 1983	Jan 12, 1985	
	Oct 25, 1983	Feb 16, 1985	
	Nov 16, 1983	Mar 15, 1985	
	Feb 18, 1984	Apr 5, 1985	
	Feb 28, 1984	May 1, 1985	
	Mar 10, 1984	May 12, 1985	
	Apr 15, 1984	Nov 18, 1985	
	May 3, 1984	Dec 15, 1985	

Table 3.3 (contd.)

Operations	Dates		Remarks
	First crop (1983-85) Exp. No. 1a, 2a, 3a	Second crop (1984-86) Exp. No. 1b, 2b, 3b	
	May 25, 1984	Jan 25, 1986	
	Jun 3, 1984	Mar 5, 1986	
	Jun 25, 1984	Mar 25, 1986	
	Jul 3, 1984	Apr 15, 1986	
	Nov 12, 1984	May 10, 1986	
	Jan 12, 1985	May 30, 1986	
	Feb 16, 1985	Jun 12, 1986	
	Mar 15, 1985		
	Apr 5, 1985		
	May 1, 1985		
	May 12, 1985		
Weeding	Sep 13, 1983	Sep 13, 1984	
	Oct 6, 1983	Oct 6, 1984	
	Jan 15, 1984	Jan 16, 1985	
	Apr 7, 1984	Apr 7, 1985	
	Jul 7, 1984	Jul 7, 1985	
	Oct 15, 1984	Oct 15, 1985	
	Jan 17, 1985	Jan 17, 1986	
	Apr 10, 1985	Apr 10, 1986	
Hoeing	Oct 16, 1983	Oct 16, 1984	
	Jan 17, 1984	Jan 17, 1985	
	Apr 10, 1984	Apr 10, 1985	
	Jul 10, 1984	Jul 10, 1985	
	Jan 17, 1985	Jan 17, 1986	
	Apr 16, 1985	Jul 10, 1986	

Table 3.3 (contd.)

Operations	Dates		Remarks
	First crop (1983-85) Exp. No. 1a, 2a, 3a	Second crop (1984-86) Exp. No. 1b, 2b, 3b	
Fertilizer application	Oct 10, 1983	Oct 10, 1984	
	Jan 17, 1984	Jan 17, 1985	
	Apr 6, 1984	Apr 6, 1985	
	Jul 10, 1984	Jul 10, 1985	
	Oct 15, 1984	Oct 15, 1985	
	Jan 17, 1985	Jan 17, 1986	
	Apr 10, 1985	Apr 10, 1986	
	Jul 10, 1985	Jul 10, 1986	
Crop protection	Jan 25, 1984	Jan 25, 1985	
	Apr 30, 1984	Apr 30, 1985	
	Jan 25, 1985	Jan 25, 1986	
	Apr 30, 1985	Apr 30, 1986	
Harvesting	Oct 4, 1983	Oct 4, 1984	
	Jan 10, 1984	Jan 10, 1985	
	Apr 17, 1984	Apr 17, 1985	
	Jul 7, 1984	Jul 7, 1985	
	Oct 13, 1984	Oct 13, 1985	
	Jan 12, 1985	Jan 12, 1986	
	Apr 8, 1985	Apr 8, 1986	
	Jul 7, 1985	Jul 7, 1986	

3.6.1 Cultural practices

3.6.1.1 Land preparation

The land was ploughed three times, harrowed and levelled twice to obtain fine tilth.

3.6.1.2 Fertilizer application

In all Experiments, nitrogen, phosphorus and potassium were applied through urea (46 % N), Single super-phosphate (16 % P_2O_5) and muriate of potash (60 % K_2O), respectively.

One-fourth of the nitrogen as per the treatments, full quantities of phosphorus and potassium (full or in splits as per treatments) were applied in furrows. In case of split application the fertilizer was applied in the space between rows and mixed with the soil by hand hoes.

3.6.1.3 Planting

Healthy and vigorous slips were selected from the previous crops. Slips were dipped in 0.2 per cent Dithane M-45 solution for 10 minutes before planting to safeguard against root rot disease. The slips were planted 45 cm apart, in 45 cm apart rows. Light irrigation was given immediately after planting to ensure good establishment.

3.6.1.4 Irrigation

The crop was irrigated at interval of 25 days. About 20 irrigations were given in the first harvest year and 15 irrigations were applied in second harvest year of the crops.

3.6.2 Methods of recording biometrical observations

3.6.2.1 Plant height and tiller production

Observations on growth attributes namely plant height and number of tillers per plant, were recorded from 5 fixed plants, randomly selected at the beginning when the observations were first recorded.

3.6.2.2 Fresh herbage yield

Crop was harvested four times in a year. The herbage yield at each harvest and total production per year was thus arrived at and reported in the chapter on Results in q / ha.

3.6.2.3 Dry matter accumulation

The observations on dry matter accumulation were made from the fixed plants selected (as stated earlier) at each harvest. The herbage were dried to a constant weight at 70°C - 80°C for 48 hours. The dry matter was expressed in q / ha.

3.6.3 Observation on oil content, oil yield and oil quality

3.6.3.1 Oil content

The essential oil content from fresh plant samples collected at each harvest from each of the plots was determined by hydro-distillation in clevenger's apparatus. Oil content was expressed in percentage on fresh herbage basis.

3.6.3.2 Oil yield

Oil yield (kg / ha) was calculated by multiplying the fresh herbage yield with oil content in respective treatments.

3.6.3.3 Quality of essential oil

Treatmentwise composite samples of essential oil at each harvest were analysed for their chemical constituents, viz: citronellal, citronellol, geraniol were determined by Gas Liquid Chromatography "Perkin Elmer model 3920B with thermal conductivity detector, 10 % OV 101.2 M x 1/8" stainless steel packed column. The column temperature was held initially at 120°C for 2 minutes and then programmed to 180°C the carrier gas (hydrogen) was flown at 4 ml / minutes. Finally it was held at 2 minutes constant rate of 30 ml / minutes. The oil samples 0.15 µl was injected with a hypodermic spring. The temperatures of the injector and the detector were maintained 250°C & 275°C respectively. The relative percentage of the constituents was printed by integrator Hip-3390 attached to the output of thermal conductivity detector for area per cent calculation.

3.6.4 Nutrient uptake

Nitrogen, phosphorus and potassium contents were estimated in the plant samples collected at different growth stages were ground in Willy Ball Mill micro-grinder to pass through 0.5 mm sieve. The uptake was worked out by multiplying the contents of the plant with the corresponding dry matter accumulation at each harvest.

3.6.4.1 Nitrogen content

Nitrogen content was estimated by modified Kjeldahl method (Jackson, 1973).

3.6.4.2 Phosphorus content

Phosphorus content in plants were estimated by Molybdo-Vanado phosphoric acid method (Jackson, 1973).

3.6.4.3 Potassium content

Potassium content in plants were determined by Flame photometer method (Jackson, 1973).

3.7 Observations on weed flora

3.7.1 Listing of weed flora

List of weeds were recorded in the experimental area.

3.7.2 Dry weight determination of weeds

Dry weight accumulation per unit area of the weed flora, was determined from each of the plots by removing the weeds from a ground level, present inside a quadrat (0.5 m x 0.5 m), randomly placed in each plot, just after each harvest.

3.7.3 Weed index

From comparative purpose, the weed index of each of the plot was determined. Weed Index actually refers to percentage of reduction in oil yield as compared to the weed free treatment and is calculated by the formula.

$$\text{Weed Index (WI)} = (\text{OWF} - \text{OT}) 100 \div \text{OWF} ,$$

where OWF is oil yield in weed free plot and OT is oil yield in treated plot.

3.8 Methods of statistical analysis

All the biometrical and chemical observations were analysed by applying the techniques of analysis of variance. Statistical significance was tested by F-test method as described by Panse and Sukhatme (1978). The critical differences were worked out at 5 per cent level of probability.

Production function or response function is the relationship between levels of input and corresponding output when output is related to variations in the levels of a single factors, a response curve is obtained for study, relationship. The standard deviation of the actuals from the expected curves were also determined.

At optimum levels of individual nutrients, the net return (or profit) per rupee investment on the fertiliser (providing the nutrient) only were determined, taking into consideration the following prices of the products : Rs.100 / kg of citronella oil, Rs.5 / kg N, Rs.8 / kg of P_2O_5 , Rs. 4 / kg K_2O , Rs.500 / ha (Hand weeding), Rs.300 / ha for weed control through herbicide (diuron).

4. RESULTS

4.1 Experiment No.1a (1983-85) and 1b (1984-86)

The Experiment No.1 was carried out with the objective to find the effect of different doses of N and weed control measures on the productivity of citronella Java. As discussed in the Material and Methods, Experiments No.1a and 1b were initiated in 1983 and 1984, respectively and their crop productivity was evaluated over two successive years. The first harvest was taken three months after planting (Jul - Sep) and the second harvest in December (Oct - Dec). The subsequent harvests were at three months intervals (third and fourth harvests depict the intervals, Jan - Mar and Apr - Jun).

4.1.1 Biometrical observations

4.1.1.1 Plant height

In the first harvest year in Experiment No. 1a (1983-85) the differences in plant height (Table 4.1) due to levels of N and weed control measures were significant and so was the case in the second harvest year in 1984-85. The plant height in all the harvests was more in weed free plots followed by that of plants in the plot in which Diuron was sprayed. Nitrogen also increased plant height significantly. The increase in plant heights at lower doses were more than in higher doses and virtually there were no differences in plant height between the crop raised with 200 and 250 kg N / ha. Similar were the trend of differences in second harvest year

Table 4.1 Plant height (cm) as influenced by weed control treatments and levels of N
(Experiment No. 1(a)-1983-85)

Weed control treatments	First harvest year (1983-84) Timings of harvest*				Second harvest year (1984-85) Timings of harvest*			
	I	II	III	IV	I	II	III	IV
Weedfree	44.2	44.7	57.6	105.2	78.0	63.50	77.3	96.4
Weedy	34.8	41.7	49.7	94.3	63.6	39.8	68.8	92.2
Murong	39.7	42.7	54.9	99.7	68.6	57.6	73.3	93.0
Sum _T	0.49	0.17	0.34	0.27	0.18	0.24	0.25	0.48
SD at 5%	1.94	0.67	1.32	1.05	0.69	0.94	0.98	1.85
CV (%)	1.8	0.6	1.1	0.5	0.6	0.9	0.7	0.9
Levels of N (g/ha)								
0	32.6	40.6	48.8	90.0	62.4	56.3	65.0	86.5
50	36.1	42.1	51.6	96.1	66.0	57.9	70.0	90.2
100	39.4	42.8	54.0	99.7	69.6	59.6	73.2	91.7
150	42.2	43.6	56.1	103.7	73.6	61.0	76.3	96.5
200	43.7	44.4	57.2	104.4	74.1	63.8	77.4	98.9
250	43.2	44.7	56.7	104.7	74.4	63.2	76.9	99.6
Sum _T	0.61	0.20	0.35	0.50	0.35	0.23	0.28	0.63
SD at 5%	1.76	0.57	1.01	1.44	1.0	0.66	0.80	1.81
CV (%)	2.0	0.7	1.1	0.7	0.8	0.8	0.7	1.0

* I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

(1984-85). Plant height were more in second harvest year than in the first harvest year. The growth in terms of plant height was more during the period Apr to Jun (fourth harvest). The plant heights were slightly lower during the period of Oct - Dec (second harvest); this might be due to low temperature prevailing in winter months.

The experimental results with regard to plant height in Experimental No.1b (1984-86) as summarised in Table 4.2 also showed similar trend of differences as have been described in Experiment No. 1a earlier.

The interaction between weed control measures and levels of N was significant in both the Experiments No. 1a and 1b, as summarised in Table 4.3, 4.4, 4.5 and 4.6. The interaction effect was significant only in fourth cutting in first harvest year. In second harvest year, the significant variations were found in first, third and fourth cuttings in Experiment No. 1a and first, second and fourth cuttings in Experiment No. 1b. Under weed free and weedy conditions, the increase in plant height was upto 200 kg N / ha, while in Diuron treated plots the increase was recorded upto 150 kg N / ha.

4.1.1.2 Tiller production

The treatment differences in the number of tillers / plant in Experiment No. 1a (1983-85) during first harvest

Table 4.2 Plant height (cm) as influenced by weed control treatments and levels of N (Experiment No. 1(b)-1984-86)

Weed control treatments	First harvest year (1984-85) Findings of harvest*				Second harvest year (1985-86) Findings of harvest*			
	I	II	III	IV	I	II	III	IV
Weedfree	63.6	63.6	72.3	94.6	98.7	66.1	90.6	91.2
Weedy	54.6	57.4	69.9	89.1	86.0	61.6	79.5	76.0
Pluron	58.9	61.1	71.2	91.8	93.3	63.0	82.3	82.1
SEM _t	0.16	0.16	0.23	0.27	0.27	0.25	0.19	0.23
CD at 5%	0.63	0.63	0.69	1.05	1.05	0.99	0.76	0.90
CV (%)	0.7	0.7	0.4	0.4	0.6	1.7	0.3	0.6
Levels of N (g/ha)								
0	50.6	55.7	65.4	76.9	85.0	55.9	77.7	76.1
50	56.8	57.3	69.7	84.9	89.4	60.6	79.0	79.4
100	59.7	60.4	70.3	91.3	92.7	62.6	80.3	85.1
150	62.0	62.1	72.6	95.9	95.7	65.3	81.6	86.4
200	62.9	64.8	74.6	99.9	96.9	67.9	83.0	86.7
250	62.3	63.7	76.0	102.1	96.4	69.1	83.2	86.9
SEM _t	0.44	0.28	0.27	0.32	0.31	0.23	0.19	0.54
CD at 5%	1.26	0.82	0.78	0.92	0.88	0.63	0.56	1.57
CV (%)	1.1	0.9	0.5	0.5	0.6	1.5	0.3	0.9

* I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

Table 4.3 Plant height (cm) as influenced by weed control treatments and levels of N (Experiment No. 1(a)-1983-85) in fourth harvest

Levels of N (g/ha)	First harvest year (1983-84) Weed control treatments (W)			Second harvest year (1984-85) Weed control treatments (W)		
	Weedfree	Weedy	Diuron	Weedfree	Weedy	Diuron
0	95.0	85.0	90.0	88.5	84.4	86.5
50	100.0	91.7	96.7	92.5	87.2	87.3
100	104.0	95.0	100.0	94.0	88.9	92.2
150	108.3	97.7	105.0	98.9	95.5	95.0
200	111.7	98.3	103.3	101.7	96.7	98.4
250	112.3	98.3	103.3	102.9	97.3	98.6
		SEM†	CD at 5%		SEM†	CD at 5%
'N' at fixed level of 'W'		0.87	1.84		1.08	2.30
'W' at fixed or different levels of 'N'		0.83	1.76		1.10	2.33

Table 4.4 Plant height (cm) as influenced by weed control treatments and levels of N (Experiment No. 1(a)-1983-85) in first and third harvest of second harvest year

Levels of N (g/ha)	First harvest				Third harvest			
	Weed control treatments (W)				Weed control treatments (W)			
	Weedfree	Weedy	Diuron		Weedfree	Weedy	Diuron	
0	70.0	54.0	63.3		68.3	61.1	65.6	
50	73.0	58.3	66.7		73.3	66.7	70.0	
100	76.0	63.3	77.3		77.3	69.0	73.3	
150	80.0	69.0	80.0		80.0	70.7	78.3	
200	84.0	68.3	83.3		83.3	72.3	76.7	
250	85.0	68.3	81.7		81.7	72.3	76.7	
		SEM _W	CD at 5%			SEM _W	CD at 5%	
'N' at fixed level of 'W'		0.60	1.27			0.48	1.07	
'W' at fixed or different levels of 'N'		0.58	1.22			0.50	1.11	

Table 4.5 Plant height (cm) as influenced by weed control treatments and levels of N (Experiment No. 1(b)-1984-86) in fourth harvest

Levels of N (kg/ha)	First harvest year (1984-85) weed control treatments (W)			Second harvest year (1985-86) weed control treatments (W)		
	Weedfree	Weedy	Diuron	Weedfree	Weedy	Diuron
0	80.7	70.7	79.3	83.3	70.0	75.0
50	86.3	83.7	85.0	86.7	73.3	79.3
100	86.3	90.0	91.0	90.0	76.7	82.7
150	99.7	93.3	96.0	93.3	79.3	86.7
200	102.8	96.5	96.5	96.7	78.3	85.0
250	103.0	96.7	97.5	97.3	78.3	85.0
		SEM _W	CD at 5%		SEM _W	CD at 5%
'N' at fixed levels of 'W'		0.55	1.21		0.94	1.97
'W' at fixed or different levels of 'N'		0.57	1.26		0.89	1.86

Table 4.6 Plant height (cm) as influenced by weed control treatments and levels of N (Experiment No. 1(b)-1984-86) in first and second harvest of second harvest year

Levels of N (kg/ha)	First harvest weed control treatment (a)		Second harvest weed control treatment (a)	
	Weedfree	Weedy	Weedfree	Weedy
0	90.0	80.0	59.3	53.5
50	95.0	83.3	63.5	60.3
100	96.3	85.7	65.0	61.3
150	101.7	87.7	66.7	62.8
200	104.0	90.0	71.2	66.0
250	103.3	89.3	71.7	66.7
		SEM _t		SEM _t
		CD at 5%		CD at 5%
'N' at fixed levels of 'W'		0.53	1.17	0.40
'W' at fixed or different levels of 'N'		0.31	0.69	0.45
				0.91
				1.03

year, were significant (Table 4.7) and similar was the trend of variation in second harvest year (1984-85). Maximum number of tillers / plant was recorded from weed free plots followed by those in diuron treated plots and the minimum number of tillers / plant was in weedy plots. Application of N also increased the number of tillers significantly up to 150 kg N / ha during first harvest year, whereas in second harvest year it was up to 200 kg N / ha. At highest level of N (250 kg), there was reductionⁱⁿ tiller number but the reduction was not significant in first harvest year and in second harvest year, it was significant only in the first cutting. Maximum number of tillers was recorded in Apr - Jun (fourth cutting), whereas the minimum was in second cutting (Oct - Dec). In the first harvest year the number of tillers / plant was lower in the first three cuttings than that was recorded in second harvest year.

The number of tillers in Experiment No. 1b (1984-86) as summarised in Table 4.8 also showed similar trend of variation as described in Experiment No. 1a. However, in Experiment No. 1b, the number of tillers / plant was more than that was recorded in Experiment No. 1a.

The interaction between weed control measures and levels of N was significant only in 4th cutting of first harvest year in both the Experiments No. 1a and 1b and first, second and fourth cuttings during second harvest year in both

Table 4.7 Number of tillers per plant as influenced by weed control treatments and levels of N (Experiment No. 1(a)-1983-85)

Weed control treatments	First harvest year (1983-84) Timings of harvest*				Second harvest year (1984-85) Timings of harvest*			
	I	II	III	IV	I	II	III	IV
Weedfree	21.8	23.1	22.9	44.3	39.0	26.4	26.3	42.0
Weedy	15.7	16.7	17.4	34.1	29.9	21.5	22.6	31.9
Diuron	18.1	18.8	19.2	37.3	33.8	23.7	24.2	35.5
SEM _t	0.28	0.28	0.27	0.29	0.30	0.24	0.28	0.54
CD at 5%	1.11	1.08	1.07	1.15	1.17	0.96	1.11	1.57
CV (%)	2.9	2.7	2.6	1.4	1.6	2.1	2.2	2.0
Levels of N (g/ha)								
0	13.4	12.6	14.6	30.0	29.6	18.9	20.3	30.8
50	16.1	17.6	18.2	37.0	31.4	21.7	22.0	34.1
100	18.8	20.2	20.8	39.3	33.8	23.3	23.6	36.3
150	20.2	21.4	21.9	41.4	36.1	25.9	26.1	38.9
200	21.7	22.3	22.4	42.4	37.9	27.0	27.8	40.0
250	20.9	22.4	21.3	41.3	36.6	26.6	26.7	38.7
SEM _t	0.53	0.70	0.52	0.48	0.41	0.41	0.47	0.58
CD at 5%	1.52	2.0	1.50	1.38	1.19	1.17	1.35	1.68
CV (%)	3.9	4.3	3.6	1.8	1.9	2.9	2.8	1.6

* I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

Table 4.8 Number of tillers per plant as influenced by weed control treatments and levels of N (Experiment No. 1(b)-1984-86)

Weed control treatments	First harvest year (1984-85) Tillings of harvest*				Second harvest year (1985-86) Tillings of harvest			
	I	II	III	IV	I	II	III	IV
Weedfree	26.1	28.3	29.1	40.3	46.1	29.6	30.6	32.2
Weedy	17.8	19.3	22.7	28.9	31.2	29.3	20.8	23.6
Pluron	22.4	24.5	25.6	33.6	39.3	25.8	26.3	28.7
SEM _t	0.10	0.36	0.21	0.53	0.52	0.46	0.36	0.58
CD at 5%	0.38	1.39	0.80	2.06	2.02	1.81	1.41	2.25
CV (%)	1.4	2.5	1.8	2.1	1.9	2.7	2.3	2.7
Levels of N (g/ha)								
0	14.8	16.7	19.4	26.1	30.7	17.2	18.9	19.4
50	19.7	22.2	24.3	32.2	36.8	23.3	24.4	25.8
100	22.4	24.4	26.3	34.8	39.3	25.7	26.6	28.4
150	24.7	26.4	27.8	37.2	42.2	27.7	28.7	31.1
200	26.1	27.8	29.0	38.4	42.8	29.3	29.9	32.7
250	25.0	26.7	28.0	36.9	41.6	26.2	28.3	31.6
SEM _t	0.55	0.73	0.66	0.62	0.64	0.44	0.58	0.52
CD at 5%	1.58	2.11	1.89	1.78	1.85	1.27	1.66	1.51
CD (N)	3.4	3.6	3.2	2.3	2.1	2.6	2.9	2.6

* I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

the Experiments (Table 4.9, 4.10, 4.11, 4.12). Significant difference in tiller production was noted up to 200 kg N / ha in weed free and weedy plots, whereas in Diuron treated plots, the difference was noted only up to 150 kg N / ha.

4.1.1.3 Fresh herbage yield

The fresh herbage yield of citronella Java as summarised in Table 4.13, revealed significant differences, between weed control measures and levels of N, in both the harvest years. Weed free plots yielded better (150.5 q / ha) than the plots treated with Diuron (124.3 q / ha) and the minimum (104.6 q / ha) of yearly herbage production was recorded in weedy plots in the first harvest year. In second harvest year, it was 223.9 q / ha in weed free plots and 204.0 and 179.4 q / ha in Diuron treated and in weedy plots, respectively.

Addition of N increased the fresh herbage yields significantly. The differences in fresh herbage yield at lower doses were more than at higher doses beyond 150 kg N / ha. The fresh herbage yield was high during the period Apr - Jun (fourth cutting) and low during Oct - Dec (second cutting), probably due to the effect of temperature. In first harvest year, minimum herbage yields were recorded in the first three cuttings, than that of subsequent harvests. The treatment variations Experiment No. 1b (1984-86) as

Table 4.9 Number of tillers per plant as influenced by weed control treatments and levels of N (Experiment No.1(a)-1983-85) in fourth harvest

Levels of N (kg/ha)	First harvest year (1983-84)			Second harvest year (1984-85)		
	Weed control treatments (W)			Weed control treatments (W)		
	Weedfree	Weedy	Diuron	Weedfree	Weedy	Diuron
0	35.0	25.0	30.0	33.3	27.3	31.7
50	42.7	31.7	36.7	40.0	29.0	33.3
100	45.0	34.7	38.3	42.7	31.3	35.0
150	46.7	36.7	41.0	44.3	33.3	39.0
200	50.0	38.3	39.0	47.3	35.7	37.0
250	46.7	38.3	39.0	44.3	34.7	37.0
'N' at fixed level of 'W'		SEM _W	CD at 5%		SEM _N	CD at 5%
		0.83	1.77		1.01	2.25
'W' at fixed or different levels of 'N'		0.81	1.73		1.07	2.39

Table 4.10 Number of tillers per plant as influenced by weed control treatments and levels of N (Experiment No. 1(a)-1983-85) in first and second harvest of second harvest year

Levels of N (t/ha)	First harvest weed control treatments (t)			Second harvest weed control treatments (t)		
	Weedfree	Weedy	Diuron	Weedfree	Weedy	Diuron
0	33.7	25.0	30.0	21.7	15.0	20.0
50	35.3	26.7	32.3	23.3	20.0	21.7
100	37.3	29.0	35.0	25.3	21.3	23.3
150	40.0	31.7	36.7	26.7	23.3	26.7
200	45.0	33.3	35.3	30.7	25.0	25.3
250	42.7	33.7	33.3	30.0	24.3	25.3
	SEM _t		CD at 5%	SEM _t		CD at 5%
'N' at fixed level of 'n'	0.71		1.54	0.7		1.67
'n' at fixed or different levels of 'N'	0.72		1.56	0.69		1.63

Table 4.11 Number of tillers per plant as influenced by weed control treatments and levels of N (Experiment No. 1(b)-1984-86) in fourth harvest

Levels of N (g/ha)	First harvest year (1984-85) Weed control treatments (W)			Second harvest year (1985-86) Weed control treatments (W)		
	Weedfree	Weedy	Diuron	Weedfree	Weedy	Diuron
0	31.7	21.7	25.0	21.7	16.7	20.0
50	36.7	26.7	33.3	30.0	20.7	26.7
100	39.3	30.0	35.0	32.0	23.3	30.0
150	42.7	31.7	37.3	34.7	26.0	32.7
200	47.3	32.7	35.3	38.3	28.3	31.3
250	44.0	31.0	35.7	36.7	26.7	31.3
		SD _W ±	CD at 5%		SD _W ±	CD at 5%
'N' at fixed level of 'W'		1.07	2.36		0.91	2.08
'W' at fixed or different levels of 'N'		1.11	2.45		1.02	2.33

Table 4.12 Number of tillers per plant as influenced by weed control treatments and levels of N (Experiment No. 1(b)-1994-96) in first and second harvest of second harvest year

Levels of N (g/ha)	First harvest			Second harvest		
	Weed control treatments (W)			Weed control treatments (W)		
	Weedfree	Weedy	Diuron	Weedfree	Weedy	Diuron
0	36.7	25.3	30.0	20.0	14.0	17.7
50	43.3	29.7	38.3	26.0	17.3	24.7
100	46.7	31.3	40.0	29.7	20.0	27.3
150	48.3	33.3	45.0	31.7	22.3	29.0
200	51.7	35.3	41.3	35.0	25.0	28.0
250	50.0	33.3	41.3	33.3	23.3	28.0
	SEM ₁			SEM ₂		
	CD at 5%			CD at 5%		
'N' at fixed level of 'W'	1.12	2.45		0.77	1.74	
'W' at fixed or different levels of 'N'	1.30	2.65		0.70	1.59	

Table 4.13 Fresh herbage yield (q/ha) as influenced by weed control treatments and levels of N (Experiment No. 1(a)-1983-85)

Weed control treatment	First harvest year (1983-84) Timings of harvest*					Second harvest year (1984-85) Timings of harvest*				
	I	II	III	IV	Total	I	II	III	IV	Total
Weedfree	16.0	18.3	20.7	95.5	150.5	50.4	37.4	58.4	77.6	223.9
Weedy	10.9	12.3	13.1	68.3	104.6	42.4	28.2	48.5	60.3	179.4
Diuron	13.1	14.6	16.3	80.3	124.3	48.9	34.0	53.3	67.8	204.0
SEM _t	0.22	0.37	0.36	1.87	1.91	0.65	0.75	1.06	1.65	2.24
CD at 5%	0.44	1.43	1.40	7.32	7.47	2.54	2.93	3.05	6.47	6.46
CV (%)	7.0	10.3	9.1	9.8	6.4	5.8	9.6	8.4	8.2	4.4
Levels of N (g/ha)										
0	9.2	10.6	12.0	60.0	91.8	36.2	24.7	42.9	45.7	149.5
50	11.1	13.2	14.1	75.0	113.4	41.3	30.0	48.9	61.5	181.7
100	13.8	15.0	16.8	83.4	129.0	48.3	34.4	54.1	66.8	203.6
150	15.3	16.9	19.4	90.0	141.6	51.3	36.9	58.0	78.0	224.2
200	15.9	17.6	19.8	91.7	145.0	53.5	37.6	59.3	81.0	231.4
250	14.5	16.9	18.2	88.2	137.8	52.6	35.6	57.1	78.7	224.0
SEM _t	0.54	0.48	0.65	2.59	2.56	1.06	0.80	0.92	1.75	2.74
CD at 5%	1.55	1.39	1.87	7.46	7.37	3.05	2.31	2.64	5.05	9.35
CV (%)	13.9	9.6	11.7	9.6	6.3	6.7	6.8	5.2	7.6	3.3

* I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

summarised in Table 4.14 also showed similar variations as have been described in Experiment No. 1a.

The interactions between weed control measures and levels of N were significant in all the cuttings of both the Experiments (Table 4.15 and 4.16). The significant variations in yearly fresh herbage yield due to different levels of N was noted up to 200 kg N / ha in weed free and weedy plots in both the harvest years. In diuron treated plots significant increase in yield was noted up to 150 kg N / ha.

4.1.1.4 Dry matter accumulation

The treatment differences in dry matter production were significant due to weed control measures and levels of N application during both the harvest years in Experiment No. 1a (Table 4.17). Maximum dry matter accumulation was recorded from weed free plots followed by those in which Diuron was sprayed and their difference was also significant. whereas, minimum dry matter yield was noted from weedy plots. Nitrogen increased dry matter yield up to 150 kg^N/ ha. There was slight but not significant increase in dry matter production at 200 kg N / ha. Further, addition of N, slightly reduced the dry matter yield, and this reduction was also not significant in both the harvest years (1983-84 and 1984-85).

Table 4.14 Fresh herbage yield (q/ha) as influenced by weed control treatments and levels of N (Experiment No. 1(b)-1984-86)

Weed control treatments	First harvest year (1984-85) Timings of harvest					Second harvest year (1985-86) Timings of harvest				
	I	II	III	IV	Total	I	II	III	IV	Total
Weedfree	30.8	43.0	60.3	75.4	209.5	93.8	47.3	65.8	66.3	273.2
Weedy	23.8	33.5	45.7	59.9	162.9	75.2	31.2	49.8	53.7	209.9
Diuron	28.0	39.3	55.6	66.3	189.2	87.7	37.8	55.4	59.3	240.2
SEM _±	0.53	0.67	1.50	1.79	3.20	1.86	0.58	1.23	1.05	3.0
CD at 5%	2.06	2.63	5.88	7.02	12.51	7.28	2.28	4.8	4.10	11.78
CV (%)	8.1	7.4	11.8	11.3	7.3	9.2	6.0	9.1	7.4	5.2
Levels of N (q/ha)										
0	22.3	30.2	42.0	44.8	139.3	64.9	29.4	38.4	42.0	174.7
50	25.2	34.5	47.3	55.2	162.2	78.6	35.6	49.0	54.8	218.0
100	27.8	38.0	50.8	65.2	181.8	85.9	38.4	58.1	62.3	244.7
150	30.6	42.0	59.9	77.7	210.2	94.9	42.0	65.2	66.2	268.3
200	30.5	43.9	62.3	81.7	218.4	95.2	44.8	67.6	67.7	274.3
250	28.7	43.1	60.7	78.6	211.1	94.1	42.4	63.6	66.7	266.8
SEM _±	0.65	1.10	1.40	2.13	2.70	2.05	0.90	1.73	1.66	3.73
CD at 5%	1.87	3.16	4.02	6.13	7.78	5.91	2.59	4.99	4.79	10.73
CV (%)	7.1	8.2	7.8	9.5	4.3	7.0	7.0	9.1	8.3	4.9

* I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

Table 4.15 Fresh herbage yield (g/ha) as influenced by weed control treatments and levels of N (Experiment No. 1(a)-1983-85)

Levels of N (g/ha)	First harvest year (1983-84) weed control treatments (g)			Second harvest year (1984-85) weed control treatments (g)		
	Weedfree	Weedy	Diuron	Weedfree	Weedy	Diuron
0	105.3	79.9	90.0	169.3	124.9	154.0
50	130.7	96.8	112.7	201.6	162.4	180.7
100	148.2	104.2	134.4	219.3	179.4	213.2
150	160.3	112.2	152.4	236.2	196.6	239.7
200	183.1	120.6	131.2	261.4	211.9	220.6
250	175.1	113.8	124.3	255.0	201.1	215.3
	SEM _t		CD at 5%	SEM _t		CD at 5%
'N' at fixed level of 'W'	4.60		9.98	3.81		11.98
'W' at fixed or different levels of 'N'	6.51		14.13	5.87		13.10

Table 4.16 Fresh herb yield (g/ha) as influenced by weed control treatments and levels of N
(Experiment No. 1(a)-1984-86)

Levels of N (g/ha)	First harvest year (1984-85) Weed control treatments (W)			Second harvest year (1985-86) Weed control treatments (W)		
	Weedfree	Weedy	Diuron	Weedfree	Weedy	Diuron
0	155.7	115.1	146.9	202.9	142.5	179.7
50	175.4	143.6	167.8	246.7	195.9	221.5
100	196.3	161.2	188.1	269.7	211.6	252.7
150	227.5	175.7	227.5	290.0	227.0	297.8
200	258.8	193.5	202.9	319.1	252.7	253.8
250	243.4	188.6	201.2	311.4	239.6	249.5
		SEM _T	CD at 5%		SEM _T	CD at 5%
'N' at fixed level of 'W'		4.61	10.64		6.91	14.99
'W' at fixed or different levels of 'N'		7.57	17.48		9.70	21.06

Table 4.17 Dry matter accumulation (g/ha) as influenced by weed control treatments and levels of N
(Experiment No. 1(a)-1983-85)

Weed control treatments	First harvest year (1983-84) Timings of harvest*					Second harvest year (1984-85) Timings of harvest*				
	I	II	III	IV	Total	I	II	III	IV	Total
Weedfree	5.8	6.6	7.5	31.9	51.8	17.3	13.2	20.0	25.9	76.4
Weedy	4.1	4.6	4.8	23.1	36.6	14.9	10.0	17.1	21.3	63.3
Diuron	4.9	5.4	5.9	27.3	43.5	17.2	12.0	19.6	23.3	71.1
SEM _t	0.08	0.14	0.13	0.56	0.49	0.16	0.27	0.38	0.47	0.78
CD at 5%	0.33	0.53	0.51	2.2	1.94	0.62	1.05	1.47	1.83	3.06
CV (%)	5.0	5.4	4.4	6.1	4.7	11.6	6.7	6.6	8.4	4.7
Levels of N (g/ha)										
0	3.5	3.9	4.4	20.7	32.5	12.8	8.8	15.2	15.9	52.7
50	4.1	4.9	5.1	25.4	39.5	14.5	10.6	17.1	21.2	63.4
100	5.1	5.5	6.1	28.3	45.0	16.8	12.2	18.8	23.0	70.8
150	5.7	6.2	7.0	30.4	49.3	17.8	13.0	20.1	26.7	77.6
200	5.9	6.5	7.1	30.2	49.7	18.5	13.3	20.5	27.6	79.9
250	5.3	6.2	6.5	29.5	47.5	18.2	12.6	19.7	26.6	77.1
SEM _t	0.22	0.18	0.24	0.87	0.94	0.35	0.29	0.35	0.56	0.75
CD at 5%	0.62	0.51	0.70	2.50	2.69	1.0	0.84	1.02	1.62	2.17
CV (%)	4.3	7.7	11.7	5.0	6.4	13.6	7.5	5.7	7.2	3.2

* I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

The dry matter production was more in second harvest year than that of first harvest year. The dry matter production was more during Apr - Jun (fourth cutting) and was minimum during Oct - Dec (second cutting). This is probably due to temperature effect. However, the lowest dry matter production was noted in first cutting of first harvest year. The results of Experiment No. 1 b (1984-85) with regard to dry matter accumulation as summarised in Table 4.18 showed similar trend of variation as described in Experiment No. 1 a.

The interaction effect of annual dry matter production between weed control measures and levels of N, was significant in Experiment No. 1 a and 1 b as summarised in Table 4.19 and Table 4.20. The significant variation in dry matter production was noticed in weed free and weedy plots up to 200 kg N / ha except weedy plots in first year of Experiment No. 1 which varied up to 100 kg N / ha whereas diuron treated plots, the differences was noted up to 150 kg N / ha.

4.1.2 Essential oil content, oil yield and oil quality

4.1.2.1 Oil content

In the first harvest year in Experiment No. 1 a (1983-85), the treatment differences due to the levels of N and weed control treatments in citronella Java were not significant; so was the case in the second harvest year in 1984-85. It may be noted from the data in Table 4.21 that in first harvest year oil contents were more than that was recorded

Table 4.18 Dry matter accumulation (g/ha) as influenced by weed control treatments and levels of N (Experiment No. 1(b)-1984-86)

Weed control treatments	First harvest year (1984-85) Timings of harvest*					Second harvest h year (1985-86) Timings of harvest*				
	I	II	III	IV	Total	I	II	III	IV	Total
Weedfree	10.9	15.2	21.3	25.5	72.9	31.4	16.2	22.5	22.6	92.7
Weedy	8.6	12.1	16.5	21.2	58.4	25.7	10.9	17.2	19.0	72.8
Diuron	10.1	14.1	20.0	23.2	67.4	29.9	13.1	19.2	20.4	82.6
SEM ₊	0.19	0.39	0.57	0.63	1.13	0.65	0.21	0.40	0.45	1.0
CD at 5%	0.76	1.52	2.25	2.46	4.42	2.56	0.81	1.58	1.76	3.89
CV (%)	8.3	11.9	12.6	11.4	7.2	9.5	6.5	8.7	9.2	5.1
Levels of N (g/ha)										
0	8.2	10.9	15.3	15.8	50.2	22.3	10.4	13.6	14.8	61.1
50	9.1	12.4	16.9	19.2	57.6	26.8	12.4	17.5	19.0	75.7
100	9.9	13.6	18.0	22.6	64.2	29.1	13.3	20.0	21.6	84.0
150	10.9	15.0	21.4	26.8	74.1	32.0	14.5	22.3	22.8	91.6
200	10.9	15.6	22.3	28.1	76.9	32.3	15.4	23.1	22.9	93.7
250	10.2	15.3	21.6	27.1	74.2	31.6	14.5	21.8	22.9	90.8
SEM ₊	0.23	0.39	0.49	0.7	0.96	0.68	0.32	0.60	0.52	1.18
CD at 5%	0.66	1.12	1.41	2.12	2.75	1.95	0.93	1.73	1.50	3.41
CV (%)	7.0	8.4	7.6	9.5	4.3	7.0	7.2	9.2	7.6	4.3

* I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

Table 4.19 Dry matter accumulation (g/ha) as influenced by weed control treatments and levels of N (Experiment No. 1(a)-1983-85)

Levels of N (g/ha)	First harvest year (1983-84) Weed control treatments (a)			Second harvest year (1984-85) Weed control treatments (a)		
	Weedfree	Weedy	Diuron	Weedfree	Weedy	Diuron
0	37.0	20.6	31.9	58.9	44.8	54.5
50	45.2	34.2	39.4	69.3	57.6	63.3
100	51.2	36.5	46.9	74.6	63.3	74.3
150	55.2	39.5	53.1	80.4	69.2	83.3
200	62.6	40.4	45.8	88.5	74.5	76.6
250	59.8	39.8	43.2	86.3	70.5	74.4
		SEM ₁	CD at 5%		SEM ₁	CD at 5%
'N' at fixed level of 'N'		1.62	3.42		1.30	2.93
'N' at fixed or different levels of 'N'		1.56	3.29		1.14	2.56

Table 4.20 Dry matter accumulation (g/h_a) as influenced by weed control treatments and levels of N (Experiment No. 1(b)-1984-86)

Levels of N (g/h _a)	First harvest year (1984-85) weed control treatments (%)			Second harvest year (1985-86) weed control treatments (%)		
	Weedfree	Weedy	Diuron	Weedfree	Weedy	Diuron
0	55.7	42.1	53.0	70.0	50.6	62.4
50	61.6	51.5	59.7	84.3	65.2	76.3
100	68.4	57.5	66.8	91.4	73.6	86.7
150	78.7	62.9	80.8	97.9	78.3	98.6
200	89.1	69.1	72.2	107.8	87.0	86.5
250	84.0	67.3	71.3	105.1	82.6	84.7
		SEM	CD at 5%		SEM	CD at 5%
'N' at fixed level of 'W'		1.66	3.81		2.05	4.51
'W' at fixed or different levels of 'N'		1.89	4.34		2.12	4.67

Table 4.21 Oil content (%) as influenced by weed control treatments and levels of N
(Experiment No. 1(a)-1983-85)

Weed control treatments	First harvest year (1983-84) Timings of harvest*				Second harvest year (1984-85) Timings of harvest*			
	I	II	III	IV	I	II	III	IV
Weedfree	1.37	1.39	1.37	1.30	1.30	1.39	1.38	1.20
Weedy	1.39	1.40	1.37	1.31	1.31	1.41	1.38	1.20
Diuron	1.39	1.40	1.37	1.31	1.31	1.41	1.39	1.20
SEM _t	0.005	0.006	0.01	0.002	0.003	0.004	0.005	0.002
CD at 5%	-	-	-	-	-	-	-	-
CV (%)	1.6	0.8	3.1	1.8	1.2	1.5	1.5	0.8
Levels of N (kg/ha)								
0	1.39	1.40	1.37	1.31	1.31	1.41	1.39	1.21
50	1.39	1.40	1.38	1.31	1.31	1.41	1.39	1.20
100	1.39	1.40	1.37	1.31	1.30	1.40	1.38	1.20
150	1.38	1.40	1.37	1.30	1.30	1.39	1.38	1.20
200	1.38	1.39	1.37	1.30	1.30	1.39	1.38	1.20
250	1.38	1.39	1.37	1.30	1.29	1.39	1.37	1.19
SEM _t	0.008	0.003	0.01	0.006	0.006	0.006	0.008	0.005
CD at 5%	-	-	-	-	-	-	-	-
CV (%)	1.8	1.3	2.3	0.7	1.3	1.2	1.8	1.2

* I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

in second harvest year. The oil content was high in second cutting (Oct - Dec) and low in fourth cutting (Apr - Jun).

The results of Experiment No. 1b (1984-86) with regards to oil content as summarised in Table 4.22 showed similar trend of variations due to treatments described in Experiment No. 1a, earlier. The interaction effects between weed control measures and levels of N were not significant in both the harvests and in two Experiments 1a and 1b.

4.1.2.2 Oil yield

The treatment differences in oil yield (Table 4.23) due to weed control measures and levels of N were significant in first harvest year of Experiment No. 1a (1983-85) and so was the case in the second harvest year (1984-85). The annual oil production (199.8 kg / ha) was more in weed free plots than those recorded in diuron treated plots (165.5 kg / ha), the minimum (139.8 kg / ha) oil yield was recorded in weedy plots in first harvest year. In second harvest year, the oil yields (234.4 to 290.3 kg / ha) was more than those recorded during first harvest year (139.8 to 199.8 kg / ha).

Application of N increased the oil yield up to 150 kg N / ha in both the harvests years in Experiment No. 1a. At the same level of N (150 kg / ha / year) citronella Java gave 188.3 kg / ha of oil in first harvest year as compared to 291.8 kg / ha oil recorded in second harvest year. At the

Table 4.22 Oil content (%) as influenced by weed control treatments and levels of N
(Experiment No. 1(b)-1984-86)

Weed control treatments	First harvest year (1984-85) Timings of harvest*				Second harvest year (1985-86) Timings of harvest			
	I	II	III	IV	I	II	III	IV
weedfree	1.38	1.40	1.33	1.30	1.28	1.39	1.38	1.20
Weedy	1.38	1.40	1.35	1.31	1.29	1.39	1.39	1.21
Diuron	1.38	1.39	1.33	1.31	1.29	1.39	1.39	1.20
SDM+	0.007	0.002	0.006	0.004	0.004	0.002	0.002	0.004
CD at 5%	-	-	-	-	-	-	-	-
CV (%)	0.5	0.2	0.5	0.3	0.8	0.7	0.7	0.8
Levels of N (g/ha)								
0	1.33	1.40	1.34	1.31	1.29	1.40	1.39	1.21
50	1.33	1.40	1.34	1.31	1.29	1.40	1.39	1.21
100	1.38	1.40	1.34	1.31	1.29	1.40	1.39	1.21
150	1.38	1.39	1.34	1.31	1.29	1.39	1.38	1.20
200	1.38	1.39	1.34	1.30	1.28	1.38	1.38	1.20
250	1.38	1.39	1.33	1.29	1.28	1.38	1.38	1.20
SDM+	0.009	0.003	0.009	0.006	0.009	0.007	0.009	0.006
CD at 5%	-	-	-	-	-	-	-	-
CV (%)	0.7	0.2	0.7	0.5	1.3	1.4	2.0	1.4

* I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

Table 4.23 Oil yield (t/ha) as influenced by weed control treatments and levels of N (Experiment No. 1(a)-1983-85)

Weed control treatments	First harvest year (1983-84) Timings of harvest*					Second harvest year (1984-85) Timings of harvest*				
	I	II	III	IV	Total	I	II	III	IV	Total
Weedfree	21.8	25.6	28.3	124.1	199.8	65.2	52.1	80.2	92.9	290.3
Weedy	15.1	17.3	17.9	89.4	139.8	55.2	39.7	67.0	72.5	234.4
Diuron	18.2	20.3	22.4	104.6	165.5	63.8	47.6	74.1	81.3	266.8
Sam+	0.35	0.54	0.59	2.44	2.05	0.55	1.06	1.54	1.70	3.10
CD at 5%	1.39	2.12	2.32	9.54	8.02	2.16	4.17	6.04	6.66	12.14
CV (%)	8.0	11.8	10.9	9.8	5.2	3.7	9.8	8.7	8.8	4.9
Levels of N (t/ha)										
0	12.9	14.8	16.5	78.6	122.8	43.3	34.8	59.7	55.2	197.0
50	15.6	18.6	19.4	98.1	151.7	54.1	42.4	68.1	73.8	238.4
100	19.1	21.0	23.0	108.7	171.8	62.9	48.1	74.9	80.2	266.1
150	21.1	23.7	26.5	117.0	188.3	66.7	51.4	80.2	93.5	291.8
200	21.6	24.8	27.0	119.2	192.6	69.6	52.4	81.6	97.1	300.7
250	19.8	23.4	24.8	114.6	182.7	68.1	49.7	78.1	93.5	289.4
Sam+	0.82	0.73	0.87	3.30	3.45	1.34	1.18	1.40	2.06	3.07
CD at 5%	2.36	2.10	2.50	9.51	9.94	3.85	3.41	4.03	5.92	10.24
CV (%)	13.3	10.0	11.5	9.3	6.2	6.6	7.5	5.7	7.5	3.2

* I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

highest level of N (250 kg / ha), there was reduction in oil yield and the percentage reduction was from 3.4 to 3.8 in both harvesting years in Experiment No. 1 a. High oil yield was recorded during the period Apr - Jun (fourth cutting) whereas the minimum oil yield was recorded during the period Oct - Dec (second cutting). Lower oil yields were recorded in first three harvests of first year than that was observed in second harvest year, which is probably due to dilution effect.

The oil yield in Experiment No. 1 b (1984-86) as summarised in Table 4.24 was high and showed similar trend of differences as described in Experiment No. 1 a, the crop gave more oil than that was recorded in Experiment No. 1 a.

The interactions in annual oil yield between weed control measures and levels of N, were significant in both the Experiments as summarised in Table 4.25 and 4.26. The oil yield increased significantly with increasing level of N application up to 200 kg N / ha in weed free and weedy plots. In diuron treated plots, oil yields increased only up to 150 kg N / ha.

4.1.2.3 Oil quality

4.1.2.3(a) Citronellal content

Citronellal contents in oil in the first harvest year of Experiment No. 1 a, as summarised in Table 4.27 did not vary significantly due to weed control treatments and levels of N; similar trend of variation was observed in second

Table 4.24 Oil yield (g/ha) as influenced by weed control treatments and levels of N (Experiment No. 1(b)-1984-86)

Weed control treatments	First harvest year (1984-85) Findings of harvest*					Second harvest year (1985-86) Findings of harvest*				
	I	II	III	IV	Total	I	II	III	IV	Total
Handfree	42.3	60.2	80.3	97.7	280.5	119.7	65.6	91.0	79.6	355.9
Weedy	32.9	46.9	61.5	78.6	219.9	97.2	43.4	69.2	64.8	274.6
Diuron	38.7	54.8	74.2	86.5	254.2	113.7	52.6	76.6	71.2	314.1
DDM	0.61	1.57	2.25	2.39	4.33	2.31	0.80	1.62	1.52	4.16
CO at 5%	2.40	6.13	8.80	9.35	16.95	9.04	3.15	6.33	5.95	16.28
CV (%)	6.9	12.3	13.3	11.6	7.3	8.9	6.4	8.7	9.0	4.5
Levels of N (g/ha)										
0	30.8	42.3	56.1	58.7	187.9	83.6	41.1	53.6	50.7	229.0
50	34.9	48.4	63.3	72.4	219.0	101.6	49.8	68.1	66.1	285.6
100	38.5	53.3	68.1	85.5	245.4	110.5	53.8	81.8	75.0	320.1
150	42.3	58.6	80.1	101.3	282.3	122.7	58.4	90.3	79.4	350.8
200	42.1	61.2	83.4	106.3	293.0	122.7	61.7	93.6	80.1	358.1
250	39.5	60.2	80.6	101.6	281.9	120.2	58.6	87.8	80.1	346.7
SEM	0.98	1.48	1.87	2.91	3.60	2.48	1.15	2.40	1.80	4.30
CO at 5%	2.82	4.24	5.38	8.38	10.37	7.15	3.31	6.92	5.19	12.38
CV (%)	7.8	8.2	7.8	10.0	4.3	6.8	6.3	9.2	7.5	5.9

* I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

Table 4.25 Oil yield (kg/ha) as influenced by weed control treatments and levels of N
(Experiment No. 1(a)-1983-85)

Levels of N (kg/ha)	First harvest year (1983-84) weed control treatments (kg)			Second harvest year (1984-85) weed control treatments (kg)		
	Weedfree	Weedy	Diuron	Weedfree	Weedy	Diuron
0	140.0	107.0	121.0	221.6	165.6	204.3
50	173.8	129.8	151.1	263.2	213.3	238.1
100	196.8	139.8	178.9	285.2	233.0	279.8
150	213.0	149.2	202.5	306.0	256.0	313.7
200	242.5	160.5	174.6	338.3	276.5	287.3
250	232.2	151.3	165.1	328.1	261.6	277.9
		SEM _T	CD at 5%		SEM _T	CD at 5%
'N' at fixed level of 'D'		5.97	19.69		4.84	17.54
'D' at fixed or different levels of 'N'		5.85	19.31		5.40	19.58

Table 4.26 Oat yield (t/ha) as influenced by weed control treatments and levels of N
(Experiment No. 1(b)-1984-86)

Levels of N (t/ha)	First harvest year (1984-85) weed control treatments (W)			Second harvest year (1985-86) weed control treatments (W)		
	weedfree	weedy	Diuron	weedfree	weedy	Diuron
0	209.2	155.9	198.7	265.0	188.0	234.1
50	235.9	194.2	226.5	322.3	244.7	289.8
100	263.7	210.1	253.8	352.5	270.8	329.0
150	305.1	237.2	305.3	378.6	297.2	376.6
200	346.2	260.7	271.6	414.1	328.8	330.8
250	323.5	253.1	269.2	404.3	311.2	324.7
	Sum		OD at 5%	Sum		OD at 5%
'N' at fixed level of 'W'	6.30		23.0	7.47		26.53
'W' at fixed or different levels of 'N'	7.23		26.41	8.05		28.60

Table 4.27 Citronellal content (%)^{*} in oil as influenced by weed control treatments and levels of N (Experiment No. 1(a)-1983-85)

Weed control treatments	First harvest year (1983-84) Timings of harvest**				Second harvest year (1984-85) Timings of harvest**			
	I	II	III	IV	I	II	III	IV
Weedfree	30.2	28.60	29.72	22.77	35.22	28.76	29.79	25.83
Weedy	30.5	28.49	28.90	23.56	35.39	28.63	29.43	25.22
Diuron	30.6	28.56	28.77	22.73	36.0	28.88	29.41	25.13
Levels of N (g/ha)								
0	30.5	28.47	29.71	22.99	35.01	28.27	29.50	26.45
50	30.5	28.74	29.21	23.03	35.02	28.69	29.78	25.18
100	30.5	28.51	30.17	23.01	35.21	29.36	29.50	25.46
150	30.3	28.65	28.62	23.12	35.43	27.58	29.43	24.96
200	30.4	28.28	28.70	22.67	36.18	29.17	29.77	25.48
250	30.4	28.65	28.40	23.29	36.34	27.98	29.27	25.26

* Values of composite samples

** I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

harvest year (1984-85) as well. The citronellal content in citronella oil was high during Jul - Sep (first cutting) and low during Apr - Jun (fourth cutting) in both the harvest years. The citronellal content was however, more in second harvest year than that was observed in first harvest year. It may also be due to the dilution effect of high herbage yield.

The results of Experiment No. 1b (1984-86) with regard to citronellal content as summarised in Table 4.28 showed similar trend of variation as have been described in Experiment No. 1a.

The interaction effects between weed control measures and levels of N on citronellal content were not significant in both the harvest years in both the Experiments.

4.1.2.3(b) Citronellol content

In the first harvest year in Experiment No. 1a (1983-85) the differences in citronellol content due to weed control measures and levels of N did not vary significantly. So was the case in the second harvest year. It is apparent from the data presented in Table 4.29 that citronellol contents during third cutting (Jan - Mar) were high, while during first cutting (Jul - Sep) they were low in both the harvest years.

Table 4.28 Citronellal content (%)^{*} in oil as influenced by weed control treatments and levels of N (Experiment No. 1(b)-1984-86)

Weed control treatments	First harvest year (1984-85) Timings of harvest				Second harvest year (1985-86) Timings of harvest			
	I	II	III	IV	I	II	III	IV
Weedfree	29.34	26.79	26.16	24.68	32.36	28.10	30.14	26.21
Weedy	29.04	26.52	28.08	24.36	32.41	28.11	30.24	26.22
Diuron	29.11	26.86	28.18	24.38	32.23	28.07	30.30	26.23
Levels of N (g/ha)								
0	28.66	26.57	27.95	24.51	32.26	28.10	30.17	26.19
50	29.06	26.78	27.92	24.51	32.37	28.06	30.22	26.22
100	29.29	26.72	28.13	24.41	32.24	28.13	30.29	26.16
150	29.38	26.82	28.25	24.50	32.34	28.10	30.24	26.25
200	29.16	26.88	28.23	24.48	32.48	28.10	30.24	26.27
250	29.21	26.55	28.33	24.44	32.29	28.07	30.18	26.24

* Values of composite samples

** I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

Table 4.29 Citronellol content (%) * in oil as influenced by weed control treatments and levels of N (Experiment No. 1(a)-1983-85)

Weed control treatments	First harvest year (1983-84) Timings of harvests**				Second harvest year (1984-85) Timings of harvest**			
	I	II	III	IV	I	II	III	IV
Weedfree	5.79	8.61	13.33	12.69	9.19	12.05	15.83	12.83
Weedy	5.99	8.28	13.45	12.53	9.76	12.14	14.71	12.37
Aluron	6.59	8.53	13.12	12.39	9.23	12.14	14.75	12.08
Levels of N (g/ha)								
0	6.74	7.94	13.23	12.53	9.20	12.14	14.93	12.40
50	5.94	8.52	13.04	12.68	9.26	11.91	15.08	11.99
100	6.15	9.24	13.43	12.64	9.41	12.07	14.95	12.40
150	6.25	8.41	13.38	12.46	9.57	11.90	15.12	12.53
200	6.44	8.64	13.13	12.45	9.37	12.21	15.09	12.54
250	5.57	8.70	13.58	12.46	9.56	12.42	15.41	12.70

* Values of composite samples

** I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

The citronellol content in crops grown in Experiment No. 1b (1984-86) as summarised in Table 4.30 also showed similar variation as described in Experiment No. 1a.

The variation in citronellol contents due to weed control treatments and levels of N, were not significant in both the years of both the Experiments No. 1a and 1b.

4.1.2.3(c) Geraniol content

Treatment variations in the geraniol contents in the first harvest year of Experiment No. 1a (1983-84) in citronella oil were not significant. (Table 4.31). Similar was the case in all the cuttings in second harvest year. It is apparent from the data summarised in Table 4.31 that citronella Java recorded high geraniol content in the first cutting (Jul - Sep) and low in third cutting (Jan - Mar) in both the harvest years. Percentage of geraniol was more in second harvest than in first harvest year.

The geraniol content of Experiment No. 1b (1984-86) as summarised in Table 4.32 showed similar trend of variations as in Experiment No. 1a, above.

The interaction effect between weed control measures and levels of N was not significant in both the Experiments.

Table 4.3) Citronellol content (%)^{*} in oil as influenced by weed control treatments and levels of N (Experiment No. 1(b)-1984-86)

weed control treatments	first harvest year (1984-85) timings of harvest**				second harvest year (1985-86) timings of harvest**			
	I	II	III	IV	I	II	III	IV
weedfree	7.0	7.41	12.53	10.92	8.21	11.82	14.80	11.02
weedy	6.80	7.41	12.53	10.55	8.27	11.61	14.88	11.03
Diuron	6.71	7.15	12.41	10.16	8.28	11.78	14.65	11.04
Levels of N (g/ha)								
0	7.07	7.33	12.67	10.60	8.35	11.81	14.58	11.04
50	6.85	7.50	12.61	10.58	8.21	11.67	14.63	11.08
100	6.91	7.16	12.43	10.63	8.25	11.73	14.86	10.95
150	6.79	7.26	12.45	10.62	8.20	11.68	14.94	11.04
200	6.88	7.42	12.38	10.47	8.27	11.83	14.89	11.03
250	6.84	7.27	12.43	10.42	8.24	11.69	14.65	11.03

* Values of composite samples

** I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

Table 4.31 Geraniol content (A) * in oil as influenced by weed control treatments and levels of N (Experiment No. 1(a)-1983-85)

weed control treatments	First harvest year (1983-84) Timings of harvest**				Second harvest year (1984-85) Timings of harvest**			
	I	II	III	IV	I	III	III	IV
Weedfree	26.67	14.94	11.21	16.25	26.62	15.51	9.83	20.91
weedy	26.63	14.61	10.33	15.80	26.47	15.32	9.89	20.86
Muron	26.90	14.81	10.45	16.54	26.63	15.52	10.13	20.85
Levels of N (g/ha)								
0	26.73	14.63	11.81	16.74	26.67	15.22	9.82	20.77
50	26.56	14.87	10.12	16.64	26.52	15.33	9.74	20.72
100	26.38	14.78	10.83	16.0	26.55	15.48	10.06	21.03
150	26.45	14.67	10.23	16.32	26.36	15.52	10.03	20.84
200	25.68	15.09	10.09	16.19	26.16	16.65	10.02	21.17
250	26.57	14.67	10.50	16.30	26.48	15.47	10.02	20.74

* Values of composite samples

** I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

Table 4.32 Geraniol content (%) in oil as influenced by weed control treatments and levels of N
(Experiment No. 1(b)-1984-86)

Weed control treatments	First harvest year (1984-85) Timings of harvest**				Second harvest year (1985-86) Timings of harvest**			
	I	III	III	IV	I	II	III	IV
Weedfree	26.04	12.12	9.66	15.09	25.99	13.23	12.17	16.14
Weedy	26.13	12.14	9.53	15.18	26.12	13.25	12.17	16.13
Diuron	26.20	12.09	9.18	15.22	26.07	13.27	12.27	16.13
Levels of N (g/ha)								
0	26.03	12.02	9.49	15.11	25.99	13.25	12.19	16.12
50	26.05	12.15	9.58	15.22	26.03	13.29	12.19	16.10
100	26.25	12.07	9.49	15.18	26.08	13.25	12.22	16.10
150	26.09	12.11	9.39	15.15	26.05	13.19	12.23	16.16
200	26.32	12.22	9.40	15.14	26.09	13.26	12.20	16.16
250	26.13	12.14	9.38	15.17	26.13	13.25	12.17	16.16

* Values of composite samples

** I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

4.1.3 Nitrogen uptake

The treatment variations in N uptake in first harvest year in Experiment No. 1 a (1983-85) were significant (Table 4.33) and so was the case in the second harvest year (1984-85). The yearly N uptake (63.2 kg / ha) was more in weed free plots than those recorded in Diuron treated plots (49.7 kg / ha) while the minimum (40.4 kg / ha) Nitrogen uptake was recorded in weedy plots in first harvest year. In second harvest year the N uptake was in order of 116.1, 104.5 and 91 kg / ha in weed free, Diuron and weedy plots, respectively.

Application of N increased the N uptake up to 150 kg / ha in both the harvest years, and annual uptake was 58.8 and 115.8 kg / ha during first and second harvest of the Experiment No. 1 a.

The maximum N uptake ranged from 17.2 to 29.4 kg / ha in fourth cutting (Apr - Jun) and from 5.1 to 9.9 kg / ha in second cutting (Oct - Dec) in first harvest year. In second harvest year, the N uptake was high in first cutting (Jul - Sep) and low in second cutting (Oct - Dec).

The N uptake in Experiment No. 1 b (1984-86) as given in Table 4.34 was relatively high but the trend of variations was similar to that described in Experiment No. 1 a.

The interactions between weed control treatments and levels of N were significant in both the Experiments No.1a and

Table 4.33 Nitrogen uptake (g/ha) as influenced by weed control treatments and levels of N (Experiment No. 1(a)-1983-85)

Weed control treatments	First harvest year (1983-84) Timings of harvest*					Second harvest year (1984-85) Timings of harvest*				
	I	II	III	IV	Total	I	III	III	IV	Total
weedy free	11.7	9.9	12.2	23.4	63.2	34.1	19.1	39.7	23.2	116.1
weedy	7.8	6.1	6.7	19.8	40.4	23.0	12.9	31.4	18.7	91.0
Aluron	9.5	7.4	8.4	24.4	49.7	31.9	16.6	36.3	19.9	104.5
30mg	0.15	0.19	0.20	0.50	0.45	0.38	0.36	0.65	0.73	0.77
CD at 5%	0.59	0.76	0.78	1.97	1.75	1.50	1.41	2.71	2.86	3.02
CV (%)	6.7	6.2	9.3	8.7	3.7	10.8	9.4	15.0	6.1	10.6
Level of N (g/ha)										
0	6.7	5.1	5.8	17.2	34.8	23.9	11.4	23.8	13.4	77.5
50	8.1	6.8	7.5	21.6	44.0	27.4	14.3	32.7	16.2	90.6
100	10.0	7.9	9.1	24.8	51.8	32.2	16.8	36.7	20.4	106.1
150	11.1	9.0	10.7	28.0	58.8	34.0	18.3	39.0	24.5	115.8
200	11.5	9.3	11.2	28.1	60.1	35.5	18.6	39.7	25.0	118.8
250	10.5	8.8	10.4	27.5	57.2	34.8	17.5	37.9	24.1	114.3
30mg	0.42	0.26	0.36	0.79	0.98	0.68	0.40	0.70	0.93	1.29
CD at 5%	1.21	0.75	1.04	2.28	2.83	1.95	1.15	2.02	2.68	3.73
CV (%)	13.0	5.2	11.9	9.7	5.8	13.5	7.4	13.5	5.2	13.1

* I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

Table 4.34 Nitrogen uptake (kg/ha) as influenced by weed control treatments and levels of N (Experiment No. 1(b)-1984-86)

Weed control treatments	First harvest year (1984-85)					Second harvest year (1985-86)				
	Timings of harvest*					Timings of harvest*				
	I	II	III	IV	Total	I	II	III	IV	Total
Weedfree	21.3	22.4	34.2	23.5	101.4	62.3	23.4	44.5	19.5	149.7
Weedy	16.5	16.0	20.3	18.9	73.7	48.9	13.9	31.7	16.6	111.1
Diuron	19.6	19.1	27.2	20.8	83.7	57.3	17.9	36.1	18.6	129.9
SEM _t	0.28	0.53	0.87	0.56	1.35	1.25	0.27	0.77	0.72	2.20
CD at 5%		2.08	3.39	2.20	5.27	4.90	1.05	3.02	2.8	8.59
CV (%)	6.2	11.7	13.1	11.3	6.5	9.4	6.2	8.7	13.5	7.1
Levels of N (kg/ha)										
0	15.8	14.0	20.1	13.5	63.4	42.1	13.3	25.4	12.4	93.2
50	17.5	16.9	24.1	16.8	75.3	51.2	16.6	32.1	16.7	116.6
100	19.3	19.0	26.6	20.3	85.2	56.4	18.2	38.1	19.5	132.2
150	21.4	21.2	31.9	24.9	99.4	62.5	20.3	42.9	21.1	146.9
200	20.9	22.2	32.4	25.9	101.4	63.2	21.6	44.2	18.6	147.6
250	19.8	21.7	32.5	25.0	99.0	61.7	20.3	41.8	21.2	145.0
SEM _t	0.45	0.57	0.79	0.67	1.26	1.33	0.47	1.17	1.26	2.64
CD at 5%	1.30	1.63	2.26	1.93	3.62	3.82	1.35	3.38	3.62	7.59
CV (%)	7.1	8.4	8.4	9.6	4.3	7.1	7.6	9.4	17.6	6.1

*I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

1 b (Table 4.35 and 4.36). Under weed free conditions, the increase in N uptake was noted up to 200 kg N / ha during both the Experiments, except in second year of Experiment No. 1 b, where the increase in N uptake was observed only up to 150 kg N / ha. In weedy plots, the increase in N uptake was noted up to 200 kg N / ha except in first year where the N uptake increased up to 150 kg N / ha. However, in Diuron treated plots it was significant up to 150 kg / ha.

4.1.4 studies on weed control

4.1.4.1 Listing of weeds

The weed flora in experimental field were collected and identified. The following weeds were : Dactyloctenium aegyptium, Digitaria sanguinalis, Digera arvensis, Commelina benghalensis, Apera spica, Chenopodium album, Gnaphalium indicum, Argemone mexicana, Solanum nigrum, Cyperus rotundus and Cynodon dactylon.

In the field of citronella Java major weed populations were of Dactyloctenium, Apera spica, Gnaphalium indicum, Cyperus rotundus.

It was further noted that weed population, particularly of broad leaved weeds were low in weedy check plots, because the rainy season grasses prevented the germination of rabi season weeds.

Table 4.35 Nitrogen uptake (g/ha) as influenced by weed control treatments and levels of N (Experiment No. 1(a)-1983-85)

Levels of N (g/ha)	First harvest year (1983-84) weed control treatments (g)				Second harvest year (1984-85) weed control treatments (g)			
	Weedfree	Weedy	Diuron		Weedfree	Weedy	Diuron	
0	40.5	29.6	34.4		88.8	63.8	79.6	
50	52.9	36.0	42.9		104.5	81.0	86.1	
100	61.9	40.2	53.0		115.9	89.9	112.2	
150	69.0	45.0	62.4		123.1	100.0	124.4	
200	79.6	46.4	54.1		134.2	108.1	114.2	
250	75.3	45.0	51.3		129.8	102.9	110.3	
		SEM _t	CD at 5%			SEM _t	CD at 5%	
'N' at fixed levels of 'W'		1.70	3.57			2.24	4.77	
'W' at fixed or different levels of 'N'		1.62	3.40			2.19	4.66	

Table 4.36 Nitrogen uptake (kg/ha) as influenced by weed control treatments and levels of N
(Experiment No. 1(b)-1984-86)

Levels of N (kg/ha)	First harvest year (1984-85) Weed control treatments (%)			Second harvest year (1985-86) Weed control treatments (%)		
	weedfree	weedy	Gluron	weedfree	weedy	Gluron
0	71.8	51.2	66.9	109.5	74.8	95.2
50	85.8	63.5	76.3	134.5	97.9	117.1
100	95.8	72.5	87.0	149.1	111.6	135.7
150	111.4	81.1	109.7	162.5	130.6	157.7
200	124.4	87.7	91.8	169.4	134.8	138.3
250	118.6	86.0	92.4	173.1	126.8	135.1
		SEM ₁	CD at 5%		SEM ₂	CD at 5%
'N' at fixed levels of 'W'		2.18	4.95		4.56	10.04
'W' at fixed or different levels of 'N'		2.40	5.45		4.71	10.36

4.1.4.2 Dry matter of weeds

Dry matter of weeds in citronella Java plots as summarised in Table 4.37 varied due to weed control measures and levels of N in both the harvest years in Experiment No. 1 a. Weedy plots recorded highest weed dry matter followed by diuron treated plots in all the cuttings during both the harvest years.

Application of N increased the weed dry matter significantly up to 150 kg N / ha. Further, addition of N reduced the weed dry matter yield significantly in all the harvests during both the harvest years.

Weed dry matter was high in fourth cutting (Apr - Jun) ranging from 7.3 to 14.8 q / ha and was minimum in third cutting (Jan - Mar) ranging from 2.5 to 3.0 q / ha in first harvest year. In second harvest year the weed dry matter ranged from 3.1 to 11.4 q / ha in fourth cutting (Apr - Jun) and the minimum dry matter ranged from 1.9 to 2.8 q / ha in third cutting (Jan - Mar).

The results of experiment No. 1 b (1984-86) with regard to weed dry matter as summarised in Table 4.38 showed similar trend of variations, as described earlier in Experiment No. 1 a. The interaction effect between weed control treatments and levels of N were not significant.

Table 4.37 Weed dry matter (g/ha) as influenced by weed control treatments and levels of N
(Experiment No. 1(a)-1983-85)

Weed control treatments	First harvest year (1983-84) Timings of harvest*				Second harvest year (1984-85) Timings of harvest*			
	I	II	III	IV	I	II	III	IV
Weedfree	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Weedy	7.5	5.5	5.0	14.8	4.9	3.6	2.8	11.4
Diuron	3.7	3.0	2.5	7.3	3.0	2.4	1.9	3.1
SEM ₊	0.009	0.008	0.005	0.004	0.002	0.003	0.002	0.002
CD at 5%	0.03	0.03	0.02	0.01	0.008	0.01	0.009	0.009
CV (%)	5.0	4.8	3.6	1.7	1.6	2.5	0.9	1.2
Levels of N (g/ha)								
0	4.9	3.8	3.5	10.4	3.4	2.6	2.1	6.7
50	5.8	4.2	3.5	10.2	3.7	2.8	2.4	7.2
100	6.1	4.6	4.0	11.5	4.1	3.2	2.6	7.7
150	6.0	4.7	4.0	11.5	4.2	3.3	2.6	7.6
200	5.4	4.1	3.9	11.1	3.9	3.1	2.4	7.2
250	5.3	4.0	3.8	11.0	3.8	2.9	2.3	7.2
SEM ₊	0.01	0.006	0.005	0.006	0.005	0.005	0.004	0.005
CD at 5%	0.03	0.02	0.01	0.02	0.02	0.01	0.01	0.01
CV (%)	4.3	2.8	2.4	1.9	2.6	2.4	2.6	1.7

* I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

Table 4.38 Weed dry matter (g/ha) as influenced by weed control treatments and levels of N (Experiment No. 1(b)-1984-86)

Weed control treatment	First harvest year (1984-85) Timings of harvest*				Second harvest year (1985-86) Timings of harvest*			
	I	II	III	IV	I	II	III	IV
Weedfree	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Weedy	6.2	5.1	4.7	14.9	4.7	3.4	2.7	10.9
Diuron	3.6	3.2	2.6	7.1	2.7	2.4	1.8	2.8
SEM ₁	0.002	0.002	0.003	0.002	0.002	0.003	0.005	0.003
CD at 5%	0.009	0.009	0.01	0.009	0.007	0.01	0.02	0.01
CV (%)	1.4	1.5	2.3	1.0	1.6	1.9	2.8	1.8
Levels of N (g/ha)								
0	4.0	3.5	2.9	10.3	3.1	2.4	1.8	6.1
50	4.4	3.9	3.2	10.7	3.5	2.6	2.1	6.5
100	4.9	4.3	3.7	11.0	3.8	3.0	2.4	6.9
150	5.7	4.5	4.1	11.2	4.0	3.1	2.6	7.3
200	5.2	4.1	4.1	11.7	4.0	3.2	2.4	7.3
250	4.9	4.1	3.8	11.1	3.8	3.0	2.3	7.1
SEM ₂	0.004	0.003	0.003	0.002	0.005	0.004	0.004	0.004
CD at 5%	0.01	0.008	0.01	0.005	0.01	0.01	0.01	0.01
CV (%)	1.6	1.3	1.7	1.4	2.2	2.0	2.6	1.6

* I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

4.1.4.3 Nitrogen uptake by weeds

The treatment variations in nitrogen uptake were significant due to weed control treatments and levels of N during both the harvest years in Experiment No. 1a (Table 4.39). Nitrogen uptake was high in weedy plots followed by those plots in which diuron was sprayed.

Addition of N increased the N uptake up to 150 kg^N/ha. Further, addition of N reduced the N uptake significantly. Nitrogen uptake was high in fourth harvest (Apr - Jun) ranging from 10.1 to 19.8 kg / ha and low in third harvest (Jan - Mar) ranging from 4.4 to 8.3 kg / ha in first harvest year, whereas in second harvest year, the corresponding figures of N uptake were 4.1 to 14.6 and 2.9 to 4.5 kg / ha in fourth and third harvest, respectively.

The Experimental results with regards to N uptake in Experiment No. 1b (1984-86) as summarised in Table 4.40 showed similar differences as have been described in Experiment No. 1a, earlier.

4.2 Experiment No. 2a and 2b

The Experiments No. 2a and 2b were conducted with the objective to evaluate the effect of levels of P and K fertilizers at high level of N (250 kg / ha / yr) on productivity and quality of citronella oil.

Table 4.39 Nitrogen uptake (g/ha) by weeds as influenced by weed control treatments and levels of N
(Experiment No. 1(a)-1983-84)

Weed control treatments	First harvest year (1983-84)				Second harvest year (1984-85)			
	I	II	III	IV	I	II	III	IV
Timings of harvest*								
Weedfree	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Weedy	19.40	8.7	8.3	19.8	12.39	5.5	4.5	14.6
Diuron	9.5	4.8	4.4	10.1	6.9	3.8	2.9	4.1
SEM _t	0.08	0.27	0.05	0.05	0.04	0.02	0.02	0.05
CD at 5%	0.32	1.06	0.18	0.06	0.16	0.09	0.08	0.18
CV (%)	1.9	6.8	0.9	6.1	0.9	0.8	0.7	1.2
Levels of N (g/ha)								
0	12.3	5.8	5.7	13.7	8.2	4.0	3.2	8.13
50	14.9	6.7	6.6	13.9	9.2	4.4	3.7	9.3
100	15.9	7.3	7.10	15.5	10.4	5.0	4.3	10.0
150	15.5	7.6	7.5	15.8	10.6	5.2	4.2	9.9
200	14.2	6.6	7.1	15.0	9.9	4.80	3.8	9.4
250	14.0	6.47	7.1	14.8	9.6	4.5	3.7	9.2
SEM _t	0.19	0.12	0.07	0.01	0.07	0.07	0.09	0.13
CD at 5%	0.54	0.33	0.19	0.04	0.19	0.19	0.27	0.38
CV (%)	2.8	2.0	1.0	4.2	1.1	1.6	1.6	0.7

*I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

Table 4.40 Nitrogen uptake (kg/ha) by weeds as influenced by weed control treatments and levels of N (Experiment No. 1(b)-1984-86)

Weed control treatments	First harvest year (1984-85) Timings of harvest*				Second harvest year (1985-86) Timings of harvest*			
	I	II	III	IV	I	II	III	IV
Weedfree	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Weedy	15.5	7.8	7.86	19.3	11.7	4.97	4.19	13.8
Diuron	9.0	4.9	4.3	9.2	6.8	3.76	2.82	3.6
SEM _t	0.05	0.03	0.03	0.02	0.02	0.08	0.02	0.02
CD at 5%	0.18	0.01	0.01	0.08	0.08	0.32	0.08	0.08
CV (%)	0.9	0.1	0.1	0.4	0.6	0.7	0.6	0.4
Levels of N (kg/ha)								
0	6.9	5.4	4.7	13.3	7.7	3.6	2.8	7.7
50	11.0	6.0	4.8	13.9	8.7	4.0	3.2	8.5
100	12.6	6.7	6.0	14.4	9.5	4.6	3.7	8.7
150	14.4	7.1	6.7	14.6	10.0	4.8	4.0	9.2
200	13.2	6.4	6.7	14.9	10.0	4.8	3.8	9.2
250	12.4	6.4	6.2	14.5	9.5	4.3	3.6	8.9
SEM _t	0.02	0.09	0.03	0.09	0.04	0.04	0.03	0.03
CD at 5%	0.06	0.27	0.09	0.27	0.11	0.11	0.09	0.09
CV (%)	0.3	1.6	0.6	0.2	0.6	0.7	0.5	0.5

*I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

4.2.1 Biometrical observations

4.2.1.1 Plant height

The variations in plant height of *Citronella Java* in Experiment No. 2a (1983-85) were significant due to application of P and K. Application of P increased the plant height significantly up to 50 kg P_2O_5 / ha in all the harvests (Table 4.41). Further addition of P did not show significant increase in plant height. However, the maximum plant height was recorded in the fourth cutting (Apr - Jun) of both harvest years, whereas, the minimum was recorded in first and second cuttings during first and second harvest.

Application of K increased the plant height significantly up to 50 kg K_2O / ha. The maximum plant heights were recorded in fourth cutting (Apr - Jun) ranging from 124.0 to 130.0 cm / plant and were minimum in first cutting ranging from 47.7 to 52.2 cm / plant in first harvest year. In second harvest year, the maximum plant heights were in [] cutting ranging from 102.7 to 110.8 and minimum in second cutting ranging from 63.2 to 67.9 cm / plant.

The results of Experiment No. 2b (1984-86) as summarised in Table 4.42 showed similar difference as described in Experiment No. 2a, except that in Experiment No. 2b recorded slightly; [] plant height than that of Experiment No. 2a.

4.2.1.2 Tiller production

Tiller number / plant increased significantly due to application of different levels of P and K during both the

Table 4.41 Plant height (cm) as influenced by different levels of P and K
(Experiment No. 2(a)-1983-85)

Levels of P_2O_5 and K_2O	First harvest year (1983-84) Timings of harvest*				Second harvest year (1984-85) Timings of harvest*			
	I	II	III	IV	I	II	III	IV
P_2O_5 (g/ha)								
0	48.9	60.2	79.3	125.4	95.4	63.9	74.8	104.8
50	51.3	65.8	83.3	131.3	103.4	67.4	76.9	110.3
100	51.5	64.7	85.2	130.1	104.8	67.3	76.1	108.6
G.M.T.	0.21	0.51	1.12	0.60	0.76	0.22	0.63	0.51
CD at 5%	0.63	1.52	3.36	1.79	2.27	0.67	1.90	1.53
CV (%)	2.1	2.4	2.6	2.3	2.5	2.4	2.5	2.2
K_2O (g/ha)								
0	47.7	59.9	77.4	124.0	94.7	63.3	74.2	102.7
50	51.7	64.2	84.8	130.0	104.8	67.9	79.3	110.8
100	52.2	66.6	85.7	128.0	104.2	67.4	78.1	110.1
G.M.T.	0.21	0.51	1.12	0.69	0.76	0.22	0.63	0.51
CD at 5%	0.63	1.52	3.36	1.79	2.27	0.67	1.90	1.53
CV (%)	2.1	2.4	2.6	2.3	2.5	2.4	2.5	2.2

* I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

Table 4.42 Plant height (cm) as influenced by different levels of P and K
(Experiment No. 2(b)-1984-86)

Levels of P_2O_5 and K_2O	First harvest year (1984-85) Timings of harvest*				Second harvest year (1985-86) Timings of harvest*			
	I	II	III	IV	I	II	III	IV
P_2O_5 (g/ha)								
0	62.4	77.7	82.2	130.4	105.7	64.0	72.2	112.7
50	69.4	84.7	88.0	138.1	114.2	66.4	75.9	117.2
100	68.1	85.0	88.1	139.6	113.8	67.0	76.3	116.7
SEM _t	0.62	0.17	0.31	0.91	0.84	0.51	0.31	0.70
CD at 5%	1.86	0.50	0.93	2.73	2.50	1.52	0.93	2.08
CV (%)	2.8	2.4	2.1	2.0	2.6	2.3	1.3	2.1
K_2O (g/ha)								
0	62.3	77.0	80.6	131.4	104.6	63.1	72.3	112.0
50	68.9	85.7	88.2	140.8	113.7	66.5	75.9	118.6
100	68.8	84.7	88.6	139.5	112.8	67.3	76.5	116.0
SEM _t	0.62	0.17	0.31	0.91	0.84	0.51	0.31	0.70
CD at 5%	1.86	0.50	0.93	2.73	2.50	1.52	0.93	2.08
CV (%)	2.8	2.4	2.1	2.0	2.6	2.3	1.3	2.1

* I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

harvest years in Experiment No. 2 a (Table 4.43). Application of 50 kg P_2O_5 / ha increased the number of tiller / plant significantly in all the harvests. Further, addition of P did not show any favourable influence on tiller production. Application of K caused similar variation in tiller production. It also increased the tiller production up to 50 kg K_2O / ha.

Maximum number of tillers / plant (ranging from 49 to 56) were recorded during fourth cutting (Apr - Jun) in first harvest year and the minimum number was recorded in first cutting (Jun - Sep) ranging from 17 to 19 tillers / plant. In second harvest year, the maximum number of tillers / plant was in fourth cutting (Apr - Jun) and it ranged from 52 to 59 tillers / plant. The minimum number was recorded in second harvest (Oct - Dec) ranging from 31 to 37 tillers / plant. This might be due to the influence of low temperature prevailing in winter months.

The results of Experiments No. 2b (1984-86) with regards to tiller production as summarised in Table 4.44 showed similar treatment variation as discussed in Experiment No. 2 a earlier.

The interaction between levels of P and K with regards to tiller production was not significant in both the Experiment No. 2 a and b.

4.2.1.3 Fresh herbage yield

The treatment variations in fresh herbage yield of citronella Java as summarised in Table 4.45, revealed significant differences, due to application of P and K. Application

Table 4.43 Number of tillers per plant as influenced by different levels of P and K
(Experiment No. 2(a)-1983-85)

Levels of P_2O_5 and K_2O	First harvest year (1983-84) Timings of harvest*				Second harvest year (1984-85) Timings of harvest*			
	I	II	III	IV	I	II	III	IV
P_2O_5 (kg/ha)								
0	17.8	18.6	19.1	50.0	46.1	32.0	45.8	52.2
50	19.7	20.1	20.4	55.2	51.3	35.8	50.7	58.3
100	18.8	19.6	20.4	56.1	50.0	36.1	50.9	58.9
SEM	0.49	0.30	0.32	1.61	1.47	0.89	1.18	1.80
CD at 5%	1.48	0.90	0.97	4.80	4.39	2.65	3.40	5.37
CV (%)	7.9	4.6	4.8	9.0	9.0	7.7	7.2	9.5
K_2O (kg/ha)								
0	17.2	17.9	18.6	49.4	45.0	31.1	44.4	52.2
50	19.8	20.3	21.0	55.9	52.2	36.7	51.2	59.4
100	19.2	20.0	20.4	56.0	50.2	36.1	51.7	57.8
SEM	0.49	0.30	0.32	1.61	1.47	0.89	1.18	1.80
CD at 5%	1.48	0.90	0.97	4.80	4.39	2.65	3.40	5.37
CV (%)	7.9	4.6	4.8	9.0	9.0	7.7	7.2	9.5

* I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

Table 4.44 Number of tillers per plant as influenced by different levels of P and K
(Experiment No. 2(b)-1984-86)

Levels of P_2O_5 and K_2O	First harvest year (1984-85) Timings of harvest*				Second harvest year (1985-86) Timings of harvest*			
	I	II	III	IV	I	II	III	IV
P_2O_5 (kg/ha)								
0	29.3	33.6	35.2	54.8	51.3	35.1	47.8	51.0
50	33.0	37.2	39.1	60.7	57.3	38.6	53.6	57.0
100	33.6	38.0	40.0	61.0	57.7	39.2	54.0	57.6
SEM _t	1.17	1.44	1.13	1.49	1.45	1.07	1.62	1.75
CD at 5%	3.49	4.30	3.37	4.46	4.34	3.21	4.83	5.23
CV (%)	11.0	11.9	8.8	7.6	7.8	8.6	9.5	9.4
K_2O (kg/ha)								
0	29.0	32.8	34.4	53.3	50.1	34.2	45.7	48.8
50	33.8	38.2	39.9	61.3	58.0	39.6	54.6	58.0
100	33.1	37.8	40.0	61.8	58.2	39.1	55.1	58.8
SEM _t	1.17	1.44	1.13	1.49	1.45	1.07	1.62	1.75
CD at 5%	3.49	4.30	3.37	4.46	4.34	3.21	4.83	5.23
CV (%)	11.0	11.9	8.8	7.6	7.8	8.6	9.5	9.4

*I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

of P up to 50 kg P_2O_5 / ha increased the fresh herbage yield. At 50 kg P_2O_5 / ha, fresh herbage increased from 163.9 q / ha in first harvest year and 278.1 q / ha in second harvest year. At the highest level of P i.e. 100 kg P_2O_5 / ha the herbage yields further increased over 50 kg P_2O_5 / ha but this increase was not significant.

The influence of K on the productivity of fresh herbage was similar to the trend of variation recorded in case of P addition. Application of K increased fresh herbage yield up to 50 kg K_2O / ha in all the harvests in Experiment No. 2 a.

The fresh herbage yield was more during fourth cutting (Apr - Jun) in first harvest year (ranging from 76.6 to 113.5 q / ha) and was minimum at first cutting (Jul - Sep) ranging from 14.4 to 18.3 q / ha. In second harvest year however, high fresh herbage yields were recorded during fourth cutting (Apr - Jun) ranging from 87.3 to 115.0 q / ha. Low yields were recorded in the second cutting (Oct - Dec) ranging from 32.5 to 38.7 q / ha. Application of K increased fresh herbage productivity slightly more than that of P application.

The results of Experiment No. 2b (1984-86) with regard to fresh herbage yield in Table 4.46 showed similar trend of variation described in Experiment No. 2a earlier. In Experiment No. 2b slightly higher herbage yield was observed than that was recorded in Experiment No. 2a.

The interaction effect on fresh herbage yield was not significant due to application of P and K.

Table 4.45 Fresh herbage yield (g/ha) as influenced by different levels of P and K
(Experiment No. 2(a)-1983-85)

Levels of P_2O_5 and K_2O	First harvest year (1983-84) Timings of harvest*					Second harvest year (1984-85) Timings of harvest*				
	I	II	III	IV	Total	I	II	III	IV	Total
P_2O_5 (g/ha)										
0	14.4	15.9	17.0	81.4	128.7	60.4	34.4	57.3	90.0	242.1
50	18.1	18.0	20.5	107.3	163.9	66.5	37.7	62.8	111.1	278.1
100	18.2	18.3	20.9	113.5	170.9	69.8	36.3	63.1	112.9	282.1
SEM ₁	0.75	0.65	0.68	3.09	3.17	1.18	0.75	1.59	2.48	3.82
CD at 5%	2.24	1.94	2.02	9.22	9.49	3.54	2.24	4.75	7.42	11.40
CV (%)	12.0	11.2	10.4	9.2	6.2	6.8	6.0	7.8	7.1	4.3
K_2O (g/ha)										
0	15.2	15.9	18.0	76.6	125.7	56.4	32.5	56.4	87.3	232.6
50	18.3	18.3	20.1	112.0	168.7	69.7	37.2	64.4	111.6	282.9
100	17.2	17.9	20.3	113.5	168.9	70.6	38.7	62.4	115.0	286.7
SEM ₁	0.75	0.65	0.68	3.09	3.17	1.18	0.75	1.59	2.48	3.82
CD at 5%	2.24	1.94	2.02	9.22	9.49	3.54	2.24	4.75	7.42	11.40
CV (%)	12.0	11.2	10.4	9.2	6.2	6.8	6.0	7.8	7.1	4.3

* I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

Table 4.46 Fresh herbage yield (q/ha) as influenced by different levels of P and K
(Experiment No. 2(b)-1984-86)

Levels of P_2O_5 and K_2O	First harvest year (1984-85) Timings of harvest*					Second harvest year (1985-86) Timings of harvest*				
	I	II	III	IV	Total	I	II	III	IV	Total
P_2O_5 (q/ha)										
0	26.2	34.9	42.0	120.6	223.7	92.1	37.5	67.8	80.6	278.0
50	33.3	40.9	47.7	134.0	255.9	100.5	44.4	74.9	89.4	309.2
100	33.0	41.5	48.6	132.9	262.0	104.4	46.4	74.7	91.2	316.7
SEM _t	0.95	1.45	1.73	3.99	3.42	2.19	1.34	1.55	2.12	4.04
CD at 5%	2.84	4.84	5.18	11.93	9.71	6.56	4.01	4.64	6.35	12.04
CV (%)	9.2	11.1	11.5	9.1	4.2	6.6	9.4	6.4	7.3	4.0
K_2O (q/ha)										
0	25.1	34.0	39.8	117.0	215.9	89.0	36.0	66.0	79.1	270.1
50	33.4	41.5	47.9	137.1	259.9	102.7	45.4	76.2	90.3	314.6
100	34.0	41.9	50.6	139.4	265.9	105.3	46.9	75.3	91.7	319.2
SEM _t	0.95	1.45	1.73	3.99	3.42	2.19	1.34	1.55	2.12	4.03
CD at 5%	2.84	4.84	5.18	11.93	9.71	6.56	4.01	4.64	6.35	12.04
CV (%)	9.2	11.1	11.5	9.1	4.2	6.6	9.4	6.4	7.3	4.0

* I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

4.2.1.4 Dry matter accumulation

The treatment variation with regard to dry matter accumulation in Experiment No. 2 a (1983-85) in Table 4.47 was significant due to levels of P and K. Application of P increased the dry matter accumulation significantly up to 50 kg P_2O_5 / ha in all the harvests. At 50 kg P_2O_5 / ha dry matter accumulations recorded were 51.6 and 96.3 q / ha in first and second harvest years, respectively. Further increase in P application to 100 kg P_2O_5 / ha caused increase in dry matter accumulation by 12.6 and 1.8 per cent in first and second harvest years, respectively.

Application of 50 kg K_2O / ha produced significantly high dry matter accumulation in all the harvests in Experiment No. 2a. Further, addition of K did not show appreciable increase in dry matter accumulation.

The dry matter accumulation was high in fourth harvest (Apr - Jun), ranging from 26.0 to 37.9 q / ha and 29.1 to 39.2 q / ha in first and second harvest years, respectively. The dry matter accumulation was low in first three harvest, in first harvest year as compared to second harvest year.

The results of Experiment No. 2b (1984-86) with regard to dry matter accumulation (Table 4.48) showed similar trend of variations due to application of P and K as described in Experiment No. 2 a earlier.

Table 4.47 Dry matter accumulation (g/ha) as influenced by different levels of P and K
(Experiment No. 2(a)-1983-85)

Levels of P_2O_5 and K_2O	First harvest year (1983-84) Timings of harvest*					Second harvest year (1984-85) Timings of harvest*				
	I	II	III	IV	Total	I	II	III	IV	Total
P_2O_5 (g/ha)										
0	5.2	5.7	6.0	27.4	43.3	21.6	12.2	20.1	30.7	84.6
50	6.5	6.4	7.2	31.5	51.6	23.7	13.3	21.4	37.9	96.3
100	6.5	6.4	7.3	37.9	58.1	24.7	12.9	22.0	38.4	98.0
SEM _t	0.23	0.23	0.24	2.66	2.68	0.43	0.28	0.57	0.97	1.39
CD at 5%	0.71	0.70	0.72	7.92	8.02	1.30	0.84	1.70	2.89	4.14
CV (%)	11.8	11.3	10.5	16.0	15.6	5.6	6.6	8.0	8.1	4.5
K_2O (g/ha)										
0	5.5	5.7	6.4	26.0	43.6	20.4	11.6	19.9	29.9	81.7
50	6.6	6.5	7.1	37.7	57.9	24.9	13.1	22.5	38.0	98.5
100	6.1	6.3	7.1	33.2	52.7	24.8	13.5	22.0	39.2	99.5
SEM _t	0.24	0.23	0.24	2.66	2.68	0.43	0.28	0.57	0.97	1.39
CD at 5%	0.71	0.70	0.72	7.92	8.02	1.30	0.84	1.70	2.89	4.14
CV (%)	11.8	11.3	10.5	16.0	15.6	5.6	6.6	8.0	8.1	4.5

* I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

Table 4.48 Dry matter accumulation (g/ha) as influenced by different levels of P and K
(Experiment No. 2(b)-1984-86)

Levels of P_2O_5 and K_2O	First harvest year (1984-85) Timings of harvest*					Second harvest year (1985-86) Timings of harvest*				
	I	II	III	IV	Total	I	II	III	IV	Total
P_2O_5 (g/ha)										
0	9.4	12.2	14.7	40.9	77.2	32.7	13.2	23.9	27.7	97.5
50	11.9	14.4	16.6	45.3	88.2	35.3	15.6	26.1	30.5	107.5
100	11.1	14.6	15.0	47.1	87.8	36.4	15.6	25.8	31.1	108.9
SEM†	0.33	0.54	1.29	1.37	1.37	0.85	0.61	0.56	0.76	1.45
CD at 5%	0.97	1.61	3.85	4.09	4.39	2.55	1.82	1.66	2.27	4.34
CV (%)	8.9	11.7	10.2	4.1	5.2	7.3	12.4	6.6	7.6	4.2
K_2O (g/ha)										
0	9.0	12.0	14.1	39.9	75.0	32.0	12.8	23.7	27.3	95.8
50	11.9	14.7	16.7	46.4	89.7	35.2	15.9	26.4	30.7	108.2
100	12.0	14.6	15.4	47.1	89.1	36.2	15.7	25.9	31.2	109.0
SEM†	0.33	0.54	1.29	1.37	1.47	0.85	0.61	0.57	0.76	1.45
CD at 5%	0.97	1.61	3.85	4.09	4.39	2.55	1.82	1.66	2.27	4.34
CV (%)	8.9	11.7	10.2	4.1	5.2	7.3	12.4	6.6	7.6	4.2

* I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

The interaction effect due to application of P and K on dry matter accumulation was not significant in both the Experiments No. 2 a and b.

4.2.2 Essential oil content, oil yield and oil quality

4.2.2.1 Oil content

The treatment differences on oil content due to levels of P and K in citronella Java as summarized in Table 4.49 were not significant during both the harvest years in Experiment No. 2a. In the first harvest year, the oil contents were higher ranging from 1.21 to 1.37 per cent than that were recorded in second harvest year ranging from 1.1 to 1.2 per cent. Maximum oil content (1.3 to 1.5 per cent) was recorded in second harvest (Oct - Dec) and minimum oil content in herbage was recorded in fourth harvest (Apr - Jun) in both the harvest years.

The results of Experiment No. 2b (1984-86) with regard to oil content as summarized in Table 4.50 showed similar trend of variations due to treatments as described in Experiment No. 2a.

The interaction effect in oil content due to levels of P and K was not significant in both the Experiment No. 2 a and b.

Table 4.49 Oil content (%) as influenced by different levels of P and K
(Experiment No. 2(a)-1983-85)

Levels of P_2O_5 and K_2O	First harvest year (1983-84) Timings of harvest*				Second harvest year (1984-85) Timings of harvest*			
	I	II	III	IV	I	II	III	IV
P_2O_5 (kg/ha)								
0	1.33	1.35	1.31	1.22	1.32	1.34	1.32	1.22
50	1.33	1.35	1.31	1.22	1.30	1.34	1.32	1.22
100	1.31	1.35	1.30	1.22	1.30	1.33	1.32	1.22
SEM _t	0.007	0.04	0.003	0.008	0.007	0.008	0.008	0.008
CD at 5%	-	-	-	-	-	-	-	-
CV (%)	1.5	2.8	1.1	1.8	1.5	1.7	1.7	1.8
K_2O (kg/ha)								
0	1.34	1.37	1.32	1.23	1.32	1.34	1.33	1.23
50	1.32	1.36	1.30	1.21	1.30	1.34	1.32	1.22
100	1.30	1.33	1.30	1.21	1.30	1.32	1.30	1.21
SEM _t	0.007	0.04	0.003	0.008	0.007	0.008	0.008	0.008
CD at 5%	-	-	-	-	-	-	-	-
CV (%)	1.5	2.8	1.1	1.8	1.5	1.7	1.7	1.8

* I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

Table 4.50 Oil content (%) as influenced by different levels of P and K
(Experiment No. 2(b)-1984-86)

Levels of P_2O_5 and K_2O	First harvest year (1984-85) Timings of harvest*				Second harvest year (1985-86) Timings of harvest*			
	I	II	III	IV	I	II	III	IV
P_2O_5 (g/ha)								
0	1.36	1.38	1.32	1.19	1.28	1.38	1.26	1.17
50	1.36	1.37	1.32	1.18	1.28	1.37	1.26	1.16
100	1.36	1.37	1.32	1.18	1.28	1.37	1.26	1.16
SEM _t	0.006	0.01	0.002	0.01	0.008	0.01	0.01	0.01
CD at 5%	-	-	-	-	-	-	-	-
CV (%)	2.2	2.4	0.5	2.8	1.9	2.2	2.4	2.7
K_2O (g/ha)								
0	1.37	1.39	1.32	1.20	1.29	1.38	1.26	1.17
50	1.36	1.37	1.32	1.18	1.28	1.37	1.26	1.16
100	1.35	1.37	1.32	1.17	1.27	1.37	1.25	1.15
SEM _t	0.006	0.01	0.002	0.01	0.008	0.01	0.01	0.01
CD at 5%	-	-	-	-	-	-	-	-
CV (%)	2.2	2.4	0.5	2.8	1.9	2.2	2.4	2.7

* I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

4.2.2.2 Oil yield

In first harvest year in Experiment No. 2a (1983-85) the treatment variations in oil yield (Table 4.51) due to levels of P and K were significant and so was the case in the second harvest year (1984-85). Addition of P increased the oil yield significantly up to 50 kg P_2O_5 / ha in all the harvests. At 50 kg P_2O_5 / ha, Citronella oil yield was 205.5 kg / ha as compared to that was recorded in second harvest year (355.1 kg / ha / year). At 100 kg P_2O_5 further increase in oil yield was to the extent of 3.3 and 1.1 per cent, in first and second harvest year, respectively.

Application of potassium at the rate of 50 kg K_2O / ha produced significant increase in oil yield in all the harvests in Experiment No. 2 a. At 50 kg K_2O / ha the yearly oil production ranged from 159.1 to 210.8 kg / ha in first harvest year and in second harvest year, the oil production ranged from 300.1 to 362.5 kg / ha. Further addition of K did not show any marked increase in oil production during both the harvest years in Experiment No. 2a. The oil yield was more at fourth harvest (Apr - Jun) during first harvest year ranging from 93.5 to 137.3 kg / ha and it was minimum in first harvest (Jul - Sep) ranging from 19.1 to 24.1 kg / ha. In the second harvest year the oil yield was also high in fourth harvest (Apr - Jun) ranging from 107.1 to 137.9 kg / ha and the minimum oil yield (ranging from 43.7 to 51.0 kg / ha) was recorded in second harvest (Oct - Dec).

Table 4.51 Oil yield (t/ha) as influenced by different levels of P and K
(Experiment No. 2(a)-1983-85)

Levels of P_2O_5 and K_2O	First harvest year (1983-84) Timings of harvest*					Second harvest year (1984-85) Timings of harvest*				
	I	II	III	IV	Total	I	II	III	IV	Total
P_2O_5 (t/ha)										
0	19.1	21.4	22.2	22.4	162.1	79.4	46.0	75.4	109.4	310.2
50	24.1	24.4	26.7	130.3	205.5	86.7	50.5	83.0	134.9	355.1
100	23.8	24.6	27.1	136.0	212.3	91.1	48.3	83.0	136.7	359.1
SDM†	0.87	0.90	0.85	3.59	4.05	1.75	0.96	2.15	3.46	4.64
CV at 5%	2.60	2.69	2.55	10.73	12.11	5.25	2.87	6.42	10.33	13.88
CV (%)	11.7	11.5	10.1	8.8	6.3	6.0	6.0	8.0	8.2	4.1
K_2O (t/ha)										
0	20.3	21.8	23.5	93.5	159.1	74.1	43.7	75.2	107.1	300.1
50	24.1	24.9	26.2	135.6	210.8	91.0	50.0	84.0	135.9	361.7
100	22.4	23.8	26.4	137.3	209.9	92.2	51.0	81.4	137.9	362.5
SDM†	0.87	0.90	0.85	3.59	4.05	1.75	0.96	2.15	3.46	4.64
CV at 5%	2.60	2.69	2.55	10.73	12.11	5.25	2.87	6.42	10.33	13.88
CV (%)	11.7	11.5	10.1	8.8	6.3	6.0	6.0	8.0	8.2	4.1

* I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

Table 4.52 Oil yield (t/ha) as influenced by different levels of P and K
(Experiment No. 2(b)-1984-86)

Levels of P_2O_5 and K_2O	First harvest year (1984-85) Timings of harvest*					Second harvest year (1985-86) Timings of harvest*				
	I	II	III	IV	Total	I	II	III	IV	Total
P_2O_5 (t/ha)										
0	35.7	47.5	55.4	143.3	281.9	117.4	51.6	85.4	93.9	348.3
50	45.1	56.1	63.0	157.6	321.8	128.3	60.9	94.1	103.1	386.4
100	44.7	56.9	64.1	163.3	329.0	133.4	61.2	93.4	105.4	393.4
SEM _t	1.23	2.12	2.33	4.59	4.42	2.74	2.26	1.82	2.76	5.27
CD at 5%	3.66	6.35	6.95	13.71	13.21	8.19	6.76	5.44	8.24	15.74
CV (%)	8.5	11.9	11.6	8.9	4.2	6.5	11.6	5.9	8.2	4.2
K_2O (t/ha)										
0	34.4	46.4	52.8	140.5	274.1	114.6	49.8	83.2	92.6	340.2
50	45.2	56.9	63.2	161.2	326.5	131.3	62.2	95.6	104.3	393.0
100	45.9	57.2	66.6	162.5	332.2	133.2	61.5	94.6	104.3	394.9
SEM _t	1.23	2.12	2.33	4.59	4.42	2.74	2.26	1.82	2.76	5.27
CD at 5%	3.66	6.35	6.95	13.71	13.21	8.19	6.76	5.44	8.24	15.74
CV (%)	8.5	11.9	11.6	8.9	4.2	6.5	11.6	5.9	8.2	4.2

*I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

The results of Experiment No. 2b (1984-86) with regard to oil yield (Table 4.52) showed similar trend of variations as described in Experiment No. 2a earlier.

The interaction effect due to application of P and K on oil yield was not significant in both the Experiment No. 2 a and b.

4.2.2.3 Oil quality

4.2.2.3(a) Citronellal content

Citronellal content in the oil of citronella Java of Experiment No. 2a (1983-85) as summarised in Table 4.53 did not show significant differences due to application of graded levels of P and K.

The citronellal content was high during first cutting (Jul - Sep) followed by those recorded in third cutting (Jan - Mar) and low during (Apr - Jun) fourth harvest in both the harvest years. The citronellal content was higher in second harvest year than that of first harvest year.

The results of Experiment No. 2b (1984-86) as summarised in Table 4.54 showed similar differences as described in Experiment No. 2a. The interaction effect between levels of P and K was not significant in both the harvest years in Experiments No. 2 a and b.

Table 4.53 Citronellal content (%)^{*} in oil as influenced by different levels of P and K (Experiment No. 2(a)-1983-85)

Levels of P_2O_5 and K_2O	First harvest year (1983-84) Timings of harvest**				Second harvest year (1984-85) Timings of harvest**			
	I	II	III	IV	I	II	III	IV
P_2O_5 (kg/ha)								
0	32.80	27.77	29.07	22.72	36.65	28.54	30.27	27.88
50	32.84	27.33	28.47	22.60	36.08	28.46	30.17	27.46
100	32.97	27.19	28.43	22.73	36.13	28.56	30.37	27.56
K_2O (kg/ha)								
0	32.76	27.46	28.50	22.59	36.57	28.45	30.32	27.68
50	32.95	27.50	28.51	22.73	35.79	28.57	30.37	27.75
100	32.88	27.23	28.96	22.73	36.51	28.54	30.12	27.47

* Values of composite samples

** I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

Table 4.54 Citronellal content (%)^{*} in oil as influenced by different levels of P and K (Experiment No. 2(b)-1984-86)

Levels of P ₂ O ₅ and K ₂ O	First harvest year (1984-85) Timings of harvest**				Second harvest year (1985-86) Timings of harvest**			
	I	II	III	IV	I	II	III	IV
P₂O₅ (g/ha)								
0	30.25	27.07	26.77	25.01	32.88	29.22	30.23	26.23
50	30.25	26.89	26.86	24.99	32.88	29.16	30.39	26.19
100	30.28	27.21	26.75	25.04	33.05	29.11	30.26	26.25
K₂O (g/ha)								
0	30.21	26.96	26.73	25.32	32.75	29.08	30.37	26.10
50	30.13	27.11	26.94	25.08	32.95	29.14	30.08	26.23
100	30.40	27.09	26.72	25.01	33.11	29.24	30.44	26.34

* Values of 0 composite samples

** I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

4.2.2.3(b) Citronellol content

The treatment variations in citronellol content in citronella Java in first harvest year in Experiment No. 2a (1983-85) were not significant due to varying levels of P and K as summarised in Table 4.55 and similar was the case in second harvest year. The citronellol content was high during third harvest (Jan - Mar) followed by fourth harvest (Apr - Jun) while during first cutting (Jul - Sep) it was low in both the harvest years.

The citronellol content in Experiment No. 2b (1984 - 86) as summarised in Table 4.56 also showed similar differences as described in Experiment No. 2a.

The interaction effect between varying levels of P and K was not significant in both the harvest years of Experiment No. 2 a and 2 b.

4.2.2.3(c) Geraniol content

Geraniol content of citronella Java in first harvest year in Experiment No. 2a (1983-85) as shown in Table 4.57 did not vary significantly due to different levels of P and K. similar trend of variations was observed in second harvest year (1984-85) as well.

The geraniol content was high in the first cutting (Jul - Sep) followed by fourth cutting (Apr - Jun) and low in third cutting (Jan - Mar) in both the harvest years.

Table 4.55 Citronellol content (%)^{*} in oil as influenced by different levels of P and K (Experiment No. 2(a)-1983-85)

Levels of P_2O_5 and K_2O	First harvest year (1983-84) Timings of harvest**				Second harvest year (1984-85) Timings of harvest**			
	I	II	III	IV	I	II	III	IV
P_2O_5 (g/ha)								
0	6.25	9.25	14.15	13.55	9.62	12.29	16.44	12.03
50	6.02	8.69	14.69	13.45	9.70	12.61	16.25	11.69
100	6.41	9.17	14.12	13.48	9.57	12.09	15.46	11.27
K_2O (g/ha)								
0	6.12	9.12	14.16	13.38	9.34	12.54	16.03	11.82
50	6.25	9.09	14.07	13.61	9.80	12.04	16.26	11.92
100	6.31	8.91	14.73	13.49	9.46	12.42	15.86	11.48

* Values of composite samples

** I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

Table 4.56 Citronellol content (%)^{*} in oil as influenced by different levels of P and K
(Experiment No. 2(b)-1984-86)

Levels of P_2O_5 and K_2O	First harvest year (1984-85) Timings of harvest**				Second harvest year (1985-86) Timings of harvest**			
	I	II	III	IV	I	II	III	IV
P_2O_5 (g/ha)								
0	6.08	9.03	10.98	10.30	4.12	8.0	9.80	9.18
50	6.04	9.04	11.36	10.17	4.05	8.03	9.84	9.07
100	6.10	8.96	11.20	10.15	4.09	8.03	9.80	9.08
K_2O (g/ha)								
0	5.96	9.07	11.32	10.15	4.08	8.07	9.92	9.01
50	6.13	8.92	11.37	10.20	4.11	8.11	9.69	9.10
100	6.13	9.05	11.19	10.27	4.06	7.98	9.84	9.22

* Values of composite samples

** I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

Table 4.57 Geraniol content (%) in oil as influenced by different levels of P and K
(Experiment No. 2(a)-1983-85)

Levels of P_2O_5 and K_2O	First harvest year (1983-84) Timings of harvest**				Second harvest year (1984-85) Timings of harvest**			
	I	II	III	IV	I	II	III	IV
P_2O_5 (g/ha)								
0	27.12	15.43	10.77	20.75	25.67	16.13	9.55	19.05
50	27.65	15.64	10.52	21.21	25.06	16.36	9.45	19.17
100	27.09	15.55	10.74	20.92	25.77	15.81	9.40	19.95
K_2O (g/ha)								
0	27.41	15.52	10.78	20.92	25.22	16.25	9.58	19.15
50	26.93	15.54	10.44	21.12	25.62	16.23	9.23	19.01
100	27.53	15.56	10.82	21.37	25.65	16.15	9.59	19.21

* Values of composite samples

** I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

The geraniol content in Experiment No. 2b (1984-86) as summarised in Table 4.58 showed similar trend of variation as in Experiment No. 2a.

The interaction effect between levels of P and K on geraniol content was not significant in both the Experiment No. 2a and b.

4.2.3 Nutrient uptake

4.2.3.1 Nitrogen uptake

The treatment difference in N uptake in first harvest year in Experiment No. 2a (1983-85) were significant due to application of P and K and so was the case in the second harvest year (Table 4.59). Application of P increased the N uptake significantly up to 50 kg P_2O_5 / ha in all the harvests. At 50 kg P_2O_5 N uptake of 65.3 kg / ha was recorded in first harvest year as compared to 146.3 kg / ha in second harvest year. At 100 kg P_2O_5 / ha, the uptake was 71.9 and 148.1 kg / ha in first and second harvest year, respectively.

Application of potassium at the rate of 50 kg K_2O / ha increased the N uptake significantly in all the harvests in Experiment No. 2a. At 50 kg K_2O / ha the yearly N uptake was 71.2 kg / ha in first harvest year and 149.2 kg / ha in second harvest year, respectively. Further, increase in application of K did not show any appreciable differences in N uptake during both the harvest year in Experiment No. 2a.

Table 4.58 Geraniol content (%)^{*} in oil as influenced by different levels of P and K
(Experiment No. 2(b)-1984-86)

Levels of P_2O_5 and K_2O	First harvest year (1984-85) timings of harvest**				Second harvest year (1985-86) timings of harvest**			
	I	II	III	IV	I	II	III	IV
P_2O_5 (g/ha)								
0	27.31	10.26	9.72	14.43	25.16	11.33	9.25	16.83
50	27.34	10.16	9.67	14.31	25.10	11.30	9.21	16.83
100	27.36	10.15	9.70	14.52	25.04	11.23	9.47	16.97
K_2O (g/ha)								
0	27.25	10.33	9.92	14.27	25.13	11.27	9.24	16.84
50	27.33	10.11	9.75	14.46	25.04	11.93	9.35	17.02
100	27.44	10.13	9.42	14.58	25.13	11.17	9.33	16.77

* Values of composite samples

** I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

Table 4.59 Nitrogen uptake (g/ha) as influenced by different levels of P and K
(Experiment No. 2(a)-1983-85)

Levels of P_2O_5 and K_2O	First harvest year (1983-84) Timings of harvest*					Second harvest year (1984-85) Timings of harvest*				
	I	II	III	IV	Total	I	II	III	IV	Total
P_2O_5 (g/ha)										
0	10.3	8.5	10.2	26.4	55.4	42.9	18.3	39.5	28.3	129.0
50	13.1	9.6	12.2	30.4	65.3	47.7	20.0	43.6	35.0	146.3
100	13.1	9.7	12.4	36.7	71.9	49.5	19.3	44.0	35.3	148.1
SDM†	0.47	0.35	0.40	2.59	2.69	1.10	0.39	1.22	0.83	1.89
CD at 5%	1.44	1.04	1.20	7.74	8.03	3.29	1.17	3.66	2.49	5.65
CV (%)	11.6	11.2	10.3	14.0	12.5	7.0	6.1	8.6	7.6	4.0
K_2O (g/ha)										
0	10.8	8.6	10.8	25.0	55.1	40.3	17.5	39.6	27.4	124.8
50	13.1	9.3	12.0	36.3	71.2	49.7	19.8	44.7	35.0	149.2
100	13.1	9.5	12.1	32.2	66.4	50.5	20.3	42.8	36.1	149.7
SDM†	0.47	0.35	0.40	2.59	2.69	1.10	0.39	1.22	0.83	1.89
CD at 5%	1.44	1.04	1.20	7.74	7.74	3.29	1.17	3.66	2.49	5.65
CV (%)	11.6	11.2	10.3	14.0	12.5	7.0	6.1	8.6	7.6	4.0

* I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

Nitrogen uptake was high in fourth cutting (Apr - Jun) ranging from 25.0 to 36.7 kg / ha and it was minimum in second cutting (Oct - Dec) ranging from 8.5 to 9.7 kg / ha in first harvest year. In second harvest year the N uptake was also high in first cutting (Jul - Sep) ranging from 40.3 to 50.5 kg / ha and the minimum N uptake in second cutting (Oct - Dec) ranging from 17.5 to 20.3 kg / ha.

The results of Experiment No. 2b (1984-86) with regard to N uptake (Table 4.60) showed similar trend of variations as described in Experiment No. 2a earlier.

The interaction effect between P and K on N uptake was not significant in both the Experiment No. 2 a and 2 b.

4.2.3.2 Phosphorus uptake

The treatment variations in P uptake (Table 4.61) due to different levels of P and K were significant in first harvest year of Experiment No. 2 a (1983-85) so was the case in the second harvest year (1984-85). Application of P increased the P uptake significantly up to 50 kg P_2O_5 / ha in all the harvests. At 50 kg P_2O_5 / ha, P uptake were 18.4 and 33.6 kg P_2O_5 / ha in first and second harvest year, respectively. Further, addition of P (100 kg P_2O_5 / ha) did not show any significant influence on P uptake.

Table 4.60 Nitrogen uptake (g/ha) as influenced by different levels of P and K
(Experiment No. 2(b)-1984-86)

Levels of P_2O_5 and K_2O	First harvest year (1984-85)					Second harvest year (1985-86)				
	Timings of harvest*					Timings of harvest*				
	I	II	III	IV	Total	I	II	III	IV	Total
P_2O_5 (g/ha)										
0	18.7	18.1	24.9	39.5	101.2	64.1	19.8	46.8	25.1	155.8
50	23.6	21.6	28.3	43.7	117.2	69.2	23.5	51.7	27.1	172.1
100	23.5	21.8	25.6	45.4	116.3	71.3	23.4	51.1	28.2	174.0
SDmt	0.66	0.78	2.22	1.32	2.41	1.65	0.96	1.23	0.80	2.29
CD at 5%	1.98	2.33	6.65	3.96	7.20	4.95	2.87	3.67	2.39	7.14
CV (%)	9.0	11.4	16.8	9.2	6.5	7.3	12.9	7.4	8.9	4.3
K_2O (g/ha)										
0	17.9	17.7	23.9	38.4	197.9	62.6	19.8	45.8	24.9	153.1
50	24.0	22.0	28.4	44.7	119.0	70.9	23.8	52.2	28.0	174.9
100	23.9	21.8	26.4	45.5	117.6	71.1	23.7	51.5	28.4	174.7
SDmt	0.66	0.78	2.22	1.32	2.41	1.65	0.96	1.23	0.80	2.29
CD at 5%	1.98	2.33	6.65	3.96	7.20	4.95	2.87	3.67	2.39	7.14
CV (%)	9.0	11.4	16.8	9.2	6.5	7.3	12.9	7.4	8.9	4.3

* I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

Table 4.61 Phosphorus uptake (g/ha) as influenced by different levels of P and K
(Experiment No. 2(a)-1983-85)

Levels of P_2O_5 and K_2O	First harvest year (1983-84) Timings of harvest*					Second harvest year (1984-85) Timings of harvest*				
	I	II	III	IV	Total	I	II	III	IV	Total
P_2O_5 (g/ha)										
0	1.7	2.1	2.4	7.8	14.0	7.2	4.4	7.8	8.6	28.0
50	2.3	2.4	2.9	10.8	18.4	8.4	5.0	8.9	11.3	33.6
100	2.3	2.4	3.0	11.3	19.0	8.7	4.8	8.9	11.4	33.8
SEM _t	0.08	0.08	0.09	0.27	0.31	0.15	0.10	0.20	0.31	0.43
CD at 5%	0.24	0.25	0.26	0.80	0.94	0.45	0.30	0.60	0.94	1.29
CV (%)	11.5	11.1	9.4	8.1	5.5	5.5	6.3	7.1	9.1	4.1
K_2O (g/ha)										
0	1.9	2.1	2.5	7.6	14.1	6.9	4.3	7.9	8.5	27.6
50	2.3	2.5	2.9	11.2	16.9	8.7	5.1	9.0	11.3	34.0
100	2.2	2.3	2.9	11.2	18.6	8.7	5.2	8.7	11.5	33.8
SEM _t	0.08	0.08	0.09	0.27	0.31	0.15	0.10	0.20	0.31	0.43
CD at 5%	0.24	0.25	0.26	0.80	0.94	0.45	0.30	0.60	0.94	1.29
CV (%)	11.5	11.1	9.4	8.1	5.5	5.5	6.3	7.1	9.1	4.1

* I = July-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

Application of 50 kg K_2O / ha increased the P uptake significantly in both the harvest years. Further, addition of K did not show any significant influence on P uptake.

The maximum P uptake were recorded during fourth harvest (Apr - Jun) ranging from 7.6 to 11.3 and 8.5 to 11.5 kg P_2O_5 in first and second harvest years, respectively. The lower P uptake were recorded in first three harvest of first harvest year than second harvest year.

The results of Experiment No. 2b (1984-86) with regard to P uptake as summarised in Table 4.62 showed similar trend of variations as described in Experiment No. 2a.

The interaction effects between levels of P and K with regard to P uptake were not significant in both the experiments No. 2 a and b.

4.2.3.3 Potassium uptake

Variations in K uptake of citronella Java in the first harvest year in Experiment No. 2a (1983-85) were significant due to different levels of P and K (Table 4.63).

Application of 50 kg P_2O_5 / ha increased the K uptake significantly in all the harvests. At this level (50 kg P_2O_5 / ha) the yearly K uptake were 80.0 and 146.3 kg / ha during first and second harvest year, respectively. Further, addition of P did not show any significant influence in K uptake.

Table 4.62 Phosphorus uptake (kg/ha) as influenced by different levels of P and K
(Experiment No. 2(b)-1984-86)

Levels of P_2O_5 and K_2O	First harvest year (1984-85) Timings of harvest*					Second harvest year (1985-86) Timings of harvest*				
	I	II	III	IV	Total	I	II	III	IV	Total
P_2O_5 (kg/ha)										
0	3.2	4.4	5.8	11.8	25.4	10.7	4.6	9.3	7.9	32.5
50	4.3	5.5	6.9	13.6	30.5	12.2	6.3	10.8	9.3	37.6
100	4.2	5.5	7.0	14.4	31.1	12.6	6.4	10.7	9.5	39.2
SEM _t	0.12	0.20	0.30	0.40	0.38	0.30	0.25	0.26	0.25	0.81
CD at 5%	0.35	0.61	0.91	1.19	1.14	0.91	0.75	0.78	0.75	2.42
CV (%)	9.0	11.9	13.9	9.0	4.0	7.6	13.2	7.6	8.5	6.7
K_2O (kg/ha)										
0	3.2	4.5	5.7	11.9	25.3	10.7	4.9	9.3	7.9	32.8
50	4.3	5.5	6.9	14.1	30.8	12.5	6.4	10.9	9.4	38.2
100	4.3	5.5	7.1	14.1	31.0	12.4	5.9	10.6	9.5	38.4
SEM _t	0.12	0.20	0.30	0.40	0.38	0.30	0.25	0.26	0.25	0.81
CD at 5%	0.35	0.61	0.91	1.19	1.14	0.91	0.75	0.78	0.75	2.42
CV (%)	9.0	11.9	13.9	9.0	4.0	7.6	13.2	7.6	8.5	6.7

* I = July-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

Table 4.63 Potassium uptake (kg/ha) as influenced by different levels of P and K
(Experiment No. 2(a)-1983-85)

Levels of P_2O_5 and K_2O	First harvest year (1983-84) Timings of harvest*					Second harvest year (1984-85) Timings of harvest*				
	I	II	III	IV	Total	I	II	III	IV	Total
P_2O_5 (kg/ha)										
0	7.7	8.6	11.2	36.1	63.6	32.6	18.6	37.2	40.4	128.8
50	9.6	10.2	13.1	47.1	80.0	35.7	20.3	40.5	49.8	146.3
100	9.7	9.6	13.3	49.7	82.3	37.3	19.6	40.9	50.5	148.3
SEM _t	0.35	0.34	0.42	1.20	1.33	0.65	0.43	1.09	1.29	2.13
CD at 5%	1.06	1.03	1.26	3.60	3.98	1.96	1.29	3.26	3.86	6.36
CV (%)	11.8	11.0	10.0	8.1	5.3	5.6	6.7	8.3	8.3	4.5
K_2O (kg/ha)										
0	8.1	8.7	11.8	34.0	62.6	30.5	17.7	36.2	38.9	123.3
50	9.7	10.0	12.9	49.6	82.2	37.6	20.1	42.0	50.1	149.8
100	9.3	9.6	13.0	49.4	81.3	37.5	20.7	40.3	51.6	150.1
SEM _t	0.35	0.34	0.42	1.20	1.33	0.65	0.43	1.09	1.29	2.13
CD at 5%	1.06	1.03	-	3.60	3.98	1.96	1.29	3.26	3.86	6.36
CV (%)	11.8	11.0	10.0	8.1	5.3	5.6	6.7	8.3	8.3	4.5

* I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

Table 4.64 Potassium uptake (kg/ha) as influenced by different levels of P and K
(Experiment No. 2(b)-1984-86)

Levels of P_2O_5 and K_2O	First harvest year (1984-85) Timings of harvest*					Second harvest year (1985-86) Timings of harvest*				
	I	II	III	IV	Total	I	II	III	IV	Total
P_2O_5 (kg/ha)										
0	14.0	18.6	26.8	52.2	111.6	49.3	19.1	43.1	36.6	148.1
50	17.8	22.2	30.3	57.8	128.1	53.4	23.9	47.8	40.2	165.3
100	17.5	22.4	30.9	59.7	130.5	55.2	24.4	47.2	41.0	167.8
SEM _t	0.49	0.82	1.23	1.75	1.73	1.27	1.05	0.97	1.0	2.13
CD at 5%	1.46	2.47	-	5.22	5.17	3.8	3.13	2.91	2.99	6.36
CV (%)	8.9	11.8	12.6	9.3	4.1	7.2	14.0	6.3	7.6	4.0
K_2O (kg/ha)										
0	13.5	18.3	25.6	50.2	107.6	48.2	19.5	41.9	35.7	145.3
50	17.9	22.5	30.6	59.3	130.3	54.8	25.0	48.6	40.8	169.2
100	18.0	22.4	31.8	60.2	132.4	55.0	22.9	47.6	41.3	166.8
SEM _t	0.49	0.82	1.23	1.75	1.73	1.27	1.05	0.97	1.0	2.13
CD at 5%	1.46	2.47	3.68	5.22	5.17	3.80	3.13	2.91	2.99	6.36
CV (%)	8.9	11.8	12.6	9.3	4.1	7.2	14.0	6.3	7.6	4.0

* I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

Application of 50 kg K_2O / ha increased the K uptake significantly in all the harvests except third harvest (Jan - Mar) in first harvest year. Further, addition of K (100 kg K_2O / ha) produced almost similar K uptake as in 50 kg P_2O_5 / ha. The maximum K uptake was recorded in fourth harvest ranging from 34.0 to 49.7 and 38.9 to 51.6 kg K_2O / ha and lowest were in second harvest ranging from 8.6 to 10.2 and 17.7 to 20.7 kg K_2O / ha in first and second harvest year, respectively.

The results of Experiment No. 2b (1984-86) summarised in Table 4.64 showed similar trend of variation as described in Experiment No. 2a earlier.

The interaction effect between levels of P and K were not significant in both the Experiments No. 2a and b.

4.3 Experiment No. 3a and 3b

The Experiment No. 3a and 3b were conducted to evaluate the effect of basal and split application of two doses of K at high level of N (250 kg / ha / yr). The Experiment No. 3a provided the results of 1983-85 and that of Experiment No. 3b provided results of 1984-86.

4.3.1 Biometrical observations

4.3.1.1 Plant height

The plant height of Citronella Java was significantly influenced due to levels and methods of K application in all

the harvests in Experiment No. 3a (Table 4.65). A significant increase in plant height was recorded at all the harvests due to application of 100 kg K_2O / ha except in the first harvest (Jul - Sep) in first harvest year.

Split application of K significantly increased the plant height in all harvests except in the first harvest in first harvest year. Basal application of K increased

plant height only in first harvest year. The plant heights increased significantly with increasing number of splits of K application. The maximum plant heights were recorded in four splits, ranging from 52.5 to 109.2 and from 68.0 to 124.2 during first and second harvest years, respectively. The plant heights were more in fourth harvest (Apr - Jun) ranging from 100.9 to 109.2 and from 111.8 to 124.2 cm in first and second harvest years, respectively. The plant heights were slightly lower during the first three harvests than that were recorded in second harvest year.

The plant height in Experiment No. 3b (1984-86) as summarised in Table 4.65 also showed similar trend of variations as described in Experiment No. 3a.

The interaction between levels and methods of K application was significant in fourth harvest (Apr - Jun) in Experiment No. 3a and 3b (Table 4.67). At 50 kg K_2O / ha increase in the number of split, significantly increased the

Table 4.65 Plant height (cm) as influenced by different levels and methods of K application
(Experiment No. 3(a)-1983-85)

Levels of K ₂ O (g/ha)	First harvest year (1983-84) Timings of harvest*				Second harvest year (1984-85) Timings of harvest*			
	I	II	III	IV	I	II	III	IV
50	53.0	56.2	49.5	103.5	98.9	67.8	79.1	117.9
100	53.3	57.1	50.5	104.8	99.8	68.6	79.6	118.4
SEM _t	0.17	1.18	0.14	0.27	0.30	0.26	0.28	0.21
CD at 5%	-	0.55	0.40	0.80	0.89	0.78	0.84	0.62
Methods of K application								
Basal	55.5	57.2	46.2	100.9	101.1	68.1	76.3	111.8
Two splits	54.0	55.5	50.3	102.9	96.2	70.3	78.2	116.2
Three splits	54.0	55.7	51.2	105.5	98.3	67.6	80.2	120.5
Four splits	54.5	58.2	52.5	109.2	101.9	68.0	82.7	124.2
SEM _t	0.24	0.26	0.19	0.38	0.42	0.37	0.40	0.30
CD at 5%	-	0.77	0.57	1.14	1.27	1.10	1.18	0.89
Control (No K)	50.0	52.0	43.3	95.0	94.3	68.0	72.0	106.5
SEM _t	0.20	0.21	0.16	0.31	0.35	0.30	0.32	0.24
CD at 5%	0.59	0.63	0.47	0.93	1.04	0.90	0.97	0.73
CV (%)	0.6	1.1	1.2	0.7	0.8	0.7	0.9	0.6

Levels of K_2O (kg/ha)	First harvest year (1984-86) Timings of harvest*				Second harvest year (1984-86) Timings of harvest*			
	I	II	III	IV	I	II	III	IV
50	50.0	53.8	78.0	119.8	102.5	61.1	69.6	120.4
100	50.2	54.0	79.3	120.5	104.3	61.9	72.7	121.8
SEM†	0.12	0.13	0.22	0.20	0.24	0.14	0.37	0.16
CD at 5%	-	-	0.66	0.59	0.73	0.42	1.11	0.49
Methods of K application								
Basal	52.0	54.3	77.5	117.5	104.2	57.2	69.0	113.7
Two splits	52.6	53.2	78.8	118.8	101.3	63.3	70.3	120.3
Three splits	52.8	53.2	79.5	120.8	102.5	62.0	72.3	123.3
Four splits	53.1	53.6	80.2	123.3	105.5	63.5	72.8	127.0
SEM†	0.18	0.18	0.33	0.28	0.34	0.20	0.52	0.23
CD at 5%	-	-	0.99	0.83	1.03	0.61	1.57	0.69
Control (No K)	46.5	50.7	72.0	111.3	98.3	55.0	65.0	109.3
SEM†	0.17	0.15	0.25	0.23	0.28	0.17	0.43	0.19
CD at 5%	0.51	0.45	0.76	0.69	0.83	0.50	1.28	0.56
CV (%)	0.6	0.5	0.8	1.0	0.8	0.8	0.7	1.3

*I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

Table 4.67 Plant height (cm) as influenced by different levels and methods of K application (Experiment No. 3a and b) in fourth harvest

Levels of K ₂ O (kg/ha)	Methods of K application				Methods of K application			
	Basal	Two splits	Three splits	Four splits	Basal	Two splits	Three splits	Four splits
Experiment No. 3a								
	First harvest year (1983-84)				Second harvest year (1984-85)			
50	100.1	102.2	103.1	106.6	111.7	115.7	121.0	123.3
100	101.7	103.6	105.9	106.8	112.0	116.7	123.0	125.0
Interaction	SEM _t	CD at 5%			SEM _t	CD at 5%		
	9.34	1.61			0.42	1.26		
Experiment No. 3b								
	First harvest year (1984-85)				Second harvest year (1985-86)			
50	116.7	118.3	120.0	124.0	113.3	119.7	123.0	126.7
100	116.5	119.3	121.7	122.7	114.0	121.0	126.7	127.3
Interaction	SEM _t	CD at 5%			SEM _t	CD at 5%		
	0.39	1.17			0.33	0.98		

plant height, whereas at 100 kg K_2O / ha increase in plant height was only significant up to three splits in first harvest year. In the second harvest year significant differences between the levels of K were recorded only when K was added in four splits. The trend of variations in Experiment No. 1b was similar to Experiment No. 1a.

4.3.1.2 Tiller production

The tiller production of citronella Java was favourably influenced due to levels and methods of K application in both the harvest years in Experiment No. 1a (Table 4.66). A significant increase in the number of tillers / plant was obtained at all cuttings (due to application of 100 kg / K_2O / ha over control and 50 kg K_2O / ha), except first cutting in first harvest year.

Application of full dose of K at planting recorded significantly lower number of tillers than that due to application significantly increased with increasing number of splits of K application. The highest number of tillers / plant was observed in four splits (ranging from 12.8 to 45.2 and from 32.5 to 42.3 tillers / per plant during first and second harvest year, respectively.

The number of tillers / plant was high in fourth cutting (Apr-Jun). The tillers / plant was slightly low during second cutting (Oct-Dec). This might be due to the

Table 4.68 Number of tillers per plant as influenced by different levels and methods of K application
(Experiment No. 3(a)-1983-85)

Levels of K ₂ O (g/ha)	First harvest year (1983-84) Timings of harvest*				Second harvest year (1984-85) Timings of harvest*			
	I	II	III	IV	I	II	III	IV
50	12.4	13.9	20.0	41.6	32.3	28.4	31.4	43.9
100	13.1	15.4	21.7	43.6	34.4	30.5	33.6	46.5
SEM _t	0.26	0.21	0.23	0.33	0.66	0.54	0.71	0.38
CD at 5%	-	0.64	0.67	0.97	1.98	1.62	2.13	1.15
Methods of K application								
Basal	14.2	15.8	17.5	38.0	29.5	25.3	29.7	41.3
Two splits	12.0	15.0	19.3	42.8	31.2	27.8	32.2	45.0
Three splits	12.0	13.5	22.7	44.3	36.2	32.2	33.7	46.2
Four splits	12.8	14.3	23.8	45.2	37.0	32.5	34.5	43.3
SEM _t	0.37	0.30	0.32	0.46	0.94	0.77	1.01	0.54
CD at 5%	1.10	0.91	0.95	1.30	2.80	2.29	3.02	1.62
Control (No K)	10.0	11.0	12.7	28.3	23.3	20.0	22.3	33.3
SEM _t	0.30	0.25	0.26	0.38	0.77	0.63	0.82	0.44
CD at 5%	0.91	0.74	0.78	1.12	2.29	1.87	2.46	1.33
CV (%)	7.3	5.2	3.9	4.3	7.1	6.6	7.9	5.5

* I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

Table 4.69 Number of tillers per plant as influenced by different levels and methods of K application
(Experiment No. 3(b)-1984-86)

Levels of K_2O (g/ha)	First harvest year (1984-85) Timings of harvest*				Second harvest year (1985-86) Timings of harvest*			
	I	II	III	IV	I	II	III	IV
50	14.6	18.8	29.0	48.7	42.1	30.0	40.2	46.0
100	15.2	20.1	32.3	50.4	44.0	32.2	41.9	48.1
SEM _t	0.36	0.21	0.54	0.47	0.64	0.51	0.55	0.34
CD at 5%	-	0.63	1.62	1.41	1.91	1.53	1.63	1.02
Methods of K application								
Basal	16.8	21.0	26.2	42.8	31.3	25.8	30.2	41.4
Two splits	14.0	20.2	28.8	48.7	42.8	29.5	41.0	46.8
Three splits	14.0	17.7	34.2	52.8	48.0	33.8	46.0	49.2
Four splits	14.7	18.8	35.0	53.8	50.0	35.2	47.0	50.8
SEM _t	0.51	0.30	0.77	0.66	0.90	0.72	0.77	0.48
CD at 5%	1.51	0.90	2.29	1.99	2.70	2.16	2.31	1.45
Control (No K)	12.0	14.3	16.7	28.3	26.0	18.3	26.3	30.0
SEM _t	0.41	0.24	0.63	0.54	0.74	0.59	0.63	0.40
CD at 5%	1.24	0.73	1.87	1.62	2.20	1.76	1.88	1.18
CV (%)	8.5	3.9	6.4	4.1	5.4	6.0	5.2	3.6

* I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

Table 4.70 Number of tillers per plant as influenced by different levels and methods of K application (Experiment No. 3a and b) in fourth harvest

Levels of K ₂ O (g/ha)	Methods of K application				Methods of K application			
	Basal	Two splits	Three splits	Four splits	Basal	Two splits	Three splits	Four splits
Experiment No. 3a								
	First harvest year (1983-84)				Second harvest year (1984-85)			
50	36.7	41.0	43.3	45.3	40.0	43.3	45.0	49.0
100	39.3	44.7	45.3	45.0	42.7	46.7	46.7	47.7
Interaction	SEM _t	CD at 5%			SEM _t	CD at 5%		
	0.65	1.95			0.77	2.30		
Experiment No. 3b								
	First harvest year (1984-85)				Second harvest year (1985-86)			
50	41.7	46.7	51.7	54.7	40.0	43.3	46.3	51.3
100	44.0	50.7	54.0	53.0	42.7	49.3	50.0	50.3
Interaction	SEM _t	CD at 5%			SEM _t	CD at 5%		
	0.94	2.81			0.69	2.05		

effect of temperature. In first harvest year, lower number of tillers / plant were observed in the first three cuttings than that was observed in second harvest year (1984-85). The results of Experiment No. 3b (1984-86) as summarised in Table 4.69 also showed similar variations as have been described in Experiment No. 3a.

The interaction effect between levels and methods of K application was significant only in fourth cutting (Apr - Jun) in both the years of Experiments No. 3a and 3b (Table 4.70). Application of K @ 50 kg K_2O / ha increased the number of tillers in all the splits, whereas at 100 kg K_2O / ha, application of K in two splits only increased the tillers significantly. It clearly indicated that the effect of the split applications was more pronounced at lower level of K than at higher level.

4.3.1.3 Fresh herbage yield

The treatment variations in fresh herbage yield (Table 4.71) due to levels and methods of K application were significant in first harvest year, except in first cutting in Experiment No. 3a (1983-85). During second harvest year, the variations due to treatments were significant in all the cuttings. Significant increase in fresh herbage yield was observed up to 100 kg K_2O / ha during both the harvest years.

Split application of K increased the fresh herbage yield. Basal application of the full doses of K showed

Table 4.71 Fresh herbage yield (q/ha) as influenced by different levels and methods of K application
(Experiment No. 3(a)-1983-85)

Levels of K ₂ O (q/ha)	First harvest year (1983-84) Timings of harvest*					Second harvest year (1984-85) Timings of harvest*				
	I	II	III	IV	Total	I	II	III	IV	Total
50	18.8	19.2	22.8	94.9	155.7	54.2	44.7	54.9	112.0	265.5
100	20.0	21.8	25.7	101.8	169.3	59.5	49.3	60.3	122.8	291.9
SEM _t	0.65	0.56	0.79	2.37	2.37	1.65	1.32	1.55	2.31	3.69
CD at 5%	-	1.68	2.35	6.42	7.09	4.94	3.95	4.63	6.91	11.04
Methods of K application										
Basal	21.6	21.2	20.1	77.8	140.7	50.4	38.4	51.6	98.4	238.8
Two splits	18.3	22.2	23.8	92.3	156.6	55.3	44.4	54.5	115.0	270.2
Three splits	19.2	18.0	24.3	106.8	168.3	60.1	51.5	61.1	125.4	298.1
Four splits	18.5	20.6	28.6	116.4	184.1	61.6	53.7	63.2	130.7	309.2
SEM _t	0.93	0.79	1.11	3.04	3.35	2.34	1.87	2.19	3.27	5.22
CD at 5%	-	2.37	3.33	9.09	10.02	6.98	5.59	6.55	9.77	15.62
Control (No K)	12.5	16.9	16.9	58.2	104.6	39.7	35.7	45.0	79.4	199.8
SEM _t	0.80	0.65	0.91	2.48	2.74	1.87	1.53	1.95	2.67	4.27
CD at 5%	2.40	1.94	2.72	7.42	8.19	5.59	4.57	5.84	7.98	12.75
CV (%)	12.9	9.7	11.7	7.9	5.3	10.3	10.1	10.4	3.6	4.7

* I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

favourable response only in first cutting in first harvest year but in subsequent cuttings it showed lower yield than that was recorded under split doses. Application of K in two splits, yielded significantly more than that was recorded under basal application of full dose. Similarly, K applied in three splits, caused further enhancement in the fresh herbage yield (168.3 and 298.1 q / ha during first and second harvest years, respectively). The respective increases in herbage yields due to two, three and four splits over basal application were of 11.3, 19.6 and 30.8 per cent and 13.1, 24.8 and 29.5 per cent during first and second harvest years. The fresh herbage yields were high during fourth cutting (Apr - Jun) but low (Oct - Dec) in second cutting which might be due to the effect of temperature. During first harvest year, lower herbage production was recorded in the first three cuttings than that in second harvest year (1984-85). The treatment differences of Experiment No. 3b (1984-86) as summarised in Table 4.72 also showed similar trend of variations as described in Experiment No. 3a.

The interaction effect between levels and methods of K application on fresh herbage yields was significant only in fourth cutting. Application of 50 kg K_2O / ha in four splits significantly increased the herbage yield over those recorded under the application in three splits; whereas at 100 kg K_2O / ha effect of application of K in three or four splits was at par (Table 4.73 and 4.74).

Table 4.72 Fresh herbage yield (q/ha) as influenced by different levels and methods of K application (Experiment No. 3(b)-1984-86)

Levels of K ₂ O (q/ha)	First harvest year (1984-85) Timings of harvest*					Second harvest year (1985-86) Timings of harvest*				
	I	II	III	IV	Total	I	II	III	IV	Total
50	22.1	30.3	41.7	108.7	202.8	68.8	39.5	67.3	91.8	267.3
100	23.0	34.3	46.7	119.5	223.5	74.7	43.9	74.8	103.3	296.7
SEM _t	0.67	0.85	1.08	2.56	3.19	1.84	1.16	2.44	1.84	3.08
CD at 5%	-	2.54	3.21	7.64	9.52	5.50	3.48	7.26	5.50	9.20
Methods of K application										
Basal	24.7	35.1	39.2	89.1	188.1	62.8	35.6	62.8	76.8	238.0
Two splits	21.2	33.7	43.9	109.9	208.7	69.9	41.9	69.6	92.7	274.1
Three splits	21.1	28.5	46.1	124.5	220.2	74.0	43.9	74.6	106.4	298.9
Four splits	23.0	31.8	47.2	133.0	235.0	80.3	45.2	77.0	114.6	317.1
SEM _t	0.95	1.20	1.52	3.62	4.50	2.60	1.64	3.45	2.60	4.35
CD at 5%	-	3.59	4.55	10.81	13.46	7.77	4.92	10.31	7.77	13.01
Control (No K)	18.6	26.3	34.0	74.0	152.9	53.7	30.7	54.8	60.3	199.5
SEM _t	0.78	0.98	1.24	2.95	3.68	2.12	1.34	2.82	2.12	3.55
CD at 5%	2.32	2.93	3.70	8.83	11.0	6.35	4.02	8.42	6.35	10.62
CV (%)	10.5	9.3	8.7	8.7	5.3	9.1	9.9	12.2	6.8	3.9

* I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

Table 4.73 Fresh herbage yield (g/ha) as influenced by different levels and methods of K application (Experiment No. 3a and b) in fourth harvest

Levels of K ₂ O (g/ha)	Methods of K application				Methods of K application			
	Basal	Two splits	Three splits	Four splits	Basal	Two splits	Three splits	Four splits
Experiment No. 3a								
	First harvest year (1983-84)				Second harvest year (1984-85)			
50	68.8	85.6	105.0	120.1	88.9	103.0	118.5	135.5
100	86.9	98.9	108.5	112.70	107.9	124.9	132.3	125.9
Interaction	SEM _t	CD at 5%			SEM _t	CD at 5%		
	4.30	12.85			4.58	13.70		
Experiment No. 3b								
	First harvest year (1984-85)				Second harvest year (1985-86)			
50	79.5	97.6	120.6	137.1	65.8	85.0	98.7	117.9
100	98.7	122.3	138.3	128.8	87.7	100.3	114.0	111.3
Interaction	SEM _t	CD at 5%			SEM _t	CD at 5%		
	5.11	15.29			3.69	10.99		

Table 4.74 Total fresh herbage yield per year (g/ha) as influenced by different levels and methods of K application (Experiment No. 3a and b)

Levels of K ₂ O (g/ha)	Methods of K application				Methods of K application			
	Basal	Two splits	Three splits	Four splits	Basal	Two splits	Three splits	Four splits
Experiment No. 3a								
	First harvest year (1983-84)				Second harvest year (1984-85)			
50	126.5	144.8	162.2	187.8	218.3	251.6	282.0	311.1
100	154.9	168.3	173.3	180.4	259.3	286.8	314.0	307.4
Interaction	SEM ₁	CD at 5%			SEM ₂	CD at 5%		
	4.76	14.23			7.39	22.09		
Experiment No. 3b								
	First harvest year (1984-85)				Second harvest year (1985-86)			
50	173.3	190.5	211.9	235.2	215.5	251.6	280.7	321.3
100	202.9	227.0	228.3	234.7	260.4	296.6	316.9	313.1
Interaction	SEM ₁	CD at 5%			SEM ₂	CD at 5%		
	6.37	19.04			6.15	18.40		

4.3.1.4 Dry matter accumulation

The treatment differences in dry matter accumulation (Table 4.75) due to levels and methods of K application were significant in all the cuttings, except in first cutting in first harvest year in Experiment No. 3a. Significant increase in annual dry matter production was observed up to 100 kg K_2O / ha (ranging from 7.1 to 57.5 kg / ha) and from 17.2 to 100.2 kg / ha during first and second harvest years, respectively.

Split application of K increased the dry matter yield significantly, in all the cuttings, except in first cutting of first harvest year. Application of K, all the planting, caused high dry matter production only in first cutting during first harvest year. Application of K in two splits caused appreciable increase in the dry matter accumulation over basal (all at one time) application. The effect of the treatments was more apparent in the fourth cutting than in others, at the fourth cutting yield were also high. Application of K in four splits caused maximum dry matter production (62.1 and 105.8 q / ha annual dry matter during first and second harvest years, respectively). The per cent increase in annual dry matter production due to two, three and four splits over basal application were 12.0, 17.6 and 28.6 in first harvest year and 12.1, 23.8 and 28.2 during second harvest year, respectively.

The experimental results with regard to dry matter accumulation in Experiment No. 3b (1984-86) as summarised in

Table 4.75 Dry matter accumulation (g/ha) as influenced by different levels and methods of K application
(Experiment No. 3(a)-1983-85)

Levels of K ₂ O (g/ha)	First harvest year (1983-84) Timings of harvest*					Second harvest year (1984-85) Timings of harvest*				
	I	II	III	IV	Total	I	II	III	IV	Total
50	6.7	6.8	8.0	31.4	52.9	18.9	15.6	19.0	37.7	91.3
100	7.1	7.8	9.0	33.6	57.5	20.8	17.2	20.8	41.4	100.2
SEM _t	0.26	0.27	0.27	0.71	0.80	0.58	0.49	0.57	0.83	1.34
CD at 5%	-	0.79	0.82	2.13	2.39	1.73	1.47	1.69	2.48	4.0
Methods of K application										
Basal	7.8	7.6	7.1	25.8	48.3	17.6	13.6	18.0	33.3	82.5
Two splits	7.5	7.9	8.3	30.4	54.1	19.4	15.6	18.8	38.7	92.5
Three splits	6.8	6.3	8.6	35.2	56.8	21.0	17.8	21.1	42.2	102.1
Four splits	6.5	7.2	10.0	38.4	62.1	21.4	18.6	21.8	44.0	105.8
SEM _t	0.36	0.38	0.39	1.01	1.13	0.82	0.70	0.80	1.17	1.89
CD at 5%	-	1.12	1.15	3.01	3.38	2.45	2.08	2.39	3.51	5.65
Control (No K)	4.6	6.1	6.0	19.8	36.5	14.3	12.9	15.9	27.2	70.3
SEM _t	0.29	0.31	0.32	0.82	0.92	0.67	0.57	0.65	0.96	1.54
CD at 5%	0.88	0.92	0.94	2.4	2.76	2.0	1.70	1.95	2.86	4.61
CV (%)	13.4	13.9	11.5	7.9	5.20	10.4	10.7	10.1	7.5	5.0

* I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

Table 4.76 Dry matter accumulation (g/ha) as influenced by different levels and methods of K application
(Experiment No. 3(b)-1984-86)

Levels of K ₂ O (g/ha)	First harvest year (1984-85) Timings of harvest*					Second harvest year (1985-86) Timings of harvest*				
	I	II	III	IV	Total	I	II	III	IV	Total
50	7.9	10.8	14.5	37.0	70.2	23.6	13.8	23.3	31.1	91.8
100	8.2	12.1	16.1	40.6	77.0	25.5	15.2	25.9	35.0	101.6
SEM _t	0.21	0.31	0.40	0.87	1.10	0.62	0.42	0.84	0.62	1.05
CD at 5%	-	0.91	1.19	2.61	3.28	1.85	1.27	2.51	1.84	3.15
Methods of K application										
Basal	8.9	12.6	13.7	30.1	65.2	21.8	12.6	21.9	26.2	82.5
Two splits	7.6	12.1	15.2	37.3	72.2	23.9	14.7	24.1	31.5	94.2
Three splits	7.4	10.0	16.0	42.3	75.7	25.2	15.1	25.7	36.0	102.0
Four splits	8.1	11.1	16.3	45.3	80.8	27.3	15.5	26.5	39.0	108.3
SEM _t	0.29	0.43	0.56	1.23	1.55	0.87	0.60	1.19	0.87	1.49
CD at 5%	0.88	1.29	1.68	3.69	4.64	2.61	1.79	3.55	2.61	4.46
Control (No K)	6.7	9.5	12.1	25.4	53.7	19.7	11.1	19.4	21.1	71.3
SEM _t	0.24	0.35	0.46	1.01	1.27	0.71	0.49	0.97	0.71	1.22
CD at 5%	0.72	1.05	1.37	3.01	3.79	2.13	1.46	2.90	2.13	3.64
CV (%)	9.1	9.4	9.2	8.1	5.3	8.9	10.4	12.1	6.7	3.9

* I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

Table 4.77 Dry matter accumulation (g/ha) as influenced by different levels and methods of K application
(Experiment No. 3a and b) in fourth harvest

Levels of K_2O (g/ha)	Methods of K application				Methods of K application			
	Basal	Two splits	Three splits	Four splits	Basal	Two splits	Three splits	Four splits
Experiment No. 3a								
	First harvest year (1983-84)				Second harvest year (1984-85)			
50	23.0	28.2	34.7	39.6	30.2	35.3	39.7	45.6
100	28.7	32.7	35.8	37.1	36.3	42.1	44.8	42.4
Interaction	SSM†	CD at 5%			SSM†	CD at 5%		
	1.42	4.25			1.66	4.96		
Experiment No. 3b								
	First harvest year (1984-85)				Second harvest year (1985-86)			
50	20.9	33.0	41.0	46.6	22.5	28.9	33.5	39.7
100	33.6	41.6	43.6	44.0	30.0	34.1	30.4	37.5
Interaction	SSM†	CD at 5%			SSM†	CD at 5%		
	1.76	5.21			1.23	3.69		

Table 4.78 Total dry matter accumulation per year (g/ha) as influenced by different levels and methods of K application (Experiment No. 3a and b)

Levels of K ₂ O (g/ha)	Methods of K application				Methods of K application			
	Basal	Two splits	Three splits	Four splits	Basal	Two splits	Three splits	Four splits
Experiment No. 3a								
	First harvest year (1983-84)				Second harvest year (1984-85)			
50	43.5	49.3	55.0	63.2	78.4	89.7	100.1	110.1
100	52.9	57.2	58.5	60.8	92.5	101.9	111.7	109.0
Interaction	SEM ₁	CD at 5%			SEM ₁	CD at 5%		
	1.6	4.77			2.77	8.28		
Experiment No. 3b								
	First harvest year (1984-85)				Second harvest year (1985-86)			
50	58.2	63.6	79.3	78.2	74.9	86.8	96.0	109.3
100	67.8	75.8	75.8	78.1	90.0	101.7	108.0	106.5
Interaction	SEM ₁	CD at 5%			SEM ₁	CD at 5%		
	2.12	6.33			2.11	6.30		

(Table 4.76) also showed similar trend of variations as have been described in Experiment No. 3a.

The interaction between levels and methods of K application was significant only in fourth cutting (Apr-Jun) in both the Experiments No. 3a and 3b (Table 4.77 and 4.78). Split application of 50 kg K_2O / ha in four splits produced significantly higher dry matter than those under three splits whereas, at 100 kg K_2O / ha no significant difference was recorded between them.

4.3.2 Essential oil content,^{oil}_n yield and ^{oil}_n quality

4.3.2.1 Oil content

The treatment differences in oil content (Table 4.79) due to levels and methods of K application were not significant in both first and second harvest years in Experiment No. 3a. It may be noted that oil content was more in first harvest year than in second harvest year. The oil content was high in second (Oct-Dec) cutting ranging from 1.36 to 1.42 and 1.30 to 1.33 per cent in first and second harvest year. It was low in fourth cutting (Apr - Jun) ranging from 1.18 to 1.22 per cent in first harvest year and from 1.12 to 1.15 per cent in second harvest year. This might be due to dilution effect in oil content caused by higher herbage production during Apr - Jun than during Oct - Dec.

The oil content in Experiment No. 3b (1984-86) as summarised in Table 4.80 was slightly higher than those

Table 4.79 Oil content (%) as influenced by different levels and methods of K application
(Experiment No. 3(a)-1983-85)

Levels of K ₂ O (kg/ha)	First harvest year (1983-84) Timings of harvest*				Second harvest year (1984-85) Timings of harvest*			
	I	II	III	IV	I	II	III	IV
50	1.32	1.38	1.23	1.19	1.26	1.32	1.21	1.13
100	1.33	1.38	1.23	1.18	1.25	1.31	1.22	1.13
SEM _t	0.01	0.01	0.01	0.005	0.008	0.007	0.007	0.008
CD at 5%	-	-	-	-	-	-	-	-
Methods of K application								
Basal	1.33	1.40	1.25	1.20	1.26	1.33	1.22	1.13
Two splits	1.32	1.38	1.23	1.20	1.25	1.33	1.23	1.13
Three splits	1.33	1.38	1.21	1.18	1.26	1.31	1.21	1.12
Four splits	1.31	1.36	1.22	1.19	1.25	1.30	1.20	1.13
SEM _t	0.02	0.02	0.02	0.007	0.01	0.009	0.01	0.01
CD at 5%	-	-	-	-	-	-	-	-
Control (No K)	1.33	1.42	1.27	1.22	1.28	1.33	1.23	1.15
SEM _t	0.02	0.02	0.01	0.006	0.01	0.008	0.008	0.009
CD at 5%	-	-	-	-	-	-	-	-
CV (%)	3.4	3.6	3.4	1.4	2.4	1.7	2.0	2.5

* I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

Table 4.80 Oil content (%) as influenced by different levels and methods of K application
(Experiment No. 3(b)-1984-86)

Levels of K_2O (g/ha)	First harvest year (1984-85) Timings of harvest*				Second harvest year (1985-86) Timings of harvest*			
	I	II	III	IV	I	II	III	IV
50	1.30	1.37	1.22	1.20	1.24	1.31	1.20	1.13
100	1.30	1.37	1.22	1.20	1.23	1.30	1.20	1.13
SEM _t	0.07	0.006	0.004	0.009	0.005	0.008	0.008	0.004
CD at 5%	-	-	-	-	-	-	-	-
Methods of K application								
Basal	1.31	1.38	1.23	1.20	1.24	1.32	1.20	1.13
Two splits	1.29	1.38	1.22	1.20	1.23	1.31	1.20	1.13
Three splits	1.30	1.36	1.21	1.19	1.24	1.30	1.21	1.13
Four splits	1.30	1.37	1.22	1.20	1.23	1.30	1.20	1.13
SEM _t	0.01	0.008	0.006	0.01	0.007	0.01	0.02	0.006
CD at 5%	-	-	-	-	-	-	-	-
Control (No K)	1.32	1.39	1.23	1.22	1.25	1.32	1.22	1.13
SEM _t	0.008	0.007	0.005	0.01	0.006	0.009	0.009	0.005
CD at 5%	-	-	-	-	-	-	-	-
CV (%)	2.0	1.5	1.2	2.7	1.3	1.9	2.3	1.2

* I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

recorded in Experiment No. 3a. similar trend of variation in oil content under different treatments as recorded in Experiment No. 3a was also observed in Experiment No. 3b.

The interaction effect between levels and methods of K application on oil content was not significant.

4.3.2.2 Oil yield

In the first harvest year in Experiment No. 3a (1983-85) significant variations were observed in oil yield of citronella Java due to levels and methods of K application (Table 4.81). Significant increase in oil yield was observed up to 100 kg K_2O / ha in all the harvests except first cutting in both the harvest years. At the same level i.e. 100 kg K_2O / ha the annual oil yield was 209.1 kg / ha in first harvest year and it was 350.2 kg / ha in second harvest year.

Split application of K exhibited favourable influence on oil yield. Application of K all at planting, produced maximum oil yield only in first cutting during first harvest year; oil yields were low in subsequent cuttings in Experiment No. 3a. Application of K in two splits significantly increased the oil yield over basal application in all the cuttings, except first and second cuttings during first harvest year in Experiment No. 3a. Further increase in number of splits up to three splits, increased the oil yield. Application of K in four splits produced maximum oil yield, 227.2 and 369.8 kg / ha in first and second harvest years,

(Experiment No. 3(a)-1983-85)

Levels of K ₂ O (g/ha)	First harvest year (1983-84) Timings of harvest*					Second harvest year (1984-85) Timings of harvest*				
	I	II	III	IV	Total	I	II	III	IV	Total
50	25.4	26.5	27.6	113.5	193.0	69.1	58.9	66.4	126.4	319.8
100	26.4	30.0	31.6	121.1	209.1	74.4	64.6	73.3	137.9	350.2
SEM _t	0.95	1.11	1.09	2.70	3.26	2.22	1.59	1.94	2.70	4.32
CD at 5%	-	3.32	3.27	-	7.96	-	4.76	5.71	8.10	12.99
Methods of K application										
Basal	28.7	29.7	25.1	93.3	176.8	63.3	51.1	62.7	111.4	288.5
Two splits	24.0	30.5	29.2	110.6	194.3	69.2	58.7	66.8	130.3	325.0
Three splits	25.4	24.8	29.5	126.4	206.1	75.6	67.3	74.0	140.0	356.9
Four splits	25.6	28.1	34.8	138.7	227.2	77.1	69.8	75.9	147.0	369.8
SEM _t	1.22	1.60	1.55	3.81	4.61	3.02	2.22	2.70	3.81	6.10
CD at 5%	-	-	4.63	11.55	13.78	9.21	6.83	8.25	11.59	18.25
Control (No K)	16.7	24.0	21.4	71.0	132.9	51.0	47.6	55.6	91.3	245.5
SEM _t	1.02	1.30	1.26	3.13	3.78	2.52	1.85	2.24	3.13	4.99
CD at 5%	3.04	3.90	3.78	9.36	11.30	7.53	5.52	6.71	9.36	14.92
CV (%)	12.3	13.9	13.2	8.4	6.3	11.0	6.7	11.5	7.3	5.7

* I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

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Table 1. Oat yield (kg/ha) as influenced by different levels and methods of K application
(Experiment No. 3(b) - 1984-86)

Levels of K ₂ O (kg/ha)	First harvest year (1984-85) Timings of harvest*					Second harvest year (1985-86) Timings of harvest*				
	I	II	III	IV	Total	I	II	III	IV	Total
50	28.6	41.6	50.7	130.4	251.3	85.4	51.6	80.6	104.1	321.7
100	29.8	46.9	56.7	142.9	276.2	92.1	57.2	90.1	116.3	355.7
SEM _t	0.52	1.16	1.32	3.29	4.22	3.15	1.42	2.96	2.47	4.10
CD at 5%	-	3.48	4.11	9.70	12.62	-	4.28	8.88	7.24	12.25
Methods of K application										
Basal	32.2	48.5	48.0	106.9	235.6	78.0	46.9	75.3	87.2	287.4
Two splits	27.5	46.1	53.5	131.9	259.0	86.2	54.8	83.6	105.1	329.7
Three splits	27.5	38.7	53.6	148.4	270.2	91.9	57.1	90.1	119.6	358.7
Four splits	29.9	43.4	57.4	159.5	290.2	99.0	58.9	92.4	129.0	379.3
SEM _t	0.95	1.64	1.97	4.61	5.58	3.29	1.97	4.28	3.45	5.79
CD at 5%	2.84	5.10	5.76	13.82	17.88	10.03	6.09	12.66	10.36	17.32
Control (No K)	24.5	36.7	41.9	90.1	193.2	67.1	40.5	66.9	68.6	243.1
SEM _t	0.78	1.34	1.55	3.76	4.87	2.74	1.64	3.47	4.28	4.72
CD at 5%	2.32	4.01	4.64	11.24	14.57	8.19	4.92	10.36	12.78	14.10
CV (%)	8.1	9.5	9.0	8.4	5.4	9.5	9.5	12.5	7.9	4.8

*I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

respectively. The per cent increases in oil yield were of 10.0, 16.6 and 28.5 due to two, three and four splits over basal application on first harvest year, whereas in second harvest year the corresponding figures were only 12.6, 23.6 and 28.1 per cent. The oil yield was more at fourth cutting (Apr - Jun), ranging from 71.0 to 138.7 kg / ha and was minimum during first cutting (Jul Sep) ranging from 16.7 to 28.7 kg / ha during first harvest year. The maximum oil yield ranged from 91.3 to 147.0 kg / ha in fourth cutting and the minimum oil yield was recorded in second cutting (Oct - Dec) ranging from 47.6 to 69.8 kg / ha. In first harvest year, low oil yields were recorded in the first three cuttings, than that were recorded in second harvest year. The oil yield in crop grown in Experiment No. 3b (1984-86) as summarised in Table 4.82 also showed similar variation as described in Experiment No. 3a.

The interaction effect between levels and methods of K application was significant only in fourth cutting of first and second harvest year in Experiment No. 3a and 3b. At 50 kg K_2O / ha oil yield significantly increased with increase in the number of splits upto four, whereas at high level (100 kg K_2O / ha) the response of oil yield to K was only limited to three splits (Table 4.83 and 4.84).

Table 4.83 Oil yield (t/ha) as influenced by different levels and methods of K application (Experiment No. 3a and b) in fourth harvest

Levels of K ₂ O (t/ha)	Methods of K application				Methods of K application			
	Basal	Two splits	Three splits	Four splits	Basal	Two splits	Three splits	Four splits
Experiment No. 3a								
	First harvest year (1983-84)				Second harvest year (1984-85)			
50	82.5	102.7	124.4	144.1	100.6	119.2	132.5	153.3
100	104.3	118.7	128.3	133.3	122.2	141.4	147.6	140.6
Interaction	SEM _t	CD at 5%			SEM _t	CD at 5%		
	5.44	16.28			5.44	16.28		
Experiment No. 3b								
	First harvest year (1984-85)				Second harvest year (1985-86)			
50	95.4	117.1	139.7	164.5	74.7	96.4	111.8	133.6
100	118.4	146.7	152.0	159.6	99.5	113.8	127.3	124.3
Interaction	SEM _t	CD at 5%			SEM _t	CD at 5%		
	6.50	19.44			4.89	14.59		

Table 4.84 Total oil yield per year ($\mu\text{g}/\text{ha}$) as influenced by different levels and methods of K application
(Experiment No. 3a and 3b)

Levels of K_2O ($\mu\text{g}/\text{ha}$)	Methods of K application				Methods of K application			
	Basal	Two splits	Three splits	Four splits	Basal	Two splits	Three splits	Four splits
Experiment No. 3a								
	First harvest year (1983-84)				Second harvest year (1984-85)			
50	158.7	180.5	199.5	233.7	264.6	304.3	338.1	372.4
100	195.1	208.4	212.5	220.8	312.7	346.0	375.6	367.3
Interaction	SEM _t	CD at 5%			SEM _t	CD at 5%		
	6.52	19.49			6.63	25.60		
Experiment No. 3b								
	First harvest year (1984-85)				Second harvest year (1985-86)			
50	216.9	236.8	261.7	290.0	261.0	303.0	338.0	384.9
100	254.6	280.8	278.6	290.6	313.7	356.1	379.4	373.5
Interaction	SEM _t	CD at 5%			SEM _t	CD at 5%		
	8.44	-			8.17	24.63		

4.3.2.3 Quality of oil

4.3.2.3(a) Citronella content

The treatment differences in citronellal content in the oil of citronella Java in first harvest year of Experiment No. 3a (1983-85) were not significant; so was the case in the second harvest year (Table 4.85). Citronellal contents were high during first cutting (Jul - Sep) and low during fourth (Apr - Jun) cutting.

The citronellal content in Experiment No. 3b (1984-86) as summarised in Table 4.86 showed similar trend of variation as described in Experiment No. 3a.

The interaction effect between levels and methods of K application was not significant.

4.3.2.3(b) Citronellol content

The citronellol content in oil of citronella Java as summarised in Table 4.87 did not vary significantly due to levels and methods of K application in both the harvest years of Experiment No. 3a. It may be noted that citronellol content at (Jan - Mar) third cutting was high while during first cutting (Jul - Sep) it was low in both the harvest years.

The citronellol content in crop grown in Experiment No. 3b (1984-86), as summarised in Table 4.88, also showed similar trend of variations as described in Experiment No. 3a.

Table 4.85 Citronellal content (%) * in oil as influenced by different levels and methods of K application (Experiment No. 3(a)-1983-85)

Levels of K ₂ O (kg/ha)	First harvest year (1983-84) Timings of harvest**				Second harvest year (1984-85) Timings of harvest**			
	I	II	III	IV	I	II	III	IV
50	31.26	27.45	28.64	24.35	31.57	28.33	29.32	26.54
100	31.88	27.43	28.68	24.65	32.64	28.35	29.03	25.71
Methods of K application								
Basal	31.84	27.35	28.37	24.69	31.82	28.19	28.97	25.99
Two splits	31.49	27.35	29.0	23.95	32.53	28.39	29.51	25.07
Three splits	31.06	27.55	28.91	24.82	31.87	28.36	28.89	26.98
Four splits	31.90	27.50	28.35	24.55	32.22	28.40	29.33	26.47
Control (No K)	31.18	27.30	27.90	23.64	31.60	28.28	29.03	25.32

* Values of composite samples

** I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

Table 4.86 Citronellal content (%)^{*} in oil as influenced by different levels and methods of K application (Experiment No. 3(b)-1984-86)

Levels of K ₂ O (kg/ha)	First harvest year (1984-85) Timings of harvest**				Second harvest year (1985-86) Timings of harvest**			
	I	II	III	IV	I	II	III	IV
50	32.30	26.72	29.48	24.49	34.55	27.33	30.20	25.31
100	32.22	26.36	29.53	24.36	34.51	27.83	30.29	25.27
Methods of K application								
Basal	32.45	26.37	29.40	24.36	34.98	26.61	30.27	25.80
Two splits	31.90	26.01	29.47	24.44	34.62	27.70	30.20	25.08
Three splits	32.21	26.43	29.00	24.56	34.47	27.66	30.00	25.18
Four splits	32.47	26.33	29.15	24.35	34.05	27.35	30.52	25.12
Control (No K)	32.91	26.35	29.00	24.55	34.05	27.05	30.15	25.25

* Values of composite samples

** I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

Table 4.87 Citronellol content (%)^{*} in oil as influenced by different levels and methods of K application
(Experiment No. 3(a)-1983-85)

Levels of K ₂ O (g/ha)	First harvest year (1983-84) Timings of harvest**				Second harvest year (1984-85) Timings of harvest**			
	I	II	III	IV	I	II	III	IV
50	6.09	6.45	14.41	13.23	8.49	10.42	15.16	12.60
100	6.27	6.42	14.58	13.33	8.59	11.28	15.45	12.75
Methods of K application								
Basal	6.29	8.42	14.45	13.11	8.47	10.98	14.78	12.85
Two splits	6.25	8.46	15.12	13.23	8.85	10.94	15.41	12.44
Three splits	6.27	8.30	14.53	13.38	8.49	10.27	15.50	13.13
Four splits	5.90	8.57	14.28	13.41	8.34	11.20	15.59	12.68
Control (No K)	6.20	8.43	14.60	12.54	8.30	10.37	15.31	12.59

* Values of composite samples

** I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

Table 4.88 Citronellol content (%) in oil as influenced by different levels and methods of K application
(Experiment No. 3(b)-1984-86)

Levels of K ₂ O (g/ha)	First harvest year (1984-85) Timings of harvest**				Second harvest year (1985-86) Timings of harvest**			
	I	II	III	IV	I	II	III	IV
50	5.28	8.34	12.25	11.24	5.86	8.35	11.02	9.96
100	5.36	8.18	12.31	10.94	6.39	8.58	10.96	9.94
Methods of K application								
Basal	5.28	8.40	12.18	11.21	5.73	8.13	11.08	10.07
Two splits	5.23	8.30	12.18	10.58	6.06	8.47	10.91	9.43
Three splits	5.11	8.30	12.35	11.17	6.07	8.82	10.92	10.00
Four splits	5.68	8.06	12.42	11.20	6.65	8.43	11.06	9.93
Control (No K)	5.39	8.03	12.34	10.99	6.05	8.05	10.99	10.10

* Values of composite samples

** I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

Table 4.89 Geraniol content (%) in oil as influenced by different levels and methods of K application
(Experiment No. 3(a)-1983-85)

Levels of K ₂ O (g/ha)	First harvest year (1983-84) Timings of harvest**				Second harvest year (1984-85) Timings of harvest**			
	I	II	III	IV	I	II	III	IV
50	26.44	15.50	10.69	16.87	27.98	16.58	9.63	19.84
100	26.66	15.59	10.54	17.24	28.08	16.99	9.70	19.99
Methods of K application								
Basal	26.65	15.64	10.33	16.72	28.16	16.89	9.41	19.68
Two splits	26.49	15.34	10.42	16.87	27.98	16.82	9.86	19.65
Three splits	26.16	15.48	11.19	17.23	27.88	17.18	9.53	21.03
Four splits	26.66	15.48	10.53	17.40	28.11	16.26	9.86	19.28
Control (No K)	26.42	14.98	9.82	16.66	25.57	16.36	9.82	19.69

* Values of composite samples

** I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

Table 4.90 Geraniol content (%) * in oil as influenced by different levels and methods of K application (Experiment No. 3(b)-1984-86)

Levels of K ₂ O (g/ha)	First harvest year (1984-85) Timings of harvest**				Second harvest year (1985-86) Timings of harvest**			
	I	II	III	IV	I	II	III	IV
50	26.38	12.26	9.27	17.59	27.01	14.47	10.38	18.12
100	26.57	12.36	9.48	17.30	27.71	14.37	10.25	18.50
Methods of K application								
Basal	26.00	12.56	9.34	17.59	27.49	14.28	10.78	18.05
Two splits	26.42	12.29	9.29	17.35	27.17	14.02	10.13	18.34
Three splits	26.81	12.12	9.26	17.17	27.16	14.62	10.23	18.36
Four splits	26.67	12.18	9.62	17.67	27.64	14.72	10.13	18.39
Control (No K)	25.36	12.55	9.27	17.65	27.25	14.63	10.10	18.00

* Values of composite samples

** I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

The interaction effect between levels and methods of K application was not significant.

4.3.2.3(c) Geraniol content

The treatment variations in first harvest year in Experiment No. 3a was not significant due to levels and methods of K application. So was the case in second harvest year (Table 4.89). The geraniol content were high in first (Jul - Sep) cutting followed by fourth (Apr - Jun) cutting in both the harvest years and low in third cutting (Jan - Mar). The results with regard to treatment variations in geraniol content in Experiment No. 3b (1984-86) as in Table 4.90 showed similar trend of variations as described in Experiment No. 3a earlier.

4.3.3 Nutrient uptake

4.3.3.1 Nitrogen uptake

significant variations were observed in nitrogen uptake of Citronella Java due to levels and methods of K application in Experiment No. 3a (1983-85) summarised in Table 4.91. Significant increase in N uptake was observed up to 100 kg K_2O / ha in all the harvests except first harvest in first harvest year.

Split application of K favourably increased the N uptake. Application of K full dose at planting recorded high N uptake only in first harvest during first harvest

Table 4.91 Nitrogen uptake (g/ha) as influenced by different levels and methods of K application
(Experiment No. 3 (a)-1983-85)

Levels of K ₂ O (g/ha)	First harvest year (1983-84 Timings of harvest*					Second harvest year (1984-85) Timings of harvest*				
	I	II	III	IV	Total	I	II	III	IV	Total
50	13.5	13.6	13.5	30.2	70.8	37.4	23.4	37.6	34.5	132.9
100	14.3	15.7	15.3	32.1	77.4	41.0	25.8	41.2	37.8	145.8
SEM _t	0.54	0.63	0.47	0.70	1.08	1.18	0.74	1.13	0.81	2.0
CD at 5%	-	1.88	1.41	2.1	3.22	3.53	2.22	3.36	2.42	5.98
Methods of K application										
Basal	15.5	15.2	12.0	24.9	67.6	34.8	20.4	35.6	30.6	121.4
Two splits	13.4	16.4	14.2	30.0	74.0	38.4	23.4	37.2	35.4	134.4
Three splits	13.5	12.7	14.5	33.7	74.4	41.4	26.8	41.9	38.6	148.7
Four splits	13.0	14.4	17.0	36.6	81.0	42.2	27.9	43.1	40.0	153.2
SEM _t	0.76	0.89	0.67	0.99	1.53	1.67	1.05	1.59	1.14	2.83
CD at 5%	-	-	1.99	2.97	4.56	4.99	3.13	4.76	3.42	8.45
Control (No K)	9.1	12.3	10.3	19.0	50.7	28.3	19.4	31.5	25.1	104.3
SEM _t	0.62	0.73	0.54	0.81	1.25	1.36	0.86	1.30	0.93	2.31
CD at 5%	1.86	-	1.63	2.42	3.73	4.07	2.56	3.89	2.80	6.90
CV (%)	13.9	15.2	11.6	8.2	5.2	10.7	10.7	10.1	8.0	5.1

* I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

Table 4.92 Nitrogen uptake (g/ha) as influenced by different levels and methods of K application
(Experiment No. 3(b)-1984-86)

Levels of K ₂ O (g/ha)	First harvest year (1984-85) Timings of harvest*					Second harvest year (1985-86) Timings of harvest*				
	I	II	III	IV	Total	I	II	III	IV	Total
50	15.5	15.9	24.5	35.1	91.0	46.3	20.5	45.7	28.0	140.5
100	16.2	17.9	27.3	38.7	100.1	49.8	22.6	50.8	31.5	154.7
SEM _t	0.41	0.45	0.66	0.87	1.3	1.17	0.65	1.66	0.57	1.76
CD at 5%	-	1.33	1.97	2.60	3.88	3.49	1.94	4.97	1.70	5.28
Methods of K application										
Basal	17.6	18.7	23.3	28.6	88.2	42.8	18.8	43.2	23.6	126.4
Two splits	15.0	17.8	25.8	35.5	94.1	46.5	21.9	47.4	28.4	144.2
Three splits	14.6	14.7	27.0	40.2	96.5	49.4	22.6	50.4	32.4	154.8
Four splits	16.1	16.5	27.5	43.1	103.2	53.6	22.9	51.5	34.7	162.7
SEM _t	0.59	0.63	0.93	1.23	1.84	1.65	0.92	2.35	0.80	2.50
CD at 5%	1.76	1.89	2.78	3.68	5.49	4.93	2.74	-	2.39	7.47
Control (No K)	13.4	14.1	20.3	24.3	72.1	37.6	16.6	38.3	19.2	111.7
SEM _t	0.48	0.52	0.76	1.01	1.50	1.35	0.75	1.92	0.65	2.04
CD at 5%	1.43	1.54	2.27	3.01	4.40	4.03	2.24	5.74	1.96	6.09
CV (%)	9.2	9.4	9.0	8.5	4.8	8.6	10.7	12.2	6.8	4.3

* I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

Table 4.93 Nitrogen uptake (kg/ha) as influenced by different levels and methods of K application (Experiment No. 3a and b) in fourth harvest

Levels of K_2O (kg/ha)	Methods of K application				Methods of K application			
	Basal	Two splits	Three splits	Four splits	Basal	Two splits	Three splits	Four splits
Experiment No. 3a								
	First harvest year (1983-84)				Second harvest year (1984-85)			
50	22.1	27.2	33.1	38.2	27.8	32.4	36.3	41.5
100	27.6	31.3	34.3	35.0	33.4	38.4	40.9	38.4
Interaction	SEM ₂	CD at 5%			SEM ₂	CD at 5%		
	1.40	4.19			1.62	4.84		
Experiment No. 3b								
	First harvest year (1984-85)				Second harvest year (1985-86)			
50	25.6	31.4	39.0	44.3	20.2	26.0	30.2	35.7
100	31.7	39.6	41.4	41.8	27.0	30.7	34.6	33.4
Interaction	SEM ₂	CD at 5%			SEM ₂	CD at 5%		
	1.74	5.20			1.13	3.39		

Table 4.94 Total nitrogen uptake per year (t/ha) as influenced by different levels and methods of K application (Experiment No. 3a and b)

Levels of K K_2O (t/ha)	Methods of K application				Methods of K application			
	Basal	Two splits	Three splits	Four splits	Basal	Two splits	Three splits	Four splits
Experiment No. 3a								
	First harvest year (1983-84)				Second harvest year (1984-85)			
50	61.4	68.0	71.6	82.3	111.5	126.5	141.0	152.9
100	74.2	78.7	77.1	79.5	131.4	142.2	156.4	153.5
Interaction	SEM _t	CD at 5%			SEM _t	CD at 5%		
	2.16	6.45			4.0	11.95		
Experiment No. 3b								
	First harvest year (1984-85)				Second harvest year (1985-86)			
50	82.1	86.6	92.6	102.3	118.1	133.4	146.1	164.7
100	94.2	101.6	100.3	104.0	138.7	155.0	163.6	161.7
Interaction	SEM _t	CD at 5%			SEM _t	CD at 5%		
	2.60	7.76			3.53	10.55		

year whereas minimum N uptake was recorded in other harvests. Application of K in two splits recorded significantly high N uptake over basal application. Application of K in three splits also recorded increase in N uptake. Further addition of K recorded maximum N uptake in both the harvest years. The N uptake in crop grown in Experiment No. 3b (1984-86) as summarised in Table 4.92 also showed similar trend of variation as described in Experiment No. 3a.

The interaction effect between levels and methods of K application was significant in fourth harvest and in total annual production in both the Experiments No. 3a and b (Table 4.93 and 4.94). At 50 kg K_2O / ha N uptake was significantly increased with increase in the number of splits upto four, whereas at high level (100 kg K_2O / ha) the N uptake increased up to two splits.

4.3.3.2 Potassium uptake

In the first harvest year in Experiment No. 3a (1983-85) the differences in potassium uptake (Table 4.95) due to levels and methods of K application were significant and so was the case in the second harvest year in 1984-85. Application of K increased the potassium uptake significantly in all harvests due to 100 kg K_2O / ha except in first cutting (Jul - Sep) in first harvest year.

split application of K increased potassium uptake. Potassium in full dose applied at planting increased significantly potassium uptake in first cutting (Jul-Sep) of

Table 4.95 Potassium uptake (kg/ha) as influenced by different levels and methods of K application
(Experiment No. 3(a)-1983-85)

Levels of K ₂ O (kg/ha)	First harvest year (1983-84) Timings of harvest*					Second harvest year (1984-85) Timings of harvest*				
	I	II	III	IV	Total	I	II	III	IV	Total
50	10.0	10.3	14.5	41.3	76.1	28.5	23.9	34.8	49.8	137.0
100	10.8	11.8	16.5	44.5	83.6	31.6	26.4	39.3	54.8	151.1
SEM _t	0.38	0.41	0.51	0.92	1.10	0.88	0.76	1.10	1.09	1.98
CD at 5%	-	1.22	1.51	2.76	3.29	2.63	2.27	3.30	3.26	5.93
Methods of K application										
Basal	11.7	11.6	12.9	34.2	70.4	26.6	20.8	33.0	44.1	124.5
Two splits	9.7	12.1	15.3	40.4	77.5	29.4	24.0	34.6	51.4	139.4
Three splits	10.0	9.6	15.6	46.6	81.8	31.7	27.3	38.7	55.7	153.4
Four splits	9.7	11.8	18.2	50.6	89.5	32.3	28.4	39.8	57.6	158.1
SEM _t	0.54	0.58	0.72	1.30	1.55	1.24	1.07	1.56	1.54	2.80
CD at 5%	-	1.73	2.14	3.90	4.65	3.72	3.20	4.66	4.61	8.38
Control (No K)	6.7	9.2	10.9	25.9	52.7	21.1	19.4	28.8	35.4	104.7
SEM _t	0.44	0.47	0.58	1.07	1.27	1.02	0.87	1.27	1.26	2.29
CD at 5%	-	1.41	1.75	3.18	3.79	3.04	2.61	3.81	3.76	6.84
CV (%)	13.4	13.1	11.7	7.8	5.0	10.5	10.7	10.7	7.5	5.0

* I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

Table 4.96 Potassium uptake (kg/ha) as influenced by different levels and methods of K application (Experiment No. 3(b)-1984-86)

Levels of K ₂ O (kg/ha)	First harvest year (1984-85) Timings of harvest*					Second harvest year (1985-86) Timings of harvest*				
	I	II	III	IV	Total	I	II	III	IV	Total
50	11.8	16.4	26.5	48.7	103.4	35.7	21.1	42.7	41.2	140.7
100	12.2	18.5	29.7	54.0	114.4	38.9	23.3	47.7	46.5	156.4
SEM ₊	0.32	0.47	0.74	1.20	1.63	0.92	1.56	1.56	0.91	1.73
CD at 5%	-	1.39	2.20	3.59	4.87	2.75	1.95	4.65	2.42	5.18
Methods of K application										
Basal	13.4	19.3	25.2	40.0	97.9	33.1	19.4	40.3	34.9	127.7
Two splits	11.4	18.3	28.0	49.6	107.3	36.5	22.6	44.5	42.0	145.6
Three splits	11.1	15.2	29.3	56.0	111.6	38.2	23.2	47.4	47.5	156.3
Four splits	12.2	16.9	29.9	59.7	118.7	41.5	23.6	48.7	50.9	164.7
SEM ₊	0.45	0.66	1.04	1.70	2.31	1.30	0.92	2.20	1.15	2.45
CD at 5%	1.36	1.97	3.11	5.07	6.89	3.89	2.76	-	4.45	7.33
Control (No K)	10.1	14.4	21.9	33.2	79.6	28.5	16.8	35.2	27.7	108.2
SEM ₊	0.37	0.54	0.85	1.34	1.88	1.06	0.76	1.80	0.94	2.0
CD at 5%	1.11	1.61	2.54	4.14	5.63	3.18	2.26	5.37	2.80	5.98
CV (%)	9.4	9.4	9.3	8.4	5.4	8.8	10.5	12.2	6.7	4.2

* I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

Table 4.97 Potassium uptake ($\mu\text{g}/\text{ha}$) as influenced by different levels and methods of K application (Experiment No. 3a and b) in fourth harvest

Levels of K_2O ($\mu\text{g}/\text{ha}$)	Methods of K application				Methods of K applications			
	Basal	Two splits	Three splits	Four splits	Basal	Two splits	Three splits	Four splits
Experiment No. 3a								
	First harvest year (1983-84)				Second harvest year (1984-85)			
50	30.3	37.3	45.6	52.2	39.9	46.8	52.3	60.1
100	38.0	43.4	47.5	49.1	48.3	56.1	59.1	55.8
Interaction	SEM _T	CD at 5%			SEM _T	CD at 5%		
	1.85	5.52			2.18	6.52		
Experiment No. 3b								
	First harvest year (1984-85)				Second harvest year (1985-86)			
50	35.5	43.7	54.2	61.4	29.8	38.2	44.3	52.4
100	44.4	55.4	57.9	58.1	39.9	45.7	50.8	49.4
Interaction	SEM _T	CD at 5%			SEM _T	CD at 5%		
	2.40	7.17			1.62	4.85		

Table 4.98 Total potassium uptake per year (kg/ha) as influenced by different levels and methods of K application (Experiment No. 3a and b)

Levels of K_2O (kg/ha)	Methods of K application				Methods of K application			
	Basal	Two splits	Three splits	Four splits	Basal	Two splits	Three splits	Four splits
Experiment No. 3a								
	First harvest year (1983-84)				Second harvest year (1984-85)			
50	63.4	71.3	78.8	90.9	113.0	130.0	144.8	158.8
100	77.3	83.5	94.7	88.1	135.3	148.8	162.1	158.0
Interaction	SEM _t	CD at 5%			SEM _t	CD at 5%		
	2.20	6.58			3.96	-		
Experiment No. 3 b								
	First harvest year (1984-85)				Second harvest year (1985-86)			
50	90.3	97.9	106.9	118.2	112.7	133.3	146.9	166.4
100	105.4	116.7	116.2	119.1	139.1	157.8	165.7	162.9
Interaction	SEM _t	CD at 5%			SEM _t	CD at 5%		
	3.26	-			3.47	10.37		

first harvest year, whereas the minimum K uptake was recorded in other harvests in Experiment No. 3a. Application of K in two splits caused significantly higher K uptake over those where full dose was applied as basal application. Similarly K applied in three splits resulted further enhancement in K uptake. The respective per cent increases in K uptake due to two, three and four splits over basal (full dose) application were 10.1, 16.2 and 27.1 in first harvest year whereas in second harvest year they were 12.0, 23.2 and 27.0 per cent respectively.

Potassium uptake was high in fourth harvest (Apr - Jun) ranging from 25.9 to 50.6 kg and from 35.4 to 57.6 kg / ha during first and second harvest years, respectively.

Treatment variation in Experiment No. 3b (1984-86) as summarised in Table 4.96 also showed similar trend of variation as described in Experiment No. 3a except that at third cutting in second harvest year in Experiment No. 3b K uptake was high.

The interaction between levels and methods of K application was significant at fourth cutting (Apr - Jun) and total K uptake in both the years of Experiment No. 3a and 3b. In fourth harvest (Apr - Jun) application of 50 kg K_2O / ha in all splits, significantly increased the K uptake whereas at 100 kg K_2O / ha, K uptake was significantly increased only up to two splits. It indicated that effect of split application was more pronounced at low level of K than at high level (Table 4.97 and 4.98).

5. DISCUSSION

Consequent to population exploitation, an enormous pressure arose on food and fibre requirements forcing to shift the cultivation of minor crops such as aromatic grasses to marginal lands. Among the essential oil bearing grasses, citronella occupies an important place due to its export value. It is a perennial grass with life cycle of three to four years in good soils and permit 12 to 16 cuts at an intervals of three to four months. Among the different agro-technologies of citronella Java, fertiliser management specially of N, P and K assumes great significance due to the perennial nature of the crop and low fertility status of the soils, on which crop is usually cultivated. so far, very limited research has been carried out on N, P & K nutrition of this crop. In the present study three field experiments were conducted to work out the strategy for efficient management of N, P & K fertilisers for the production of oil of good quality. An attempt has also been made to investigate the right weed control method and its relationship to fertilization. Results obtained from the three experiments, reported earlier, have been discussed in this chapter.

5.1 Effect of nitrogen on crop growth and productivity

Often the crop is cultivated on soils characterised by coarse texture and low available nutrients status. A

great demand for N can be visualised in this crop due to frequent harvesting of foliage and high loss of N during monsoon season. In citronella Java research efforts, with respect to optimum dose and timing of application are necessary to improve N use efficiency.

5.1.1 Plant height and tiller production

Plant height, tillering and phytomass production are some of the important growth parameters to judge the influence of N on citronella Java. Plant height and number of tillers / plant increased significantly with increase in level of N upto a range of 150 to 200 kg N / ha (Table 4.1, 4.2, 4.7 & 4.8). As nitrogen is the structural component of protein, it's increased supply promotes shoot elongation and proper development of auxiliary buds into tillers. Enhancement of plant structure and tiller production due to high level of N supply was reported in citronella Java, but optimum dose varied depending on the agro-climatic conditions (Chandra et al., 1970; Chandra, 1973; Ghosh and Chatterjee, 1978; Monnegowda et al., 1983 and Prakash Rao et al., 1983).

Increase in plant height and tiller production were maximum in fourth harvest (Apr - Jun) and least during second harvest (Oct - Dec) of second harvest year. High temperature and bright sunshine, under irrigated condition favoured growth of plants.

5.1.2 Fresh herbage yield

Fresh herbage yield per year increased significantly with increase in N levels up to 150 kg / ha in Experiment No. 1 a and b (Table 4.13 and 4.14), except in first harvest year of Experiment No. 1 b where response was significant up to 200 kg N / ha. Interestingly, pooled analysis of the data for two crop cycles (Experiment No. 1 a and b) showed (Fig. 4) significant response up to 200 kg N / ha in first and second harvest year (Table 5.1). Increase in fresh herbage yield can be attributed to the favourable influence of N on plant height and tiller production, which favour dry matter accumulation. Similar results were reported by several investigators in citronella Java (Chandra, 1972; Marayana et al., 1975; Dutta and Mishra, 1973; Sonnegowda, 1978; Singh et al., 1980; Prakasa Rao et al., 1983 and 1985; Yadav et al., 1984). At some places low levels of N resulted in significant increase of herbage yield which are specific to the situations like fine soil texture and cool climatic conditions (Singh et al., 1983).

5.1.3 Dry matter accumulation

Dry matter accumulation, an important parameter of plant growth assessment, was in general positively influenced by the application of N up to 150 kg / ha (Table 4.17 and 4.18). Pooled analysis of the data of two Experiments (1983-85 and 1984-86) as summarised in Table 5.1 and Fig. 5

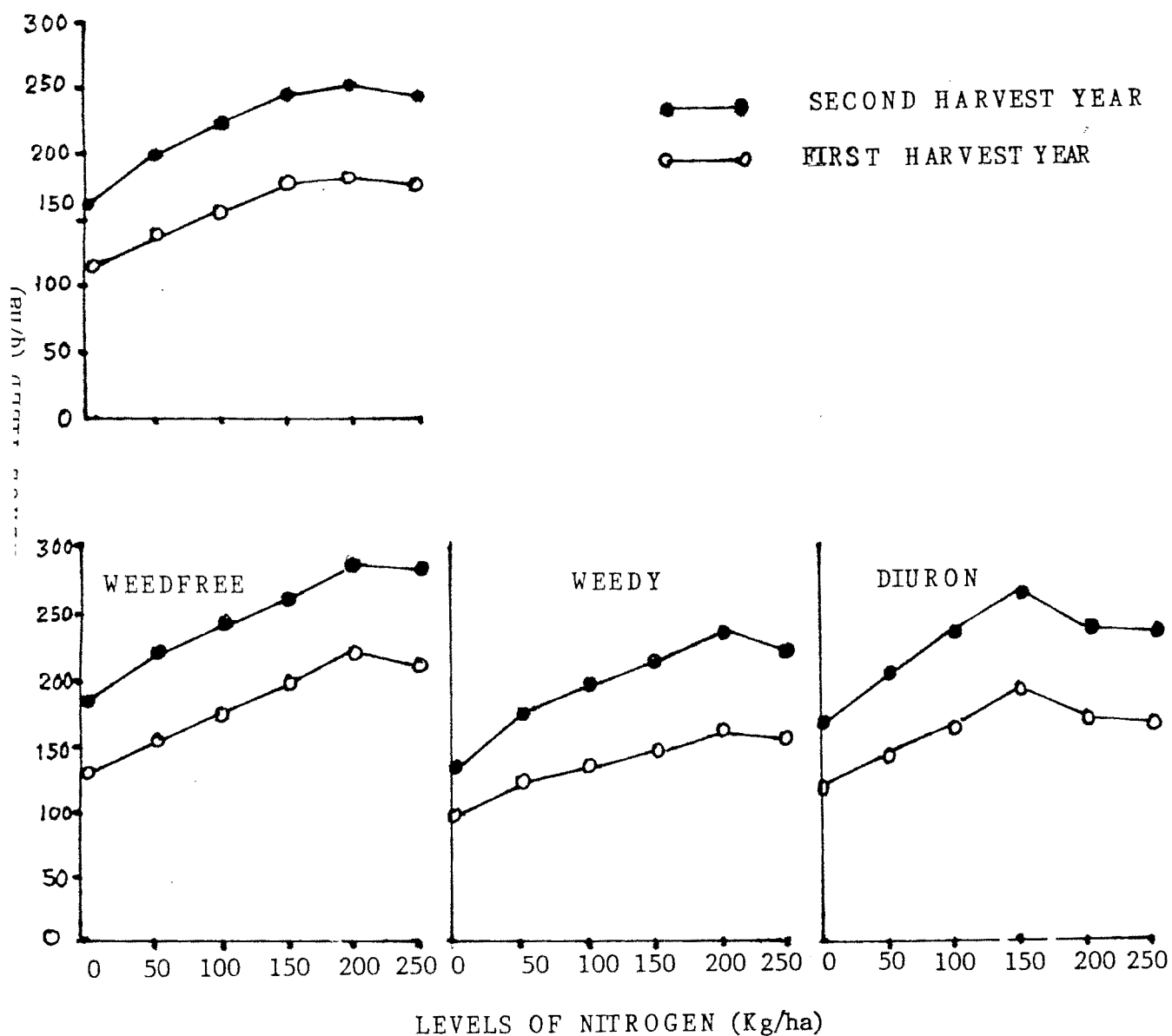


FIG. 4: POOLED FRESH HERBAGE YIELD AS INFLUENCED BY DIFFERENT WEED CONTROL TREATMENTS AND LEVELS OF N (EXPERIMENT No.1a & b)

Table 3.1 Pooled analysis of fresh herbage, dry matter accumulation, oil yield and nitrogen uptake as influenced by weed control treatments and levels of nitrogen (Experiment No. 1a and b)

Weed control treatments	First harvest year (1983-84 (1a) and 1984-85 (1b))				Second harvest year (1984-85 (1a) and 1985-86 (1b))			
	Fresh herbage yield (q/ha)	Dry matter accumulation (q/ha)	Oil yield (kg/ha)	Nitrogen uptake (kg/ha)	Fresh herbage yield (q/ha)	Dry matter accumulation (q/ha)	Oil yield (kg/ha)	Nitrogen uptake (kg/ha)
Weed free	180.0	62.4	240.2	82.3	248.6	84.6	323.1	132.9
Weedy	133.8	47.5	179.9	57.1	194.7	68.1	254.5	101.1
Digiron	156.5	55.5	209.9	66.7	222.1	76.9	290.5	117.2
SEM $\pm$	1.88	0.69	2.42	1.00	1.82	0.64	2.63	1.65
CD at 5%	7.36	2.69	9.48	3.93	7.12	2.50	10.29	6.48
Levels of N (kg/ha)								
0	155.6	41.4	155.4	51.1	162.1	56.9	213.0	85.4
50	137.8	48.6	185.4	59.7	199.9	69.6	262.0	103.6
100	155.4	54.6	208.6	68.5	224.2	77.4	293.1	119.2
150	175.9	61.7	232.8	79.1	246.3	84.6	321.3	131.4
200	181.7	63.3	242.8	80.8	252.9	86.8	329.4	133.2
250	174.5	60.9	232.3	78.1	245.4	84.0	318.1	129.7
SEM $\pm$	1.94	0.68	2.54	1.14	2.29	0.71	2.57	2.09
CD at 5%	5.58	2.66	7.32	3.29	6.60	2.03	7.40	6.02

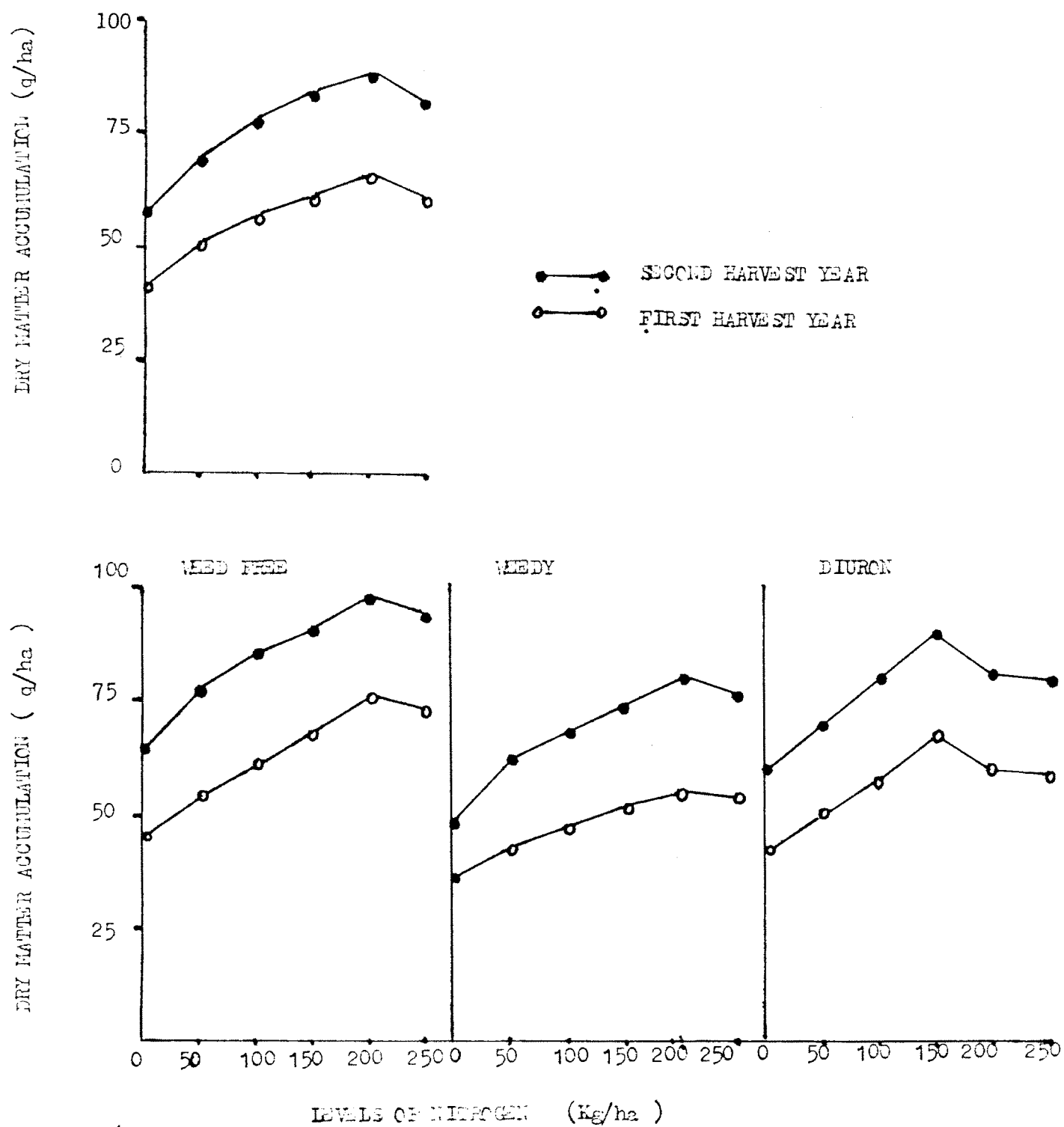


FIG.5: POOLED DRY MATTER ACCUMULATION AS INFLUENCED BY DIFFERENT WEED CONTROL TREATMENTS AND LEVEL OF N (EXPERIMENT NO.1a and b)

showed significant increase in dry matter accumulation up to 150 kg N / ha during first harvest year and up to 200 kg N / ha in second harvest year.

5.1.4 Oil content and oil yield

Essential oil content like any plant nutrient may be subjected to dilution effect mediated by the degree of crop growth. There was no appreciable change in the oil content due to increase in levels of N (Table 4.23 and 4.24). Essential oil being the product of secondary metabolism (Peitsem, 1958) may not have been influenced by N nutrition. Addition of nitrogen enhanced the phytomass production of citronella Java and it positively increased the succulence. Other investigators also did not find significant changes in the oil content of citronella Java and in other aromatic grasses with addition of N (Sarma and Bordoloi, 1982; Singh et al., 1983; Prakasa Rao et al., 1985). Nonetheless, oil yield, a product of herbage yield and oil content, was favourably influenced by N up to 200 kg N / ha when the results of both the harvest years were pooled (Table 5.1 and Fig. 6). Increase in oil yield may be treated as a direct consequence of enhancement in the herbage yield. Increase in oil yield with addition of N was also reported by different workers in citronella (Jeachen and Pandittasaham 1953; Ng, 1972; Shyu and Yang, 1973; Dimari et al., 1973).

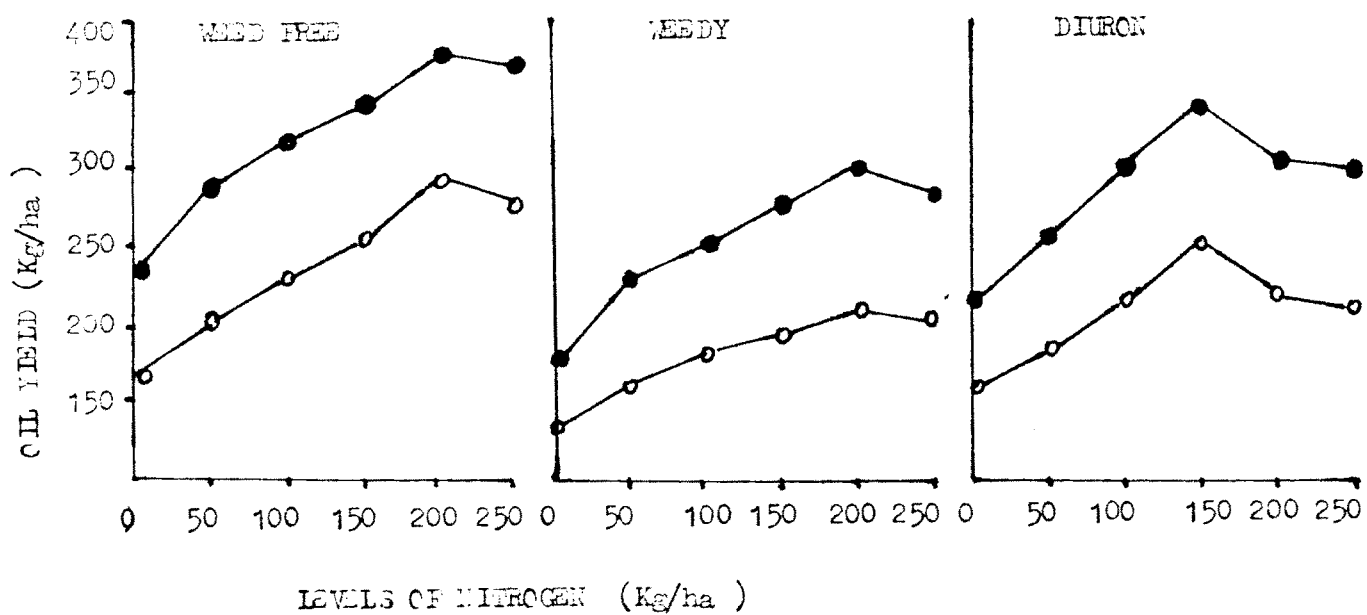
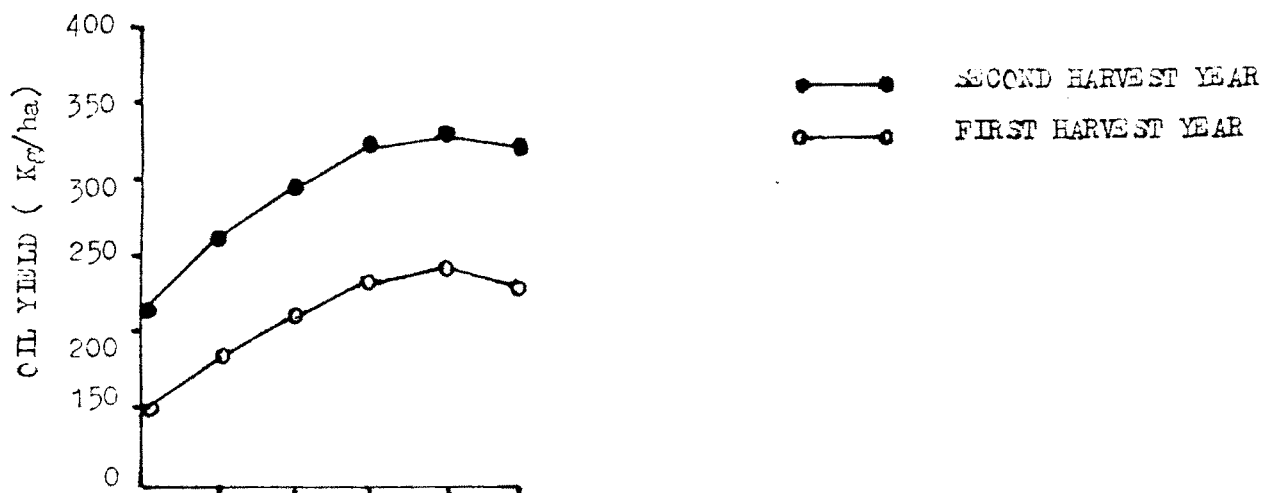


FIG.6: POOLED CIL YIELD INFLUENCED BY DIFFERENT WEED CONTROL TREATMENTS AND LEVELS OF N (EXPERIMENT NO.1a and b)

Response curve (Table 5.2 and Fig. 7) from the pooled analysis indicated that under weed free, weedy and Diuron treated plots the optimum doses of N (kg N / ha) application and oil yields (kg / ha) were 160.0 and 255.9, 156.1 and 190.2 and 137.4 and 224.2, respectively in first harvest year; in second harvest year the corresponding figures were 175.9 and 340.6, 157.8 and 271.5, and 122.1 and 306.5, respectively. It confirmed the observations recorded in other field crops, that weed rob nitrogen and reduce response to N of the crop as well as their productivity.

From the pooled analysis (Table 5.3) it was further deduced that the response per kg N under weed free, weedy and diuron treated plots were 0.29, 0.22 and 0.31 kg oil in first harvest year and the corresponding figures in second harvest year were 0.28, 0.30 and 0.38 kg / ha, respectively. The net returns in Rupees were 3,840, 2,193 and 3,589 in first harvest year and 4,023, 3,985 and 4,023 in second harvest year, respectively in weed free, weedy and Diuron treated plots (Table 5.3). The net return per Rupee investment thus came out to be 4.8, 2.8 and 5.2 Rupees in first harvest year and the corresponding figures in second harvest year were 4.6, 5.1 and 6.6 Rupees, respectively. Thus, under weedy situation, the efficiency in the utilisation of added nitrogen is drastically reduced. Further, application of Diuron for weed control always showed an edge over the benefits accrued under weed free checks.

Table 5.2 The response curve showing relationships of nitrogen levels under different weed control measures with oil yields (both maximum and optimum) drawn from the pooled results (Experiment No. 1a and b)

weed control treatments	Response curve equation	N doses in kg/ha (X)		Oil yield in kg/ha (Y)		S.D. (+)
		Max.	Opt.	Max.	Opt.	
First harvest year						
weed free	$209.50 + 0.530 x - 0.0015 x^2$	176.7	160.0	256.3	255.9	41.51
weedy	$160.46 + 0.331 x - 0.0009 x^2$	183.9	156.1	190.9	190.2	26.72
Diuron	$181.43 + 0.572 x - 0.0019 x^2$	150.6	137.4	224.5	224.2	29.32
Second harvest year						
weed free	$291.54 + 0.507 x - 0.0013 x^2$	191.2	175.9	341.1	340.6	45.38
weedy	$223.76 + 0.555 x - 0.0016 x^2$	173.4	157.6	271.8	271.5	41.86
Diuron	$260.20 + 0.709 x - 0.0027 x^2$	131.3	122.1	306.8	306.5	39.65

Table 5.3 Net profit at optimum level of N under different weed control measures from the pooled analysis of the results (Experiment No. 1a and b)

Weed control treatments	Oil yield at optimum level of N (kg/ha)	Oil yield O level of N (kg/ha)	Increase in yield over control (kg/ha)	Response per kg N applied in kg (oil)	Value of increase in yield in Rs/ha	Cost of fertilizer in Rs/ha	Net return in Rs/ha	Net return per rupee investment on fertilizer in Rs.
First harvest year								
Weed free	255.9	209.5	46.4	0.29	4640	800	3840	4.80
Weedy	190.2	160.5	29.7	0.22	2974	781	2194	2.80
Diuron	224.2	181.4	42.8	0.31	4275	687	3588	5.20
Second harvest year								
Weed free	340.6	291.5	49.0	0.28	4903	880	4023	4.60
Weedy	271.5	223.8	47.7	0.30	4774	789	3985	5.10
Diuron	306.5	260.2	46.3	0.36	4634	610	4024	6.60

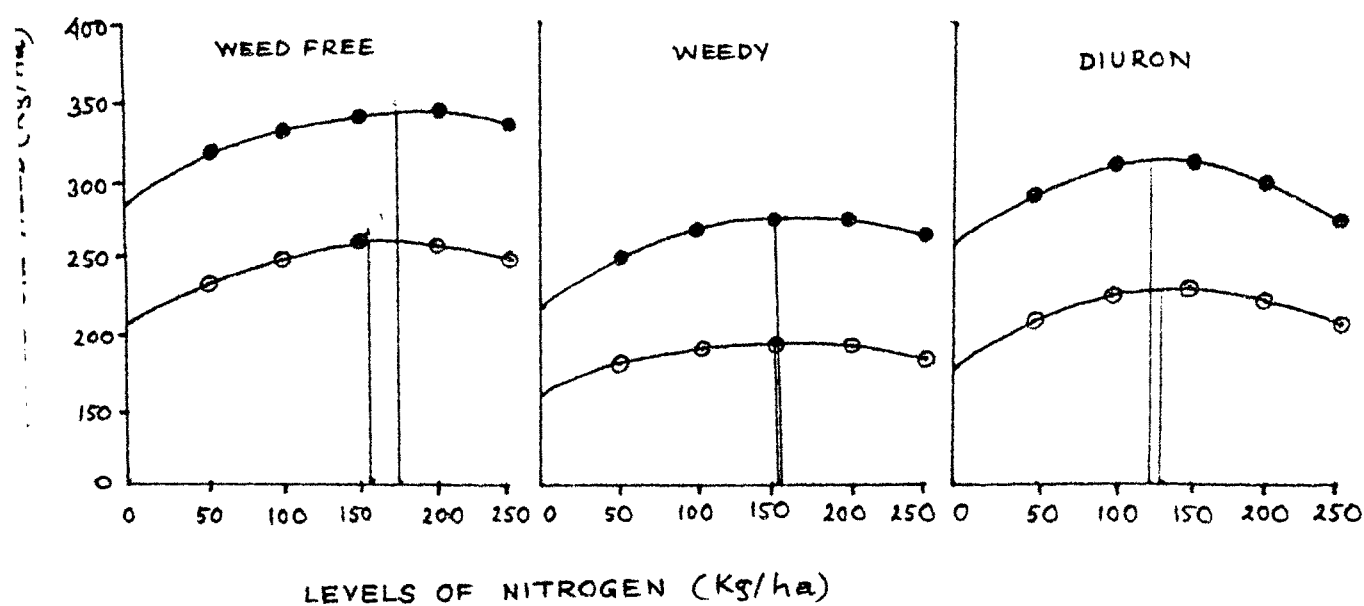
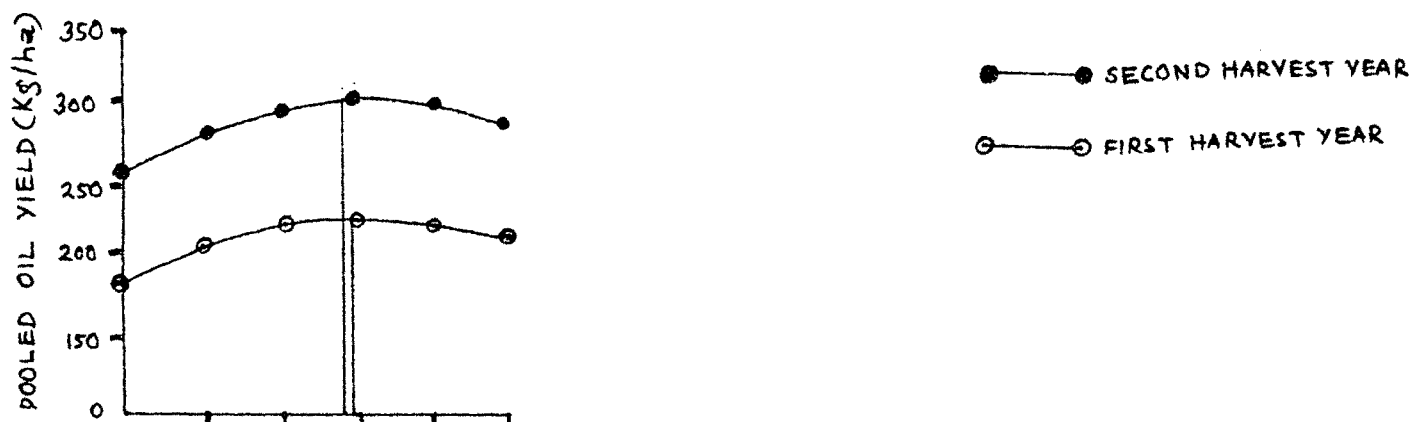


FIG. 7 : RESPONSE CURVE SHOWING THE RELATIONSHIP BETWEEN LEVELS OF NITROGEN AND MEAN OIL YIELD (POOLED)
(Perpendicular lines show optimum values)

5.1.5 Oil quality

Quality of essential oil in citronella Java is judged by aldehydes (calculated as citronellal) and total alcohols (calculated as geraniol and citronellol). Structure elucidation of these fractions revealed that N do not form the constituent. Therefore, it is assumed that N has no direct role on the quality of oil. The oil quality, evaluated in terms of citronellal, citronellol and geraniol contents in the present study did not vary appreciably in both the experiments No. 1 a and b (Table 4.27 to 4.32). Singh et al., (1976) and Prakasa Rao et al. (1985) also did not observe appreciable variation in the oil quality due to the influence of nitrogen. However, few workers reported significant influence of N, on quality of oil, but failed to mention the reasons for this effect (Marayana and Rao, 1969; Chandra et al., 1970; Dev Kumar et al., 1970; Ghosh and Chatterjee, 1978; Bommegowda and Krishnamurthy, 1979; Munsli and Mukherjee 1982). In fact oil quality was influenced more by seasonal variations during the crop growth than by any other factor. Citronellal synthesis was maximum in the cool season, while it was low in hot season. The influence of weather on geraniol synthesis was extremely opposite to that of citronellal. These observations are in agreement with the results reported by Singh et al. (1976), Ganguly (1978) and Prakasa Rao (1985).

5.1.6 Nitrogen uptake

Nitrogen uptake in this study, as usual, increased significantly with increase in levels of added N up to 150 kg / ha in both the harvest years in both the experiments (Table 4.33 and 4.34). Pooled analysis data of the two experiments also showed similar response of N uptake during both harvest years (Table 5.1); the uptake was more in weed free treatment (Fig. 8).

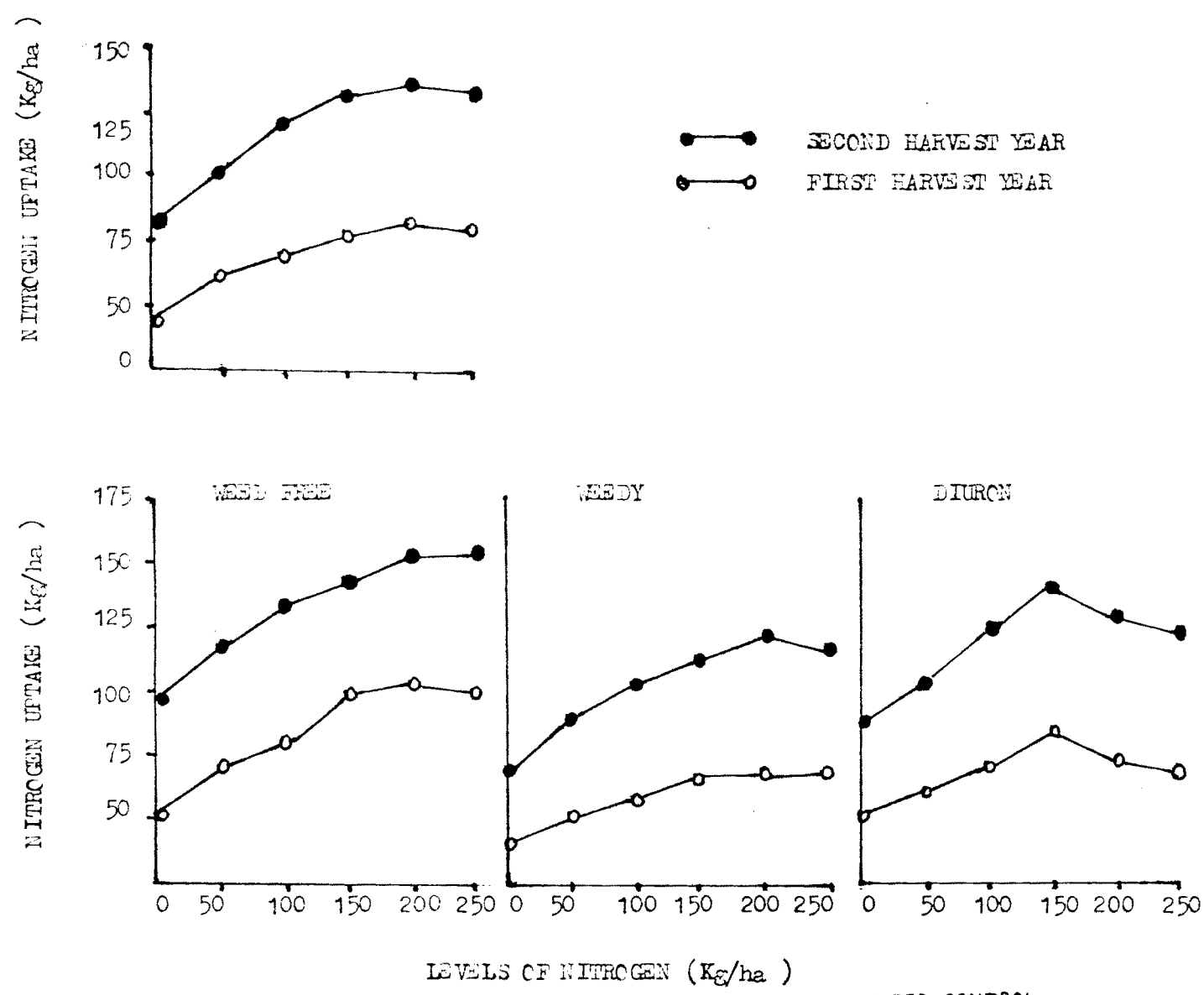
5.2 Effect of phosphorus on crop growth and productivity

5.2.1 Plant height and tiller production

The experimental soil was very poor in phosphorus. As such plant height and number of tillers per plant of citronella Java were significantly influenced up to the application of 50 kg P_2O_5 / ha. Response of crop growth to added P may be attributed to low native P of the experimental soil (Table 4.41 to 4.44). In addition, frequent harvesting of herbage may exhaust considerable amount of P from the soil. Several workers have reported favourable response of citronella Java to 75 to 100 kg P_2O_5 / ha, depending on the soil conditions (Chandra, 1973; Ganguly and Thyagarajan, 1976; Ghosh and Chatterjee, 1978).

5.2.2 Fresh herbage yield

Favourable influence of P on plant height and tiller production, resulted in high herbage yield at 50 kg P_2O_5 /



WEED CONTROL
 FIG.8: POOLED NITROGEN UPTAKE AS INFLUENCED BY DIFFERENT TREATMENTS AND
 LEVELS OF N (EXPERIMENT NO.1a and b)

ha / yr in both harvest years of the experiment No. 2 a and b (Table 4.45 and 4.46). Joachem and Pandittesekera (1953), Khan and Narayana (1972), Ng (1972), Chandra (1973), Shyue and Yang (1973), Munshi and Mukherjee (1982), Sarma and Bordoloi (1982) and Singh et al. (1983) have also obtained significant increase in herbage yield of citronella Java with addition of 50 kg P_2O_5 / ha. Further, increase of P i.e. to 100 kg P_2O_5 / ha did not improve in yield significantly. It is a clear indication that the crop require medium dose of P and it does not respond to high levels even on soils of low P status. Pooled analysis of the data on two seasons 1983-85 and 1984-86 also showed similar type of variation (Table 5.4 and Fig. 9).

5.2.3 Dry matter accumulation

Application of P up to 50 kg P_2O_5 / ha exhibited favourable effect on dry matter production. Pooled analysis of the data over two seasons (Fig. 9 and Table 5.4) also showed significant response in dry matter accumulation in citronella Java up to 50 kg P_2O_5 / ha. Increase in dry matter accumulation may be attributed to higher tiller production under the influence of P nutrition. Further, dry matter production was higher in second harvest year than that of first harvest year. During the second harvest year, crop was well developed with well distributed root

Table 5.4 Pooled analysis of the results obtained on fresh forage, dry matter accumulation, oil yield, N, P and K uptake as influenced by different levels of P and K (Experiment No. 2 a and b)

Levels of P_2O_5 and K_2O in kg / ha	First harvest year 1983-84 (2 a) and 1984-85 (2 b)					Second harvest year 1984-85 (2 a) and 1985-86 (2 b)						
	Fresh dry her- bage yield (q/ha)	Oil yield (kg/ha)	N up- take (kg/ha)	P uptake (kg/ha)	K uptake (kg/ha)	Fresh dry her- bage yield (q/ha)	Oil yield (kg/ha)	N uptake (kg/ha)	P uptake (kg/ha)	K uptake (kg/ha)		
P_2O_5 levels												
0	176.2	60.3	222.0	78.3	19.7	90.1	260.1	91.1	329.3	142.4	30.3	138.5
50	209.9	69.9	263.5	91.3	24.5	104.1	293.7	101.9	370.8	159.2	35.6	155.8
100	216.5	73.0	270.7	94.1	25.1	106.4	299.4	103.5	376.3	161.1	36.5	158.1
S.E.m ±	3.31	1.57	4.31	1.83	0.35	1.36	2.85	1.02	5.04	1.54	0.65	2.16
C.D. at 5%	9.90	4.68	12.89	5.49	1.06	4.68	8.52	3.04	15.08	4.60	1.95	6.47
K_2O levels												
0	170.8	59.3	216.6	76.5	19.7	85.1	251.4	88.8	320.2	139.0	30.2	134.3
50	214.3	73.8	268.7	95.1	24.9	106.3	298.8	103.4	377.4	162.1	36.1	159.5
100	217.4	70.9	271.1	92.0	24.8	106.9	303.0	104.3	378.7	162.2	36.1	158.5
S.E.m ±	3.31	1.57	4.31	1.83	0.35	1.36	2.85	1.02	5.04	1.54	0.65	2.16
C.D. at 5%	9.90	4.68	12.89	5.49	1.06	4.68	8.52	3.04	15.08	4.60	1.95	6.47

 FIRST HARVEST YEAR
 SECOND HARVEST YEAR

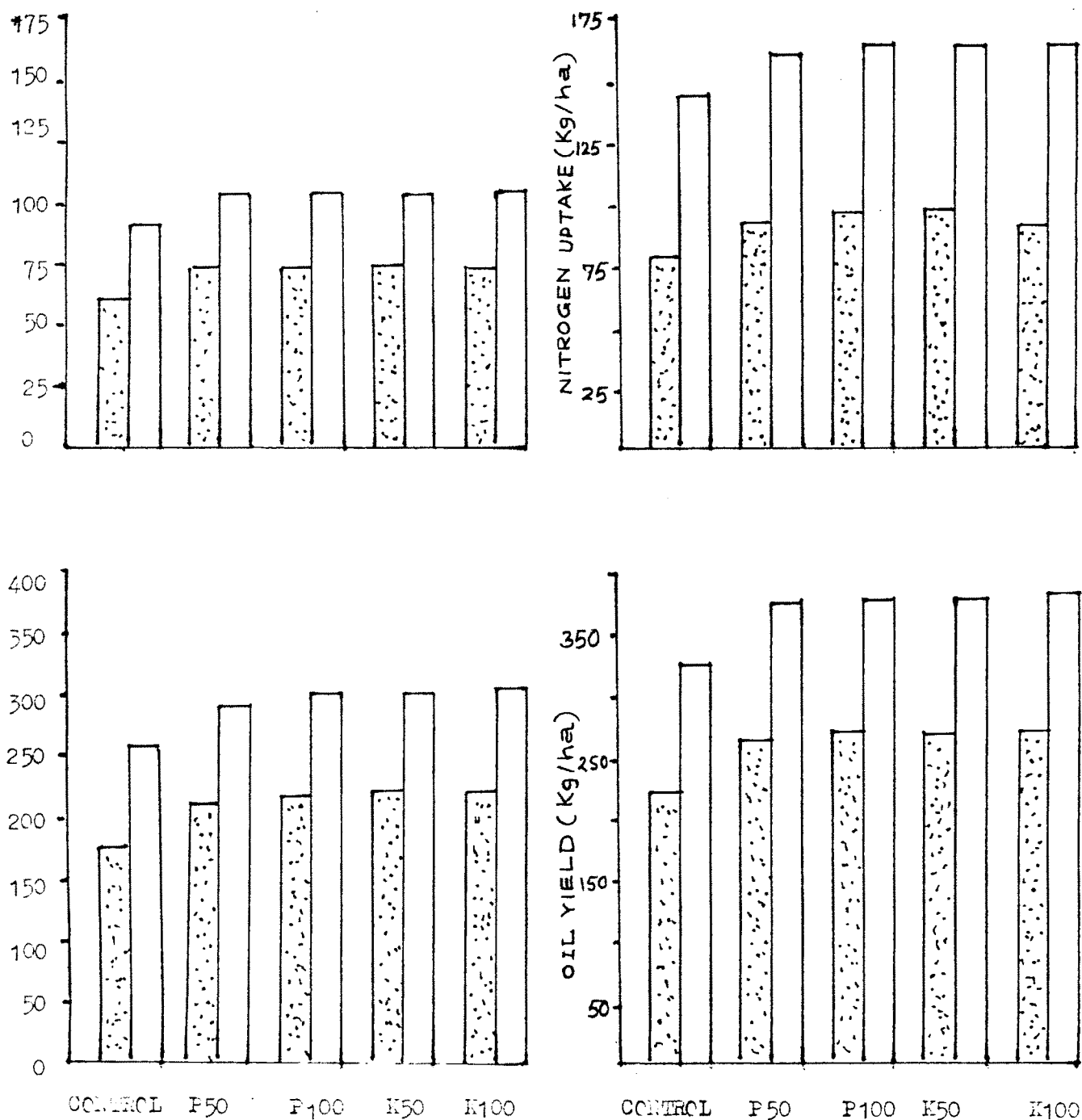


FIG.9: ROOT LENGTH, NITROGEN UPTAKE, OIL YIELD AND NITROGEN UPTAKE AS INFLUENCED BY DIFFERENT LEVELS OF P_2O_5 AND K_2O
 (EXPERIMENT 10. 2a and b)

system which might have helped for better utilization of P and favoured high dry matter production. Similar results were reported in citronella Java by Ganguly and Thyagarajan (1976) and Ghosh and Chatterjee (1978).

5.2.4 Oil content and oil yield

so far there is no clear indication about the role of P in the synthesis of secondary metabolites in the form of essential oil. However, oil content like any nutrient element may be subjected to dilution effect brought out by changes in phytomass. Similar results have been reported by Singh *et al.*, 1976; Singh *et al.*, 1983.

Oil yield, however, significantly increased with the addition of P up to 50 kg P_2O_5 / ha it can be attributed to favourable effect of P on herbage yield although, oil concentration remained unaffected. Pooled analysis also showed significant response up to 50 kg P_2O_5 / ha (Table 5.4 and Fig. 9). From the response curve, the optimum dose was found to be 54.5 and 78.5 kg P_2O_5 / ha during the first and second harvest year, respectively (Table 5.5 and Fig. 10). Higher P response during second harvest year may be due to better utilization as a result of better root development. Similar observations have been reported by Ng, 1972; Shyu and Yang, 1973; Marayana *et al.*, 1975; Ghosh and Chatterjee, 1978.

Table 5.5 The response curve showing the relationship of P_2O_5 and K_2O level with oil yield (both maximum and optimum) drawn from the results (Experiment No. 2 a and b)

Harvest years	Quadratic equations	Level of P_2O_5 & K_2O (X) in kg/ha		Oil yield in kg/ha		S.D. ($\bar{x}$)
		Max.	Opt.	Max.	Opt.	
Response to P_2O_5						
First	$222.0 + 1.173 x - 0.007 x^2$	83.8	80.2	271.1	271.1	21.46
Second	$329.3 + 1.190 x - 0.007 x^2$	85.0	81.4	379.9	379.8	20.98
Response to K_2O						
First	$216.5 + 1.542 x - 0.010 x^2$	77.1	74.6	276.0	275.9	25.14
Second	$320.2 + 1.702 x - 0.011 x^2$	77.4	75.1	386.0	386.0	27.27

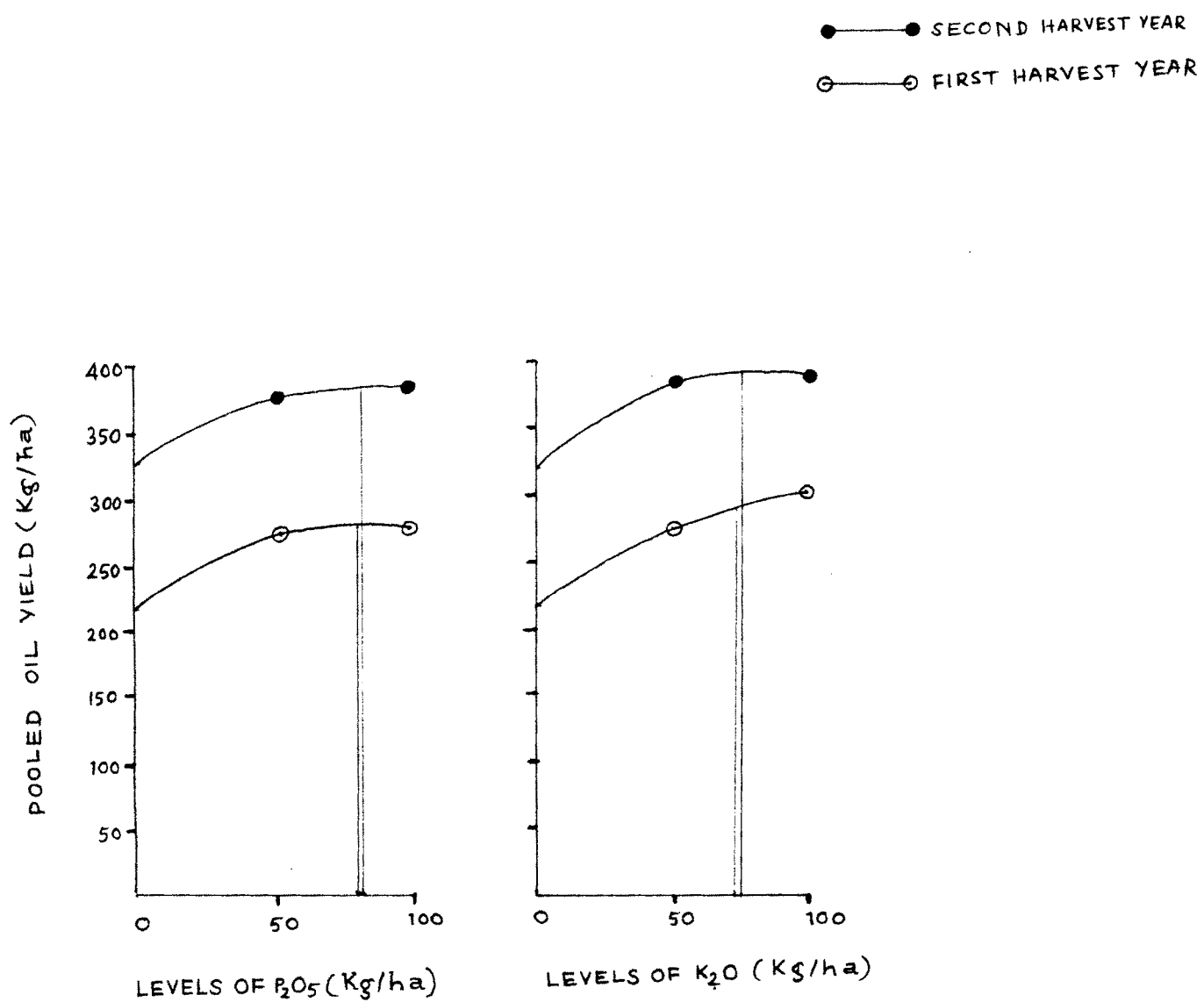


FIG.10 : RESPONSE CURVE SHOWING THE RELATIONSHIP BETWEEN LEVELS OF P_2O_5 AND K_2O AND MEAN OIL YIELD (POOLED)
(Perpendicular lines show optimum values)

Table 5.6 Net profit at optimum level of P_2O_5 and K_2O application from the pooled analysis of the results (Experiment No. 2 a and b)

Harvest years	Oil yield at opt. level of P_2O_5 (kg/ha)	Oil yield at 0 level (kg/ha)	Increase in yield over level (kg/ha)	Response/ kg P_2O_5 & K_2O in kg (oil)	Value of increase in yield (Rs/ha)	Cost of ferti-liser (Rs/ha)	Net return (Rs/ha)	Net return per rupee invest-ment on fertili-ser in Rs.
P_2O_5 (kg/ha)								
First	252.1	222.0	30.1	0.38	3010	642	2368	3.70
Second	379.8	329.3	50.5	0.62	5050	651	4398	6.80
K_2O (kg/ha)								
First	275.9	216.5	59.4	0.80	5940	298	5642	18.90
Second	386.0	320.2	65.8	0.88	6580	300	6280	20.90

5.2.5 Oil quality

Like nitrogen, P addition also did not cause any significant variation in the quality of essential oil and the results are in conformity with findings of Singh et al., (1976).

5.2.6 Nitrogen uptake

Application of 50 kg P_2O_5 / ha significantly increased the uptake of N which was the result of higher dry matter accumulations (Table 5.4). Addition of P in presence of high levels of N, promoted root development, crop growth and increased uptake of N in wheat (Shukla et al., 1974; Rathore and Singh, 1978) crop.

5.2.7 Phosphorus uptake

Phosphorus uptake by the crop was significantly increased due to addition of 50 kg P_2O_5 / ha at all stages of harvest in both the experiments No. 2 a and b (Table 5.4 and Fig. 11). Further, increase in level of added P did not enhance the nutrient uptake by crop. It may be recalled that the dry matter yield was maximum at 50 kg P_2O_5 / ha which might be responsible for more uptake of P. Munsil and Mukherjee (1982) also reported that uptake of P by citronella was significantly influenced with the application of 60 kg P_2O_5 / ha.

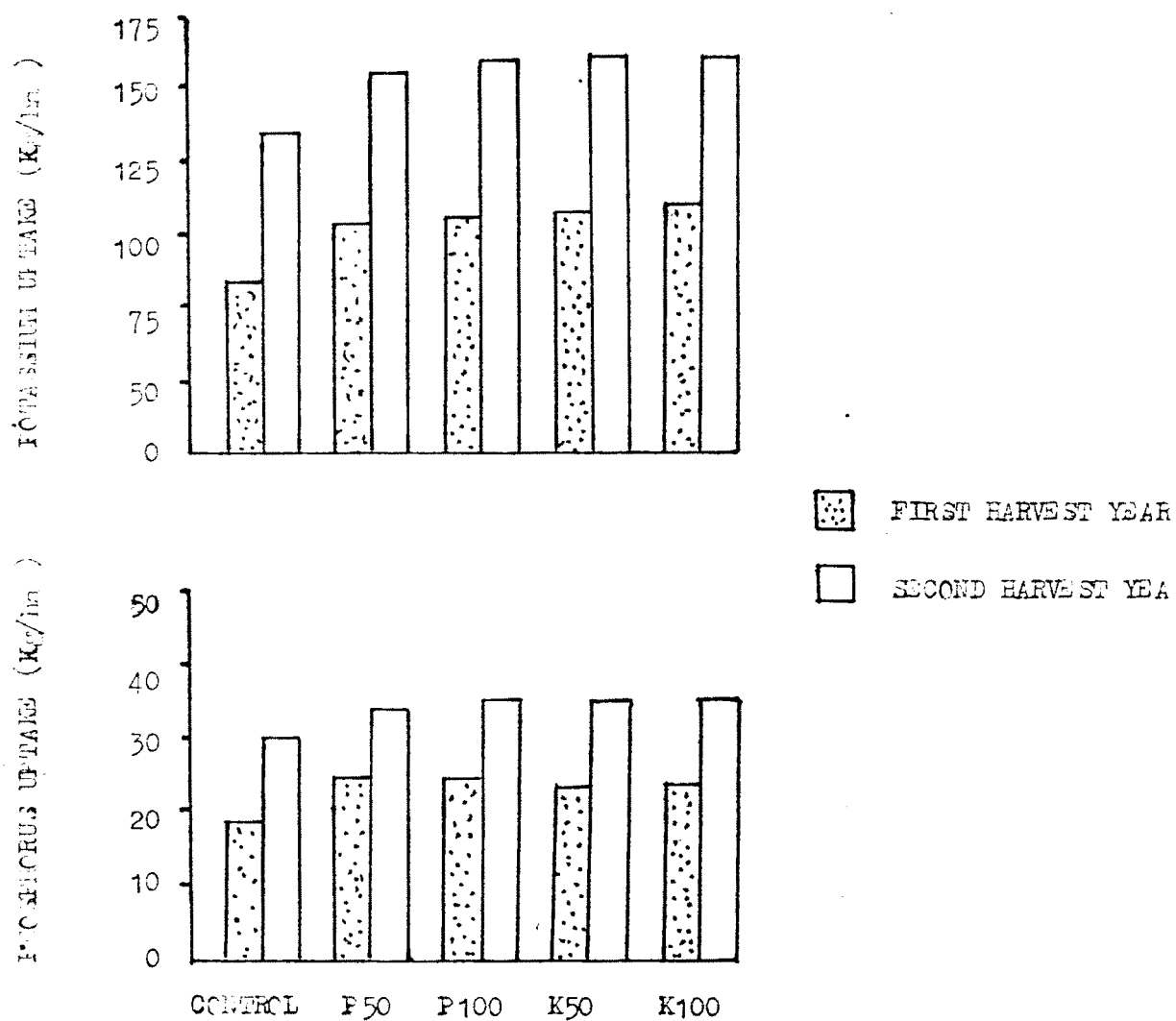


FIG. 11 : POOLED PHOSPHORUS AND POTASSIUM UPTAKE AS
INFLUENCED BY DIFFERENT LEVELS OF P AND K
(EXPERIMENT 10.2a and b)

5.2.8 Potassium uptake

Although P application does not play an important role in the uptake of K, the results have shown that it influenced K uptake by the crop, through its favourable effect on crop growth.

5.3 Effect of potassium on crop growth and productivity

The effect of K nutrition in citronella Java was studied in two different aspects in Experiment No. 2 a and b and Experiment No. 3 a and b. In the former experiment the influence of levels of K in combination with levels of P was investigated whereas in the latter experiment the effect of levels and methods of K application were studied.

5.3.1 Plant height and tiller production

Plant height and number of tillers per plant were significantly increased with addition of 50 kg K_2O / ha during both the harvest years in Experiment No. 2 a and b whereas in experiment No. 3 a and b, the crop growth response was significant up to 100 kg K_2O / ha except in first cutting in first harvest year. The differential response in the two experiments may be assigned to the fact that in Experiment No. 2 a and b, full dose of K was added at planting, which might have met the crop requirement of K from planting to the end of the crop cycle. While, in Experiment No. 3 a and b

splitting of K in Experiment No. 3 a and b might have supplied inadequate quantity of K for the new flush after every harvest and hence, response was up to 100 kg K_2O / ha. Response of citronella Java to K addition up to 60 kg K_2O / ha was reported by different workers (Chandra, 1972; Ghosh and Chatterjee, 1976).

Regarding methods of application, basal application was superior to split application in promoting the plant height and tiller production only in first cutting of first harvest year, while application in two, three and four splits significantly increased the plant height and tiller production throughout crop cycle. The results clearly indicated the significance of split application of K on coarse texture soils for promoting good growth of the grass. Effect of split application in the growth of citronella Java was not studied by any other worker in the past.

5.3.2 Fresh herbage yield

Herbage yield increased significantly up to 50 kg K_2O / ha in Experiment No. 2 a and b and up to 100 kg K_2O / ha in Experiment No. 3 a and b. Pooled analysis of the data of the two harvest years from the two experiments also showed similar trend of variation (Table 5.4 and 5.7 and Fig. 12). Crop response to K may be attributed to low available K status of the soil in addition the coarse nature of the texture soil, which might have caused considerable leaching

Table 5.7 pooled analysis of the results obtained on fresh herbage, dry matter accumulation, oil yield, N and P uptake as influenced by different levels and methods of K application (Experiment No. 3 a and b)

Levels of K_2O (kg/ha)	First harvest year 1983-84 (1 a) and 1984-85 (1 b)					Second harvest year 1984-85 (1 a) and 1985-86 (1 b)				
	Fresh herbage yield (q/ha)	Dry matter accumulation (q/ha)	Oil yield (kg/ha)	Nitro-gen uptake (kg/ha)	Pota-sium uptake (kg/ha)	Fresh herbage yield (q/ha)	Dry matter accumulation (q/ha)	Oil yield (kg/ha)	Nitro-gen uptake (kg/ha)	Pota-sium uptake (kg/ha)
50	179.2	61.6	222.2	80.9	89.8	266.5	91.6	320.8	136.7	138.9
100	196.4	67.3	242.7	88.8	99.0	294.3	100.9	353.0	150.3	153.8
S.E.m $\pm$	2.85	0.97	3.83	1.22	1.41	3.48	1.23	4.29	1.92	1.90
C.D. at 5%	8.92	2.91	11.45	3.66	4.20	10.40	3.68	12.82	5.75	5.68
Methods of K application										
Basal	164.4	56.8	206.2	77.9	84.2	238.4	82.5	288.0	124.9	126.1
Two splits	182.6	63.2	226.7	84.1	92.4	271.7	93.4	327.4	139.3	142.5
Three splits	194.3	66.3	238.2	85.5	96.7	298.5	102.1	357.8	151.8	154.9
Four splits	209.6	77.5	258.7	92.1	104.1	313.2	107.1	374.6	158.0	161.4
S.E.m $\pm$	4.03	1.37	5.41	1.73	1.99	4.92	1.74	6.06	2.72	2.69
C.D. at 5%	12.05	4.11	16.19	5.18	5.94	14.71	5.20	18.13	8.14	8.04
Control (No K)	128.7	45.1	163.1	61.4	66.2	199.6	70.8	244.3	108.0	106.5
S.E.m $\pm$	3.29	1.12	4.42	1.41	1.62	4.02	1.42	4.95	2.22	2.19
C.D. at 5%	9.84	3.35	13.22	4.23	4.85	12.01	4.25	14.80	6.64	6.56

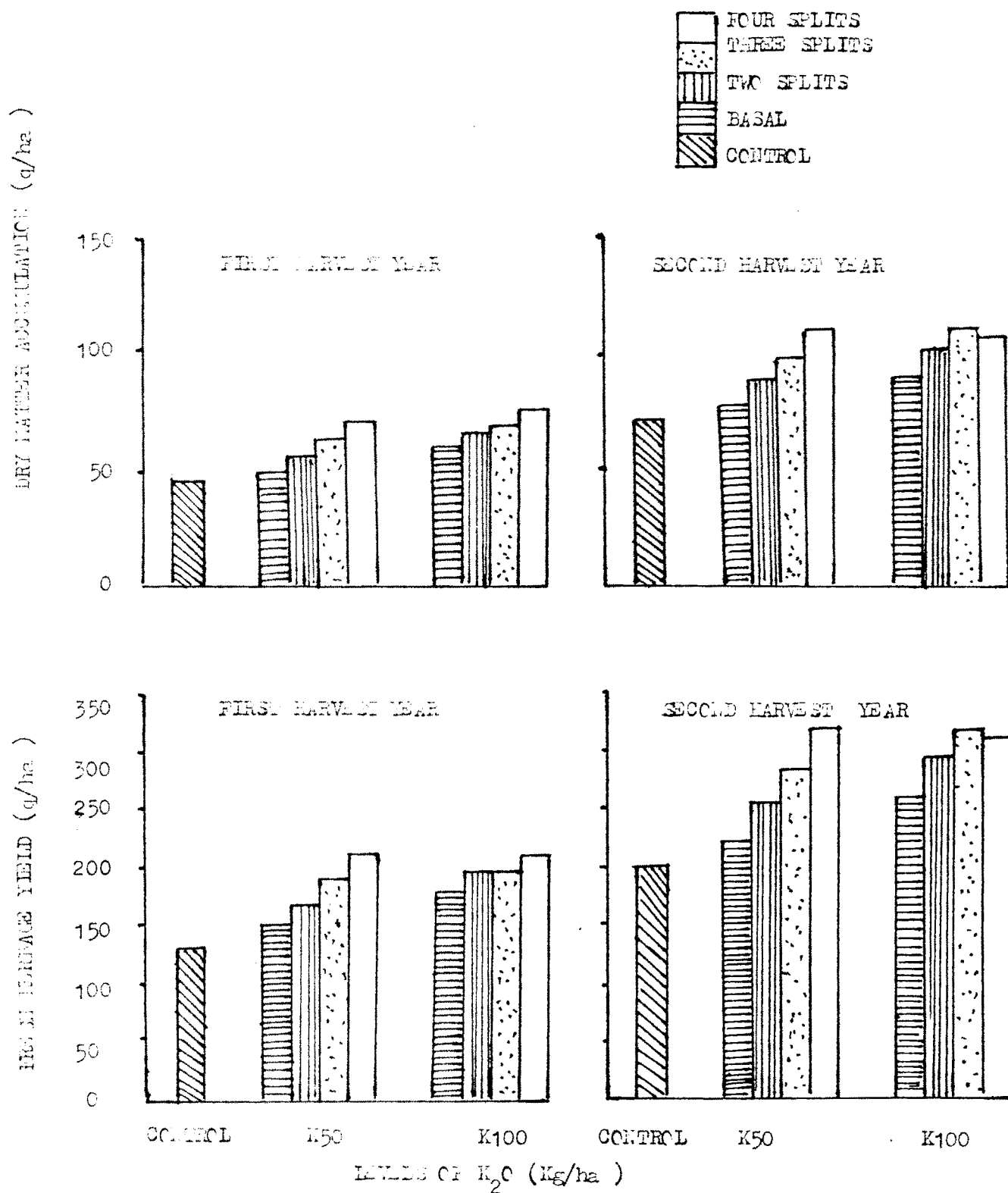


FIG.12: POOLED FORAGE YIELD AND DRY MATTER ACCUMULATION AS INFLUENCED BY DIFFERENT LEVELS AND METHODS OF K APPLICATION. (EXPERIMENT NO. 3a and b)

of K. Further, frequent crop harvesting might have depleted K from soil to give response to added K. Increase in the yield of citrohella Java due to K application ranging from 80 to 125 kg K_2O / ha was reported by Khan and Narayana, 1972, Ng, 1972 and Dimri, 1973.

The effect of basal application was apparent only at first cutting of first harvest year in both the Experiments No. 3 a and b, for the reason that the crop received the entire dose at this stage. On the other hand, split application of K exhibited appreciable influence on crop growth at subsequent stages which resulted in high herbage yield during both the harvest years. The same influence was also observed from the pooled analysis of the data of the two seasons (Table 5.7). It is evident from the data that the herbage yield increased with increase in the number of split application. Thus, for obtaining yield, K should be added in splits in long duration crop and on light soils of low available K status. Lack of response to basal application at the later stages of crop growth was presumably due to leaching and other losses of K.

5.3.3 Dry matter accumulation

The effect of graded levels and methods of K application on dry matter accumulation was quite similar to that of fresh herbage yield (Fig. 12). Chandra (1973), Ghosh and Chatterjee (1978), Khan and Narayana (1975) reported response

of citronella Java to levels of K application but they did not study the effect of split application of K on the growth of the grass.

5.3.4 Oil content and oil yield

As discussed earlier, neither levels nor methods of K application caused marked variation in oil content of citronella Java. However, application of K at the rate of 50 kg K_2O / ha in Experiment No. 2 a (where all the K was applied at the time of sowing) and b and 100 kg in Experiment No. 3 a and b (where the K was applied in splits) significantly increased the oil yield (Fig. 13).

Response curve from pooled analysis indicated that the optimum dose (K_2O kg / ha) and yields (kg / ha) were 74.6 & 275.9 and 75.1 & 386.0 in first and second harvest year in Experiment No. 2 a and b (Fig. 10 and Table 5.5). From Experiment No. 3 a and b, the optimum dose (K_2O kg / ha) and optimum yields (kg / ha) were interpolated to be 94.9 & 239.8 in first harvest year and 96.0 & 341.3 in second harvest year, respectively, only when doses were taken into consideration. But there was significant interaction between levels of K application and method of application. At high level of N (250 kg N / ha), split application of potassium showed advantage (Experiment No. 3 a and b) over basal application of entire dose. Deductions

FOUR SPLITS
 THREE SPLITS
 TWO SPLITS
 BASAL
 CONTROL

22

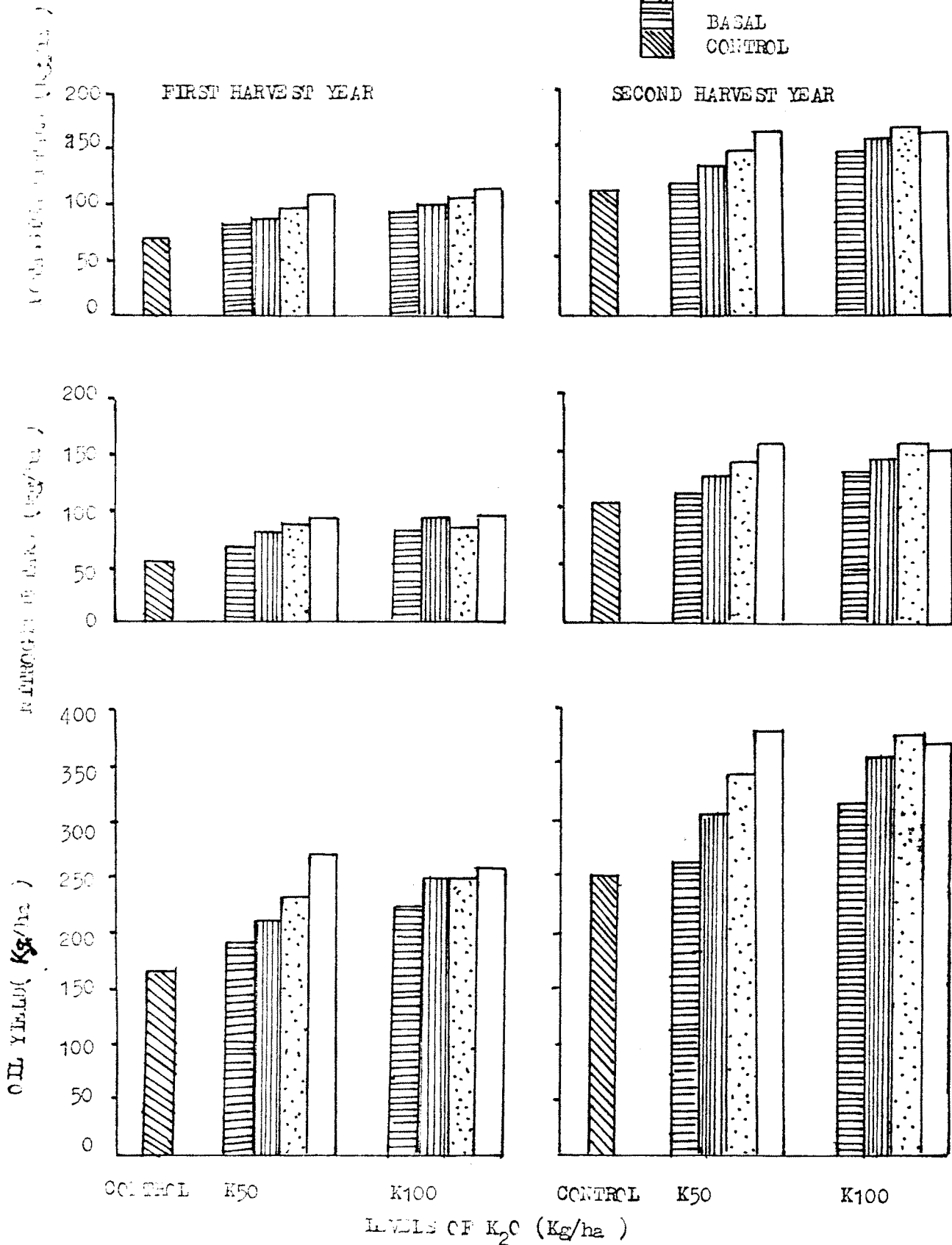


FIG.13: POOLED OIL YIELD, NITROGEN AND POTASSIUM UPTAKE AS INFLUENCED BY
 DIFFERENT LEVELS AND METHOD OF K APPLICATION(EXPERIMENT NO.3a and b)

of net return per rupee investment on fertilizer (Table 5.8) revealed that with increasing levels of splits (up to 4) the net return per rupee investment on fertilizer also increased.

5.3.5 Oil quality

So far no evidences were shown to depict the role of K in the synthesis of citronellal, citronellol and geraniol, which decide the quality of essential oil in citronella Java. These were not affected either due to graded levels or due to split application. Singh et al., (1976) reported that levels of K did not influence oil content in citronella Java.

5.3.6 Nitrogen uptake

Application of K at 50 and 100 kg K_2O / ha significantly increased the uptake of N (Table 5.7) in both the harvest years in Experiment No. 2 a and b and in Experiment No. 3 a and b. Addition of K in combination with N possibly promoted the nutritional balance and resulted in high uptake of N. Similarly, application of K in splits proved more effective than basal application, causing high N uptake. This may be due to high herbage yield with the treatments.

5.3.7 Potassium uptake

High uptake of K due to levels and methods of application may be because of low available K status of soil and

Table 5.8 Net profit at optimum level of K_2O application under different methods of application from the pooled analysis of the results (Experiment No. 3 a and b)

Methods of K - application	Oil yield at opt. level of K_2O (kg/ha)	Oil yield in control plot (kg/ha)	Increase yield over control (kg/ha)	Response/ kg K_2O applied in kg (oil) Rs/ha	Value of increase in yield Rs/ha	Cost of ferti- lizer Rs/ha	Net return Rs/ha	Net return per rupee investment on ferti- lizer
First harvest year								
Basal	233.1	159.0	74.1	0.47	7410	637	6773	10.63
2 - splits	294.9	163.1	133.9	0.53	13,390	1,010	12,380	12.25
3 - splits	247.1	163.1	84.0	0.96	8,400	349	8,051	23.10
4 - splits	272.0	163.1	106.9	1.54	10,590	283	10,607	37.40
Second harvest year								
Basal	302.4	233.7	68.7	0.69	6,870	399	6,471	16.21
2 - splits	421.8	244.3	177.0	0.68	17,700	1,047	16,653	15.90
3 - splits	377.1	244.3	132.8	1.23	13,280	430	12,850	29.90
4 - splits	392.7	244.3	148.4	2.08	14,840	285	14,555	51.03

high herbage yield. Split application improved uptake of K than basal application due to the fact that concentration of K in soil solution throughout the growth period may be high as compared with basal application (Table 5.7). Similar views were also held by Agrawal (1978), while working on other crops.

5.3.8 Interaction between levels and methods of potassium application

Crop growth in terms of plant height, tiller, dry matter production, herbage and oil yield and uptake of N and K were significantly increased with addition of 50 kg K_2O / ha (in splitted doses) whereas at 100 kg K_2O / ha the crop response was significant with only upto two or three splits. Superiority of split application of K particularly at low level of K content in soil have also been reported in other crops.

5.4 N : K ratio in citronella herbage

At high level of N application the N / K ratio, as determined from the contents of N and K in the herbage (dry weight basis), was high at the fourth cutting (grown during Apr - Jun) in both the harvest years. During kharif season (i.e. herbage growth in Jul - Sep) the N / K ratio was low (Tables 5.9 and 5.10). Different method of application of potassic fertilizer did not show wide differences

**Table 5.9 N / K ratio based on N and K contents (in percentage),
in the herbage harvested in first and second year
(Experiment No. 3 a 1983-85)**

Level of K ₂ O (kg/ha)	First harvest year Timings of harvest*				Second harvest year Timings of harvest*			
	I	II	III	IV	I	II	III	IV
50	0.74	1.01	1.07	1.38	0.76	1.01	0.92	1.43
100	0.74	1.01	1.07	1.39	0.77	1.02	0.93	1.46
Methods of K application								
Basal	0.75	1.01	1.08	1.38	0.76	1.03	0.93	1.45
2 - splits	0.74	1.01	1.08	1.39	0.76	1.03	0.93	1.45
3 - splits	0.74	1.01	1.08	1.38	0.76	1.03	0.92	1.43
4 - splits	0.74	1.01	1.08	1.40	0.76	1.03	0.92	1.43
Control (No K)	0.74	1.00	1.06	1.36	0.75	1.00	0.91	1.41

* I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun

**Table 5.10 N / K ratio based on N and K contents (in percentage)
in the herbage harvested in first and second year
(Experiment No. 3 b - 1984-86)**

Level of K ₂ O (kg/ha)	First harvest year Timings of harvest*				second harvest year Timings of harvest*			
	I	II	III	IV	I	II	III	IV
50	0.76	1.03	1.08	1.39	0.77	1.03	0.92	1.47
100	0.78	1.02	1.08	1.40	0.78	1.03	0.93	1.44
Methods of K application								
Basal	0.76	1.04	1.08	1.40	0.77	1.03	0.94	1.44
2 - splits	0.78	1.04	1.08	1.40	0.77	1.04	0.94	1.44
3 - splits	0.76	1.04	1.08	1.40	0.77	1.03	0.93	1.47
4 - splits	0.77	1.03	1.08	1.39	0.77	1.03	0.93	1.47
Control (No K)	0.76	1.03	1.06	1.36	0.75	1.00	0.91	1.44

* I = Jul-Sep; II = Oct-Dec; III = Jan-Mar; IV = Apr-Jun.

in the N : K ratio; This needs further verification by determining the exchangeable and non-exchangeable potassium status of soil. The N / K, K_2O / N and K / N ratio based on the total annual uptake of N and K by the crop grown in Experiment No. 3 a and b, have been summarized in Table 5.11. Without where K was not applied to the soil there was slight reduction in N / K ratio. N / K ratio in plants influence disease and pest incidences which have not been recorded in this work.

5.6 Effect of weed control treatment

Citronella Java is normally planted in rainy season and it continues for two to three years. During the growth period the crop is infested with a variety of weed flora of both rainy and winter seasons.

The weed index i.e. percentage reduction in oil yield due to weed control measures as compared to weed free check, was high at 0 level of nitrogen application and then it was gradually reduced up to 100 to 150 kg N / ha and then again it increased (Table 5.12). Use of Diuron did reduce weed index appreciably. The negative value recorded at 150 kg N / ha in the second harvest year was due to slight increase in yield recorded in the pooled value. This needs to be further checked; at this stage the grass appeared to be more green than other treatments.

Table 5.11 N / K, K_2O , N and K / N ratios based on annual uptake in the herbage, during first and second harvest year from the pooled analysis of the results (Experiment No. 3 a and b)

Levels of K_2O (kg/ha)	<u>N / K ratio</u>		<u>K_2O / N ratio</u>		<u>K / N ratio</u>	
	I year	II year	I year	II year	I year	II year
50	1.11	1.02	0.75	0.82	0.90	0.98
100	1.11	1.02	0.75	0.82	0.90	0.98
Methods of K application						
Basal	1.08	1.01	0.78	0.83	0.93	0.99
2 - splits	1.09	1.02	0.76	0.82	0.91	0.98
3 - splits	1.13	1.02	0.73	0.82	0.88	0.98
4 - splits	1.13	1.02	0.73	0.82	0.88	0.98
Control (No K)	1.08	0.99	0.73	0.84	0.88	1.01

Table 5.12 Weed index reduction (in percentage) of oil yield compared to weed free treatment,
as influenced by different weed control measures and levels of N from the pooled
analysis of the results (Experiment No. 1 and b)

Weed control measures	First harvest year						Second harvest year					
	Levels of nitrogen - kg / ha						Levels of nitrogen - kg / ha					
	0	50	100	150	200	250	0	50	100	150	200	250
weedy	24.7	20.9	22.2	25.3	28.5	27.2	27.3	21.5	19.8	19.2	19.5	21.8
Diuron	8.5	7.8	6.0	1.8	24.2	21.8	9.9	9.8	4.5	-0.8	17.9	17.7

As discussed earlier the weed control measures did not affect the oil content in herbage and the quality of oil. Chemical weed control measure, however, showed higher net return per rupee invested on weed control measures than hand weeding (Table 5.13).

Table 5.12 Net return per unit rupee invested on weed control measures (Pooled analysis of results of Experiment No. 1 a and b)

Weed control measures	Value of increase yield over control (Rs/ha)	Cost of input (Rs/ha)	Net return (Rs/ha)	Net return per rupee investment on weed control
First harvest year				
Hand weeding (weed free)	4640	2000	2640	1.32
Diazon spray	4275	300	3975	13.30
Second harvest year				
Hand weeding (weed free)	4903	2000	2903	1.50
Diazon spray	4634	300	4334	14.50

6. SUMMARY AND CONCLUSION

Three separate field experiments were conducted during 1983-86 to study the effect of N, P & K applications and weed control measures on growth, yield and quality of citronella oil in Cymbopogon winterianus Jowitt at the Central Institute of Medicinal and Aromatic Plants, Lucknow. In the first experiment, three weed control treatments (weed free, weedy and diuron treatment) in main plots and six levels of N (0, 50, 100, 150, 200 and 250 kg / ha) in sub-plots were replicated thrice in split plot design. In second experiment graded levels of P_2O_5 and K_2O each at 0, 50 and 100 kg / ha were tested in a Randomised Block Design in three replicates, at 250 kg N / ha. In the third experiment three levels of K_2O (0, 50 and 100 kg / ha) and four methods their applications viz, basal (full at planting), two splits (equally after first and third harvest), three splits (equally after first, second and third harvest) and four splits (equally at planting first, second and third harvest) were tested in Randomised Block Design with in three replicates, at 250 kg N and 50 kg P_2O_5 . The salient features of the results were as indicated below.

1. Application of N up to 200 kg N / ha significantly increased the plant height and number of tillers in all the harvests. Plant height and number of tillers in weed free and weedy plots were significantly increased with N addition

up to 200 kg / ha while it was only up to 150 kg / ha in diuron treated plots.

2. Weed free plots produced maximum fresh herbage yield, dry matter and oil yield followed by diuron treated plots and minimum production was recorded in weedy plots. Application of N up to 200 kg / ha significantly increased the fresh herbage yield, dry matter production and oil yield in all the harvests. The fresh herbage, dry matter and oil yield in weed free and weedy plots were significantly increased up to 200 kg N / ha, while in diuron treated plots response was observed only up to 150 kg N / ha.

The response in oil yield indicated that the optimum dose (kg N / ha) and yield (kg / ha) in first harvest year were 160 and 256; 156 and 190; and 137 and 224 in weed free, weedy and diuron treated plots, whereas in second harvest year the respective values were 176 and 341; 158 and 272; and 122 and 307.

The net returns were Rupees 3,840, 2,194 and 3,588 per hectare in first harvest year, whereas in second harvest year the respective values were Rupees 4,023, 3,985 and 4,024/-. Net return per rupee investment on weed control measures were Rupees 4.30, 2.80 and 5.20 in first harvest year and Rupees 4.60, 5.10 and 6.60 in second harvest year in weed free, weedy and in diuron treated plots.

3. Oil content and quality were not influenced by weed control measures and levels of N.
4. Nitrogen uptake by the crop was maximum from weed free plots followed by diuron treated plots. In weed free and weedy plots, increases in N uptake was up to 200 kg N / ha whereas in Diuron treated plots it was up to 150 kg N / ha.
5. Dry weights of weeds amounted to 32 and 22 q / ha in the first and second harvest years in weedy plots; the corresponding figures under Diuron treated plots were 17 and 10 q / ha. This removed about 53 and 36 kg N / ha from weedy plots in first and second harvest years, respectively; the corresponding figures in Diuron treated plots were 28 and 18 kg N / ha.
6. Application of 50 kg P_2O_5 and K_2O / ha separately increased plant height, tiller production, fresh herbage, dry matter, and oil yield in both the harvest years.

From the response curves, the optimum phosphatic dose (kg P_2O_5 / ha) and oil yields (kg / ha) were 80 and 271 in first harvest year and 81 and 380 in second harvest year respectively; the corresponding values for K were 75 kg K_2O / ha and 276 kg / ha in first harvest year and 75 kg K_2O / ha and 386 kg / ha, in second harvest year, respectively.

The net returns per hectare were Rupees 2,368 and 4,399 in first and second harvest years due to application of P; while the respective values for K were Rupees 5,642 and 6,280 in first and second harvest years. The net returns per rupee invested on fertilizer at the optimum dose were Rs.3.70 and Rs.6.80 in first and second harvest years due to P application; due to K application at optimum doses the respective values were Rs.18.9 and Rs.20.9 in first and second harvest years.

7. The graded levels of P and K had no influence on oil content and oil quality.

Plant height and number of tiller per plant were maximum in first cutting (Jul-Sep) with basal application of K. While split application showed superiority at subsequent harvests over basal application. Application of 100 kg K_2O / ha significantly increased the fresh herbage yield, dry matter and oil yields in all the harvests except first cutting (Jul-Sep) in first harvest year; at the time of first cutting the split doses of K were not applied.

8. Application of 50 kg P_2O_5 and K_2O / ha significantly increased the N, P and K uptake. The interaction effects between levels of P and K were not significant.

9. From the response curve of K_2O fertilization, there was an indication that the optimum dose and oil yields were

95 kg K_2O / ha and 240 kg / ha in first harvest year and the corresponding figures in second harvest year were 96.0 kg K_2O / ha and 341 kg / ha.

10. Oil content and quality were not influenced by the levels and methods of K application.

11. In the third experiment application of 100 kg K_2O / ha significantly increased the N and K uptake in all the cuttings except in first cutting of first harvest year. Application of K at planting caused maximum nutrient uptake at first cutting in first harvest year. Nutrient uptake increased with increase in number of splits.

12. N : K ratios calculated on the basis of total uptake of major nutrients, were usually low at first cutting (below 1) and high at fourth cutting (more than 1) and medium (about one) in second and third cuttings.

13. The reductions in oil yield as compared to that recorded in weed free plots were high in weedy plots and medium in Diuron treated plots.

It was, thus, concluded that under weed free environment citronella grass should be fertilised with 160 kg N, 80 kg P_2O_5 and 75 kg K_2O / ha in first harvest year and the corresponding figures in second harvest year would be 176 kg N, 81 kg P_2O_5 and 75 kg K_2O / ha; N and K are to be applied

in 3 to 4 split doses. Weed control through Diuron appeared to be cheaper than hand weeding. Fertilizers affected oil yield but not the contents and quality of oil.

7. FUTURE SCOPE OF WORK

The plantations of Citronella grass need proper weed management and a lot of nitrogen for maintaining good production. There is great need to work upon the crop on efficient control measures and slow release fertilizers like Urea super granules, neem or shellac or rock phosphate coated urea, on the productivity of grass. The grass, as usual will need balanced nutrients. so there is scope to work out the productivity of the grass where swerage disposal can be made available to the crop. There is also scope to work on the efficiency of chemical fertilizers in conjunction with organic manuring.

The present work has focussed that oil yield varies due to seasons. The reason for such variation, need to be very carefully investigated and the possibility of increasing its productivity in winter months need to be explored. The grass is usually grown in poor soils and so there is scope to investigate as to how does the crop responds to micro-nutrients, in such soils.

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