EVALUATION OF SELECTIONS AND HYBRIDS OF VETIVER (*Vetiveria zizanioides* (Linn) Nash)

By

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THESIS

Submitted in partial fulfilment of the requirement for the degree of

Master of Science in Agriculture

Faculty of Agriculture
Kerala Agricultural University

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COLLEGE OF HORTICULTURE
Vellanikkara Trichur

1991

DECLARATION

I hereby declare that this thesis entitled **"Evaluation of selections and hybrids of Vetiver (Vetiveria zizanioides (Linn.) Nash.)"** is a bonafide record of work done by me during the course of research work and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society

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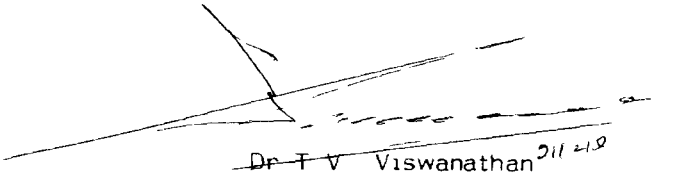
Certified that this thesis is a record of research work done independently by Sri G R Radhakrishnan under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him



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ACKNOWLEDGEMENT

I express my deep sense of gratitude and indebtedness to Dr T V Viswanathan, Chairman of my Advisory Committee and Associate Professor, AICRP on M and AP, College of Horticulture, Vellanikkara for the advice, constructive criticisms, constant encouragements and guidance which I have received during the entire period of investigation and preparation of this manuscript

I am also grateful to Dr K M N Namboodiri, Professor and Head, Department of Agricultural Botany and Dr V K Mallika, Associate Professor, Cocoa Research Project, College of Horticulture, Vellanikkara, members of the Advisory Committee for their valuable and critical suggestions during the course of investigation

I wish to express my thanks to Sri V K G Unnithan, Associate Professor, Department of Agricultural Statistics and a member of the Advisory Committee for his help and guidance in statistical analysis and interpretations of the data Heartfelt thanks are also due to Dr Achamma Oommen, Associate Professor, Department of Agricultural Botany for her everwilling readiness for going through the manuscript timely and critically

I avail myself of this opportunity to thank Dr Sosamma Jacob, Associate Professor, AICRP on M and AP, who was graceous enough to render me her generous help and sincere co-operation in conducting the experiment

I am greatly indebted to Dr N P Chinnamma Professor, Department of Soil Science and Agricultural Chemistry and Dr Luckin C Babu Associate Professor, College of Forestry for their valuable suggestions during the course of study

My sincere thanks are due to Sri V K Raju, Associate Professor, Department of Processing Technology for extending help in the preparation of photograph

I am very much grateful to the members and staff of the Department of Agricultural Botany and also AICRP on M and AP, for the timely assistance rendered to me by each and every of them at all stages of my work

I wish to record my deep sense of indebtedness to Sri Vasant D Deo, Chemical Engineer, D V Deo Industries, Kalamassery, for providing facilities and extending a helping hand for the analysis of vetiver oil

I sincerely acknowledge the help rendered by my friends

On a personal note, I am extremely grateful to my father, mother and sister whose love and affection have always been a source of inspiration to me

Vellanikkara,
15 -12 -1991

G R RADHAKRISHNAN

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Introduction

INTRODUCTION

Vetiver plant Vetiveria zizanioides (Linn) Nash occurs wild in the plains and lower hills of India, Burma and Sri Lanka Its roots contain highly fragrant essential oil which is an important constituent of many popular scents, soaps, perfumes and cosmetics Vetiver oil is also used for isolation and preparation of vetiverol, vetiverone and vetiveryl acetate it has good export potential since Indian oil has very high content of vetiveryl esters in natural state Its potential as an important soil conservation plant has been recognised recently at international level

In India the plant is grown both in the wild and cultivated forms In Kerala the crop is cultivated in a few villages in Trichur, Palghat, Calicut and Wyanad Districts Vetiver plant grows in any soil but loamy cum sandy soil is most suitable Warm and damp climate and adequate water are the two main requirements for its successful growth In the coastal areas vetiver is usually harvested after one year and the root is marketed as such for the manufacture of items like mats, fans etc without extraction of oil The oil is extracted from the roots in the midland area using locally made distillation units

India produces about 20 tonnes of oil annually, yet this cannot meet our demand for manufacture of perfume, essence soap

etc Owing to the high demand of vetiver roots for extraction of oil and weaving of different objects, both wild as well as cultivated plants are harvested Wild sources account for major supply of roots However, the fast depletion of wild sources due to indiscriminate collection has not only created acute shortage of roots but also sharp increase in its price during the last few years To ensure regular supply of roots to industries, vetiver cultivation must be taken up on large scale

The distillation of vetiver root is beset with considerable difficulties due to the viscid nature of the oil, low volatility and high boiling point constituents The separation of oil is also troublesome owing to its specific gravity which almost approximates to that of water In vetiver, root yield and essential oil content of the roots are the major components of economic importance The economic worth of the crop is dependent on high root production and high essential oil content

There are two main types of grasses, the North Indian (wild type) and South Indian (cultivated) Essential oil obtained from two types differs in their physico-chemical properties

The germplasm collection of vetiver available in AICRP on M & AP Project, College of Horticulture, Vellanikkara includes 13 South Indian types, 8 North Indian types including five national

collections viz , NC 66403, NC 66404, NC 66406, NC 66415 and NC 66416 and 3 hybrids viz hybrid 7, hybrid 8 and hybrid 26 These types are reported to be superior with respect to the root yield and oil content The evaluation of these entries for their root production, oil production and oil quality needs immediate attention

With this view in mind, the present investigations were undertaken to fulfil the following objectives

1 To evaluate the performance of selections and hybrids of vetiver in comparison with the popular cultivated varieties

2 To attempt morphological evaluation of the available selections and hybrids of vetiver in the germplasm of AICRP on M & AP Project of Vellanikkara, in order to develop a descriptive blank for the crop

3 To estimate the root and oil yield of these types along with an assessment of the quality of oil

Review of Literature

REVIEW OF LITERATURE

Vetiver is an essential oil yielding perennial grass found in the tropics It comes up well under the agroclimatic condition existing in Kerala

In this chapter an attempt is made to review the work carried out till recently, on origin and distribution, species and varieties, morphology, root and oil yield, methods of distillation and physico-chemical properties of oil Literature relating to the influence of biometric characters, stage of harvest, soil and other agroclimatic conditions on root and oil yield is also presented briefly

2.1. Origin and distribution

Cultivation of vetiver in Burma, Sri Lanka, Java and Tropical Africa was reported by Ranga Achariyar (1921) He also reported its cultivation throughout the plains and lower hills of India Bews (1929) found vetiver as a native of Tropical Asia He reported its occurrence in African countries also Menon and Ittyachan (1945) found the plant growing wild throughout Punjab, U P , Baratpur and Ajmer districts in Rajasthan In central India, it was seen partially growing wild and partially cultivated It was also found in Chota Nagpur, Bihar, Assam and seen wild in Orissa, Gujarat,

Andhra Pradesh, Karnataka, Kerala and Tamil Nadu

Vetiver was seen cultivated in Southern India, Java, Malaya, Philippines, Japan, Reunion Island, Angola, Haiti, Dominian Republic, Brazil, Argentina, British Guiana, Jamaica and Mauritius (Arctander, 1958)

The occurrence of Vetiver species, Vetiveria filipes was reported by Celarier (1959) in Australia [illegible] had wide ecological distribution almost all over the Indian continent (Bor, 1960) He described two species Vetiveria zizanioides and Vetiveria lawsonii, the former being found throughout India and the latter in Bombay and Tamil Nadu He found Vetiveria zizanioides also cultivated in Burma, Sri Lanka, South East Asia and Tropical Africa

Vetiver root was known from ancient times in India The word 'vetivert' more correctly spelled as 'vetiver' was derived from Tamil word ' vetivern' The Tamils inhabited the island of Sri Lanka as well as Southern tips of India across Sri Lanka, cultivated vetiver in these regions The plant was also seen wild (Wildner, 1960)

The centre of origin of the Genus Vetiver should be either Africa or Australia and not India where only two species Vetiveria zizanioides and Vetiveria lawsonii occurred Vetiveria zizanioides

was however distributed throughout the humid tropics where it was cultivated for its aromatic roots (Ramanujam and Kumar 1964)

The cultivation of vetiver in Honduras and Gautemala was reported by Ishida and Kawatake (1967) Guenther (1972) found the plant to be cultivated systematically in certain places of Kerala, Tamil Nadu, Karnataka and Andhra Pradesh In Kerala State, the cultivation was mainly done in the villages of Kaipamangalam, Chentrapinni, Peringanan, Koolimuttam, Andathode and Panniyur in the Chowghat and Ponnani taluks of Trichur and Palghat Districts, in Nilambur of Kozhikode District, and in Neyyattinkara of Trivandrum District Cultivation had also been taken up in Wynad and along its foot hills

In the State of Tamil Nadu, the places where vetiver cultivation was done extensively were Tirunelveli, Srivelliputhur, Madurai, Thanjavur and Tiruchi (Virmani and Dutta, 1975)

According to Morris (1984) Vetiveria zizanioides (Linn) Nash sometimes referred to by the name Andropogon muricatus Retz , had been known to the Indians from the time of the vedas During Mogul times, French traders became aware of this fine aromatic grass and introduced it to Bourbon Island in the Indian ocean and to the world colonies of Louisiana and Haiti He thus considered India as the true home of vetiver

2.2. Species and varieties

Celarier (1959) had found close relationship between Chrysopogon and Genus Vetiveria except for many jointed racemes He also described the intermediate forms such as Vetiveria fulvibarbis from Africa and Vetiveria filipes and allied species from Australia He considered Vetiveria zizanioides as the most primitive and ancestral in the tribe Andropogonae based on the studies on Vetiveria zizanioides, Vetiveria lawsonii and Vetiveria filipes,

Haeckel included vetiver in the Genus Andropogon and named it as Andropogon squarrosus but it was named afterwards as Vetiveria zizanioides by Linnaeus (Bor, 1960)

The Genus Vetiveria was found to be comprised of at least ten species (Purseglove, 1975, Cobley and Steele, 1976) Out of the ten species Vetiveria, Vetiveria zizanioides most commonly found in Asia, have aroma, whereas Vetiveria nigritana, a similar type found in Africa, was not known to be aromatic (Morris, 1984)

2.3. Morphology

Ramanujam and Kumar (1963) had classified Indian vetiver under two major categories viz , North Indian types and South Indian types They observed considerable variation among the types

grown in South India and North India for quantitative and morphological characters. They suggested that one could recognise a North Indian complex, characterised by larger number of tillers and panicles, lower root production, lesser number of leaves in main tillers, yellowish brown roots of lesser diameter, larger internodes and narrower leaves than the South Indian type.

Pillai (1967) suggested that it might be necessary to recognise the existence of two morphologically differentiated complexes in India. Morris (1984) had described vetiver found in India belonging to two types, flowering type found in North India and non flowering type found in the commercial plantation of the South India.

2.4. Root yield

Reddy (1954) reported an yield of about 2-8 tonnes of dry roots/ha from Bharatpur area. In the cultivated area from South India an average yield of 4 to 5 tonnes of washed roots/ha was obtained. In Anamallai certain areas had yielded about 7.5 tonnes of fresh and washed roots/ha, while harvested at 16-18 months of age (Rao, 1963). Chandra et al (1966) reported a root yield of 0.20 to 0.24 tonnes/acre from Bharatpur area where vetiver was growing naturally.

Eleven hybrids of vetiver were selected and put under multilocational trials at 6 centres Results showed that the root yields were in the order 1 264 tonnes/ha for hybrid 16 and hybrid 6 and 1 209 for hybrid 8 (Sethi et al , 1978) Comparative trials of 14 hybrids and 2 controls at Delhi gave root yield varying from 1 2 tonnes/ha to 2 04 tonnes/ha during 1974-75 (Sethi and Gupta, 1980)

Stability analysis for root yield on ar average of 4 replication/location and an overall average of 6 location by Sethi et al (1981) showed that four hybrids viz hybrid 26, hybrid 16, hybrid 8 and hybrid 7 gave significantly higher root yield than control (0 75 tonnes/ha) Sethi (1982) reported highest root yield of 59 g/plant for hybrid 26 (1 458 tonnes/ha) among the 14 hybrids followed by hybrid 6 (1 354 tonnes/ha), hybrid 7 and hybrid 8 (1 310 tonnes/ha) and hybrid 16 (0 94 tonnes/ha)

Thirteen vetiver hybrids were studied at AICRP or M & AP, College of Agriculture, Indore by Gupta et al (1983) during the period 1976-78 The data revealed that hybrid clone 16 gave the highest root yield over all other hybrid clones (90 40 g/plant) followed by hybrid 8, hybrid 14, hybrid 23, hybrid 7 which gave root yields of 87 60 84 70 and 86 10 and 85 3 g/plant respectively

Trials with 12 hybrid clones of vetiver were carried out at Aromatic and Medicinal Plants Research Station, Odakkali to identify a high yielding variety with regard to root and oil yield suitable to Kerala condition and the result indicated that the hybrid clone ODV-13 (a North Indian hybrid) was superior to all other varieties with regard to the root yield (Nair et al , 1983)

The results of extension trials by Sethi et al (1986) to assess the performance of hybrids during the year 1983-85 confirmed that hybrid 8 outyielded others on different locations with an average yield of 1 314 tonnes/ha of roots followed by hybrid 7 which yielded 1 225 tonnes/ha of roots

Breeding works at NBPGR by Sethi et al (1987) could release a new promising hybrid of vetiver viz , hybrid 8, which gave a fairly high root yield of 1 4 tonnes of roots per hectare

Punia et al (1989) based on the multilocational trial to study the performance of hybrids, found that from among the 9 vetiver hybrids used for the trial, hybrid 4 showed the highest root yield followed by hybrid 2 and hybrid 26 The overall performance was 1 98 tonnes/ha being higher than at Delhi (1 67 tonnes/ha), Kanpur (1 51 tonnes/ha) and Indore (0 84 tonnes/ha) indicating better adaptability Mini (1989) based on her observations on morphological characters of 11 vetiver cultivars, reported a root yield of 83-176 g/plant under pot condition

Pareek et al (1991) reported that hybrid 8 culture released from NBPGR produced 1 1 to 1 5 tonnes/ha of air dried roots

2 5 Oil yield

Puran Singh (1914) distilled the roots grown in different localities in India and obtained yield between 0 37 to 1 14 percentage Menon and Iliyachan (1945) had reported oil yield of roots from different locations The highest oil yield 0 23 per cent was obtained for roots from Musanagar and Bharatpur while lowest yield of 0 15 per cent was for roots from Sirsa (Punjab)

Rao et al (1963) obtained an yield of 13 to 15 kg of oil per hectare in vetiver Chandra et al (1966) reported oil recovery of 0 1 per cent from Bharatpur vetiver by distillation in locally made Bhapkas (Distillation Unit) Dhingra (1969) conducted comparative yield trials, results of which had shown that roots from Bharatpur as the highest yielders with 0 19 to 0 25 per cent and that from Musanagar (Kanpur) as the lowest yielders with 0 08 to 0 1 per cent

It was quoted by Virmani and Dutta (1975) that the range of oil per cent in dry vetiver roots grown in some countries viz Angola, Brazil and British Guinea was 2 to 4 6 whereas oil content in vetiver roots from France was only upto 0 25 per cent

Singh et al (1978) reported that hybrid 8 was superior for oil followed by hybrid 12, hybrid 26, hybrid 14 and hybrid 4 at Kanpur Essential oil studies, conducted by them with 15 hybrid clones of vetiver at Department of Horticulture, C S Azad University of Agriculture and Technology, Kanpur, revealed that hybrid clone 23 gave the highest oil per cent (2 4%) over all other hybrid clones while hybrid clone 11 had lowest oil content (0.99%)

An analysis of dry root samples of hybrid vetiver varieties was done for their essential oil content for 2 years (1975-76 and 1976-77) Highest oil content (2 5%) was obtained in three hybrids viz , hybrid clone 3, hybrid clone 2 and hybrid clone 14 (Bajpai et al , 1979)

Preliminary screening of 29 hybrids at Delhi resulted in identifying 14 hybrids which gave better oil content Comparative performance of these four hybrids gave an essential oil content ranging from 0 35 to 1 55 per cent (Sethi and Gupta, 1980)

Stability analysis for essential oil content on an average of 4 replications/location and an overall average of all the 6 locations by Sethi et al (1981) revealed that 4 hybrids viz , hybrid 26, hybrid 16, hybrid 8 and hybrid 7 gave significantly higher essential oil content of 1 487, 1 267, 1 727 and 1 510 per cent,

respectively They also reported that the present hybrids were the progeny selections made from crosses between North Indian and South Indian complexes and they outyielded their parents in oil content Hybrids 8 and 7 having a high oil per cent retained their superiority in yield even in different types of soils

Gupta et al (1983) found that among the 13 hybrid vetiver clones used for the trials at College of Agriculture, Indore, oil content was the highest for hybrid 8 (1 60%) followed by hybrids 12, 26, 4 and 14 These hybrid clones were observed to be significantly higher oil yielding than local cultivars The oil content ranged from 0 77 to 1 6 per cent

Studies conducted at AMPRS, Odakkali by Nair et al (1983) have shown that ODV-13 was superior to all other 12 hybrid clones used for the trial with regard to oil yield, oil recovery and quality of oil It gave 30 per cent more oil over the local variety Nilambur

The results of extension trials by Sethi et al (1986) to assess the performance of hybrids during the year 1983-85 confirmed that hybrid 8 yielded highest in different location with an average of 21 29 l/ha of oil followed by hybrid 7 which yielded 18 3 l/ha of oil In yet another study, the same authors reported the oil

content in ml/100 g of vetiver root Hybrid 9 gave 1 73 ml which was the highest followed by hybrid 12 (1 68), hybrid 14 (1 54), hybrid 4 (1 54) and hyrbid 7 (1 50)

Maheswari et al (1986) showed that there was wide variation in oil content ranging from 0 25 to 0 75 per cent on fresh weight basis from the roots of 21 national collections they selected for experiments at NBPGR, New Delhi The highest oil yielding collection was NC 66403 (0 75%) followed by NC 66413 (0 66%), NC 66416 (0 65%), NC 66408 (0 62%), NC 66404 (0 60%), NC 66407 (0 60%), NC 66415 (0 60%) and NC 66423 (0 60%) The accession NC 66422 had the lowest oil content whereas others like NC 66405, NC 66404, NC 66410, NC 66411, NC 66412, NC 66419, NC 66420 and NC 66424 possessed oil between 0 30 per cent to 0 37 per cent

Trial data from 6 different experimental stations with hybrids viz , hybrids 8, 7, 14 and 26 showed that hybrid 8 gave the highest oil yield both in normal soils (27 65 l/ha) as well as alkaline soils (15 21 l/ha) An overall oil yield of 20 78 l/ha was obtained in this variety (hybrid 8) (Sethi et al , 1987)

Punia et al (1989) based on the trials with 9 hybrids of vetiver at Haryana Agricultural University during 1981, reported that oil content ranged from 0 57 (hybrid 6) to 1 11 per cent (hybrid 3) General mean was 0 78 per cent which was more than

1 0 per cent at Delhi, Kanpur and Indore (Sethi et al , 1978) Oil yield varied from 9 72 kg/ha (hybrid 16) to 22 88 kg/ha for hybrid 3 The average oil yield was 15 00 kg/ha, hybrid 8 and 7 gave above average oil yield

Pareek et al (1991) reported that hybrid 8 culture released from NBPGR could yield 15-18 kg oil per hectare

2.6. Biometric Parameters and its influence on root and oil yield

Study on the natural growth of vetiver at Bharatpur by Chandra et al (1966) showed that maximum dense growth of root was seen upto 25 cm and as the depth increased the penetration of root decreased The maximum depth to which the roots were found to have normal thickness was 84 cm

Bajpai et al (1979) based on their studies of varietal performance of Khus reported the highest fresh root yield of 81 2 g (dry root yield 47 59 g) and highest plant height of 212.6 cm for hybrid clone 3 Root length (43 8 cm) was the maximum in hybrid clone 15

In an experiment conducted at National Bureau of Plant Genetic Resources, New Delhi to study the relationship between

root parameters and oil yield, Sethi et al (1986) reported that short and thin rooted cultivars gave higher percentage of oil The root length in the National collection under study varied from 23 cm (NC 66403, NC 66404 and NC 66416) to 27 cm in NC 66414 Root diameter varied from 2 1 mm in NC 66418 to 2 9 in NC 66413 and NC 66414 Compared to other collections NC 66415 which possessed root diameter of 2 4 mm and root length of 23 cm gave high percentage of oil (0 65%) But exceptions were noticed in NC 66403 and NC 66404 which yielded 0 75 and 0 60 per cent oil and possessed a root diameter of 2 8 mm Some high yielding accessions gave low oil content (NC 66422)

Sethi et al (1987) reported a root shoot ratio of 6 25 at harvest on fresh weight basis in hybrid 8, a promising vetiver hybrid Pareek (1989) based on his experiment to study the performance of 12 vetiver strains at Delhi had reported the number of roots ranging from 253 to 800, root diameter 1 6 to 2 9 mm, and root length 31 5 to 45 5 cm

2.7. Stage of harvest and its effect on root and oil yield

Puran Singh (1914) reported that 18 months after sowing is the optimum period for the harvest of vetiver

With respect to the maturity of roots at harvest time, Murti and Moosad (1949) found that oil content increased progressively upto 21 months (yield 0 87%) At 10 months it was 0 1 per cent, at 15 months 0 50 per cent and at 17 months 0 79 per cent He also stated a period of maturity of 15-18 months for the roots as the optimum A reduction of oil percentage to 0 25 and 0 20 for 24 and 23 months old roots was also noticed in their experiment It was concluded that harvesting of vetiver roots before a minimum maturity of 15 months as well as after 21 months was uneconomical

Systematic examination was undertaken by Sadgopal (1960) on vetiver in the forest blocks in Bharatpur and Musanagar He showed that the average content of the oil in roots increased from 0 28 per cent to 1 83 per cent in 30 months old plants and the corresponding figures for plants at 12 to 18 months were 1 1 to 1 5 per cent

Sreedharan et al (1973) reported that there was no significant difference in the yield of root and oil when plants were harvested at different intervals of 11 to 18 months after planting, but there was significant difference in the yield of the harvests in the same year

Virmani and Dutta (1975) suggested that the best time for harvest of vetiver is 18 months after planting and that it would give the maximum percentage of essential oil Sethi et al (1986) found that delayed harvesting ie after 18 months, was totally uneconomical both for yield and quality According to them the root yield and oil content was maximum between 15-18 months after planting for hybrid 8 vetiver Early harvesting affected root yield and essential oil content considerably

Pareek et al (1991) showed that crop at 15-16 months age had maximum oil in the roots with characteristic woody earthy, balsamic, pleasant odour After 16 months oil percentage was found decreasing in the roots

2.8. Influence of soil and climate on root and oil yield

According to Murti and Moosad (1949) the white sandy soils on the west coast of Southern India were first considered to be best suited for the cultivation of vetiver and later studies by these scientists proved that pure (white) sandy soil was not suited for vetiver cultivation The roots on distillation (for 16 hrs) yielded only 0 18 to 0 22 per cent of oil Root grown in red laterite loam, on the other hand yielded from 0 76 to 0 94 per cent of oil The roots produced in loamy soil were found to be thick and wiry with only a small proportion of hairy rootlets,

whereas the roots grown in sandy soils were thin and hairy In yet another study on the effect of manuring on oil per cent, it is reported that fertilizing with ammonium sulphate and groundnut cake increased the oil content of the roots to some extent, but increase was far less than that of roots cultivated in a good soil

The quality of vetiver varied from locality to locality even in the same district with similar climatic condition The roots extracted from the area which had lesser clay content and lesser water logged condition produced better quality oil It had further been noticed that with decrease in clay content in the soil there was a marked improvement in the oil yield but an appreciable fall in quality of oil (Singh and Sankhala, 1957)

The colour of root was not related to the quality of the oil However, both yield and quality varied considerably depending on whether the roots had been grown in a rich soil, volcanic laterite for example, or in a poor sandy soil (Wildner, 1960) Wood ash had no effect enhancing the yield, cattle manure or bone meal either singly or in combination appeared to have increased the yield of roots (Sambashiva Rao, 1964)

Chandra et al (1966) found the yield of vetiver as between 2 7 and 3 7 tonnes/ha which in turn depended on a number

of factors like amount of rainfall in the preceeding monsoon, the winter rainfall, the moisture retaining capacity of the soil and the age of the crop

In order to know the performance of hybrids of vetiver under saline - alkaline conditions a trial was conducted simultaneously at Banthra in collaboration with NBRI, Lucknow during 1974-76 crop season Results showed that there were significant differences between the hybrids for root yield and number of tillers Though salinity of the soil affected the root yield and oil content it was not relative (Sethi et al , 1976)

Multilocational trials conducted at 6 centres with 11 hybrids of vetiver by Sethi et al (1978) showed that there was variation in oil content in all the centres with the change in soil condition They found that hybrid 8 and 7 outyielded their parents in oil content with 1 87 and 1 60 per cent which retained their superiority on yield even in different types of soil They also reported an oil yield of 1 72 per cent for hybrid 14 which was the highest in average fertile soils of pH 7-8 But the roots degenerated in saline - alkaline soils giving only 1 36 per cent Hybrids 26, 16, 8 and 7 maintained their oil yield in both types of soils

Pilot scale cultivation of vetiver taken up at 4 types of problem soils viz water logged soil, alkali soil with pH 9 and pH 10 and sandy soils at the Research Farm CIMAP, Lucknow during 1982-85 showed that vetiver could be very well grown in these soils The crop produced 4 56 tonnes/ha of root and 27 3 kg of oil/ha, in water logged soil which was on par to the yield obtained from normal soil (Morris, 1984) Alkali soils with pH 9 and 10 gave 2 72 and 1 99 tonnes/ha root yield and 16 3 and 11 3 kg of oil The lowest root yield and oil yield were from sandy soil (1 48 tonnes/ha and 8 9 kg/ha, respectively) (Singh et al , 1987)

2.9 Distillation of roots

The distillation of vetiver root is beset with considerable difficulties due to the viscid nature of the oil, low volatility and high boiling point constituents The separation of the oil from water is also troublesome, owing to its specific gravity which is almost approximately to that of water Dry and mature thick roots give more viscous oil than green and fresh roots The older the roots, the longer is the period of distillation and the higher the steam pressure required For large scale distillation the roots are cleaned and steeped in water for 12-16 hrs Chopped pieces

2-4" long are charged into the copper still along with aqueous distillate from the previous distillation The still is heated over low fire in the beginning, the intensity of heat being increased towards the close of distillation (Sobti and Rao, 1976)

Rao et al (1925) reported an oil yield of 0 79 per cent when roots were soaked for 3 days whereas an oil yield of 0 28 per cent was obtained when soaked for 24 hrs

Before distillation the roots are to be put in water and allowed to soak for about 12 hrs The soil adhering to the roots get dissolved in the water The clean roots are then chopped into 5 to 8 cm size (Singh and Sankhala, 1957)

Brilho and Santos (1965) based on the study of distillation of vetiver roots obtained better results with fresh roots than with dried roots and fine chopping before distillation was found to be advantageous The optimum temperature range for distillation was 50-60°C

A steam distillation unit with boiler can be used for distillation of vetiver roots A part of vetiver oil is heavier than water and therefore a small quantity of salt is added to the

chopped roots in the still to facilitate easy evaporation of the oil (Pareek et al , 1991)

2.10. Physicochemical properties

Puran Singh (1914) had reported the physicochemical properties of Indian vetiver oil as follows

Specific gravity at 15°C	- 1 01
Acid value	- 10 50
Ester value	- 69 60
Optical rotation	- -30° 85'

Rao et al (1925) found the following physicochemical properties for oil obtained from vetiver of Bangalore region

Specific gravity at 15°C	- 1 0028
Refractive Index at 25°C	- 1 5215
Optical rotation	- +25 5°
Acid value	- 21 4
Saponification value	- 31
Ester value	- 10 4
Ester value after acetylation	- 43 4
Total alcohol as $C_{15}H_{20}O$	43

The physicochemical properties of vetiver oil from Agra was given by Rao et al (1925)

Specific gravity at 15°C	- 1 004
Refractive Index at 25°C	- 1 519
Optical rotation	-65°
Acid value	- 41 2
Ester value after acetylation	- 146 8
Total alcohol as $C_{15}H_{20}O$	- 64 8

According to Guenther (1950) and Rao et al (1963) there appeared to be considerable similarity on the characteristics of the essential oil obtained from South India and that from Java, Reunion, Haiti etc While the essential oil produced by the North Indian type stood out in this respect

Dhingra et al (1952) reported the following characteristics of the vetiver oil

Specific gravity at 30°C	- 0 9857
Refractive Index	- 1 5190
Optical rotation	- +27 3
Acid value	- 19 8
Ester value	- 21 08
Free vetiverol	- 67 5
Combined vetiverol	- 8 44

The sweet heavy characteristic odour of vetiver oil was due to the presence of several Ketonic Sesquiterpenes of which vetiverol, α vetivone and β vetivone were the most important components (Zutshi and Sadgopal, 1957)

Studies by Sadgopal (1960) on the physicochemical properties of the essential oil of North and South Indian strains had revealed the interesting fact that the essential oil from the two types differed in respect of aroma, physical properties (specific gravity, optical rotation, solubility etc) and chemical properties (carbonyl value, acid value, ester value particularly after acetylation etc) and that these differences were not concerned by the different environments obtained in the two regions He considered the oil having high specific gravity, esters, and free alcohols as the best vetiver oil

The Indian Standard Institution (1969) had laid down specification for vetiver oil

		South Indian type	North Indian type
1	Colour and appearance	Light to reddish brown sometimes greenish viscous liquid	Same as in South Indian type
2	Odour	Characteristic and persistant aroma with pleasant woody character	Same as in South Indian type
3	Specific gravity at 30°C	0 9900 to 1 015	0 9900 to 1 032

4	Optical rotation	+10° to 25°	-50° to -130°
5	Refractive Index at 30°C	1 5160 to 1 5300	1 5120 to 1 5230
6	Acid value	35	40
7	Ester value	25-50	25-80
8	Total alcohols, minimum	55	70
9	Carbonyl value	55	24
10	Solubility	Soluble in 1 to 2 vols of ethanol (80%)	

Anderson (1970) found difference in quality as well as quantity of oil obtained from Northern and Southern parts of India although there was no morphological difference in plants He further noticed that the North Indian vetiver oil differed from vetiver oil of Haiti, Reunion, Congo, Angola and South India being leavo-rotatory Major constituents were vetiverone, vetiverols, vetivenyl, vetivenate, Benzoic acid, palmitic acid etc

Indian vetiver oil contained higher percentage of esters and alcohols as vetivenyl esters and vetiverols and these were the cause for the better aroma of the Indian vetiver oils (Virmani and Dutta, 1975)

Isolation and identification of antipodal sesquiterpenes ie epikhusinol and Khusinol oxide related to Khusimol, the major

constituent of Khus oil had been discussed (Kalsi et al , 1979)

Distilled oil and disolute of Vetiveria zizanioides analysed for their main components by Ashour and Moshtohor (1980) yielded hydrocarbons, sesquiterpenes, alcohols and Ketones The important components were vetiverol and α and β, vetivone

Gupta et al (1983) attributed the superiority of oil of hybrid viz , hybrid 12, 23, 16 and 26, due to the high content of esters, free alcohols and high specific gravity, to the local vetiver types They studied the physicochemical properties of hybrid vetiver oil viz , hybrid 7, 8, 14, 16, 23, 12, 4 and 26 and control and showed that oils from these hybrids had high specific gravity, high esters, as well as free alcohols showing thereby that their quality was superior than control

Maheswari (1985) conducted a comparative study of the gas chromatography of vetiver of India, Indonesia, Haiti and Reunion and showed that South Indian vetiver oils were more or less similar in G C pattern to that of Indonesia, Haiti and Reunion But all hybrid oils were having main components like Khusilal, Khusinol, Khusimol and Khusol Certain components like Khusimol, Khusol were common in both wild and cultivated vetiver oils but Khusilal and Khusinol were chemomarkers of wild vetiver oils

Odour evaluation of hybrids viz , hybrid 7, 8, 16 and 26 was carried out with standard oils Confirmed findings of gas chromotography revealed that all hybrids were more towards North Indian style though lacking somewhat in odour volume Whenever there was increase in Khusilal peak, aldehyde note got increased This had also been observed among different oil samples of Bharatpur (wild) type Among the 4 hybrids under study hybrid 7 and hybrid 8 were superior in odour and were evolved from the cross Though hybrid 7 gave better tope note in comparison to hybrid 8, the odour of hybrid 8 develop later on, growing more sweet balsamic characters Its overall effect was preferred and considered attractive enough as compared to others (Maheswari, 1985)

A perusal of values presented for physicochemical properties of essential oil of the vetiver germplasm showed that most of the National Collections were characterised with high leavo specific rotation, high ester values as well as free vetiverol content Free vetiverol in the case of NC 66416 was to the tune of 79 09% with the total vetiverol content of 85 74% This genetic line gave highest leavo rotation (68), lowest acid value (13 01) and ester value (16 96) Accession NC 66403, NC 66404 and NC 66408 gave dextro optical rotation and contained less free vetiverol (Maheswari et al , 1986)

Sethi et al (1986) confirmed from their study on National Collection that out of the 21 germplasm collections under study most preferred was NC 66416 where overall odour effect was very attractive with specific saffron type tope note and long lasting sweet balsamic note whereas among others most preferred were NC 66404 and NC 66403 having round note Odour of NC 66406 was superior to that of NC 66403 and would be useful when good quality vetiver was preferred Other types which follow in the decreasing odour value were NC 66415, NC 66413 and NC 66423

Materials and Methods

MATERIALS AND METHODS

The present experiment was conducted in the Department of Agricultural Botany, College of Horticulture, Vellanikkara during the period 1989-91 Germplasm of vetiver including selections and hybrids available in the AICRP on M & AP project were used for the present study They were evaluated by observing the biometric characters like root length, root diameter, root spread, number of roots per plant, root yield, oil yield, root shoot ratio etc and also by studying the physico-chemical properties of oil like specific gravity, ester value, ester content, acid value, refractive index, optical rotation, major chemical constituents etc

The experimental area was located in the main campus of Kerala Agricultural University at 10° 32' N latitude and 76° 10' E longitude at an altitude of 22 25 m above MSL

The details of the meteorological observations recorded during the crop period (18 months) are presented in Appendix-I

The details of materials and techniques adopted during the course of the investigation are presented hereafter

3.1. Soil analysis

Composite soil samples were taken and used for the determination of physico-chemical properties and the data are given below

3 1 1 Mechanical composition

Fraction	Per cent composition	Procedure adopted
Coarse sand	26 18	Robinson International
Fine sand	27 10	Pipette method
Clay	36 20	(Piper, 1950)
Silt	10 00	
Textural class	Sandy clay loam	ISSS system

3 1 2 Chemical properties

Description of properties	Values	Method employed
Organic carbon	0 47%	Walkley and Black rapid titration method (Jackson, 1958)
Available nitrogen	0 058%	Alkaline permanganate method (Subbiah and Asija, 1956)
Available phosphorus	0 003%	Chlorostannous reduced molybdophosphoric blue colour method in hydrochloric acid system (Jackson 1958)
Available potassium	0 003%	Flame photometry, neutral normal ammonium acetate extraction (Jackson, 1958)

Soil reaction (pH)	5 4	Soil water suspension of 1 2 5 (Jackson, 1958)
Electrical conductivity mmhos/cm	0 35	Soil water extract of 1 2 5 (Jackson, 1958)

3.2. Experimental material

The following five selections and 4 hybrids of vetiver were received from National Bureau of Plant Genetic Resources, IARI Campus, New Delhi namely NC 66403, NC 66404, NC 66406, NC 66415, NC 66416 (5 selections), hybrid 7, hybrid 8 and hybrid 26 (3 hybrids) and ODV-3 a local variety collected from Nilambur and maintained at AMPRS, Odakkali was used as control The eight entries were compared with the ODV-3 using a randomised block design with four replications

The experimental field was thoroughly ploughed 4-5 times to get a uniform soil condition Four blocks were made in the experimental area The size of each plot was 4 x 5 m (Gross) 3 6 x 4 m (Net)

Inorganic fertilizers alone was used for the crop Fertilizers used in this experiment were urea (46 per cent N) super phosphate (16 per cent P_2O_5) and muriate of potash (60 per cent K_2O) The fertilizers were applied at the rate of 60 30 30 kg N,

P_2O_5 and K_2O per hectare respectively Half of the fertilizer dose was applied during planting, $\frac{1}{4}$, 2 months after planting and remaining $\frac{1}{4}$, 8 months after planting

3.3. Pedegree of the experimental materials

Treatments	Pedigree	
Hyb 7	39-1 x 48-2	From Pusa, New Delhi
Hyb 8	39-1 x 48-2	
Hyb 26	55-2 x 35-5	
NC 66403	Collections made from Bharatpur - Bayana, Bharatpur - Sewar, Bharatpur - Agra and Roophas highways adjoining the unprotected reserve forests in Bharatpur district of Rajasthan	
NC 66404		
NC 66406		
NC 66415		
NC 66416		

ODV-3 - Collection from Nilambur (maintained at AMPRS, Odakkali)

3.4. Planting

Slips of 6-10 cm length were planted on 9-6-89 at the rate of 3 slips per hole 5-8 cm deep at a spacing of 45 x 30 cm The soil around the slips were pressed firmly and levelled Gap filling was done after 3 weeks

Periodical weeding was done during the first 4 months By this time the shoot portion had attained sufficient growth to cover the soil in between the hills, which smother the weed

growth However, weeds in between the blocks were removed after every 3 months

3.5. Harvesting

Harvesting was done after eighteen months of planting, before the onset of monsoon, since harvesting roots during rainy season might reduce the oil yield considerably

The soil around the hills was moistened before digging started Shoot portions were cut uniformly at 10 cm above the soil surface and were tagged accordingly The roots were dug by using pick-axe and long thick iron rods The soil around the hills was loosened by few sturdy strokes The clumps were then uprooted with clodes of soil adhering to it The clods of earth were separated from the roots with hoe handle All observations of roots were taken after thorough washing It was then dried and bundled

3.6. Characters studied

Observations were taken from five plants at random marked out from each replication for each treatment, after leaving the border plants The following characters were chosen for study in the present investigation

3 6 1 Shoot weight

Shoot weights of five observation plants were taken separately on dry weight basis i e after drying in sunlight for 3 days first and then drying in hot air oven, at 70-80°C

3 6 2 Root length

Length of root from the base of the clumps to the tip of the roots was measured and recorded in centimeters

3 6 3 Root spread

Root spread was taken by spreading the side roots to the maximum to both sides and measured the entire length from one side to other in centimeters

3.6 4 Root diameter

Diameter of root was taken (basal portion of root, 1 cm away from the clump was used for taking the same) on an average using vernier calipers and recorded in millimeters

3 6 5 Number of roots per plant

Number of roots produced per plant were counted and recorded

3 6 6 Root yield

Root yields of all plants were taken on dry weight basis after drying in sunlight for 3 days For confirmation drying in hot air oven at 70-80°C was also done The root yield per hectare was then calculated

3.6.7 Shoot root ratio

Shoot root ratio was obtained by taking the root and shoot weights separately from each plant Five observation plants from each replication were considered for getting the same.

3 6 8 Oil yield

Oil yield was estimated by taking 3 samples from each replication and distilling 100 g dry root, for 8 hours continuously The oil percentage in millilitre was then converted into litres per hectare by multiplying the oil yield per kilogram of root with the total root yield per hectare

3.7. Physico-chemical properties of the oil

The samples obtained from each treatment was examined for all important physical and chemical parameters by standard analytical procedures The oil collected was analysed by Gas-Liquid Chromatograph also

3 7 1 Physical properties

Physical properties such as specific gravity and refractive index were determined by the methods prescribed by Guenther (1950) and Indian Standard Institution, IS 326

3 7 2 Chemical constituents and chemical properties

Gas liquid chromatographic analysis of the oil obtained from all treatments was conducted by using Sigma make FID, Gas chromatograph of Dev Aromatics, Cochin The carrier gas used was Nitrogen (2 4 kg/cm^2) and Hydrogen as burning gas (1 2 kg/cm^2), column material used was 10% SE30, oven temperature 200°C and FID temperature 250°C

Volume of the sample used was 0 ? µl The quantity of the main components viz , vetiverol, vetiverone and terpenes were identified by comparing their retention times with those of the authentic reference sample

3.8. Statistical analysis

The data pertaining to the different biometric characters were recorded and tabulated These data were subjected to analysis of variance (Panse and Sukhatme, 1967)

3 9 Pot culture experiment

In order to compare the performance and to formulate a descriptive blank for each cultivar under study vetiver types viz hybrid 7 hybrid 8 hybrid 26 (3 hybrids) NC 66403 NC 66404, NC 6641 NC 6416 (5 selections) ODV-3 and Kaipamangalam were raised in concrete pots of 40 cm diameter and 50 cm height Kaipamangalam was used in the study since it was the most common type of vetiver cultivated on a large scale in the coastal belt of Trichur One plant from one treatment was grown in each pot Plants were harvested after 18 months Dry root (100 g each) was distilled in clevenger apparatus for 8 hours to assess the oil yield Observations on vegetative and floral characters were recorded as detailed below

3 9 1 Shoot characters

3 9 1 1 Plant height Length from the base of the culm to the tip of the terminal leaflets was recorded for five tillers from each pot and the average was worked out

3 9 1 2 Leaf length From the total number of five tillers (selected at random) the total length of leaves was taken and the mean for each tiller and that again for each leaf was calculated

3 9 1 3 Leaf width Width of leaves (middle portion of leaf where the width is maximum) was recorded for five tillers and the average was arrived at

3 9 1 4 Terminal leaflet length Length of terminal leaflets of five tillers of each entry was taken and the mean value was worked out

3 9 1 5 Leaf colour Colour of the leaves from each entry was noticed

3 9 1 6 Leaf shape Shape of leaves was observed and classified

3.9.1.7 Number of leaves per tiller Total number of leaves in 5 tillers were taken and the average number of leaves in each tiller was recorded

3 9 1 8 Internodal length Length of the third internode from the base of 5 tillers was taken and mean value was calculated

3 9 1 9 Number of nodes/tiller Number of nodes of 5 tillers was counted and the mean number worked out

3 9 1 10 Number of tillers/clump Total number of tillers of each entry was taken and recorded

3 9 1 11 Shoot weight (Dry weight) Shoot weights were taken and expressed in grams

3 9 2 Root characters

3 9 2 1 Root length Average length of roots for each entry was measured

3 9 2 2 Root spread Root spread was taken for each entry (It is the maximum spread of the roots to both sides from the clump)

3 9 2 3 Root diameter Root diameter was taken as the thickness of root one centimeter away from the clump by using vernier calipers Measurement from 10 roots were taken and average was arrived at

3 9 2 4 Number of roots Number of roots for each entry was counted and recorded

3 9 2 5 Root weight (Dry weight) Root weight for each entry was taken and expressed in grams

3 9 2 6 Root colour Colour of root was observed and classified accordingly

3 9 2 7 Shoot root ratio The shoot root ratio on dry weight basis was worked out

3 9 3 Floral characters

3 9 3 1 Panicle colour Colour of panicle was observed for each entry

3 9 3 2 Panicle length Panicle length from 5 tillers was taken and the average was recorded

3 9 3 3 Peduncle length Average penduncle length was calculated

3 9 3 4 Length of rachilla Length of ten rachilla (from middle portion of rachis) of each panicle was taken and average length was worked out from panciles of five tillers selected at random

3 9 3 5 Number of whorls of branches/rachilla Total number of whorls/panicle of five tillers was taken and average number of whorls/panicle in each tiller was calculated

3 9 3 6 Spikelet number/rachilla Number of spikelets was counted for ten rachillae/panicle selected at random from each tiller and average was worked out from 5 tillers

3 9 3 7 Length of spikelets Length of both sessile and pedicellate spikelets were taken Ten spikelets were observed per panicle of each tiller Average value was arrived at after observing the character in five tillers

3 9 3 8 Days to flowering Number of days taken for first flowering was recorded for each entry

3 9 4 Oil percentage

Oil percentage was calculated by taking a sample from each entry and distilling 100 g dry root for 8 hours continously

Results

RESULTS

4.1. Biometric characters

Observations taken for field experiment were subjected to statistical analysis and the results are presented below

4 1 1 Shoot weight (per plant)

From the Table 1 it could be seen that there was significant difference in shoot weight among the treatments It ranged from 256 250 g to 401 675 g Maximum value was obtained in ODV-3 (401 675) and minimum value in NC 66404 (256 250) Hybrid 8 recorded the second highest (381 063) followed by NC 66403 (325 063), NC 66416 (288 688), hybrid 7 (286 688) hybrid 26 (285 063), NC 66406 (281 563) and NC 66415 (274 563)

4 1 2 Root length

Root length of the types studied ranged from 27 450 cm to 44 18 cm The entry NC 66406 had the shortest root (27 450) and ODV-3 had the longest root (44 181) followed by hybrid 8 (41 258), hybrid 7 (37 551) NC 66404 (33 836), hybrid 26 (31 656), NC 66416 (31 405), NC 66415 (31 156) and NC 66403 (31 100) The data showed significant difference for the character (Table 1)

Plate 1 A view of the vetiver crop in the field

4 1 3 Root spread

From the result it could be seen that there was significant difference in root spread among the treatments Root spread varied from 46 687 cm to 76 488 cm (Table 1) Minimum value was recorded in NC 66406 (46 681) and maximum in ODV-3 (76 488) The other treatments were in the series as follows

Hybrid 8 (73 526), hybrid 7 (66 564), NC 66404 (58 368), hybrid 26 (54 995), NC 66416 (54 961), NC 66403 (54 748) and NC 66415 (53 0)

4 1 4 Root diameters

Root diameter varied from 1 26 mm to 1 65 mm (Table 1) NC 66416 had the maximum root diameter (1 65) and ODV-3 had the minimum root diameter (1 26) The other treatments were in the order as follows

NC 66403 (1 585), NC 66404 (1 528), NC 66415 (1 465), hybrid 7 (1 465), hybrid 26 (1 388), NC 66406 (1 348) and hybrid 8 (1 300)

4 1 5 Number of roots

The data showed that ODV-3 was significantly superior to all other treatments (Table 1) The number of root had a range

of 142 688 to 289 863 The minimum number was in NC 66404 (142.688) and maximum in ODV-3 (289 863) The number of roots in other treatments were Hybrid 8 (223 688) hybrid 7 (198 813) NC 66403 (184 813), NC 66406 (181 50), hybrid 26 (169 188), NC 66416 (164 063) and NC 66415 (156 813)

4 1 6 Root weight (per hill)

The data showed that there was significant difference in root weight of the different treatments under study (Table 1) The range was from 43 285 g to 75 093 g NC 66404 recorded the minimum root weight of 43 285 g and ODV-3 recorded the maximum of 75 091g This was followed by hybrid 8 (64 3), NC 66403 (56 47), NC 66416 (53 205), hybrid 7 (52 632), NC 66406 (50 983), NC 66415 (49 027) and hybrid 26 (45 83)

4 1 7 Root yield (per hectare)

The per hectare root yield varied from 1 70 tonnes to 4 9 tonnes (Table 1) Maximum yield was recorded in ODV-3 (4 9) and minimum in NC 66415 (1 7) The other treatments viz , NC 66404, NC 66416, hybrid 26, NC 66463, NC 66406 and hybrid 7 had the values 2 43, 2 93, 3 33, 3 55, 3 68, 3 48 and 4 42 respectively

4 1 8 Shoot root ratio

Shoot root ratio mean values ranged from 5 362 (ODV-3) to 6 263 (hybrid 26) (Table 1) Statistical analysis showed that there was no significant difference among the treatments The values in the ascending order were 5 423 (NC 66416) 5 4 5 (hybrid 7), 5 53o (NC 66 06), 5 598 (NC 66415) 5 765 (NC 66403) 5 930 (NC 66404) and 5 955 (hybrid 8)

4 1 9 Oil percentage (per 100 g dry root)

From the Table (Table 1) it could be seen that NC 66404 (0 745) was significantly superior to all other treatments The minimum was obtained in ODV-3 (0 227) and other values in the ascending order were hybrid 26 (0 27) hybrid 7 (0 308) NC 66406 (0 368), NC 66416 (0 408), hybrid 8 (0 505), NC 66403 (0 558) and NC 66404 (0 633)

4 1 10 Oil yield (per hectare)

Per hectare oil yield ranged from 8 85 litres to 22 63 (Table 1) The maximum oil yield was recorded in hybrid 8 and the minimum in hybrid 26 The other values were in between these two, viz , 11 15 (ODV-3), 11 50 (hybrid 7), 11 95 (NC 66416), 12 60 (NC 66415), 13 60 (NC 66406), 15 03 (NC 66404) and 19 67 (NC 66403)

Table 1 Observation on the biometric characters*

	Shoot weight (g)	Root length (g)	Root spread (cm)	Root diameter (cm)	Number of roots	Root weight per plant (g)	Root yield per hectare (t/ha)	Shoot-root ratio	Oil percentage (%)	Oil yield per hectare (l/ha)
Hyb 7	286 688	37 551	66 564	1 425	198 813	52 633	3 78	5 475	0 308	11.50
Hyb 8	381 063	41 258	73 526	1 300	223 688	64 300	4 42	5 955	0 505	22.63
Hyb 26	285 063	31 656	54 995	1 388	169 188	45 830	3 33	6 262	0 270	8.85
NC 66403	325 063	31 100	54 748	1 585	184 813	56 470	3 55	5 765	0 558	19.67
NC 66404	256 250	33 836	58 368	1 528	142 688	43 285	2 43	5 930	0 633	15.03
NC 66406	281 563	27 450	46 681	1 348	181 500	50 983	3 68	5 535	0 368	13.60
NC 66415	274 563	31 156	53 000	1 465	156 813	49 027	1 70	5 598	0 745	12.60
NC 66415	288 688	31 405	54 961	1 650	164 063	53 205	2 93	5 428	0 408	11.95
ODV-3	401 675	44 181	76 488	1 260	289 863	75 093	4 90	5 362	0 227	11.15
SEm+	24 9538	0 6234	1 0677	0 0106	14 4963	1 7187	0 6765	0 5141	0 0368	1 760
CD (0 05)	51 5047	1 2868	2 2037	0 0218	29 9204	3 5474	0 3643	NS	0 0760	3 6417

* Field experiment

The data pertaining to the physico-chemical properties of the oil are presented in Tables 4 and 5

4.2 Physical properties

4 2 1 Refractive Index

Refractive index ranged from 1 517 to 1 524 (Table 2) The highest value was observed in NC 66415 (1 52434) and the lowest in hybrid 7 (1 51750)

4 2 2 Specific gravity

The data showed that NC 66416 had the highest value (0 9995) and ODV 3 had the lowest value (0 92468 (Table 2)

4 2 3 Optical rotation

Highest value of laevo rotation was observed in NC 66416 (-75) and the lowest in hybrid 7 (-48) ODV-3 had dextro-rotatory oil (+18)

4.3. Chemical properties

4 3 1 Acid value

Acid value ranged from 15 26 to 38 47 (Table 3) Maximum acid value was obtained in hybrid 8 (38 47) and the minimum was in NC 66416 (15 26)

Table 2 Physical properties of oil

Properties	Hyb 7	Hyb 8	Hyb 26	NC 66403	NC 66404	NC 66406	NC 66415	NC 66416	ODV-3
Refractive Index	1 51756	1 51834	1 51784	1 52034	1 52384	1 52134	1 52434	1 52334	1 52034
Specific gravity	0 9840	0 9768	0 9469	0 9994	0 9989	0 9990	0 9982	0 9995	0 92468
Optical rotation	-48	-58	-53	-72	-71	-68	-65	-75	+18

*Mean value

Table 3 Chemical properties of oil*

Properties	Hyb 7	Hyb 8	Hyb 26	NC 66403	NC 66404	NC 66406	NC 66415	NC 66416	ODV-3
Acid value	35 82	38 47	31 14	34 97	36 78	26 008	23 42	15 26	27 08
Ester value	47 14	42 86	43 16	42 09	50 56	50 48	48 49	42 65	43 01
Ester content	18 48	16 80	16 92	16 50	9 82	19 79	19 01	16 72	16 86
Total vetiverol	68 69	73 35	73 89	70 41	75 63	76 76	76 03	78 49	73 01

* Mean value

4 3 2 Ester content

Ester content had a range from 16 50 to 19 82 (Table 3) Highest values of 19 82 was recorded in NC 66404 and the lowest in NC 66403

4 3 3 Ester value

In the case of ester content, NC 66404 had the maximum value (50 56) and NC 66403 had the minimum (42 09) (Table 3)

4 3 4 Total vetiverol obtained by chemical analysis

Total vetiverol content was the highest in NC 66416 (78 40) and lowest in hybrid 7 (68 69) (Table 3) The other values in the ascending order were NC 66403 (70 41) ODV-3 (73 01) hybrid 8 (76 06), NC 66404 (76 63)

4.4. Free vetiverol, vetiverone and terpenes obtained by GLC analysis

4 4 1 Vetiverol

The maximum value was obtained in ODV-3 (57 67) and the minimum in hybrid 7 (35 67) (Table 4)

4 4 2 Vetiverone

Vetiverone content varied from 35 34 (ODV-3) to 55 50 (hybrid 8) (Table 4)

Table 4 Major constituents of vetiver oil (determined by GLC)

Constituents	Hyb 7	Hyb 8	Hyb 26	NC 66403	NC 66404	NC 66406	NC 66415	NC 66416	ODV-3
Vetiverol	35 67	37 85	41 06	51 30	46 69	45 38	45 86	51 09	57 67
Vetiverone	53 02	55 50	52 83	39 11	48 94	51 38	50 27	46 40	35 34
Terpenes	11 28	6 64	6 08	9 50	4 32	3 20	3 85	2 50	6 58

4 4 3 Terpenes

Terpene content was the maximum in hybrid 7 (11 28) and minimum in NC 66416 (2 50) (Table 4)

4.5. Morphological characters of vetiver types observed in pot culture experiment is furnished below:

4 5 1 Shoot characters

4 5 1 1 Plant height

The different types of vetiver exhibited difference in the character It ranged from 121 cm (NC 66415) to 176 cm (ODV-3)

4 5 1 2 Leaf length

With respect to leaf length the maximum value was obtained in ODV 3 and minimum in NC 66415 Leaf length varied from 67 cm to 102 cm

4 5 1 3 Leaf width

The values varied from 5 mm to 10 mm The highest value was observed in ODV-3 (10 mm) and lowest value in hybrid 8 (5 mm)

4 5 1 4 Terminal leaflet length

Terminal leaflet length ranged from 38 cm to 82 cm ODV-3 had the longest terminal leaflet and NC 66415 had the shortest

4 5 1 5 Leaf colour

There was no varietal difference for this character and hence this is not furnished in the table The leaf colour was pale green in all the cultivars

4 5 1 6 Leaf shape

Since there was no varietal difference for leaf shape, no data were presented It was observed that leaf blades were linear, acute, rigid and firm

4 5 1 7 Number of leaves/tiller

ODV-3 produced tillers with maximum number of leaves (10) and minimum of 8 leaves was recorded in NC 66403, NC 66407 and hybrid 8

4 5 1 8 Internodal length

Internodal length was the highest in ODV-3 (13 cm) and it was the lowest in NC 66415 (8 cm)

4 5 1 9 Number of nodes per tiller

Highest number of nodes was recorded in ODV-3 (12) and the lowest in NC 66415 NC 66416, hybrid 7 and hybrid 8 (8)

4 5 1 10 Number of tillers per clump

There was considerable difference among the entries with respect to the number of tillers ODV-3 had the maximum number of tillers (179) and NC 66404 had the minimum (72)

4 5 1 11 Shoot weight (dry weight)

ODV-3 had the maximum shoot weight (416 g) and NC 66404 had the minimum (262 g)

4 5 2 Root characters

4 5 2 1 Root length

Root length was found to vary widely among the different types It ranged from 27 5 cm (NC 66406) to 53 cm (ODV-3) The maximum root length in field grown crop was only 44 18 cm in ODV-3 Minimum length was almost the same in NC 66406 both in field and pot conditions

4 5 2 2 Root spread

Root spread was maximum in ODV-3 (81 5 cm) and minimum in NC 66406 (59 5 cm) Under field condition the maximum root spread was in ODV 3 (76 488 cm) and the minimum in NC 66404 (46 681 cm)

4 5 2 3 Root diameter

Root diameter was the highest in NC 66403 and NC 66416 (1 6 mm) and lowest in hybrid 7, hybrid 8 and ODV-3 (1 2 mm) The values did not show much variation from that of field condition

4 5 2 4 Number of roots

Wide variation was noticed in number of roots among the selected types ODV-3 stood first with 301 roots and NC 66404 was the last with 140 roots, whereas the values for the same under field condition were 289 863 and 142 688 respectively

4 5 2 5 Root weight (dry weight)

Root weight was found to be the maximum in ODV-3 (96 g) and minimum in NC 66404 (32 5 g) The maximum root weight in field grown crop was 75 093 g in ODV-3 and the minimum was 43 285 g in NC 66404

4 5 2 6 Root colour

Root colour was creamy white in South Indian cultivars (ODV 3, Kaipamangalam) while it was light brown and deep brown in hybrids and North Indian cultivars respectively

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k length m	37 5	44 0(	4	4 0(	1 65	37 50	31 1	3((	84	41 00	2 45	27 5(		37	31 41	36 10	44 18	53 x
⁶ʸ sr ead m	6(5	50	3	78 5(	4 99	68 00	59 7	(	8 3	71 0	4(	59 5	x	8 x	54 9	65 X	7 4	8
ᵖ d am er m	1 4ᵢ	20	30	1 20	39	1 30	1 54	1 (0	53	1 5	1 3	1 4	4			1 60	1 2(	1 2
umber of oot	198 80	242 00	2 69	246 00	169 19	222 00	184 81	240 00	142 69	140 00	181	282 00	15(8	231 00	164 06	245 00	289 86	301 00
Root weight plant g	52 63	61 00	64 30	67 50	45 83	55 00	56 47	63 00	43 29	32 50	50 98	92 00	49 03	56 50	53 21	62 50	75 09	96 0(
ᵗ ox weight plan	286 69	300 00	381 06	332 00	28 06	88 00	325 06	286 00	2 2	202 00	281 56	295 0(	27ᵢ 5	282 00	288 69	299 00	401 68	41(0(
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e d t a	1 50	9	2 63	19 90	8 85	4 07	19 67	5 70	03	9 60	13 50	20 40	12 (0	16 0	11 95	3 87	11 1	7 0

F C - Field condition
P C - Pot condition

4 5 2 7 Shoot root ratio

The shoot root ratio on dry weight basis was the maximum for NC 66404 (6 2) and minimum for NC 66406 (3 2) The other types showed ratios of 4 9 (hybrid 7, hybrid 8 NC 66415) 5 2 (hybrid 26), 4 5 (NC 66403), 4 7 (NC 66416 and Kaipamangalam) and 4 3 (ODV-3) The shoot root ratio was the maximum for hybrid 26 (6 263) and minimum in ODV-3 (5 362) under field condition

4 5 3 Floral characters

Most of the floral characters showed no difference among the selected types However, observations revealed that panicles were narrow, whorled, spikelets in pairs narrow, acute, appressed and awnless One spikelet was sessile and hermaphrodite, some what flattened laterally, with short sharp spines, 3 stamens and 2 plumose stigmas, and the other pedicelled and staminate

4 5 3 1 Panicle colour

Panicle colour appeared to be a distinct varietal character in vetiver ODV 3 had panicle of light green colour and NC 66403 and NC 66404 had purple colour The other types exhibited colour which were blendings of green and purple colours at different intensities

Fig 1 Comparative performance of shoot weight per plant of different cultivars under field and pot conditions

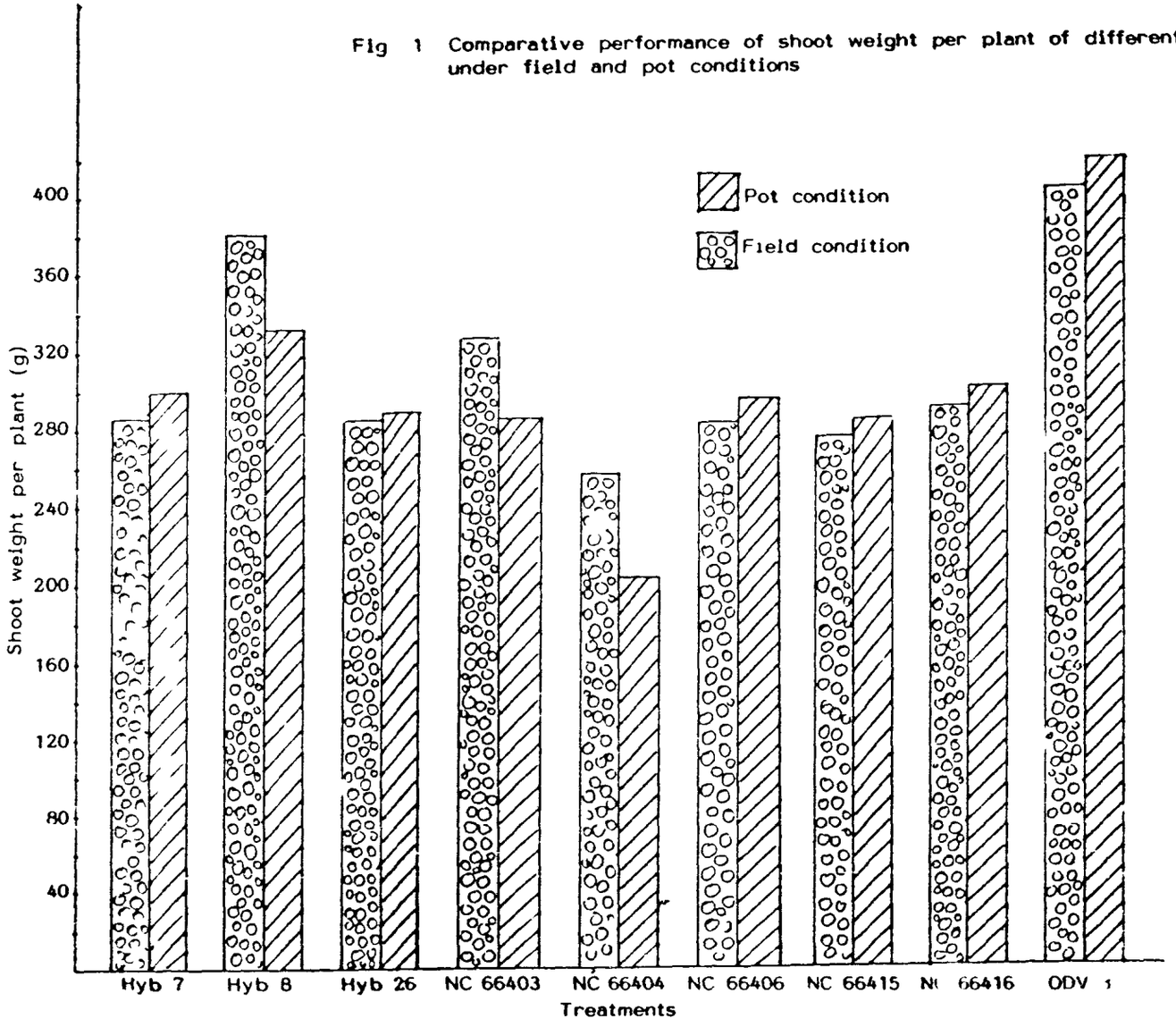
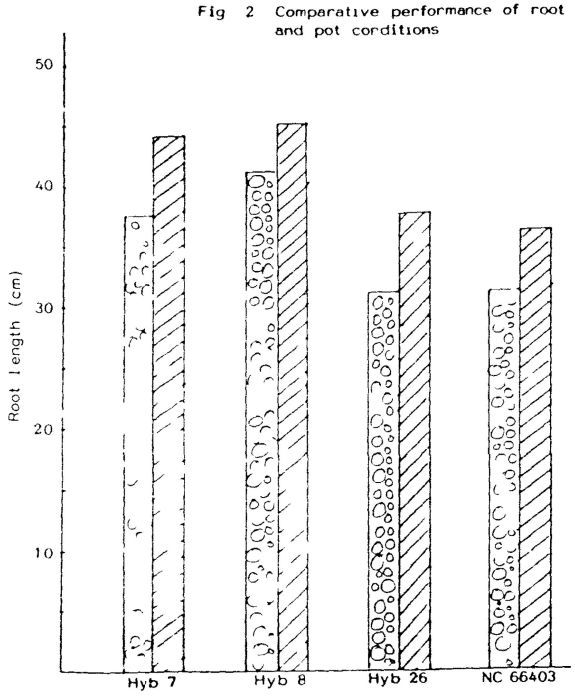


Fig 2 Comparative performance of root and pot conditions



length of different cultivars under field

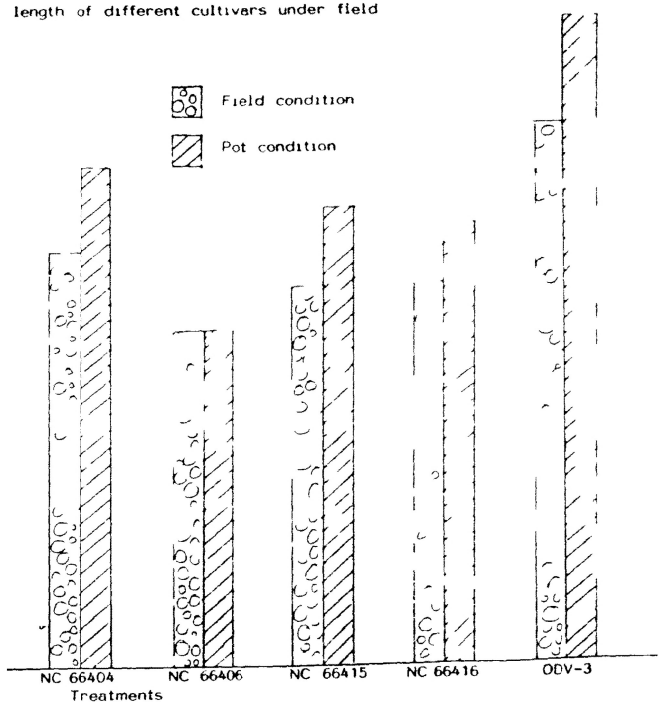


Fig 3 Comparative performance of root spread of different cultivars under field and pot conditions

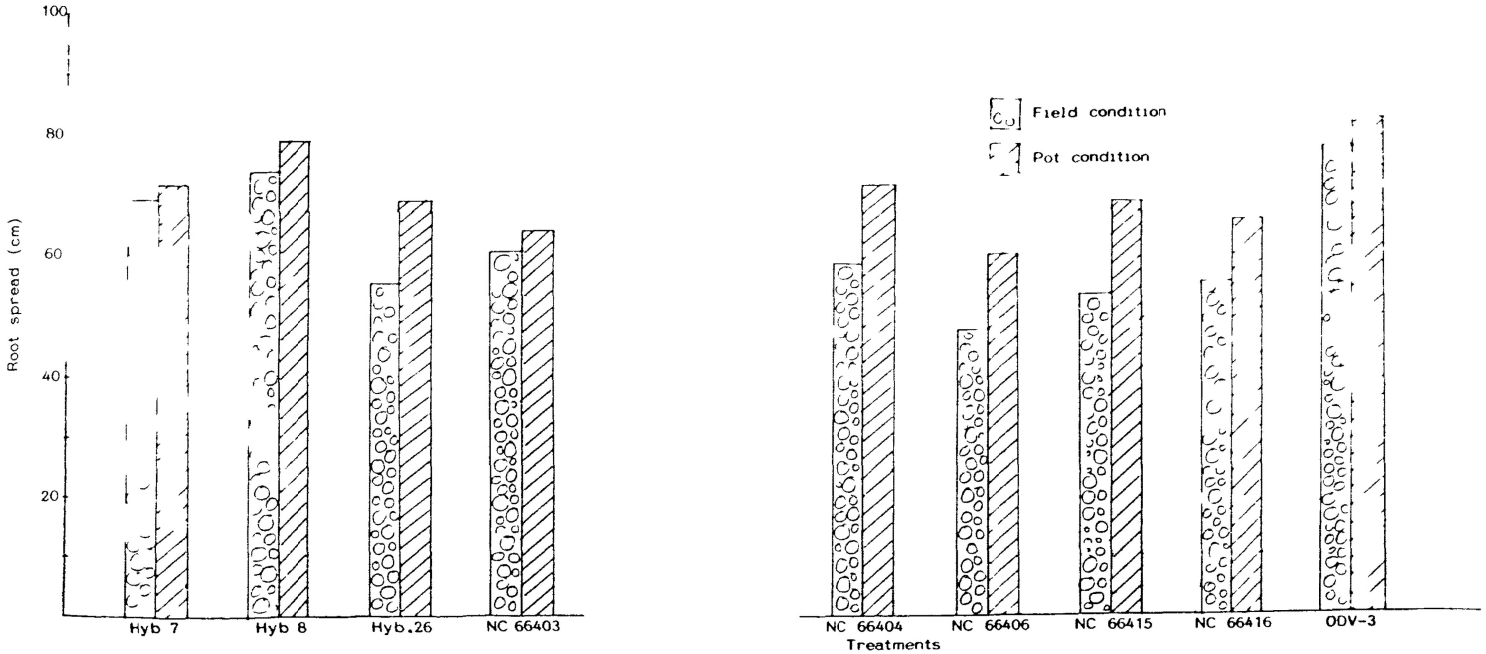


Fig 4 Comparative performance of root diameter of different cultivars under field and pot conditions

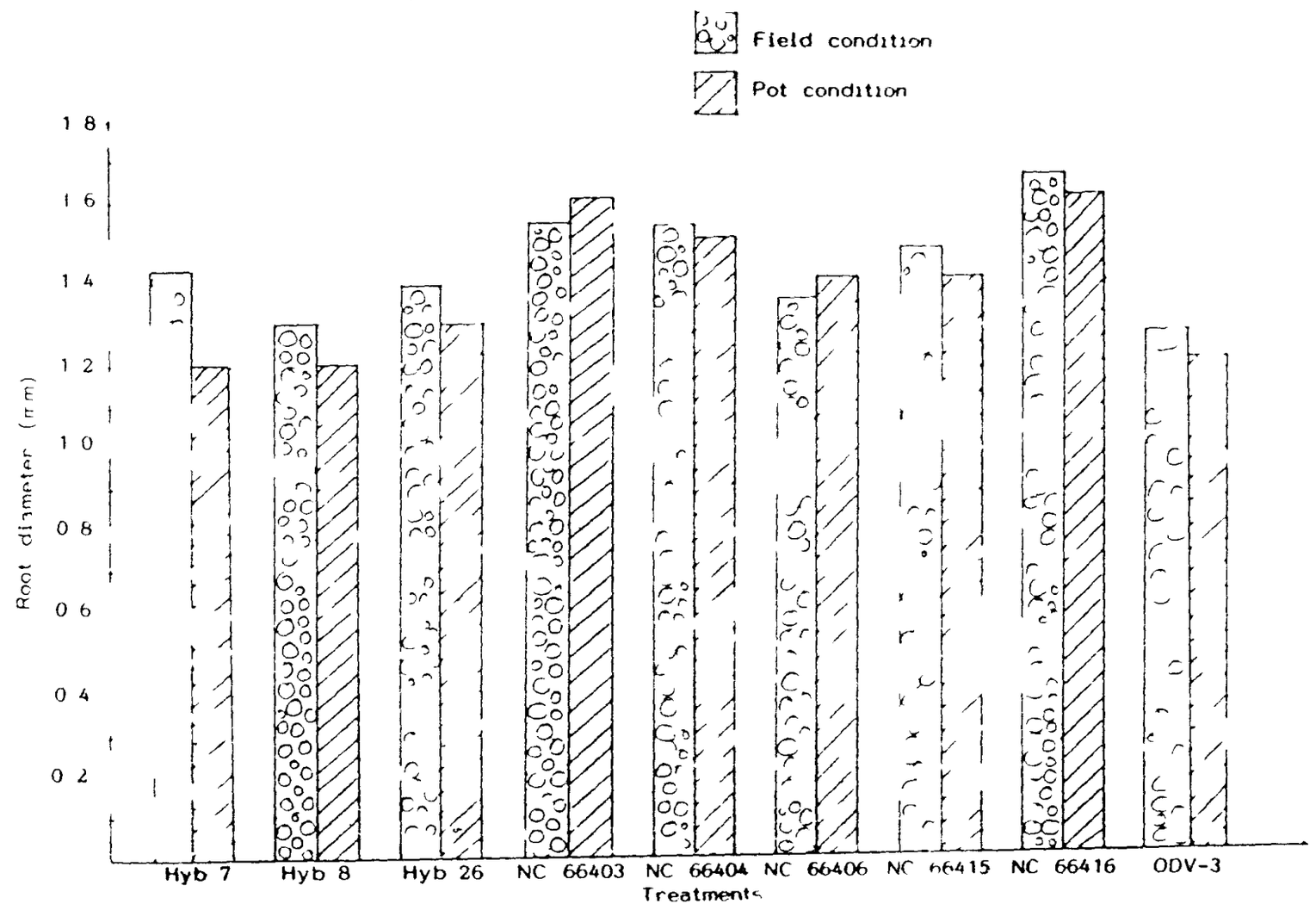


Fig 5 Comparative performance of number of roots of different cultivars under field and pot condition

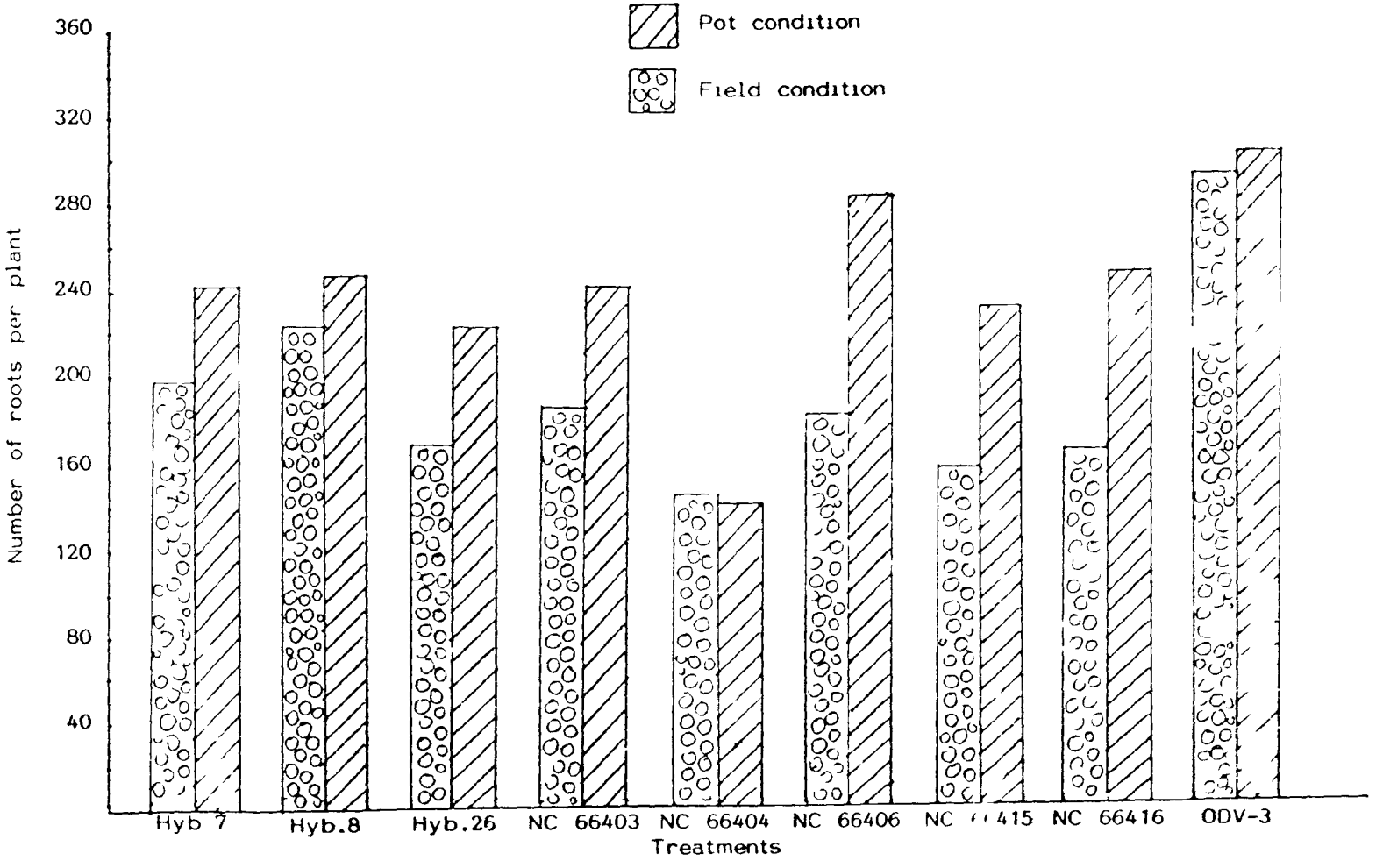


Fig 6 Comparative performance of root weight per plant of different cultivars under field and pot conditions

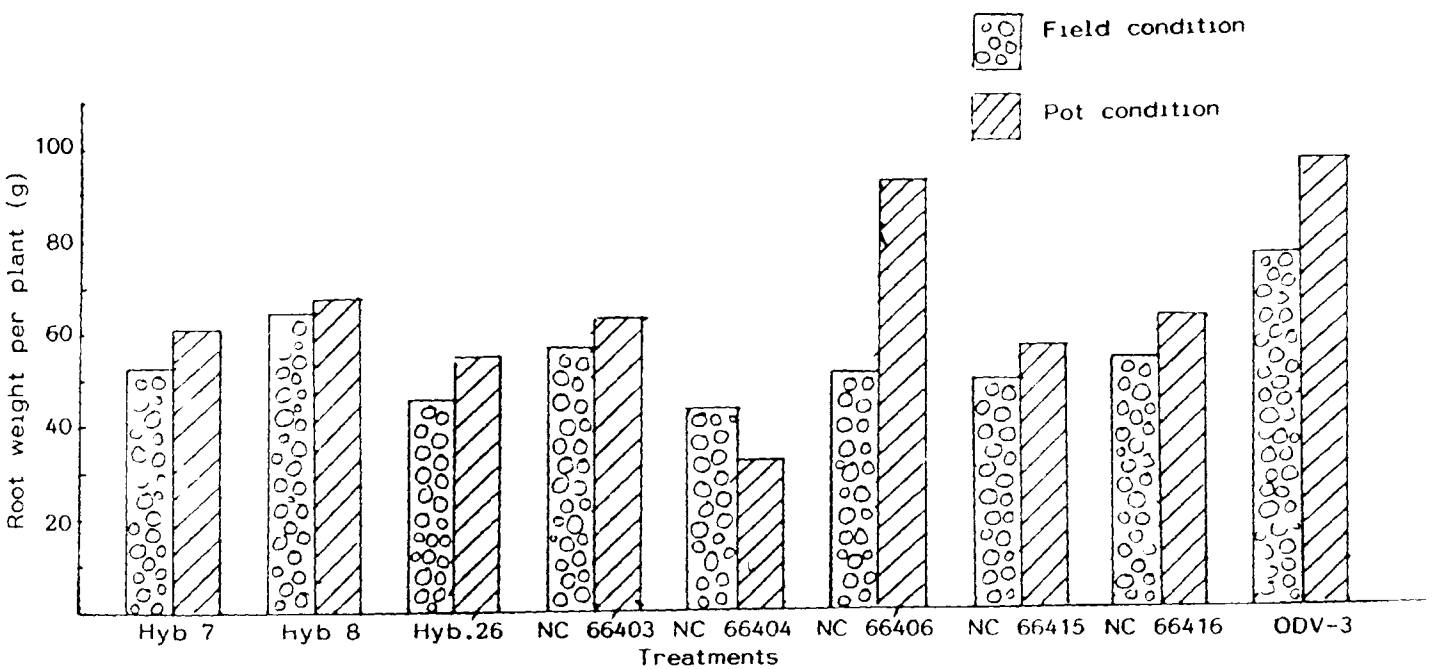
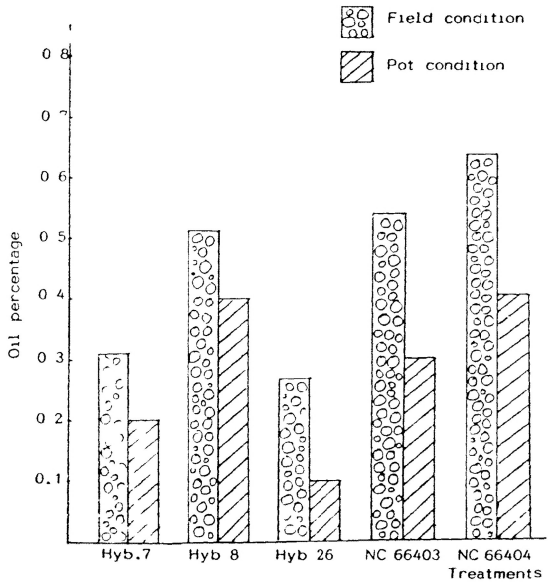


Fig. 7. Comparative performance of shoot root ratio of different cultivars under field and pot conditions

Fig 8 Comparative performance of c
and pot conditions



›il percentage of different cultivars under field

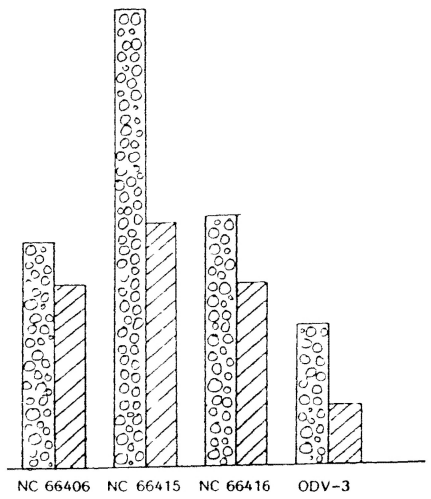
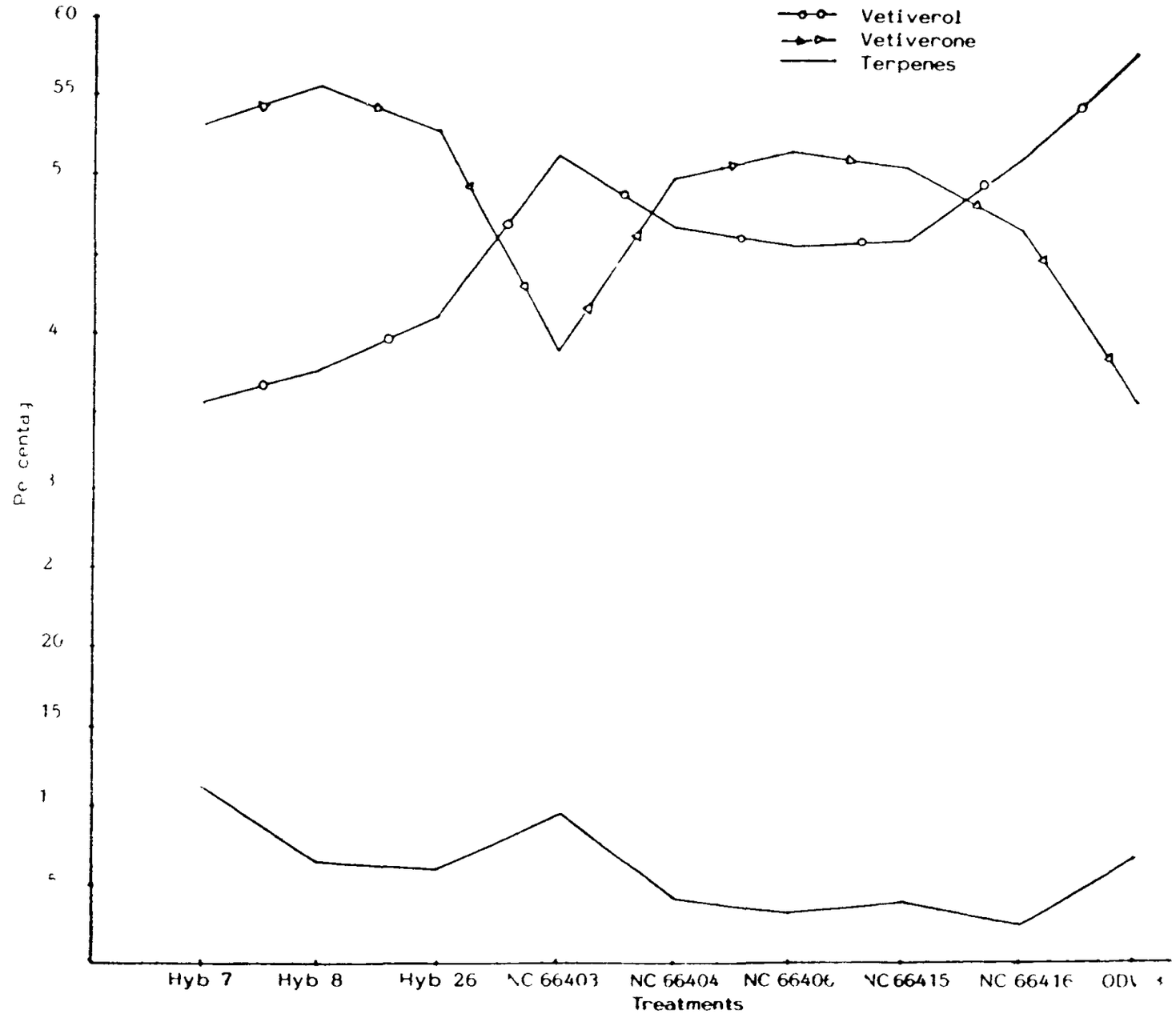


Fig 9 Percentage of major components of oil in different cultivars



4 5 3 2 Panicle length

From the result it could be seen that the different cultivars exhibited wide variation with reference to panicle length Maximum length was obtained in ODV-3 (93 5 cm) and minimum in NC 66403 (62 cm)

4 5 3 3 Peduncle length

Peduncle length ranged from 40 cm (NC 66403) to 60 cm (ODV-3)

4 5 3 4 Length of rachilla

With respect to the length of rachilla, the maximum value was recorded by hybrid 8 and NC 66404 (11 7 cm) eventhough the average value for hybrids and national collections were low South Indian cultivars Kaipamangalam and ODV-3 had values 8 6 cm and 8 2 cm respectively, which were comparatively higher than the average values of the North Indian cultivars

4 5 3 5 Number of whorls of branches/panicle

No significant difference was observed for this character between the North Indian and South Indian cultivars Number of whorls was the lowest in hybrid 7 (10) and highest in NC 66404 and ODV-3 (14)

4 5 3 6 Number of spikelets/rachilla

Maximum number of spikelets was recorded in NC 66404 (11) and minimum in NC 66403, NC 66415 and hybrid 26 with eight spikelets each

4 5 3 7 Length of spikelet

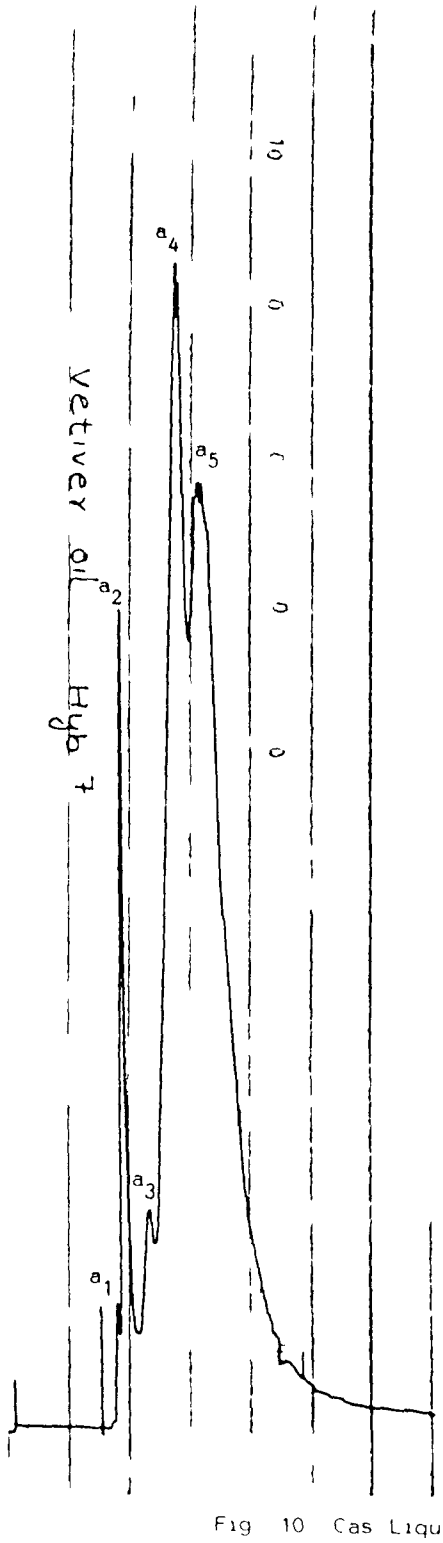
Hybrid 7, NC 66415 and NC 66406 had the longest spikelets The values for sessile and pedicellate spikelets were 4 5 mm and 6 7 mm respectively

4 5 3 8 Days to flowering

Number of days taken for flowering was the maximum in NC 66406 (197) and the minimum in ODV-3 (136)

4.6. Oil percentage

Highest oil percentage was recorded in hybrid 8, NC 66404 and NC 66415 (0 4%) and the lowest in hybrid 26, Kaipamangalam and ODV-3 (0 1%) The oil percentage in other accessions were 0 2% (hybrid 7), 0 3% (NC 66403, NC 66406 and NC 66416) In field grown crop, the highest oil percentage was obtained in NC 66404 (0 745%) and the lowest in ODV-3 (0 227%)



a_1 a_2 & a_3 - Terpene

a_4 - Vetiverol

a_5 - Vetiverone

Fig 10 Gas Liquid Chromatogram

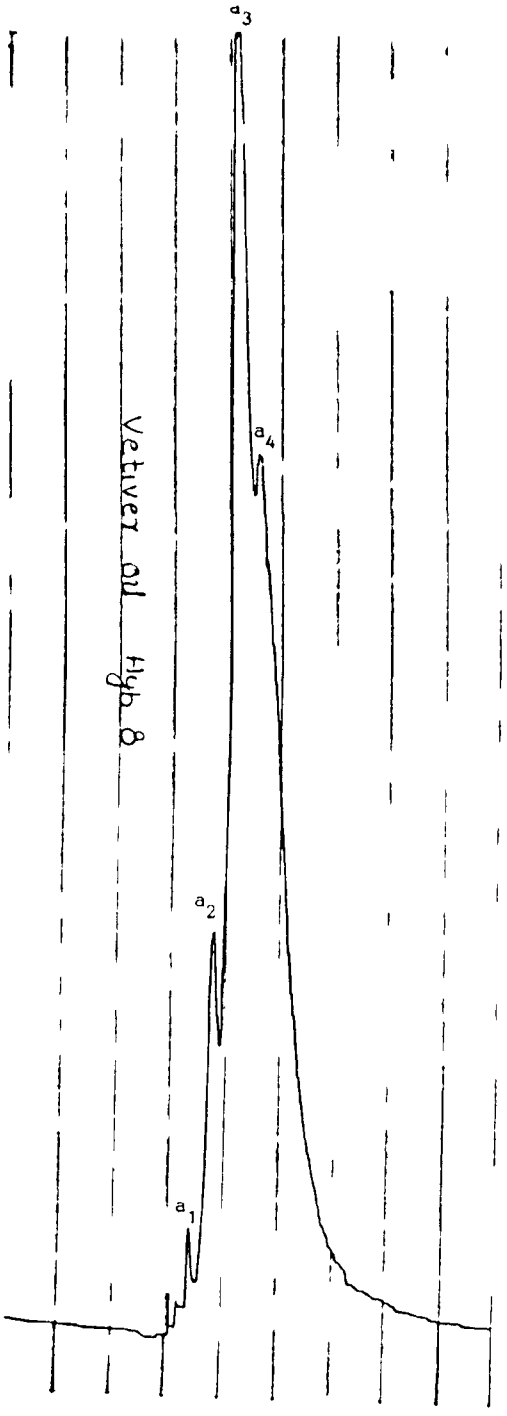


Fig 11 Gas Liquid Chromatogram

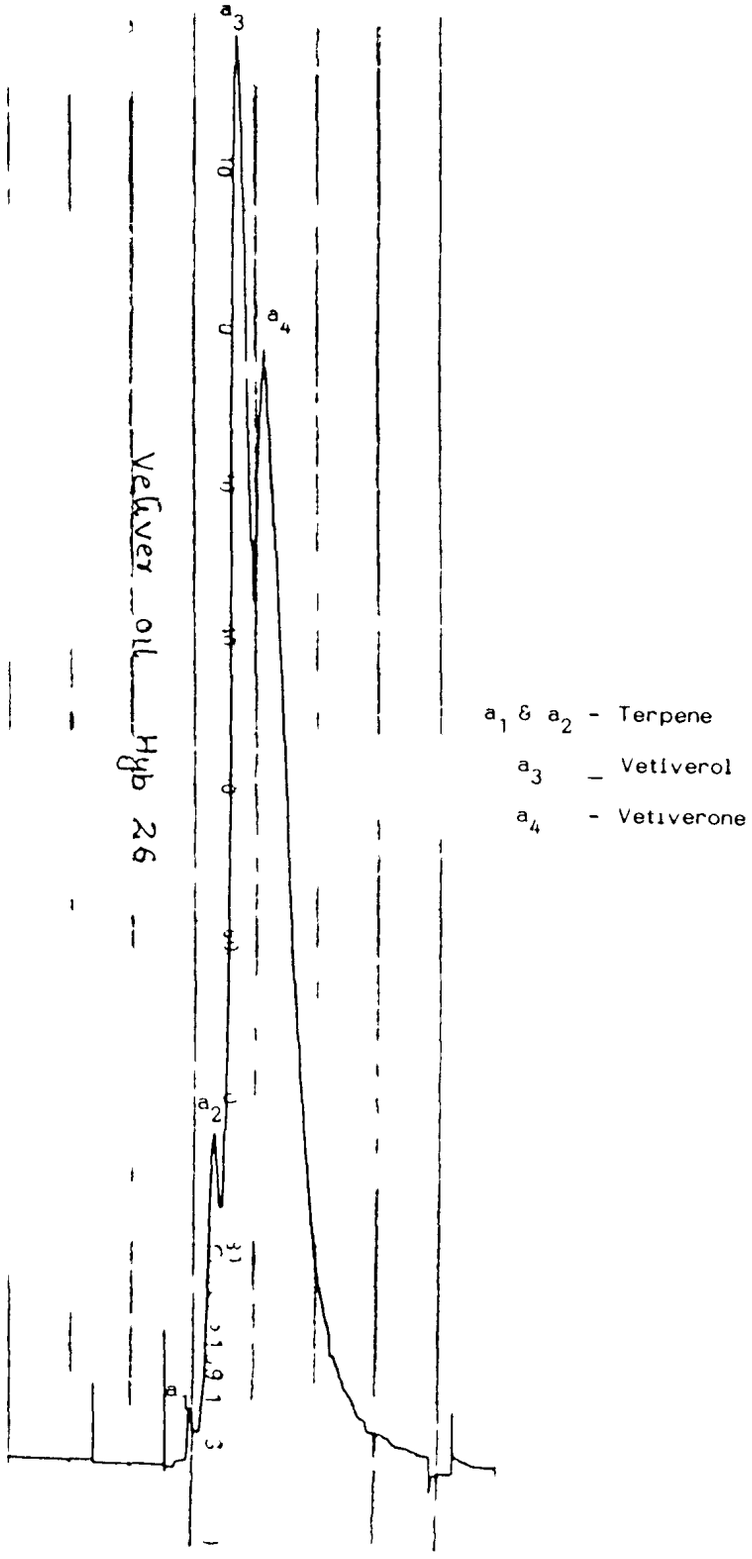


Fig 12 Gas Liquid Chromatogram

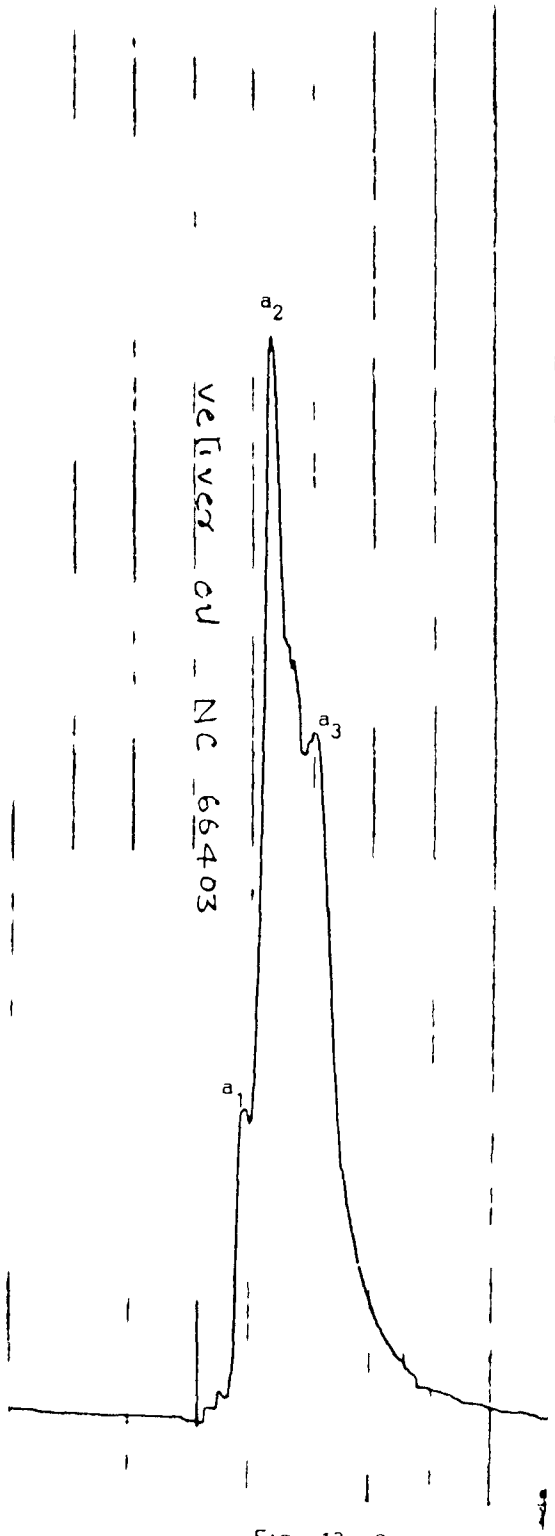
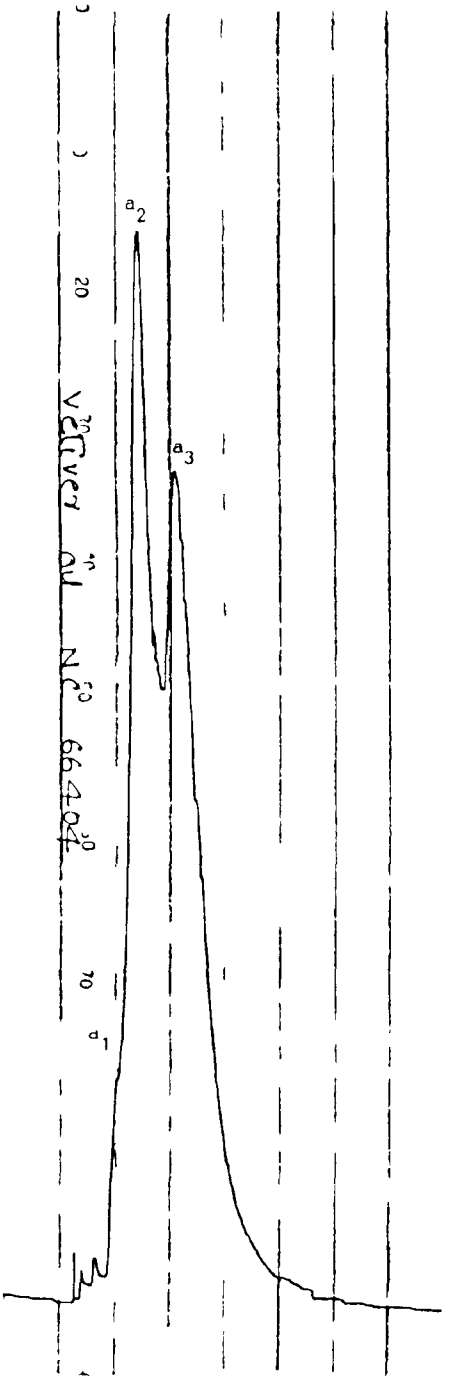


Fig 13 Gas Liquid Chromatogram

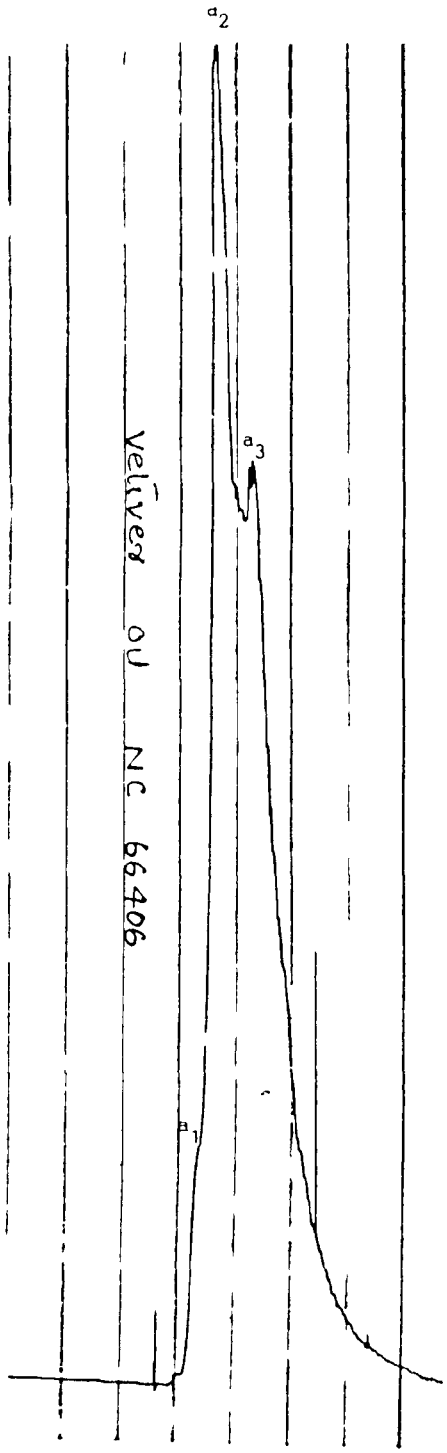


a_1 - Terpene

a_2 Vetiverol

a_3 Vetiverone

Fig 14 Gas Liquid Chromatogram

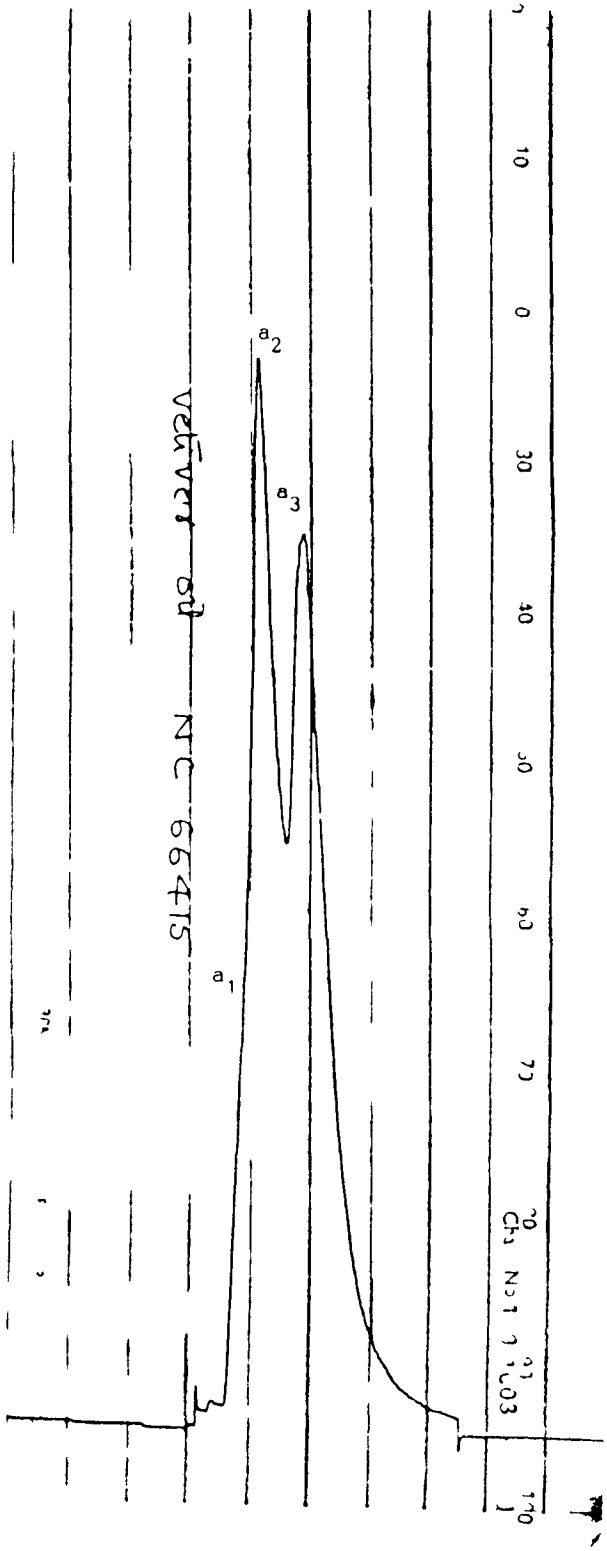


a_1 Terpene

a_2 Vetiverol

a_3 Vetiverone

Fig 15 Gas Liquid Ch o atogran



a_1 Terpene

a_2 - Vetiverol

a_3 - Vetiverone

Fig 16 Gas Liquid Chromatogram

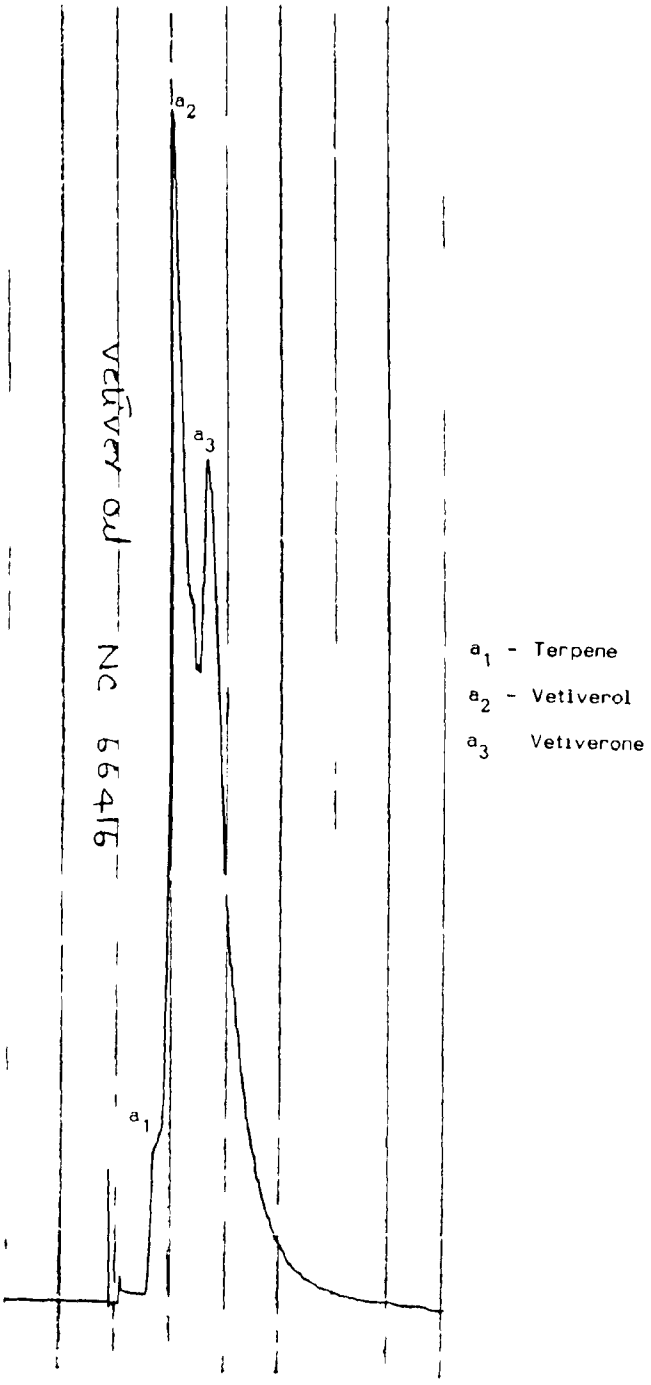


Fig 17 Gas Liquid Chromatogram

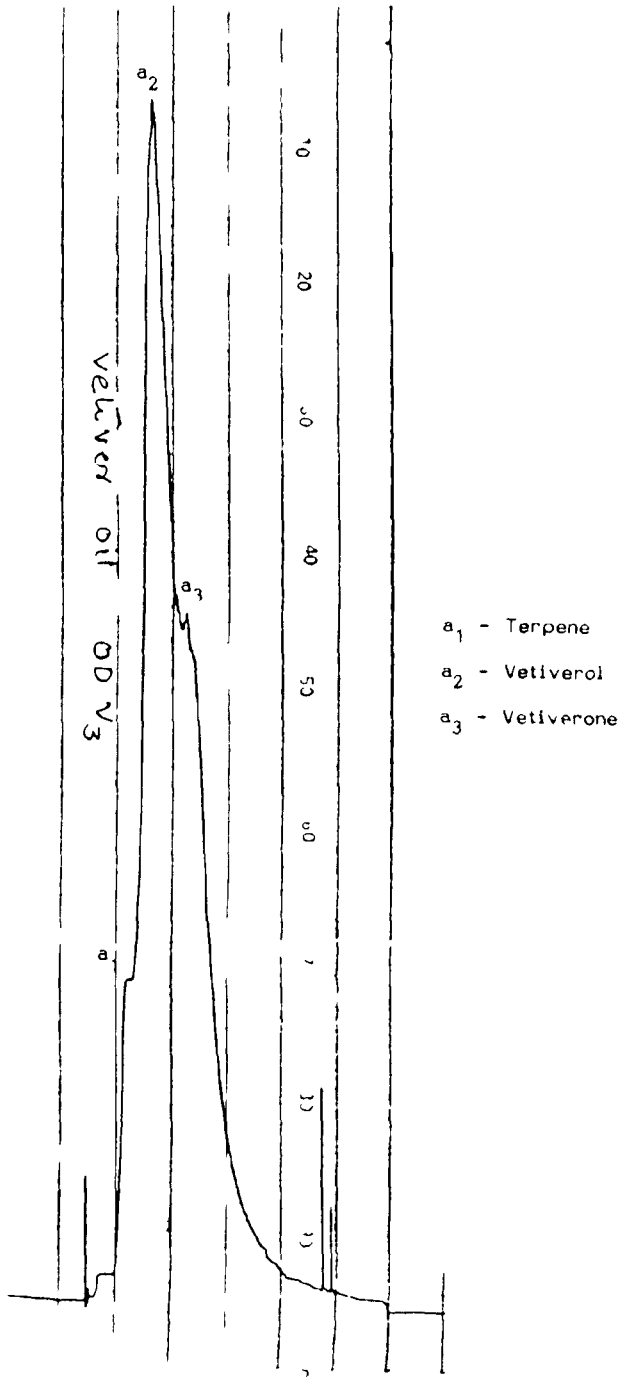


Fig 18 Gas Liquid Chromatogram

Descriptive Blank

A descriptive blank has been prepared for Vetiver The materials used for the study have been described and classified by using the same A critical study of the descriptive blank shows that the national collections hybrids and South Indian types can be distinguished by using the root characters and quantity and quality of oil No other vegetative character can be projeted as one by which the plant can be identified

Descriptors and Descriptor States

1	Accession No	Number denotes the indegenous accession number given at the headquarters of NBPGR
2	Description of source of collection	Original Source of collection 1 NBPGR New Delhi 2 AMPRS, Odakkali 3 AICRP on M & AP KAU
3	Acquisition date	Date on which the original collection is made A March 1988 B August 1988 C April 1988
4	Botanical name	Botanical name Vetiveria zizanioides (Linn) Nash

5	Other names	Names by which the plant was known earlier - Andropogon muricatus (Retz) Andropogon squarrosus (Linn)
6	Local name	Names by which the plant is known in local languages Sanscrit Usheera, Veeranam, Amaranalam Hindi Khus, Khusbena Bengali Khaskhas Gujarati Valo Maharashtra Vala Telugu Veti Vellu Vetti-veru Tamil Vettiver Malayalam Ramacham Kannada Lavanchi English Cuscus grass
7	Pedigree	Pedigree as given in the records of NBPGR
8	Wild/cultivated	Denotes the habitat of the plant Wild (w), Cultivated (c)
9	Family	Family to which the species belong - Gramineae
10	Duration of the crop	16-20 months
11	Leaf colour	Leaf colour is the same for all entries Pale green

12	Leaf shape	Leaf shape is linear in all entries
13	Terminal leaflet length	Measurement of length of the terminal leaves taken from 5 tillers and their average given in cm
14	Leaf length	Length of lamina taken from 5 tillers and their average given in cm
15	Leaf width	Measurement of width at the broadest point on the same leaves of 5 tillers and their average given in mm.
16	Number of leaves per tiller	Average number of leaves in each tiller
17	Number of tillers per clump	Number of tillers in each clump
18	Height of plant	Measurement of the distance from the base of culm to the tip of terminal leaflet for 5 tillers and their average represented in cm.
19	Internodal length	Measurement of the length of the 4th internode from the top of 5 tillers and their average represented in cm
20	Number of nodes per tiller	Number of nodes in 5 tillers and their average is given
21	Colour of root	Colour of root is depicted as creamy white (CW), Light brown (LB) and Dark brown (DB)

22	Root length	Average length of roots represerted in cm
23.	Root spread	Maximum spread of roots to both sides from the lump represented in cm
24	Root diameter	Diameter of root, 1 cm away from the clump taken for 10 roots and their average given in mm
25	Number of roots	Number of roots per clump
26	Root weight	Root weight per clump represented in grams
27	Shoot weight	Shoot weight per plant represented in grams
28	Shoot root ratio	Shoot root ratio calculated for each entry
29	Days to flowering	Number of days taken for Ist flowering
30	Panicle length	Measurement of length of panicle taken from 5 tillers and their average given in cm
31	Panicle colour	Panicle colour is represented as Light purple (LP), Deep purple (DP), Deep Green (DG) and Green Purple (GP))
32	Peduncle length	Measurement of length of peduncle taken from panicles of 5 tillers and their average given in cm

33	Length of rachilla	Average length of 10 rachillae taken and represented in cm
34	Length of sessile spikelets	Length of 10 sessile spikelets in each panicle of 5 tillers taken and the average is given in mm
35	Length of pedicellate spikelet	Length of 10 pedicellate spikelets in each panicle of 5 tillers taken and the average given in mm.
36.	Number of spikelets per rachilla	Average number of spikelets from 10 rachillae and that again for 5 tillers taken
37	Number of whorls of branches per rachilla	Average number of whorls of branches per panicle of 5 tillers
38	Seed set	All entries were found to produce seeds
39	Commercial use	Based on the purpose for which the plant is utilised it is grouped as that for roots (R) and that for oil (O)
40	Oil content	Percentage of oil in ml per 100 g dry root

Physico-chemical properties of oil

41	Refractive index	High (H) - >1.5 Low (L) - <1.5

42	Specific gravity	High (H) - > 1 0 Medium (M)- 90- 99 Low (L) - 0 90
43	Optical rotation	High Laevo-rotatory (HL) - $^{-}60$ Medium Laevo-rotatory (ML) - $^{-}40$-$^{-}60$ Low Laevo-rotatory (LL) - < $^{-}40$ High Dextro-rotatory (HD) - > $^{+}60$ Medium Dextro-rotatory (MD) - $^{+}40$-$^{+}60$ Low Dextro-rotatory (LD) - < $^{+}40$
44	Acid value	Very Low (VL) - 21-25 Low (L) - 26-30 Medium (M) - 31-35 High (H) - 36-40
45	Ester value	Low (L) - 26-35 Medium (M) 36 45 High (H) 46-55 Very High (VH) - 56-65
46	Ester content	Low (L) - 11-15 Medium (M) - 16-20 High (H) - 21-25
47	Total vetiverol	Low (L) - 50-59 Medium (M) - 60-69 High (H) - 70-79 Very High (VH) - 80-89
48	Vetiverone	Low - 26-35 Medium - 36-45 High - 46-55 Very High - 56-65

49	Vetiverol	Very Low (VL)	- 35-39
		Low (L)	- 40-44
		Medium (M)	- 45-49
		High (H)	- 50-54
		Very High (VH)	- 55-59
50	Terpene	Low (L)	- 1-5
		Medium (M)	- 6-10
		High (H)	- 11-15

1	2	3	7	8	13	14	15	16	17	18	19	20
Hybrid 7	1	A	39-1 x 48-2 of	C	59 5	87 5	6 2	9 2	114	153 0	12 0	9 5
Hybrid 8	1	A	39-1 x 48-2	C	61 5	76 3	5 3	8 9	132	150 6	10 0	8 0
Hybrid 26	1	A	55-2 x 35-5	C	58 1	73 2	7 2	9 1	105	142 5	12 2	8 0
NC 66403	1	B	Selection from Bharatpur	W	51 2	72 5	8 1	8 2	108	139 8	9 5	7 7
NC 66404	1	B	,	W	69 6	71 0	7 1	9 2	72	154 0	12 0	9 0
NC 66406	1	B	,,	W	48 5	73 1	7 0	8 5	128	135 0	8 5	7 2
NC 66415	1	B	,,	W	38 5	67 8	8 3	8 2	102	121 2	8 3	8 5
NC 66416	1	B	,,	W	68 2	82 2	7 2	9 0	108	145 4	10 4	8 0
ODV-3	2	C	Selection from Nilambur	C	82 0	102 5	10 5	10 0	179	176 0	13 5	12 5
Kaipamangalam	3	C	Collection from Kaipamangalam, Trichur District	C	46 0	73 0	9 1	9 5	122	152 0	10 5	10 2

Contd

Continued

21	22	23	24	25	26
LB	44 2	71 5	1 2	242	61 5
LB	45 0	78 5	1 2	246	61 5
LB	37 5	68 0	1 3	222	55 0
DB	36 0	63 5	1 6	240	63 0
DB	41 0	71 0	1 5	140	32 5
DB	27 5	59 5	1 4	282	92 0
DB	37 5	68 0	1 4	231	56 5
DB	36 1	65 0	1 6	245	62 5
CW	53 3	81 5	1 2	301	96 0
CW	48 0	79 0	1 3	276	72 5

27	28	29	30	31	32	33
300 0	4 9	138	77 8	GP	47 5	7 7
332 0	4 9	142	81 2	GP	49 6	12 8
288 5	5 2	195	65 0	GP	43 2	7 0
286 5	4 5	175	62 2	LP	40 5	7 9
202 5	6 2	140	82 3	LP	52 5	11 7
295 0	3 2	197	69 0	GP	46 0	7 9
282 0	4 9	180	63 5	GP	43 0	7 8
299 5	4 7	176	70 0	GP	45 0	7 6
416 5	4 3	136	93 5	LG	60 5	8 6
343 5	4 7	181	77 5	DP	47 4	8 2

Contd

Continued

34	35	36	37	39	40	41	42	43	44	45	46	47	48	49	0
4 5	6 7	8 0	10 2	0	0 2	H	M	M	H	H	M	M	H	M	H
4 3	5 8	9 5	12 1	0	0 40	H	M	M	H	M	M	H	VH	M	M
4 3	6 2	8 5	12 1	0	0 1	H	M	M	M	M	M	H	H	M	M
4 3	5 9	8 2	12 0	0	0 3	H	M	H	M	M	M	H	M	H	M
4 2	6 0	11 5	14 3	0	0 4	H	M	H	H	H	M	H	H	H	L
4 5	6 7	10 8	13 6	0	0 3	H	M	H	L	H	M	H	H	M	L
4 5	6 7	8 4	12 5	0	0 4	H	M	H	VL	H	M	H	H	H	L
4 0	6 3	9 2	11 5	0	0 3	H	M	H	VL	M	M	H	H	H	L
4 2	6 0	10 0	14 5	R	0 1	H	M	L	L	M	M	H	L	VH	M
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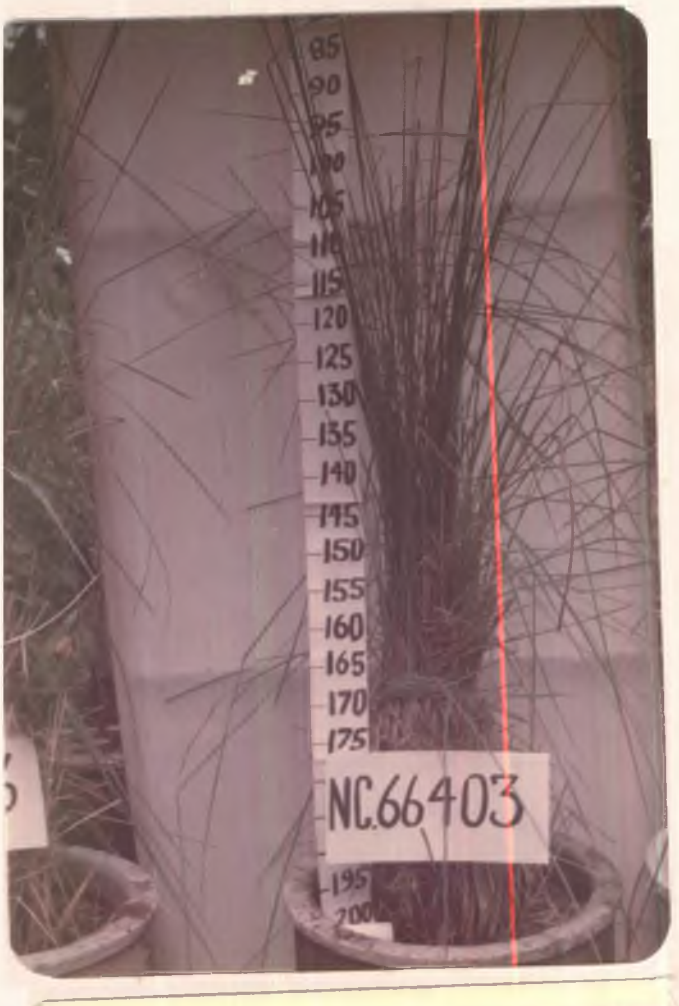
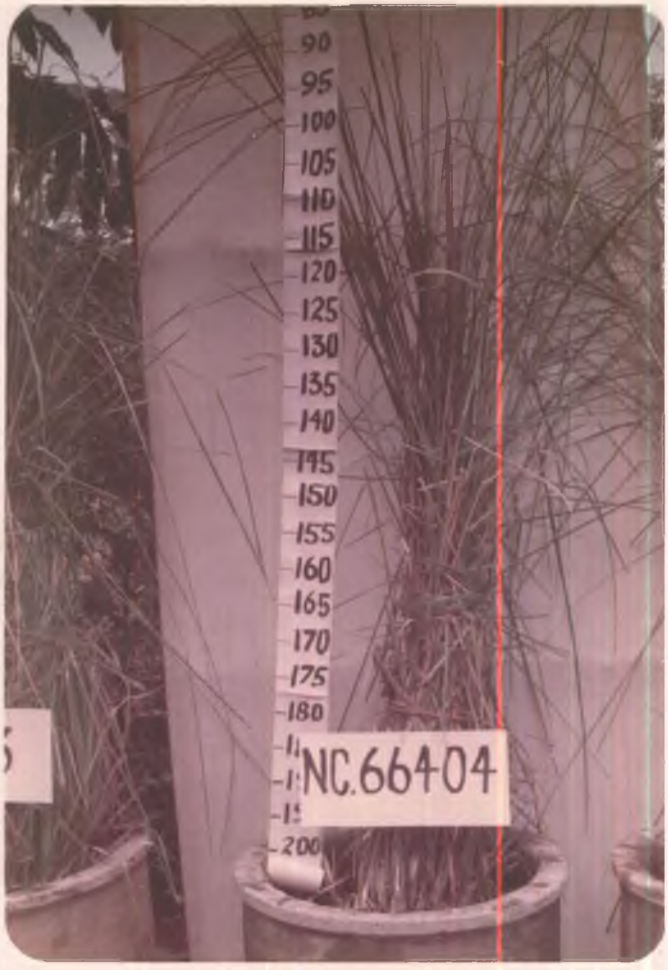

NC.66403


NC.66403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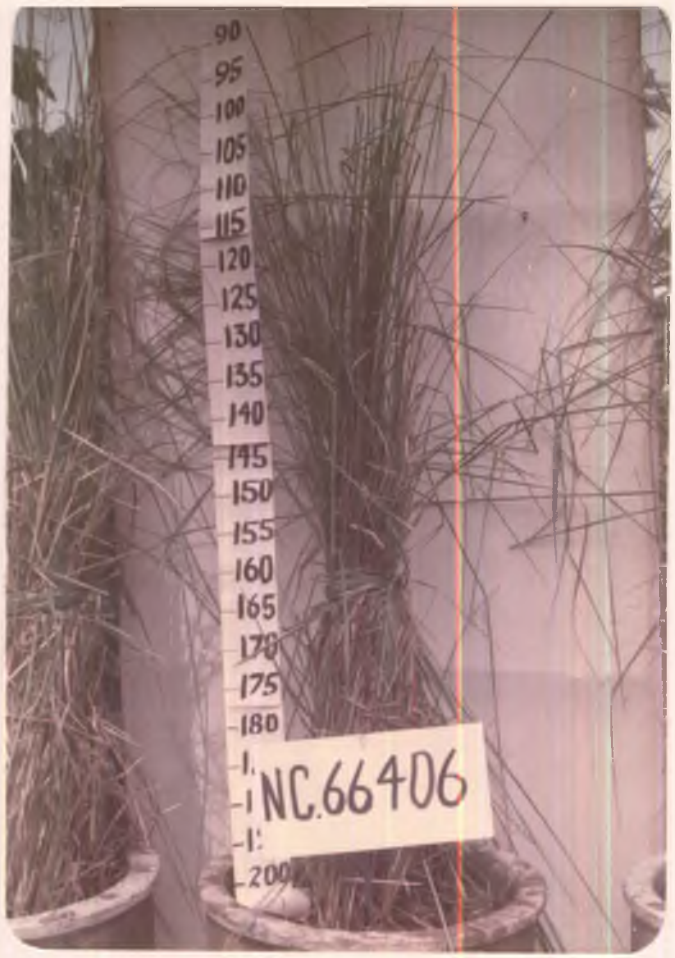
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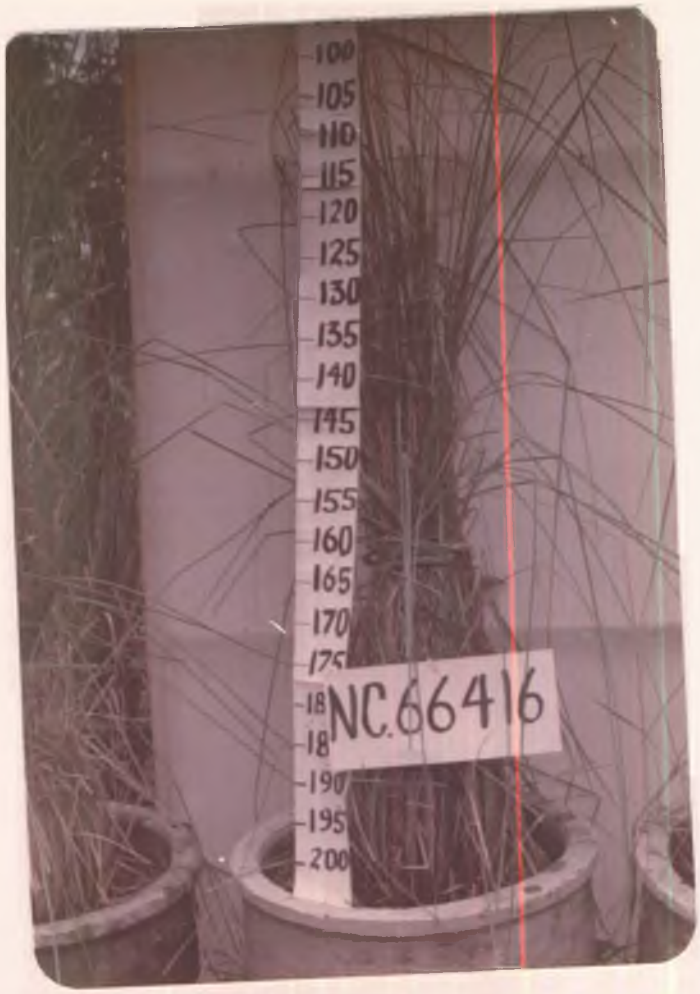
NC. 66415


NC. 66415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NC.66416
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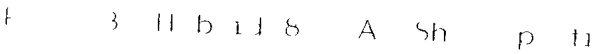
Hyb.7


Hyb.7



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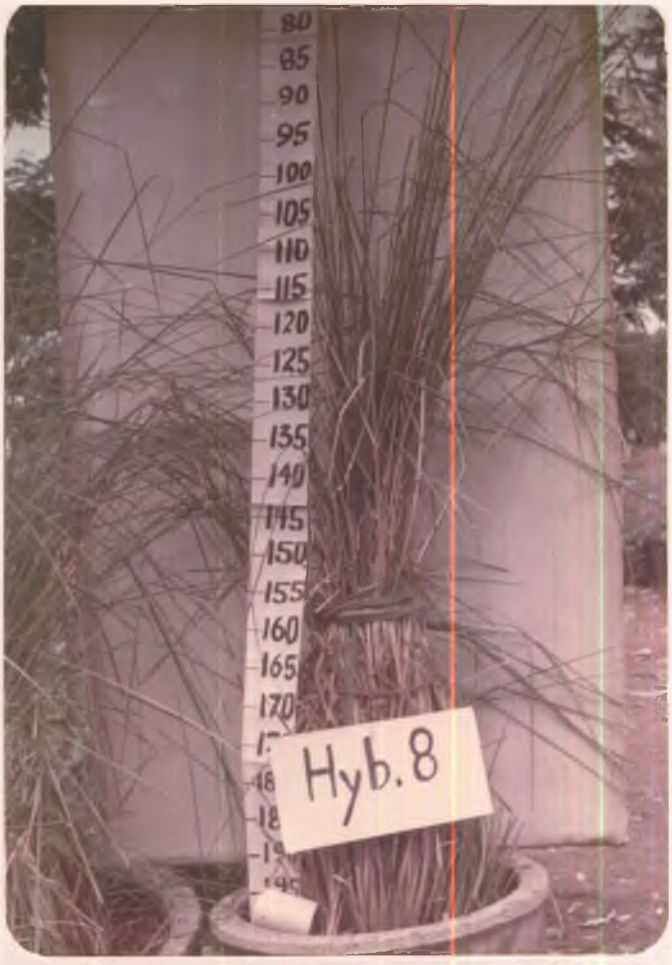
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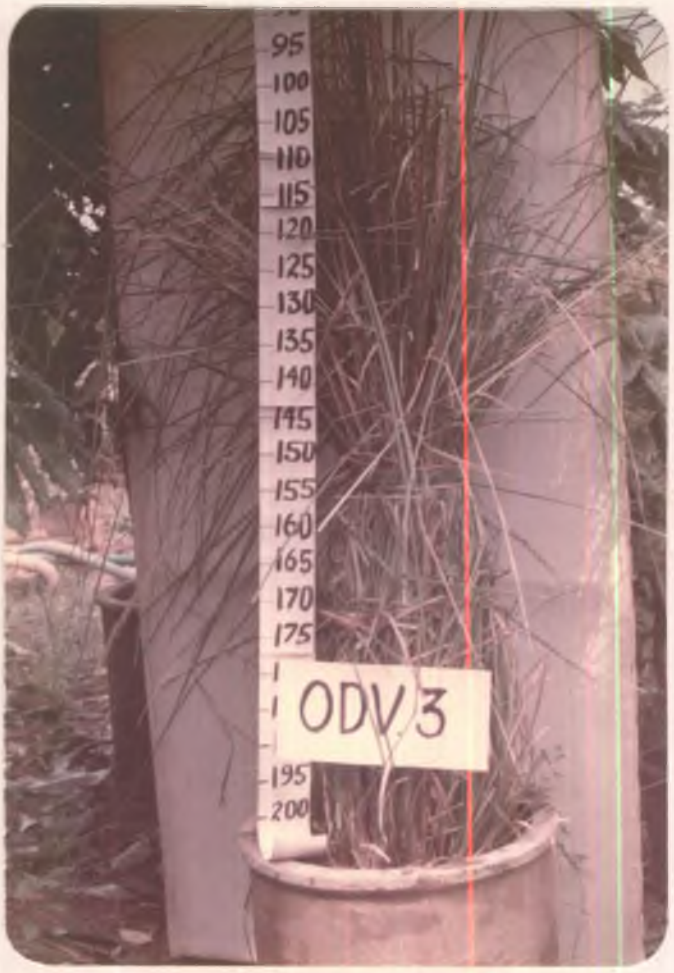
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Discussion

DISCUSSION

The results on the evaluation of selections and hybrids of vetiver based on the Biometric characters as well as the quantity and quality of oil are briefly discussed in the following pages

5.1. Biometric characters

Among the morphological characters the main items of observations viz , root length, root diameter, number of roots, root spread and root yield have been studied thoroughly under both field and pot conditions

5 1 1 Root length

Root length is one of the most important yield characters in vetiver In the present investigation maximum root length was obtained in South Indian entry, ODV-3, which was significantly superior to that of the hybrids and national collections A comparison on the root length of hybrids and national collections showed that hybrids were better in the production of longer roots than national collections Out of the 3 hybrids used in the study hybrid 8 was found to be the best followed by hybrid 7 and hybrid 26 Among the national collections NC 66406 was found to

have the shortest roots However, the root length of national collections in the present study (27 45 to 33 84 cm) was more compared to its performance at Delhi, reported by Sethi et al (1986) who had obtained on an average 23-27 cm long roots in national collections The variation in root length in the present study might be due to the changes in soil and climatic factors

Hence with respect to the root length the order of preference should be South Indians, hybrids and national collections The result also envisaged the need for further production of hybrids involving South Indian entry like ODV-3 as one of the parents, thereby incorporating the desirable characters of the South Indian types with that of the North Indian type into a single hybrid

5 1 2 Root spread

With respect to the root spread, the maximum spread was seen in ODV-3, a South Indian type, which was significantly superior to that of the other entries As in the case of root length, this was followed by hybrids and national collections in performance From the result it is evident that the roots were not only longer but also had sufficient spread especially in the upper 25-50 cm depth of soil This is in comparison with the findings of Chandra et al (1966) who had shown that the maximum dense growth of the root was seen in the upper layers of soil

and as the depth increased the growth as well as the penetration decreased

The results further indicated the growth of roots to all sides, which ensures a higher production Moreover, the profuse branching may help in binding soil together, thereby acting as a barrier against soil erosion Hence, it is inferred that ODV-3 may be considered as a good vetiver type for planting in areas prone to soil erosion

5 1 3 Root Diameter

With reference to the root diameter, national collections in general, produced thicker roots compared to hybrids and South Indian types ODV-3 which was found superior with respect to all other root characters, produced roots having the lowest diameter. These results are in disagreement with the reports of Ramanujam and Sushilkumar (1963) that the North Indian complex p oduce roots of lesser diameter compared to the South Indian complex However, the root diameter in the present study for national collections (1 35 to 1 65 mm) was far below compared to the same at Delhi reported by Sethi et al (1986) who had obtained root diameter varying from 2 1 to 2 9 mm A decrease in root diameter in the present investigation might be the result of variation in soil and other environmental factors

Among the hybrids, hybrid 7 had roots of maximum diameter and the performance of hybrids on an average was better than the South Indian entry, ODV-3

5 1 4 Number of Roots per hill

In the case of number of roots/hill ODV-3 was superior to all other entries Among the hybrids, hybrid 8 and hybrid 7 performed well Hybrid 26, on the other hand, was not upto the level Out of the 5 national collections used in the study NC 66404 was found to be poor with respect to the number of roots, while the other four types had moderate values Pareek (1989) had reported a higher number of roots in international collections of vetiver at Delhi Similar results had also been obtained for Sethi et al (1986) for national collections from Bharatpur area This difference in the character might be attributed to the change in soil and climatic factors existed in the different experimental areas

Moreover a higher number of roots reported by Pareek (1989) might have arrived by counting the primary, secondary and tertiary roots, whereas in the present study primary roots have only been considered

5 1 5 Root yield

Yield, as we know is a complex character, which in vetiver showed significant difference among the different entries ODV-3, a South Indian entry was proved to be the highest root producing type, while national collections NC 66416 and NC 66404 were found to be poor yielders Hybrids, as in other root characters showed good performance here also, especially hybrid 8 The difference in root yield between the North Indian and South Indian entries in the present study is in agreement with the findings of Ramanujam and Sushilkumar (1963) that one could tentatively recognise a North Indian complex characterised by lower root production and South Indian complex by larger root production Reddy (1954), Sambashiva Rao (1964), Chandra et al (1966) have also reported a similar range of root yields for the North Indian and South Indian complexes A higher root yield in South Indian types had also been reported by Pareek (1989) based on his trials on vetiver types at New Delhi, Faizabad and Indore Hybrid 8, a promising hybrid of vetiver, which gave a fairly high root yield elsewhere (reported by Sethi, 1982, Sethi and Sapra, 1983) was found to be superior in present study also

The entry ODV 3 produced the highest root yield It also had the highest root length, root spread and number of roots So it may be concluded that all these root characters might have

contributed for the higher root yield in this entry Hybrid 8 and 7 performed better than the other hybrid and national collections

5 1 6 Shoot weight

From the results it could be seen that there was significant difference for the character among the different entries In the present study the same has been recorded in order to get the shoot root ratio of the different entries

5 1 7 Shoot root ratio

Statistical analysis showed that there was no significant difference among the entries under study The ratio, however, is in agreement with the shoot root ratio reported by Sethi et al (1987) for hybrid 8

5.2. Oil estimation and quality assessment

The vetiver roots, on distillation yields a thick mobile fragrant essential oil, having a large demand in the perfumery, cosmetics and agarbatti industries The oil of vetiver is a perfume by itself, besides it has an excellent fixative property for other fragrance for which it is commonly used in the industry At present a large part of demand of this oil in the trade is met by distillation of wild growing material in north-western parts

of India whereas cultivation exist over scattered small holdings in states of Kerala, Karnataka, Andhra Pradesh and Tamil Nadu in the South India It is widely known that oil originating from Rajasthan and parts of Uttar Pradesh in the North-Western India is different in oil content of roots, its quality and odour value from the ones cultivated in the peninsular India

In the present study a comparison of the quantity and quality of oil have been made both by chemical methods and also by using gas liquid chromatogram and the results obtained are discussed in the following pages

5.2 1 Oil yield

From the results it could be seen that the quantity of oil varied considerably between the different types under study Maximum oil yield was obtained in national collections, NC 66415 was found to be the most promising one with respect to oil yield having the highest percentage of oil (0 745%) From among the 3 hybrids used in the experiment, hybrid 8 gave a fairly good oil yield while hybrid 26 was found to be a poor yielder. South Indian entry ODV-3 gave the lowest oil percentage These results are in disagreement with the earlier reports by Pareek (1989) that North Indian types gave a lesser oil yield but of superior quality compared to South Indian types having oil with a typical

South Indian style odour, which was considered inferior In the present study, eventhough a general statement cannot be made based on the performance of the single South Indian type, ODV-3, the same had showed a poor performance in pot condition also. Further, Kaipamangalam, another South Indian entry used in the pot study was also found to give a poor oil yield compared to other vetiver types

The national collections, which are originally, selections from Bharatpur gave higher oil yield compared to the earlier reports on the same by Menon and Ittyachan, 1945, Dhingra, 1969 and Chandra et al , 1966 Maheswari et al (1986), however, reported a higher percentage of oil for national collections at Delhi which was more than that obtained for the same in the present study The low yield in oil content might probably be due to variation in soil and climatic factors Further the time taken for distillation in the present experiment was standardised as 8 hours which would have been more in the experiments at Delhi

Among the national collection NC 66416 had yielded the maximum percentage of oil while NC 66404, NC 66403 and NC 66416 were also superior in oil content Hybrids, on the other hand, gave a low yield compared to the earlier reports by several workers (Singh et al , 1978, Bajpai et al , 1979, Sethi and Gupta, 1980, Sethi, 1982, Sethi et al , 1981, Gupta et al , 1983, Maheswari, 1985 and Punia et al , 1989)

A comparison of the performance of oil yield among the hybrids revealed that hybrid 8 was superior compared to the other hybrids, hybrid 7 and hybrid 26 It is to be noticed that hybrid 8 which gave a fairly good root yield was found good in oil yield also This findings are in confirmity with the earlier reports by Singh et al , 1978, Sethi, 1982, Sethi and Gupta, 1980 and Maheswari, 1985 Sethi et al (1981) had further confirmed that hybrid 8 retained its superiority in oil content and oil yield even in different types of soil

With respect to the oil yield on per hectare basis, hybrid 8 ranked first among the hybrids and selections since, the root yield per hectare was more in hybrid 8 than the other entries. NC 66416 which was superior in oil content, however, could not do much with respect to oil yield per hectare due to poor root yield per hectare A higher percentage of oil in NC 66416 was also reported by Pareek (1989)

A comparison of oil percentage under field and pot condition has shown that the oil yield was very poor under pot condition. This could be attributed to the heavy rain prevailed during the harvest season which might have caused a reduction in the oil content Murti and Moosad (1949) had reported that a drop in oil content was noticed in their experiment due to washing out of the oil from the underground roots during heavy rains

5 2 2 Oil quality

It has been observed that the roots of North Indian, South Indian and hybrid types differed considerably with respect to both physical and chemical properties of oil as well as the major components of oil The important physical properties considered in the present study included refractive index, specific gravity and optical rotation while acid value, ester value and ester content were considered as chemical properties Percentage of major components in vetiver oil viz , vetiverol, vetiverone and terpenes were estimated by using gas liquid chromatogram Since vetiver oil in the market is highly adulterated and pure sample is not available ISI specification was taken as a standard for the comparison of the quality of oil

5 2 2 1 Physical properties

5 2 2 1 1 Refractive index

From among the different physical properties, refractive index, specific gravity and optical rotation were considered in the present study From the results furnished in the Table 2 it is evident that refractive index of national collection was slightly high compared to that of hybrids The present findings are in confirmity with the results of Gupta et al , 1983, Maheswari, 1985 and Maheswari et al , 1986 A higher refractive index in national

collection might be attributed to the higher vetiverol content even-though the pattern of increase and decrease was not exactly according to the increase and decrease of vetiverol content It was also noticed that refractive index was higher in national collections, which had a low terpene content while a low refractive index value in hybrids and ODV-3 corresponds to the high terpene content in them This might probably be the reason for the variation in refractive index among the different entries under study It has to be further noticed that the different North Indian, South Indian and hybrid types were having values as per the ISI specification, thereby ensuring the better quality These results are in confirmity with the findings of Puran Singh, 1914, Rao et al , 1925, Guenther, 1950, Dhingra et al , 1952 and Rao et al , 1963

5 2 2 1 2 Optical rotation

From the results given in Table 2 it is evident that there is clear demarcation between the North Indian types, hybrids and South Indian types with respect to the optical activity of oil. North Indian types had a higher values of laevo-rotation compared to the hybrids, which were more towards the North Indian Vetiver oil, but had only lower values These results are in agreement with the possible range of optical rotation specified by ISI NC 66416 had the maximum value, while hybrid 26 had the minimum

ODV-3, a South Indian type was found to have dextro-rotatory oil. Similar reports were given by Rao et al , 1925, Dingra et al , 1952, Anderson, 1970, Maheswari, 1985 and Maheswari et al , 1986 These authors also attributed the better odour value of North Indian oil as chiefly due to the laevo-rotation which in turn depended upon a number of other components in the oil Still elaborate studies are needed, in order to find out what exactly contribute to the change in optical rotation of the different vetiver oils

5 2 2 1 3 Specific gravity

With reference to the specific gravity a higher value was obtained for national collections. The South Indian type ODV-3, had the lowest value, thus revealing its inferior quality with respect to specific gravity These results are in agreement with the reports of Pareek (1989) that North Indian types gave oil of superior quality while South Indian material gave oil of inferior quality Sadgopal (1960) reported best vetiver oil as the one having high specific gravity, esters and free alcohols Gupta et al (1983) have found that the superiority of oil in hybrids as due to the high content of ester, free alcohols and specific gravity. Virmani and Dutta (1975) have also reported a higher specific gravity for oils obtained from Bharatpur and Musanagar A low

specific gravity in hybrids and ODV-3 might be due to the high percentage of terpenes Similarly in the national collections the terpene content was found to be lower which might have caused an increase in the specific gravity

5 2 2 2 Chemical properties

5 2 2 2 1 Acid value

With respect to the acid value a higher value was obtained in hybrids compared to that of national collections and South Indian type The ISI specification of acid value for North Indian type is 40 and that of South Indian is 35 From the result it could be seen that the oil quality of North Indian type was not good with respect to acid value since the values were far below the needed one except for hybrid 8 which was somewhat nearer to 40 NC 66404 and hybrid 7 had higher values compared to the others South Indian type ODV-3 had only a very low acid value thus showing the inferior quality with respect to the above property

5 2 2 2 2 Ester value and Ester content

Ester value is also one of the important properties based on which the quality of the oil is assessed In the present investigation, a higher ester value was obtained for national collection

compared to hybrids and ODV-3 However, the values were in the range given in ISI specification Among the different entries NC 66404 and NC 66406 had very high values revealing their superiority with respect to the above property Sadgopal (1960) reported that a high ester content might be the reason for better quality in addition to few other criteria Gupta et al (1983) attributed the high content of esters, high specific gravity and free alcohols being the reason for the superiority of oil in hybrids However, the values in the present study was higher compared to the reports of Rao et al (1925) and Dhingra et al (1952) on ester values for Indian vetiver oils Guerther (1972) opined that the characteristic odour of vetiver oil was due to the ester which vetivenic acid forms with vetiverols Virmani and Dutta (1975) have also confirmed the presence of vetiverols and vetivenyl esters as the cause for the better aroma of Indian vetiver oil

5 2 2 3 Gas chromatography

Gas chromatography showed that most of the selections and hybrids including the local varieties, under study possessed main components like vetiverol, vetiverone and terpenes The values of each and it effects on the quality of oil are briefly discussed below

5 2 2 3 1 Vetiverol

Vetiverol content was found to be higher in national collections compared to that in hybrids It is the most important component in vetiver oil which contribute to the quality of oil especially the better aroma The price of vetiver oil in the commercial market, also vary with respect to the vetiverol content in it Among the national collections, NC 66416 and NC 66403 were superior with respect to the vetiverol content ODV-3, a South Indian type also possessed a higher vetiverol content which was in disagreement with the earlier reports by Pareek (1989), that South Indian type, though showed superiority in oil production, had oil of inferior quality Vetiverol, being the major component contributing to the quality of oil, was higher in ODV-3 The higher value might be due to the low percentage of other components in the high boiling point fraction, which could not obtained in the present study, since the period of distillation was only upto 8 hours The percentage of vetiverol would have been low, if distillation was continued for 24-30 hours in the present experiment Sadgopal (1960) and Gupta et al (1983) also reported the presence of free alcohol being the major contributor to the quality of oil Dhingra et al , 1952, Anderson, 1970, Virmani and Dutta, 1975 and Maheswari et al , 1986 have confirmed the presence of vetiver l ll j mp n nt f tiver il

Virmani, O P and Datta, S C 1975 Vetiveria zizanioides (Linn.) Nash Indian Perfumer 19 35-73

Wildner, P 1960 Vetiver oil from Reunion Indian Perfumer 31-34

Zutshi, N L and Sadgopal 1957 Physico-chemical examination of the essential oil from the roots of Vetiveria zizanioides (Linn) Nash (Part II) Indian Soap J 23(3):43-47.

* Originals not seen

5 2 2 3 4 Total Vetiverol

Total vetiverol of the different entries under study was obtained by chemical analysis A high content of total vetiverol was observed in national collections Among the hybrids, hybrid 26 had a high total vetiverol content ODV-3 had also high total vetiverol content Similar trend on the total vetiverol in national collection and hybrids were reported by Gupta et al , 1983, Sethi et al , 1986 and Maheswari et al , 1986

5.3. Pot culture experiment

In order to make a descriptive blank (page 61) several other morphological characters were studied which were restricted to the pot condition only These included both vegetative and floral characters, the result of which had shown that none of the morphological characters except root characters could be projected with which North Indian, hybrid and South Indian types can be identified

A comparison of the different root characters in field and pot condition, in general, revealed that the performance was better in pot condition than in the field condition Exception was seen in NC 66404 for number of roots and root yield Root diameter,

on the other hand, was less than that in field condition except for NC 66404 and NC 66406 Mini (1989) also had reported a higher root yield for vetiver under pot condition Thus a preliminary conclusion may be drawn from these observation that the increase in performance of the plant, with respect to the root characters in pot condition could be due to the loose column of soil available in pot (enables the easy penetration of roots to deeper layers) which was not too much disturbed by climatic and soil factors and also the favourable environmental condition present in the pot

The South Indian entries (ODV-3 and Kaipamangalam) showed an increase in vigour both in vegetative and floral characters In this juncture, it should be stressed that, attention has to be given to the South Indian types since they produce more number of roots which are longer than that of the hybrids and selections Kaipamangalam which is cultivated on a larger scale in the coastal belts of Trichur in Kerala are more preferred for its roots People of these area are using the vetiver roots as such for making fans, mats, screens etc and never go for oil extraction ODV-3 which performed better than Kaipamangalam can also be added into this category which may help in larger production of roots with profuse branching and this may be a suitable type for the areas where vetiver is cultivated for root production only

In conclusion it can be seen that by taking into consideration the root characters and quantity and quality of oil together, out of the 9 entries under study, hybrid 8 can be pronounced as the one having high root yield, oil yield as well as quality of oil In addition, a consistency in yield of root and oil has also been noticed in hybrid 8 These results further envisaged the production of more hybrids, by which the dominating odour characters of wild vetiver (North Indian) and high oil content characters of cultivated type (South Indian) can be incorporated

Out of the 9 entries under study it was understood that NC 66416 had a high content of both vetiverols and vetiverone, whereas terpene content was low which turn had caused an increase in specific gravity Total vetiverol was also highest in this entry. NC 66403 also proved to be superior Similar results were reported by Sethi et al (1986) based on their studies at NBPGR, New Delhi With respect to the aroma NC 66416 is again preferred since the major aroma contributing components vetiverol, vetiverone etc were higher in it Moreover, it has got an oil with high laevo-rotation, which is preferred in international market due to the dominant odour characters

Vetiver met in India shows a great variation in root yield, oil percentage and quality of oil It is possible to cultivate this

plant in India at various places Before its large scale cultivation is taken up, it is advisable to select the plant with high root yield, and oil percentage The quality of oil which shows great variation from plant to plant should also be kept in mind while selecting the plants for further multiplication and clonal propagation

Summary

SUMMARY

Investigations were undertaken in the Department of Agricultural Botany, College of Horticulture, Vellanikkara during 1989-90 and 1990-91 season on evaluation of selections and hybrids of vetiver Vetiveria zizanioides (Linn.) Nash. The different objectives were, (1) to evaluate the performance of selections and hybrids of vetiver in comparison with the popular cultivated varieties, (2) to attempt morphological evaluation of the available selections and hybrids of vetiver in the germplasm of AICRP on M and AP Project of Vellanikkara, in order to develop a descriptive blank for the crop, and (3) to estimate the root and oil yield of these types along with an assessment of the quality of oil.

The results of the experiment are summarised hereunder.

1. Out of the 9 entries used in the experiment, ODV-3 was found superior with respect to root characters viz., root length, root spread, number of roorts, root weight per plant and root yield per hectare. Root diameter, on the other hand was the lowest in ODV-3. NC 66416 produced roots with maximum diameter. Hybrid 8, a promising vetiver hybrid was also found superior with respect to almost all root characters except root diameter. Shoot weight was also higher in it. Regarding shoot weight

per plant, ODV-3 was superior to all other entries However, shoot root ratio did not show any significant difference between the different treatments

2 With respect to the oil content per 100 g dry root national collections were superior to the hybrids and ODV-3 NC 66415 had roots with maximum oil content and the minimum was in ODV-3 Hybrid 8, also had a higher percentage of oil in its root

The trend shown in oil content was not the same in oil yield on a per hectare basis since the root yield per hectare had an influence on it Hybrid 8 having a good root yield and oil percentage stood first while NC 66415 with highest oil percentage could not perform well because of low root yield/ha

3 The mean values of physical and chemical properties also showed variation eventhough they were not statistically analysed due to the lack of sufficient number of oil samples in some entries National collections in general, had higher values of specific gravity refractive index and optical rotation compared to the same for hybrids ODV-3, the only South Indian type used in the study had high refractive index, lowest specific gravity and dextro-rotatory oil

With regard to acid value, hybrids had a higher value whereas the national collections had maximum esters and total vetiverol ODV-3 had low acid value, ester value and ester content but had moderately high total vetiverol content

4 The results of the studies using Gas Liquid Chromatography showed that vetiverol content in oil was the maximum in ODV-3 whereas the other component, vetiverone, was the minimum Terpene content was also high NC 66416 was found to have the best quality oil since it had high vetiverol, vetiverone and low terpenes in it Moreover, the refractive index, specific gravity and optical rotation were high in it

5 The observation on morphological characters under pot cordition revealed that none of the morphological characters except root characters, could be projected as one with which the South Indian, hybrid and North Indian could be distinguished South Indian types in general had roots with maximum length, spread and minimum root diameter whereas the national collections had roots with minimum length, spread and maximum diameter The hybrids in general had values midway between the South Indian and North Indian types Regarding oil content maximum oil percentage was in national collections whereas the performance of South Indians was found to be very poor

6 A comparison of the root characters and oil content under field and pot condition showed that performance of the entries under pot condition was better than in the field condition for root characters, in general A reduction in oil content was noticed in pot condition in almost all entries under study

7 In short the studies revealed the superiority of South Indian types with regard to their root growth, root weight per plant and root yield per hectare Hence they can be cultivated in areas as in Kerala, in a commercial scale where the roots are used as such without extraction of oil from it, whereas in areas as in North India, where vetiver is grown mainly for oil extraction national collection can be preferred Among the 9 entries evaluated for root yield, oil yield and oil quality hybrid 8 has shown high values for all the above characters Hence it is observed that there is scope for improvement of vetiver through hybridization and selection Cultivation of hybrid 8 can be taken up in areas where it has not been tried so far since it was found to be the most promising based on the present study

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5 2 2 3 2 Vetiverone

Vetiverone is the second most important component in vetiver oil Vetiverone content was higher in hybrids compared to the North Indian and South Indian entries Among the hybrids, hybrid 8 was found superior while NC 66406 and NC 66415 performed well among the national collections ODV-3 had the lowest content of vetiverone According to Guenther (1972) the odour of vetiver oil was chiefly due to the Ketonic sesquiterpeness of which only α vetivone and β vetivone have so far been isolated Presence of vetiverones in vetiver oil have also been reported by Zutshi and Sadgopal, 1957, Anderson, 1970 and Ashour and Moshtohor, 1980

5 2 2 3 3 Terpenes

Gas Liquid Chromatography studies have revealed the presence of higher content of terpenes in hybrids and South Indian entry compared to national collections A low specific gravity in hybrids could be attributed to the high terpene content while the low terpenes in national collections might be the reason for high specific gravity in it South Indian entry having a high terpene content was also found to have a low specific gravity

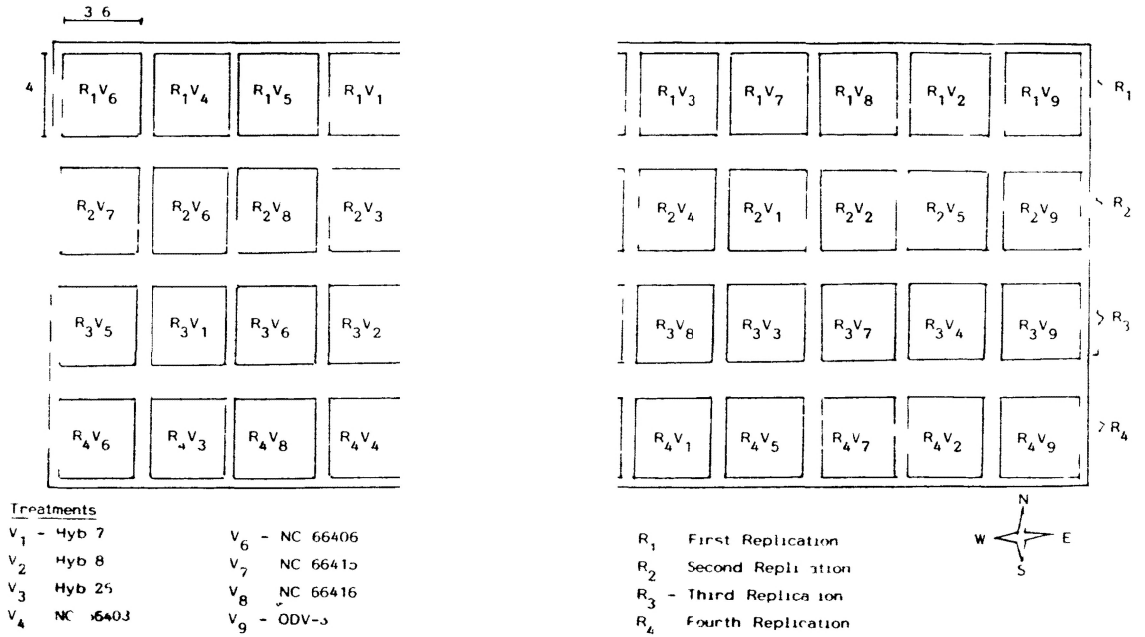
Appendices

APPENDIX-I

Mean monthly weather parameters for the crop growth

Month	Air temperature mean maximum °C	Air temperature mean minimum °C	Rainy days	Sunshine hours	Relative humidity (%)	Mean sunshine hours	Total evaporation (mm)	Total rainfall (mm)
				1989				
June	29.4	22 7	27	96.7	86	3 2	83 0	784 6
July	29 1	23 3	17	130.2	86	4 2	98 1	562 0
August	29 5	23 1	19	166.8	83	5 4	110 0	319 9
September	29 9	23 1	15	164.3	82	5 5	97 8	180 1
October	31 0	23 0	16	193.2	80	6 2	112 4	351 3
November	82 5	22 7	2	253.9	63	8 5	141 3	8 1
December	32 7	23 2	0	299.5	60	9 7	204 7	0
				1990				
January	33 5	20 8	0	270.3	50	9 0	222 0	3 5
February	34 9	21 9	0	280.7	58	10 0	210 6	0
March	36 0	23.8	1	299.5	64	9 7	213 7	4 4
April	35 8	25 4	2	250.2	68	8 3	189 8	38 8
May	31 5	24 1	18	139.1	82	4 5	109 5	583 9
June	29 7	23.3	25	102.0	85	3 4	84 3	467 3
July	28 4	22.5	28	74.8	88	2 4	79 1	759 3
August	29.0	23.0	22	107.7	85	3.5	90 4	356 4
September	30 7	23.4	8	186.9	79	6 2	101 4	87 5
October	31 9	23.2	12	202.8	70	6 5	109.9	313 3
November	31 2	22.6	3	178.7	74	6 0	101.7	69 8
December	32 3	23.1	0	315.3	59	10 2	184 5	1 8

APPENDIX-II
LAYOUT PLAN



Treatments

V_1 - Hyb 7
V_2 Hyb 8
V_3 Hyb 25
V_4 NC x5403
V_5 NC 66404
V_6 - NC 66406
V_7 NC 66415
V_8 NC 66416
V_9 - ODV-3

R_1 First Replication
R_2 Second Replication
R_3 - Third Replication
R_4 Fourth Replication

EVALUATION OF SELECTIONS AND HYBRIDS OF VETIVER (*Vetiveria zizanioides* (Linn) Nash)

By

G. R. RADHAKRISHNAN

ABSTRACT OF A THESIS

Submitted in partial fulfilment of the requirement for the degree of

Master of Science in Agriculture

Faculty of Agriculture
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Vellanikkara, Trichur

1991

ABSTRACT

Investigations on evaluation of selections and hybrids of vetiver Vetiveria zizanioides (Linn) Nash. were undertaken using 9 cultivars of vetiver including 5 national collections, 3 hybrids and one South Indian type (ODV-3)

The observations on root characters revealed the superiority of ODV-3 in almost all root characters except root diameter National collections had roots with maximum diameter Hybrid 8 was also found superior in root characters

Shoot weight was the highest in ODV-3 No significant difference was observed among the different treatments with respect to shoot root ratio

National collection, in general produced highest percentage of oil per 100 g root especially NC 66415 and NC 66403 whereas ODV-3 produced the lowest percentage of oil. Hybrid 8, had maximum oil yield on per hectare basis

Studies on physico-chemical properties revealed that national collections had in general high specific gravity, refractive index and optical rotation Oil from national collections was found laevo-rotatory whereas ODV-3 had dextro-rotatory oil

Acid value was higher in hybrids Ester content, ester value and total vetiverol were higher in national collections ODV-3 also had high total vetiverol

GLC studies revealed the superiority of NC 66416 with respect to oil quality It had high vetiverol, vetiverone and low terpene content. Vetiverol was maximum in ODV-3 but had minimum vetiverone in its oil Hybrid 8 was also found superior with maximum vetiverone content and fairly high content of vetiverol But terpene content was higher it

Results of the experiment in pots showed that crops had better performance in pot condition with respect to almost all characters, but for oil content

The observations on plant morphology indicated no clear-cut morphological features employable for exact identification of hybrids, North Indian and South Indian types However, data on root characters had shown that the South Indian types had in general long roots with maximum number and weight, than national collections. Root diameter in South Indian types was less Performance of hybrids was better than national collections