AGROTECHNOLOGICAL PRACTICES FOR QUALITY CRUDE DRUG PRODUCTION IN NILAPPANA
(*Curculigo orchioides* Gaertn.)

P. P. JOY

Doctor of Philosophy in Agriculture

2003

Department of Agronomy
COLLEGE OF HORTICULTURE
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KERALA, INDIA

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Thesis submitted in partial fulfilment of the requirement for the degree of

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Dedicated to

my beloved parents

Mrs. and Mr. Varkey Paulose

who toiled in the background and taught me

the first lessons of hard work and prayerful life

DECLARATION

I hereby declare that this thesis entitled 'Agrotechnological practices for quality crude drug production in *nilappana* (*Curculigo orchioides* Gaertn.)' is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship, associateship or other similar title of any other university or society.

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Certified that the thesis entitled 'Agrotechnological practices for quality crude drug production in *nilappana* (*Curculigo orchioides* Gaertn.)' is a record of research work done independently by Sri P. P. Joy under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

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P. P. Joy

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ABBREVIATIONS AND SYMBOLS USED IN THE THESIS

Most of the units used in the thesis are SI (Systeme Internationale) Units. Chemical symbols are as given in the periodic table of elements. Some of the common abbreviations, symbols and notations used in the thesis are given below.

%	Per cent	LAI	Leaf area index
°C	Degree Celsius	LAD	Leaf area duration
*	Significant at 0.05 level of probability	m	Metre
**	Significant at 0.01 level of probability	*M*	Molar solution
2,6-DA	2,6-dimethoxybenzoic acid	m^{-2}	per square metre
a.i.	Active ingredient	MAP	Month after planting
AMPRS	Aromatic and Medicinal Plants Research Station	Mg	Magnesium
Anon.	Anonymous	mg	Milligram
C	Carbon	$mg\ g^{-1}$	milligram per gram
Ca	Calcium	mm	Millimetre
CD	Critical difference	Mn	Manganese
CO_2	Carbon dioxide	MSL	Mean sea level
Cu	Copper	mV	Millivolt
DNA	Deoxyribo nucleic acid	N	Nitrogen/North direction
dS	deciSiemen	*N*	Normal solution
E	East direction	Na	Sodium
et al.	And others	ND	Not detected
Exp.	Experiment	NS	Not significant
Fe	Iron	O	Oxygen
Fig.	Figure	P	Phosphorus
FYM	Farmyard manure	P_2O_5	Phosphorus pentoxide
g	Gram	pH	Soil reaction
GAP	Good agricultural practices	ppm	parts per million
h	Hour	PSB	Phosphate solubilising bacteria
ha	Hectare	R	Replication
ha^{-1}	per hectare	r	Simple correlation coefficient
HI	Harvest index	Rt	Retention time
HPLC	High pressure liquid chromatograph(y)	S	Sulphur
K	Potassium	SEm	Standard error of the means
KAU	Kerala Agricultural University	t	Metric tonne (1000 kg)
K_2O	Potassium oxide	VAM	Vesicular arbuscular mycorrhizae
kg	Kilogram	*viz.*	Namely
l	Litre	Zn	Zinc

1. INTRODUCTION

1. INTRODUCTION

Recent years have witnessed a resurgence of interest in traditional medicines and plant-derived drugs and a return to 'nature cure' all over the world. Many adverse and undesirable side-effects, some times toxic, and the high cost of modern drugs are prompting public health workers, governmental and non-governmental organizations to study, promote and market plant based health foods, functional foods, drugs and neutraceuticals. Modern drugs are inadequate to treat diabetes, amoebic dysentery, rheumatoid arthritis and hepatitis for which effective treatments are available in ayurveda. More over, medicinal plants assume special significance in preventive medical practices especially against aging, obesity, hypertension and depression.

The characteristic property of medicinal plants is due to a variety of complex chemical compounds and hence these plants are generally referred to as `natural bio-chemical factories' or `chemical goldmines'. The herbal products today symbolise safety in contrast to the synthetics that are regarded unsafe to man and the environment. Over three-quarters of the world's population rely mainly on plants and plant extracts for health care. It is estimated that world market for plant derived drugs may account for about Rs. 2,00,000 crores. It has been estimated that in developed countries such as United States, plant drugs constitute as much as 25 per cent of the total drugs, while in developing countries such as China and India, the contribution is as much as 80 per cent. Thus, the economic importance of medicinal plants is much more to countries such as India than to rest of the world (Thomas *et al*., 1999, 2000a).

The therapeutical property of medicinal plants depends on physiologically active chemical compounds produced in the plant as secondary metabolites like glycosides, terpenes, alkaloids, phenolics, steroids, coumarins, saponins, *etc* (FAO, 1993; UNDP, 1997; Walton and Brown, 1999). Though the essentiality of active chemical compounds is not accounted in various indigenous systems of medicines, strict norms and methods have been laid down for crude drugs and formulations. A number of medicinal principles have already been identified and no synthetic substitutes are currently available for many of them (Wijesekera, 1991; Kumar *et al*., 1997b).

The country's rich diversity of plants and knowledge systems in harnessing the plant diversity provide an opportunity to meet the future challenges in agriculture, health care systems and allied areas. The Western Ghats, one of the hot spots of biodiversity in the country, harbours around 500 medicinal plant species of which around 150 species are used in Ayurveda; the rest contribute to the tribal and folklore medicines. More than 90 per cent of the medicinal plant species used by the phytopharmaceutical industry are collected from the wild, out of which 70 per cent involve destructive harvesting. This loss of natural resource can be counteracted only by promoting cultivation (Anon., 2000). More over, cultivation of medicinal plants has now become an economically viable proposition owing to their ever increasing demand in health care programmes, mainly in the industrial production of phytochemicals, traditional medicines and in new drug discovery. It is, therefore, inevitable to develop cultural practices and propagate these plants in suitable agroclimatic regions (Kumar *et al., 1997a*; Gupta, 1998). Commercial cultivation will put a check on the continued exploitation from wild source and serve as an effective means to conserve the rare floristic wealth and genetic diversity.

Golden eye grass or black musali (*Curculigo orchioides* Gaertn.) belonging to the family Amaryllidaceae is a key member of the *dasapushpa* and one of the highly useful plants in the indigenous system of medicine. Nilappana, as is known in Malayalam, is a small, geophilous herb, the tuberous rootstock of which is used as a rejuvenating and aphrodisiac drug. It cures morbid *vata* and *pitta*, improves complexion and is useful in general debility, deafness, cough, asthma, piles, skin diseases, impotence, jaundice, urinary disorders, leucorrhoea and menorrhagia. The demand of the raw materials and derivatives of the plant for the indigenous drug industries is satisfied mainly from the wild source, depleting the natural population. Therefore, this important medicinal plant has to be conserved and domesticated for which suitable agrotechnology is to be developed. More over, large variations may occur in the crude drug available in the market as the plant materials are coming from varying sources. This tells up on the necessity for standardising the quality parameters for the crude drug. Hence this study was taken up to develop suitable agrotechnology and to assess the quality variations in *C. orchioides*.

The specific objectives of the research programme were

1. to study the developmental pattern of *C. orchioides*
2. to characterise the primary and secondary metabolites in *C. orchioides*
3. to assess the quantity and quality variations in *C. orchioides* as influenced by biotypes, shade, spacing, manuring and different sources of nutrients
4. to find out the quality variations due to domestication of the plant and in the market crude drug and
5. to formulate suitable agrotechnological practices for quality crude drug production in *C. orchioides*.

2. REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Nilappana, one of the ayurvedic *dasapushpas*, has been used in the indigenous systems of medicine since ancient times. Since its requirement was mostly met from the wild, not much effort was taken for its cultivation. Though much information is available on its medicinal aspects, literature is meagre on the agrotechnological side. The available literature on the plant *nilappana*, its growth and development, production and accumulation of primary and secondary metabolites and characterization of glycosides is reviewed hereunder. Owing to scanty information on the plant, the variation in biotypes and the effects of time of harvest, shade, spacing, organic manures, inorganic fertilizers, biofertilizers and mulching on related medicinal plants are reviewed in this chapter. Besides, quality variations in crude drug in trade and due to domestication of wild plants noted in the literature are also highlighted.

2.1 THE PLANT NILAPPANA

One of the highly useful plants in the indigenous systems of medicine is Golden eye grass or Black musali *(Curculigo orchioides* Gaertn.) belonging to the family Amaryllidaceae. It is known as *Talamuli* in Sanskrit, *Kalimusli* in Hindi and *Nilappana* in Malayalam (Kirtikar and Basu, 1988; Thomas *et al*., 2000b).

It is believed to have originated in the shady forests of Asia. It is found in all parts of India from near sea level to 2300 m altitude, especially in rock crevices and laterite soil. It has been recorded to occur in the subtropical Himalayas from Kumaon eastwards ascending to 1800 m, the Khasia hills, Bengal, Assam, Konkan, Kanara, the western peninsula and Tamil Nadu extending south as far as Cape Comerin (Agharkar, 1953; Atal and Kapur, 1982; Gupta *et al*., 1994; Joy *et al*., 1998a). It is also distributed in Sri Lanka, Japan, Malaysia and Australia (Pandey *et al.*, 1983). The demand of the raw materials and derivatives of the plant for the indigenous drug industries is satisfied mainly from the wild source, depleting the natural population and thus the species has become near extinct or endangered (Ansari, 1993; Augustine and Souza, 1995). *C. orchioides* was included in the IUCN category of "LOWER RISK near threatened" (Sharma, 2001).

C. orchioides is reported to be available only during the monsoon season in India, which lasts for 4 months each year. It is a small herbaceous plant with an elongated tuberous rootstock and lateral roots; root stock elongate, 5-25 cm, vertical; leaves (5-20 x 0.8-1.5 cm), very much variable, narrowly linear to lanceolate, acute, plicate or flat, crowded on the short stem with sheathing leaf bases; petiole short to 3 cm, often absent; flowers throughout the year, light yellow, bisexual, sessile, regular, 1.2 cm. perianth six lobed, lobes yellow (0.6-1 x 0.2-0.3 cm), stamens-6, filaments filiform, to 2 mm, anthers 2 mm, ovary 3-celled, oblong to 4 mm. Ovules numerous per cell, style 2 mm, stigma-3, lobes elongate; fruit oblong, 1.5-2 cm long 8 mm broad; seeds 8, globose to 2 mm, black, beaked, deeply grooved in wavy lines (Bhaskaran and Padmanabhan, 1983; Dong and Zhang, 1998; KAU, 1998, 2003).

The tuberous rootstock of *C. orchioides* is used as a restorative, rejuvenating and aphrodisiac drug (Porwal and Mehta, 1985; Manandhar, 1991; Samanta, 1992). It cures morbid *vata* and *pitta*, improves complexion and is useful in general debility, deafness cough, asthma, piles, skin diseases, impotence, jaundice, urinary disorders, leucorrhoea and menorrhagia (Nadkarni, 1954; Aiyer and Kolammal, 1963; Moos, 1978; Srivastava, 1989; Singh *et al.*, 1989; Banerjee and Pal, 1994; Govil, 1998). The root stock is mucilaginous, sweet, cooling, bitter, emollient, diuretic, aphrodisiac, depurative, alterative, appetiser, carminative, viriligenic, antipyretic and tonic. Thin slices of the rhizome without root hairs are employed in drug formulations like *Vidaryadighrta, Vidaryadi lehya, Marmagulika, Musalyadi churna, etc.* (Porwal and Mehta, 1985; Sivarajan and Balachandran, 1994; Warrier *et al.*, 1994). It delays ageing process and forms ingredient of many health foods and other preparations (Kurup *et al.*, 1979; Nadkarni, 1982; Nagarajan *et al.*, 1982; Jogleker *et al.*, 1984; Kumar and Prabhakar, 1990; Sharma *et al.*, 1991).

The plant possesses uterine stimulant (Dhawan and Saxena, 1958; Sharma *et al.*, 1975; Dhar *et al.*, 1979; Rastogi and Mehrotra, 1991), hypoglycaemic, spasmolytic and anticancer (Dhar *et al.*,1968; Aruna and Sivaramakrishnan, 1990), phagocytic (Kubo *et al.*, 1983), immunoadjuvant (Oru and Kogyo, 1983), antineoplastic (Sharma *et al*, 1991) immuno-stimulant (Saxena, 1992) and hepatoprotective (Latha *et al.,* 1999; Rajesh *et al.,* 2000) activities. Xu *et al.* (1992a,b) reported adaptogenic, anti-inflammatory, anticonvulsant, sedative, androgenic and immunopromoting activities for the plant. Ignacimuthu (1998) cited its potential as biopesticides.

The rhizome contains curculigoside, a phenolic glycoside characterized as 5-hydroxy-2-O-beta-D-glucopyranosyl benzyl 2,6-dimethoxy benzoate (Oru and Kogyo, 1983; Chen and Chen, 1989; Buckingham, 1994; Mamta *et al.*, 1995; Chen and Ni, 1999). It also contains a flavone glycoside (Dhawan and Saxena, 1958) and saponin G (Xu *et al.,* 1992b).

2.2 PRODUCTION AND ACCUMULATION OF PRIMARY AND SECONDARY METABOLITES

Plant chemicals can be classified as primary or secondary constituents, depending on whether or not they have an essential role in plant metabolism and are universally present in all plants (Hitchcock and Nichols, 1980). Primary constituents include sugars, protein, amino acids, purines and pyrimidines of nucleic acids, chlorophylls and so on. Secondary constituents make up all the remaining plant chemicals from alkaloids to terpenoids and acetogenins to phenolics and represent substances which do not appear to have an essential role in metabolism and which vary in their distribution from plant to plant.

According to Manitto (1981) polysaccharides, proteins, fats and nucleic acids are the fundamental building blocks of living matter and are thus considered primary metabolites (Fig. 2.1). The processes by which they are synthesized or demolished constitute primary metabolism. Primary metabolism of all organisms is similar. Other chemical processes, not essential for the existence of the organism constitute secondary metabolism and the products are termed secondary metabolites, which play a key role in the survival of the species. Examples are defense chemicals, sex attractants, pheromones, *etc.* Secondary metabolites may be a store of energy and food in plants. Intermediate metabolism indicates reactions, which allow exchange of materials between different metabolic pools and producing energy required by both single cells and whole organism, usually involving small molecules.

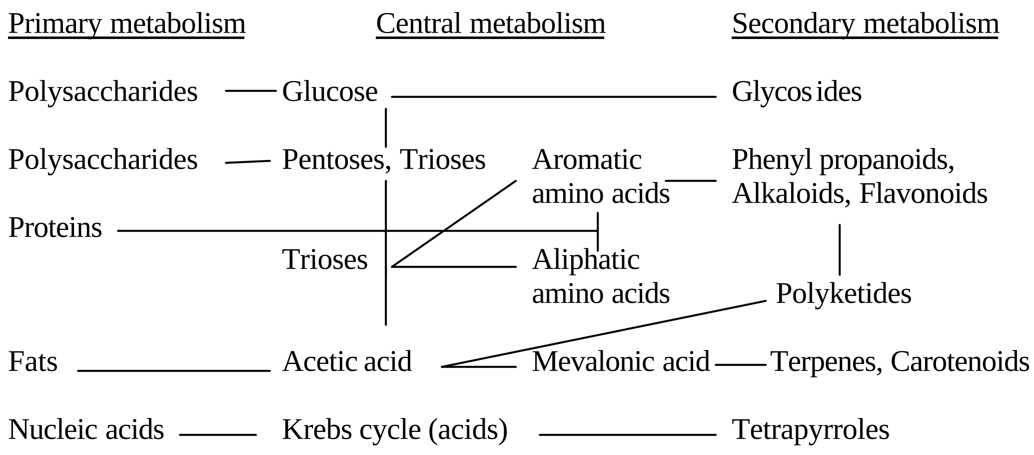


Fig. 2.1. Relationship between primary and secondary metabolism (Manitto, 1981)

The secondary metabolites are biosynthesized from the basic photosynthetic products (Fig. 2.2). For instance, the alkaloids in general are biosynthetically derived from amino acids. The secondary metabolites such as steroids, terpenoids, cardiac glycosides, *etc* are biosynthetically derived from acetic acid. Gums, mucilage, antibiotics, certain vitamins, *etc* are derived from carbohydrates. Arnason *et al.* (1995) reported that plants produced more than 80000 different compounds through their secondary metabolic pathways. Secondary products are mainly stored in specially constructed reservoirs or storage organelles (glands, hair, storage cells, chromoplasts, vacuoles, membrane systems, *etc*). These plant chemical constituents are used as pharmaceuticals, agrochemicals, dyes, flavours, fragrances, pesticides, *etc* and they represent multibillion-dollar industries (Abraham *et al*., 1986; Gautam *et al*., 1998).

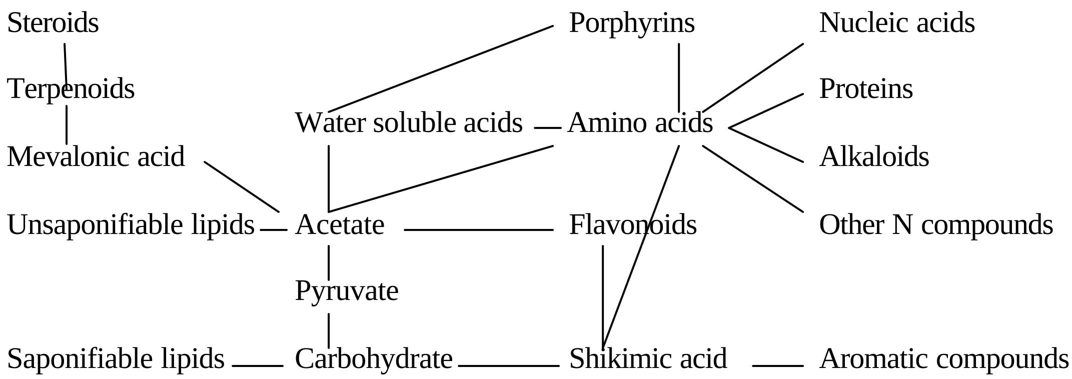


Fig. 2.2. Biogenetic pathways of plant metabolites (George *et al.*, 2000)

The formation and storage of secondary metabolites may be restricted to certain developmental stages of the plant, specific organs, tissues or specialized cells. In the intact plant, close correlation exists between the expression of secondary metabolism and morphological and cytological differentiation. Secondary metabolism is therefore, an aspect of the developmental process. Specific morphological differentiation may not be a prerequisite for secondary product formation. Some of the common plant secondary metabolites are flavonoids (chalcone, flavanone, flavone, flavanols, anthocyanins, isoflava nones, aurones); quinones (benzo-, naphtho-, anthra-quinones); alkaloids (pyrrolidine, piperidine, pyridine, tropane, quinolizidine/lupine, quinoline, isoquinoline, morphine, indole, steroidol, benzodiazepine and purine alkaloids); phenolic acids (cinnamic acids, benzoic acids, phenyl acetic acids); other flavonoids (biflavonoids, proanthocyanidins, c-glycosyl flavonoids, neoflavonoids). These chemicals are the results of the physiological activity and biochemical reactions in the plants (Conn, 1981; Cordel, 1981; Adam and Marquardt, 1986; Harborne, 1993, 1994, 1999; CIMAP, 1999; Krishnaswamy, 1999).

Rao and Beri (1951) identified glucose, mannose, xylose and glucuronic acid from the rootstock of *C. orchioides*. The rootstock was also reported to contain glycoside, polysaccharides (hemicellulose and other polysaccharides), starch, resin, tannin, mucilage, fat and calcium oxalate (Thakur *et al.*, 1989). The hexane extract contained an alkaloid-lycorine, sterols including β-sitosterols and sapogenin identified as yuccagenin (Chopra *et al.*, 1956, 1980; Rao *et al.*, 1978; Husain *et al.*, 1992). The flavone glycoside from the rootstock has been identified as 5,7- dimethoxy glucopyranoside (Yadav *et al.*, 1974; Sharma *et al.*, 1975). Mehta *et al.* (1980) isolated a number of fatty acids from *C. orchioides* root oil by GLC techniques. They were palmitic, oleic, linolenic linoleic, arachidic and behenic acids. Kubo *et al.* (1983) isolated a phenolic glycoside namely curculigoside from the rhizomes and its structure had been elucidated as 5-hydroxy-2-0-β-d-glucopyranosyl benzl 1,2,6-dimethoxy benzoate. Yamasaki *et al.* (1994) developed HPLC method for estimating the curculigoside content in *C.* rhizome.

Two aliphatic hydroxy ketones, 27-hydroxy tricontan-6-one (M.P. 84-85^{o}C) and 23-hydroxy tricontan-2-one (M.P 109-110°C), were isolated from the rhizome of *C. orchioides* (Misra *et al.*, 1984a,b). They further isolated 21-hydroxy tetracontan-20-one and 4-methyl heptade canoic acid from the rootstock. Porwal *et al.* (1988) isolated and identified three new compounds from the rhizome as N-acetyl-N-hydroxy-2-carbamic acid methyl ester, 3-acetyl-5-carbomethoxy-2H-3,4,5,6-tetrahydro-1,2,3,5,6-oxatetrazine and N, N, N', N'-tetra methyl succinamide. The rhizomes of *C. orchioides* yielded a phenolic glycoside (orchioside), characterised as orcinol-3-β-D-xylopyranosyl-(1→6)- β-D-glucopyranoside and Hentriacontanol (Garg *et al.*,1989).

An aliphatic compound had been isolated from the rhizomes and characterised as 25-dihydroxy-33-methyl pentatricontan-one (Mehta *et al.*, 1990). Misra *et al.* (1990) isolated a natural triterpene alcohol-curculigol characterised as 24-methyl cycloart-7-en-3-beta-20-diol. A novel pentacyclic triterpene had been isolated from the rhizomes of *C. orchioides* and characterised as 31-methyl-3-oxo-20-ursen-28-oic acid (Mehta and Gawarikar, 1991). Xu and Xu (1992a,b) and Xu *et al.* (1992a,b) isolated 13 cycloartane types. Triterpene glycosides from *C. orchioides* rhizome were characterised as C. saponin A-M.

Climate, soil and management practices influence the production and accumulation of metabolites in plants. Samuelson (1992) reported that climatic (radiation, temperature and water) and soil (physical, chemical and microbiological) factors influenced the formation of secondary plant chemicals. The soil factors included physical (humidity, temperature and particle size) chemical (pH, availability of N, P, Ca and trace elements) and microbiological factors.

Subramonium (2000) reported that in the case of *Podophyllum hexandrum* (antitumour medicinal plant) alpine and temperate populations differed in photosynthetic rate and podophyllotoxin production at varying temperature and light intensities. Various physical factors such as wind tossing, falling of water on the leaves and temperature affected cell signaling which in turn influenced the synthesis of certain phytochemicals. Seasonal variations in the content of pharmacologically active chemicals in *Bacopa monnieri* had also been reported.

Subramonium (2000) also recorded that very high soil salinity decreased the production of artemisinin (antimalarial drug) by *Artemisia annua*. The essential oil yields of *Artemisia annua* was the highest in the herbage of the plant grown in the modestly alkaline soils and lowest in the acidic soil. Soil potassium had been shown to have a direct influence on medicinally valuable oil production in *Eucalyptus globulus*. Under experimental conditions, 50 per cent shading of *Centella asiatica* resulted in higher yields of asiaticoside and herbage in most of the accessions collected from ecologically different areas. The pharmacological and toxicological properties of medicinal plants could also be altered by the association of other organisms such as bacteria, fungi and other plants. Presence of pesticides, heavy metals, *etc* in the soil adversely affected the medicinal value of plants.

Fulrich *et al.* (1998) reported a stimulation of growth and the triterpenoid saponin accumulation in *Saponaria officinalis* cell and *Gipsophila paniculata* root suspension cultures by improvement of the mineral composition of the media. Hirota *et al.* (1998) reported that the contents of major flavonol glycosides in onion bulbs were localized in the abaxial epidermis of scales and they increased on aging. In alfalfa, Oleszek (1998) synthesized monodesmosidic medicagenic acid glycoside after four days of germination and subsequently followed by bidesmodic saponin production. The total saponin concentration increased from 2.12 μM g^{-1} of dry matter at the beginning of germination to around 6 μM g^{-1} after 18-16 days of seedling growth.

An HPLC investigation of the alkyl amides in *Echinacea purpurea* indicated the alkyl amide content of the vegetative tissue decreased as the plant matured but progressively accumulated in the roots, reaching a maximum at plant fruiting stage (Gengaihi *et al.,* 1998). Menghini *et al.* (1998) reported that urea application significantly increased the tyrosine and beta asarone contents but it decreased those of phenyl alanine and alpha asarone in *Acorus calamus*. Mia *et al*. (1998) observed that *Astragalus mongholicus* under deep tillage conditions for two years had increased tap root length, dry weight, isoflavonoids and astragaloside contents.

Dutta and De (1998) studied the seasonal variations of sennoside and rhein contents in leaves and pods of *Cassia fistula*. Both these anthraquinone glycosides remained high in the mature and old leaves during January-April when the contents of mature pods were low. In the developing green pods, the content was high compared to their mature stage. Leaves were found to be a richer source of these glycosides.

Menkovic *et al.* (2000a,b) studied the production of secondary metabolites gentiopicrin and mangiferin in shoots, roots and hairy roots of *Gentiana lutea* obtained *in vitro*. They reported that the amount of secondary metabolites varied depending on development stage. In the phase of flowering, leaves were rich in compounds possessing C-glycoside structures while O-glycoside structures accumulated mainly before flowering. In henbane, leaf harvest in full bloom along with 60:40:20 kg NPK ha^{-1} recorded more alkaloids in leaf (Singh and Singh, 2001).

Biotic and abiotic factors acted as elicitors and triggered production of secondary metabolites in plants. The elicitation process was accompanied by an increase in biosynthetic enzyme activity regulated at the level of transcription. Activation of gene transcription required recognition of stimulus at the plant or cell surface and subsequent transduction of a signal to the nucleus (Sankar, 1998; Luca, 1999; Sindhu, 1999; Dilip, 2000; KAU, 2000; De, 2001).

The production and accumulation of primary and secondary metabolites is a consequence of active physiological functions during growth and development. They are regulated by both intrinsic and extrinsic factors of biotic origin and abiotic causes.

2.3 EXTRACTION AND CHARACTERISATION OF GLYCOSIDES

According to Encyclopedia Britannica (BCD, 1999) glycoside is any of a wide variety of naturally occurring substances in which a carbohydrate portion, consisting of one or more sugars or a uronic acid (*i.e.,* a sugar acid), is combined with a hydroxy compound. The hydroxy compound, usually a non-sugar entity (aglycon), such as a derivative of phenol or an alcohol, may also be another carbohydrate, as in cellulose, glycogen, or starch, which consist of many glucose units. Many glycosides occur in plants, often as flower and fruit pigments; for example, anthocyanins. Various medicines, condiments and dyes from plants occur as glycosides; of great value are the heart-stimulating glycosides of *Digitalis* and *Strophanthus.* Several antibiotics are glycosides (*e.g.,* streptomycin).

Generally, the glycoside is extracted from the crude drug with alcohol. Adding basic lead acetate to the alcoholic extract causes the impurities to fall to the bottom. After being poured through a filter, the alcoholic extract is concentrated, and the glycosides may crystallize out. Often, however, concentration of the extract is not sufficient to cause crystallization, and more complicated procedures must be employed.

Medicinal principles are present in different parts of the plant like root, stem, bark, heartwood, leaf, flower, fruit or plant exudates. These medicinal principles are separated by different processes; the most common being extraction. Extraction procedures in medicinal plants are based on two major principles (Paroda, 1993). (a) Where it is sufficient to achieve within set limits equilibrium of concentration between drug components and the solution. *Eg*. Tinctures, decoction, teas, e*t*c. (b) Where it is necessary to extract the drug to exhaustion, *i.e.*, until all solvent extractables are removed by the solvent.

Technology for the manufacture of standardised extracts and phytochemicals is available and many extracts are already there in the international market as drugs. A drug, such as an extract of *Centella asiatica* could be manufactured as an extract containing a fixed standard of asiaticoside. Similarly for senna a standardised extract containing a standard quantity of sennosides a and b could easily be produced with equipment that could be designed and constructed in developing countries (Wijesekera, 1991).

Xu *et al.* (1992b) isolated four new cycloartane-type triterpene glycosides, named curculigosaponins G, H, I and J, from the rhizomes of *C. orchioides* (Chinese name, Xiao Mao). Their structures were elucidated from FAB-MS, 1H-, 13C-NMR and 2D-NMR data and chemical analyses. Wang and Shi (1993) employed TLC-densitometry for the quantitative determination of curculigoside in *C. orchioides.*

Yamasaki *et al.* (1994) reported an assay method for the determination of curculigoside in *Curculiginis Rhizoma* by HPLC. After extraction with ethyl acetate, curculigoside was quantitatively converted to 2,6-dimethoxybenzoic acid (2,6-DA) by hydrolysis with 1 *M* NaOH. Determination of curculigoside in Chinese *Curculiginis Rhizoma* was performed indirectly by measuring the content of 2,6-DA by HPLC. The calibration curve for this method exhibited good linearity with a correlation coefficient of 1.00 over the concentration range 1.0-81.0 µg 2,6-DA ml^{-1} (3-207 µg ml^{-1} as curculigoside). According to this method, 7 lots of *Curculiginis Rhizoma* contained 0.2 per cent curculigoside on an average. To estimate the reliability of this method, the curculigoside content of *Curculiginis Rhizoma* was determined by direct assay using HPLC with curculigoside as the standard. The two methods agreed very well, showing the adequacy of the indirect method for estimating the contents of curculigoside in *Curculiginis Rhizoma*.

Friedman *et al*. (1998) reported that a twenty-minute hydolysis in 1*N* HCL at $100^{o}C$ appeared useful for the formation of a mixture of the monosaccharide delta-tomatine, the disaccharide gamma-tomatine and the trisaccharide beta one-tomatine. Guo *et al.* (1998) isolated cyanoglycoside as an aroma precursor of benzaldehyde from fresh tea leaves. Prunasin was readily hydrolysed by a crude enzyme prepared from the fresh tea leaves to liberate benzaldehyde. Oleszek (1998) determined the concentrations of individual saponins in germinating alfalfa seeds and seedlings between one and sixteen days of growth by HPLC and synthesized monodesmosidic medicagenic acid glycoside after four days of germination.

Brantner and Males (1999) described an HPLC method for the separation and quantification of flavonoid glycosides in methanolic extracts of the different plant parts (leaves, flowers and fruits) of *Paliurus spina-christi*. Karchar *et al.* (1999) developed a capillary electrophoresis method for the profiling and determination of individual glucosinolates *via* their isothiocyanate degradation products upon myrosinase digestion. Palma *et al.* (2000) developed super critical fluid extraction with methanol-modified CO_2 to extract glycosides from grapes, which could substantially reduce the total time for analysis.

Braddock and Bryan (2001) extracted limonin glucoside and phlorin from citrus fruit tissues and assayed by capillary electrophoresis. Ichiyanagi *et al.* (2001) reported that hydrolytic rate of anthocyanin glycoside was not dependent on the aglycon structure, but on the type of conjugated sugar.

Glycosides are generally extracted with organic solvents, such as, alcohol, petroleum ether, ethyl acetate or acetone and characterized using TLC, HPLC or NMR techniques.

2.4 BIOTYPE VARIATIONS IN GROWTH, YIELD AND QUALITY

Genetic variations are commonly observed in growth and development pattern, yield expression and production and accumulation of quality principles in plants. The evaluation of 54 adhatoda, 48 plumbago, 34 asparagus, 30 kacholam, 24 holostemma and 24 gymnema germplasm accessions by Kurian *et al.* (2000) revealed wide range of variability in yield of officinal part and quality components. Krishnamoorthy and Madalageri (2002) reported that ajowan genotypes varied significantly in their response to nitrogen and phosphorus with respect to plant height, primary and secondary branches, dry matter production and seed yield.

Kurian *et al.* (2000) reported that in *O. sanctum* lines, green leaved types had better aroma than purple leaved ones. A comparison of the morphotypes of adapathiyan, with respect to yield, suggested a high positive correlation of purple types (elongate and cordate) with yield.

The rhizome yield in 30 kacholam types ranged from 0.67 to 5.35 t ha^{-1} on fresh weight basis and 0.22 to 1.54 t ha^{-1} on dry weight basis. The volatile oil content ranged from 0.71 to 2.80 per cent and oleoresin from 4.0 to 8.0 per cent. The yield of roots in plumbago ranged from 27.5 g to 937.4 g $plant^{-1}$. Variation in whole plant yield of adhatoda types ranged from 0.19 to 3.90 kg $plant^{-1}$ and that of roots from 40 g to 875 g $plant^{-1}$. In asparagus types, the root yield ranged from 175 g to 2650 g $plant^{-1}$. In holostemma types, the root yield ranged from 10 g to 275 g $plant^{-1}$ (Kurian *et al.*, 2000).

Paly *et al.,* (1989) reported that different strains from the same plant could produce very different contents of the derived metabolites. Subramonium (2000) opined that depending on the ecotypes, medicinal plants could exhibit variations in their pharmacological properties and phytochemical profiles.

Comparison of two biotypes of *njavara* rice *viz.*, black glumed and golden yellow glumed revealed that they differed between themselves in growth, yield and quality characteristics, with the former being richer in free amino acid content but a poor yielder and the latter producing high grain yield but with less amino acid content (Menon, 1996; Menon and Potty, 1998; 1999). Cinnamon (*Cinnamomum verum*) genotypes exhibited wide variability in leaf oil quantity and quality, in terms of eugenol content in the oil (Joy *et al*., 1998b,c).

Joy *et al.* (1999) observed that two types of *Alpinia calcarata* varied with regard to essential oil content; type 2 contained higher oil (0.275%) when compared to type 1 (0.225%). In the case of oleoresin content, type 2 was superior (3.06%) to type 1 (2.6%). Significant difference existed between them in the content of methyl cinnamate and also cineole in the essential oil. Type 1 had a high content (34.94%) of cineole when compared to type 2 (13.53%). The reverse was true in the case of methyl cinnamate. Methyl cinnamate content of type 2 (7.44%) was about double that in type 1 (3.81%). The two types, which were genetically close to each other, exhibited chemically distant characteristics.

Sreevalli *et al.* (2000) reported that periwinkle genotype effects were significant for leaf and root yields and their alkaloid contents. Menon and Potty (2001) reported that all the eight ecotypes of medicinal rice variety, *njavara* (*Oryza sativa)* differed significantly in growth and yield characteristics which suggested the possibility of differences in the medicinal value also.

Plumbagin, the therapeutic principle of plumbago varied from 0.20 per cent to 1.00 per cent (Menon, 1999). Kurian *et al.* (2000) recorded that in adhatoda types, the mean vasicine content varied from 1.42 to 2.83 per cent. In asparagus types, the range in total saponins, protein, total free amino acids, soluble sugars and insoluble sugars observed was 0.50 to 2.00 per cent, 0.054 to 0.37 per cent, 0.17 to 0.80 per cent, 43.80 to 64.50 per cent, 1.43 to 8.25 per cent, respectively. In holostemma, the variation in phytoconstituents was from 0.21 to 0.58 per cent for protein, 0.18 to 0.41 per cent for total free amino acids, 4.12 to 8.33 per cent for soluble sugars and 34.85 to 46.26 per cent for insoluble sugars.

Wide variability has been reported due to biotypes on the growth, yield and quality of the produce and variations seem to be more in quality than in quantity.

2.5 EFFECT OF TIME OF HARVEST ON GROWTH, YIELD AND QUALITY

A crop is cultivated not only for the quantity of yield but also for the quality of produce. Usually there exists an inverse relation between quantity and quality as the quality components are formed from quantity components. Hence, the time of harvest needs to strike an ideal balance between the two on the one hand and be economically viable on the other hand.

Kurian *et al.* (2000) reported that in *Costus speciosus,* though the yield of green rhizomes and diosgenin content were higher at six months after planting the dry matter content was low at that stage. Yield of dry rhizomes was higher at nine months after planting. Hence, the optimum stage of harvest for obtaining maximum yield of diosgenin was fixed at eight months after planting.

Kurian *et al.* (2000) further reported that in kacholam, mother rhizomes planted during third week of May and harvested after six months were significantly superior to the rest of the treatments with respect to fresh and dry rhizome yield. In plumbago, ideal harvesting stage was 1½ years as inter crop and 2 years as pure crop. In holostemma, harvesting the roots at 18 months after planting resulted in maximum yield (4.14 t ha^{-1} and 1.56 t ha^{-1} of fresh and dry roots, respectively). Biometric characters related to yield such as internodal length, diameter of the vine and number of branches and all the root characters, driage and harvest index were maximum at this stage.

Kordana *et al.* (1998) observed that the content of aucubin depends mainly on the time of harvest and less on fertilization. Shiva and Mahtolia (1998) reported that stage of the plant was very crucial for yield and quality. Vascicine content of *Adhatoda zeylanica* leaves was the highest at full bloom stage. Xanthotoxine content in *Heracleum candicans* was the highest when the aerial portions had dried up. Hyoscine content in datura leaves was the highest at flowering stage while in fruits just before ripening. *Terminalia chebula* fruits should be collected at near maturity but have not started turning yellow. In *Aegle marmelos,* fruits should be collected at full-grown ripe stage, roots and rhizomes from mature parts only, leaves and flowering tops before the fruits and seeds mature and flowers before pollination.

Singh *et al.* (1999) reported that optimum tuber yield in *Asparagus racemosus* could be harvested from the 39 months of planting. In *Alpinia galanga*, the optimum stage of harvest for obtaining maximum rhizome and oil yields was 36-42 months after planting (Joy *et al*., 2001c).

Bahl *et al.* (2000) reported that the full flowering stage of *Ocimum basilicum* offered the most profitable time of harvest. Quality analysis of oil of *Mentha arvensis* by Kattamani and Reddy (2000) and Kattamani *et al*. (2000a) revealed that menthol contents were more in the first harvest compared to the second. Shah *et al.* (2000) observed that harvesting of *Plumbago zeylanica* at 12 months after planting was the optimum stage of harvesting due to better growth and yield. In *Valeriana wallichii*, yield of dry roots, root/shoot ratio and production of roots in the whole plant biomass observed increase with advancement in age after transplanting (Singh *et al.,* 2000c). Srivastava *et al.* (2000) noted that *Mentha arvensis* aged 3-4 months gave higher yields of high quality oil. Nemade *et al.* (2001) reported that growth and yield attributes of *Andrographis paniculata* were not influenced by date of harvest but by date of planting.

In holostemma, asparagus and adhatoda, as inter crop in coconut, all the quality attributes increased progressively with advance in age except insoluble sugar and maximum contents were recorded in second year. Total free amino acids was maximum at second year whereas soluble and insoluble sugars were maximum at 1½ years which might be due to the inter conversion of sugar to amino acids for the production of secondary metabolites at a later stage (Kurian *et al.,* 2000).

2.6 EFFECT OF SHADE ON GROWTH, YIELD AND QUALITY

Solar radiation is one of the prime factors governing the growth and yield of crop plants. Growing shade loving plants under shade does not affect photosynthesis as long as the shade was not too intense.

Menon and Potty (1998, 1999) reported that heavily shaded uplands gave high quality grains in *njavara* rice. Vyas and Nein (1999) observed that shade increased plant height, number of nodes, mean internodal length and various growth attributes in *Cassia angustifolia*. The leaf growth also increased in terms of number and dry matter accumulation. The promoting effect was more prominent at 25 per cent shade; however, the impact of further increase in shade level was marginal.

Dhopte *et al.* (1999) observed that the growth of *Aloe barbadensis* in green poly net house (50 per cent light intensity) was increased by 84.1 per cent along with 80.8 per cent increase in leaf number and 83.6 per cent increase in leaf length compared to growth under ambient conditions.

In *Valeriana wallichii*, overhead shade due to nylon nets provided better growth as compared to natural shade *vis-a-vis* the crop raised in open field and maximum valepotriates content was noted under nylon net shade (Singh *et al.*, 2000c).

Under experimental conditions, 50 per cent shading of *Centella asiatica* resulted in higher yields of asiaticoside and herbage in most of the accessions collected from ecologically different areas whereas in some cases high yield was obtained under full light. In the case of *Podophyllum hexandrum* (antitumour medicinal plant) alpine and temperate populations differed in photosynthetic rate and podophyllotoxin production at varying temperature and light intensities (Subramonium, 2000).

Zingiberaceous spice crops like ginger, turmeric and mango ginger exhibited better growth and yield in partially shaded situation (25-50%). Ginger produced high quality rhizomes with increased volatile oil content when grown under coconut shade (Nizam and Jayachandran, 1997).

Fertilizer requirement of turmeric shaded to 50 per cent was about 20 per cent more than the general recommendation given to a sole crop in the open (Bhai, 1981). This called for standardization of fertilizer requirement of shaded crops. Fertilizer application promoted nutrient uptake under shaded situation and was highest at 25 per cent shade in ginger (Ancy and Jayachandran, 1998). In mango-ginger, Jayachandran and Nair (1998) observed that rhizome yield under open and 25 per cent shade were on par indicating that the crop was shade tolerant.

2.7 EFFECT OF SPACING ON GROWTH, YIELD AND QUALITY

Plants require adequate space for its existence, solar interception and drawing water and nutrients. Optimum spacing is essential for realizing best growth, yield and quality.

In thippali, total alkaloid yield was highest at 50 x 50 cm spacing (Sheela, 1996). Ayisha (1997) reported that uptake of major nutrients, yield and quality were highest at 60 x 60cm spacing. A study in *Hemidesmus indicus* revealed that high density planting at 10 x 10 cm spacing resulted in high root yield, oil yield, total returns and net returns (Shina, 1998).

Gill and Randhawa (1999) reported that row spacing in *Ocimum basilicum* did not affect the oil content. The cineole, linalool, methyl chavicol and eugenol content in herb did not change in herb oil under various spacing.

Studies by Joy *et al.* (1999, 2002b) revealed that the optimum spacing for obtaining maximum rhizome yield in *Alpinia* was 40x30 cm under low fertility and a narrow spacing of 30x20 cm under good fertility conditions. *Kasthurimanjal* (*Curcuma aromatica*) was highly adaptable to a wide range of spacing, producing similar yields by adjusting the number of plants hill^{-1}. A spacing of 60 x 40 cm was recommended with a saving in seed rate. In *Kaempferia rotunda* the optimum spacing was 20 x 20 cm for obtaining maximum rhizome yield, which translated to a plant population of 27 plants m^{-2} or a seed rate of 2500-3000 kg ha^{-1} with a rhizome bit size of 10-15 g.

Studies at the Kerala Agricultural University (KAU, 1999) showed that Kacholam, *Plumbago, Asparagus* and *Holostemma* were suitable for intercropping in coconut garden and the optimum spacing recommended were 20 x 10 cm for Kacholam, 60 x 15 cm for *Plumbago* and 70 x 30 cm for *Adhatoda, Asparagus* and *Holostemma*.

Srinivasappa *et al.* (1999) observed that number of berries per plant had an inverse relation with plant densities in *Solanum viarum*, but dry weight per plant was unaffected.

Kattamani and Reddy (2000) reported that plant height, number of branches per plant, number of leaves per plant and leaf area index were significantly increased with respect to runners as planting material at 60 cm row spacing in *Mentha arvensis*. Spacing trial in kacholam indicated that planting kacholam at a closer spacing of 20 x 10 cm resulted in maximum rhizome yield. Spacing significantly influenced plant height, spread and yield characters. The widest spacing of 50 x 45 cm registered the highest per plant yield of roots (Kurian *et al.*, 2000). Sundharaiya *et al.* (2000) observed that the number of fruits per plant, fruit weight and yield per plant increased with increase in spacing and fertilizer application in *Solanum khasianum*. Yaseen *et al.* (2000) observed that different varieties of menthol mint produced higher herb yield at closer spacing. Kanjilal *et al.* (2001) reported that *Wedelia calendulacea* gave the highest herb yield with 60 x 60 cm spacing.

Kurian *et al.* (2000) reported that in *Asparagus racemosus*, the soluble and insoluble sugar content was the maximum for the spacing 75 x 30 cm, whereas total free amino acids and total saponins were maximum at the spacing 75 x 60 cm. In kacholam, the closest spacing of 50 x 15 cm recorded the highest yield of plumbagin on unit area basis. In holostemma, planting at a spacing of 75 x 30 cm was found to be most beneficial for achieving maximum root yield. In adhatoda, planting at a spacing of 75 x 30 cm resulted in maximum root yield and vasicine content. In *Costus speciosus,* spacing experiments observed that low density planting (75 x 75 cm) enhanced overall vegetative growth. However, per hectare yield of rhizomes were significantly higher at the closest spacing (50 x 50 cm).

Reeleder *et al.* (2000) reported that the concentration of ginsenosides in *Panax quinquifolius* roots was not affected by seedling density. Sarma and Kanjilal (2000) observed that the oil content and quality of oil of patchouli was not affected by spacing and planting time.

Ram *et al.* (2001) suggested that in order to get proper utilisation of above and underground growth resources for achieving high root yield, *Asparagus racemosus* and *A. adscendens* should be grown at a high plant density following square crop geometry of 30 x 30 cm. Singh and Chauhan (2001) obtained maximum yield of quality isabgol husk with 20 cm row spacing.

The foregoing review reveals that the growth, yield and quality of crops vary with spacing.

2.8 EFFECT OF ORGANIC MANURES ON GROWTH, YIELD AND QUALITY

Apart from the supply of nutrients organic manure improves the physical properties of soil by increasing its capacity to absorb and store water, by enhancement of aeration and by favouring the activities of lower organisms.

In thippali, Ayisha (1997) reported that uptake of major nutrients and yield were highest at 20 t FYM ha^{-1}. Sadanandan and Hamza (1997) reported that application of organic cakes increased the nutrient availability, improved the physical conditions of the soil and increased the yield of ginger. *Kaempferia galanga* responded well to organic manuring and gave higher yields with 30 t ha^{-1} of FYM (Thomas *et al.*, 1997, 1998).

Menon and Potty (1998, 1999) reported that FYM application led to more balanced development of yield components in *njavara* rice. In *Hemidesmus indicus,* application of FYM 10 t ha^{-1} resulted in high root yield, oil yield, total returns and net returns (Shina, 1998). Joy *et al.* (1999) noted that application of FYM at 20 t ha^{-1} $year^{-1}$ produced significantly higher rhizome yields in alpinia. FYM application at 20 t ha^{-1} was the best for realising maximum yield of rhizome in *Curcuma zedoaria*. Joy and Thomas (1999) observed that organic manure application enhanced growth, bloom and tuber formation in *Gloriosa superba*. Riba (2000) observed better growth of ginseng due to the addition of cow dung. Kasera and Saharan (2001) reported that application FYM at 8 t ha^{-1} was suitable for obtaining maximum plant growth and biomass in *Evolvulus alsinoides.*

Singh *et al.* (2000b) concluded that higher yields of *Plantago ovata* could be achieved by sowing in ridges with the application of organic fertilizer Celrich 23.

Kurian *et al.* (2000) reported that the growth, yield and quality of *Piper longum* under differential manurial regimes as intercrop in coconut garden increased with an application of 20 t ha^{-1} of organic manure.

In thippali, total alkaloid yield was highest at 20 t FYM ha^{-1} (Sheela, 1996; Ayisha, 1997). Sadanandan and Hamza (1997) reported that application of organic cakes increased the oleresin production of ginger. Pereira *et al.* (1998) noted that organic fertilization increased caumarin concentration in *Mikenia* *glomerata.* Chand *et al.* (2001) reported that essential oil yield was significantly affected by combined application of manures and fertilizers in *Mentha arvesis.*

Organic manure application generally increases the growth, yield and quality of crops.

2.9 EFFECT OF INORGANIC FERTILISERS ON GROWTH, YIELD AND QUALITY

Inorganic fertilizers are increasingly used for crop production, particularly as a source of major nutrients. Though medicinal plants are mostly raised under organic farming, many of them show good response to inorganic fertiliser application.

Ayisha (1997) reported that in thippali, NPK uptake and yield were highest at 30:30:60 kg NPK ha^{-1}. Gowda and Melanta (1997) noted that the application of 150 kg N, 75 kg P_2O_5 and 50 kg K_2O per hectare resulted in higher yield in ginger. Subbaraj and Thamburaj (1997) found that vines of *Gymnema sylvestre* needed a fertilizer dose of 10 kg N + 2.5 g P per vine for better growth of plants. Kordana *et al.* (1998) reported that *Echinacea purpurea* gave highest yield with mineral fertilization of 100:60:100 kg $N:P_2O_5:K_2O$ ha^{-1}. Pereira *et al.* (1998) observed that inorganic nutrients increased phytomass accumulation more in stems than in leaves of *Mikania glomerata.*

Menon and Potty (1998, 1999) observed that it was the quantity of nutrient rather than the source, which influenced yield of *njavara* rice and the highest yield was obtained at 30 kg N ha^{-1}. However, even 15 kg ha^{-1} of N, P and K were found in excess under shaded condition.

Chalapathi *et al.* (1999) reported a significant fertilizer response in terms of growth and yield of *Stevia rebaudiana* up to 40:20:30 kg NPK ha^{-1} and further increase in fertilizer dose to 60:30:45 kg NPK ha^{-1} caused marginal increase in growth and yield attributes. The uptake of N, P and K increased with increase in levels of fertilizers. Joy *et al.* (1999) found that application of NPK at 100:50:50 kg ha^{-1} $year^{-1}$ produced significantly higher rhizome yields in *Alpinia calcarata.* However, the growth and yield of mulched *Kaempferia rotunda* were not significantly influenced by fertiliser treatments. Maurya *et al.* (1999)

observed that 60 kg N ha^{-1} was suitable for higher root yield of *Rauvolfia serpentina*. Muthumanickam and Balakrishnamurty (1999) reported that a fertiliser dose of 40:60:20 kg N:P_2O_5:K_2O ha^{-1} resulted in the highest dry root yield of 770 kg ha^{-1} in *Withania somnifera*. There were also improvements in the length of roots and number of root primaries due to the nutrient application. Pareek *et al.* (1999) recorded that fresh weight of *Aloe barbadensis* pads was the highest with 100 kg FYM + 125 kg P_2O_5 and 124 kg N ha^{-1}. Application of N alone increased pad yield more than that obtained by combined application of fertilizers.

A review by Kurian *et al.* (2000) indicated that in *Costus speciosus* application of N increased the growth of plants in terms of height, length and breadth of leaves and leaf area. Highest levels of N (150 kg ha^{-1}) and P (90 kg ha^{-1}) and lower levels of K (30 and 60 kg ha^{-1}) recorded higher values for root and shoot yield. Ojha *et al.* (2000) reported that application of 120 kg N ha^{-1} was optimum for spear mint. Prasad *et al.* (2000) observed that equal proportion of NPK in a mixture at 125 kg ha^{-1} enhanced the biomass yield of *Gymnema sylvetre*.

Singh and Ramesh (2000) found that application of 150 kg N ha^{-1} was optimum for rosemary. Tiwari *et al.* (2000a) observed that *Acorus calamus* responded well to N up to 100 kg ha^{-1} and further increase up to 200 kg ha^{-1} did not increase the yields. Tiwari *et al.* (2000b) found that *Abelmoschus moschatus* responded well up to 75 kg N ha^{-1} and 50 kg P_2O_5 ha^{-1}.

Kattamani *et al.* (2001) reported that combined application of 225 kg N along with 40 kg P_2O_5 ha^{-1} recorded highest biomass yield, essential oil yield and nutrient uptake in *Mentha arvensis*. Kumawat and Majumdar (2001) reported that application of sulphur increased plant height, bunches per plant, chlorophyll content and number of effective and total nodules per plant, number of pods per plant, seeds per pod and seed and straw yields in fenugreek. Roki *et al.* (2001) noted that fresh flower yields of *Arnica chamissonis* were improved by inorganic fertiliser application. Singh *et al.* (2001a) found that isabgol needed 30 kg N and 40 kg P_2O_5 ha^{-1} for getting maximum yield of husk.

Nehara *et al.* (2002) recorded that increasing level of phosphorus up to 40 kg P_2O_5 ha^{-1} and potassium up to 45 kg K_2O ha^{-1} significantly increased all the growth characters, yield attributes, yield, net return and B:C ratio in fenugreek. Rai *et al.* (2002) reported that growth parameters increased with increasing dose of N and P and reached the maximum at 90 kg N and 50 kg P ha^{-1} in *Foeniculum vulgare*.

In thippali, total alkaloid yield was highest with 30:30:60 kg NPK ha^{-1} (Sheela, 1996; Ayisha, 1997). Gengaihi *et al.* (1998) recorded that high levels of nitrogen and low potassium increased the alkyl amide in the plant tissues. Menghini *et al.* (1998) observed that urea addition significantly increased the photosynthetic rate and the contents of chlorophylls, carotenoids, proteins and amino nitrogen in *Acorus calamus*. Ruan *et al.* (1998) reported that potassium and magnesium application improved the nitrogen metabolism, leading to an increased synthesis of free amino acids in tea leaves. Ram *et al.* (1999a,b) noted that N had a positive effect on farnesene and bisabolol oxide-A in the oil but bisabolol Oxide-B decreased with increase in the nitrogen levels. Kurian *et al.* (2000) reported that phosphorus had a favourable influence on the diosgenin content of *Costus speciosus*. Highest levels of N (150 kg ha^{-1}) and P (90 kg ha^{-1}) and lower levels of K (30 and 60 kg ha^{-1}) recorded higher values for total crude alkaloid in leaf. However, qualitative analysis of mentha oil by Kattamani *et al.* (2000a, 2001) found that the application of nitrogen and phosphorus decreased the menthol content and increased the esters and ketones. Singh (2000) reported that application of 50 and 100 kg N ha^{-1} increased oil and artemesinin yields by 26.2 per cent and 40.1 per cent respectively. There was no response to phosphorus and potassium. Oil and artemesinin contents were not influenced by N, P and K nutrition in semi-arid tropical condition. Singh *et al.* (2001a) found that isabgol needed 30 kg N and 40 kg P_2O_5 ha^{-1} for better quality husk. Nehara *et al.* (2002) reported that Menthol content decreased while menthone and methyl acetate increased with the application of N and P in *Mentha arvensis*.

The above review reveals that though the growth and yield of medicinal plants can be increased by inorganic fertiliser application the quality may be affected adversely.

2.10 EFFECT OF BIOFERTILISERS ON GROWTH, YIELD AND QUALITY

Because of the growing concern over the ill effects of inorganic fertilizers alternate sources of nutrients have been sought for and biofertilisers are an effective alternative or a supplement especially in the context of organic farming. According to Subramonium (2000), the pharmacological and toxicological properties of medicinal plants could also be altered by the association of other organisms such as bacteria, fungi and other plants.

Mehrotra *et al.* (1998) reported that VAM improved *Grindelia camporum* plant growth in terms of height, average leaf area and the shoot biomass and the beneficial effect could be attributed to its effect on root growth, P uptake and translocation in the plant system and on the resulting biomass. Sreeramulu and Bhagyaraj (1998) reported that cardamom seedlings inoculated with VAM fungi grew taller, had more number of leaves and tillers, increased seedling biomass and uptake of nutrients.

Joy *et al.* (1999) noted that application of the biofertilizer *Azospirillum* at 10 kg ha^{-1} resulted in significantly superior rhizome yield in *Alpinia calcarata.* Application of biofertilizers, inorganic fertiliser and cowpea green manuring *in situ* were on par and inferior to mulching and application of compost, FYM or vermicompost in *Kaempferia rotunda.* Kothari *et al.* (1999) reported that the *Glomus intraradices* (mycorrhiza) substantially increased the root and shoot ratio, specific and total root length, concentration of P, Zn and Cu in root and shoot, total nutrient uptake in *Mentha citrata.* Little response to VAM was observed when the soil was amended with 50 or 100 mg P kg^{-1} soil. Negative response was noted in respect of leaf-stem ratio, essential oil concentration in herbage and acquisition of K, Fe and Mn per unit root length even when the soil was not amended with P.

Jat and Sharma (2000) observed that combined inoculation of *Rhizobium* + PSB significantly enhanced fenugreek plant height, branches, dry matter, pods per plant, seeds per pod, pod length, dry seed and straw yield, protein content in seed, N and P contents in seed and straw and their total uptake. Kalavathi *et al.* (2000) observed that combined inoculation of VAM and phosphobacteria markedly increased the growth of neem seedlings. The increase in the growth had been attributed to the increase in nutrient uptake by the neem seedlings and the synergistic effect. Lakshmi and Anand (2000) used filtrates of two cyanobacterial strains, namely, *Oscillatoria foreaui* (A 1340) and *Anabaena ambigua* (A100) as fertilizer supplement on *Solanum nigrum* which increased chlorophyll content, plant height and number of branches.

Gupta *et al.* (2001) observed that application of VAM and plant growth promoting rhizobacteria (PGPR) *Pseudomonas fluorescens* as alone or in combination has dramatically enhanced the growth and biomass yield of a number of medicinal and aromatic plants. The capabilities of these microorganisms to solubilise the bound forms of P in the soil and render them available to plants contributed to their growth and productivity. These soil inhabiting ecofriendly microorganisms also produce growth promoting substances, antibiotic compounds, *etc* which contribute to the improvement of seed germination and plant growth by inhibiting the activity of soil borne plant pathogens. Kumawat *et al.* (2001) reported that combined application of 0.5 kg Mo ha^{-1} and rhizobium significantly increased the protein content of fenugreek seed.

Jena and Das (1998) reported that in *Curcuma longa*, inoculation of *Azotobacter* and *Azospirillum* increased the curcumin and protein content and dual inoculated treatments observed better curcumin content as compared to single inoculated and uninoculated treatments at 0, 30 and 60 kg ha^{-1} of N levels and they suggested dual inoculation of *Azotobacter* and *Azospirillum* along with fertilizer N (30 kg ha^{-1}) for quality improvement of turmeric. Murthy *et al.* (1998) suggested *Azospirillum* and phosphobacterium treatments to *Emblica officinalis* seedlings and analysed for their physiological and biochemical parameters. They found that the use of these bacteroids on the soil observed a significant improvement in the seed germination and seedling vigour along with an improvement in soil quality.

Biofertilisers such as *Rhizobium*, *Azotobacter*, *Azospirillum*, *Pseudomonas fluorescens*, phosphobacteria and VAM (*Glomus intraradices*) are ecofriendly microorganisms which can be very efficiently employed in organic farming of medicinal plants as nutrient sources.

2.11 INTEGRATED NUTRIENT APPLICATION

Integrated application of organic manure, inorganic fertiliser and biofertiliser is a more pragmatic approach in nutrient management of crops.

Harinkhede *et al.* (2000) reported that Plumbago zeylanica gave highest dry root yield with 10 t ha^{-1} of FYM and 60:40:30 kg NPK ha^{-1} as a result of increased root length, number of branches per plant, plant height and root weight per plant. Kurian *et al.* (2000) reported that in kacholam, integrated application of FYM 20 t ha^{-1} + Azospirillum 2.5 kg ha^{-1} + 25 kg N and 50 kg each of K_2O and P_2O_5 + neem cake 1.5 t ha^{-1} + P solubilizer was beneficial for obtaining a consistently higher yield. Chand *et al.* (2001) noted that herb yield as well as accumulation of major and micronutrients were significantly affected by combined application of manures and fertilizers in Mentha arvesis.

Integrated nutrient application has a more favourable influence on the growth, yield and quality of crops.

2.12 EFFECT OF MULCHING ON GROWTH, YIELD AND QUALITY

Mulch, either organic or synthetic, is of great use to protect the soil and crop, conserve soil moisture, control weeds and to provide an ideal microclimate for the favourable growth of microorganisms and crop plants.

Das (1999) observed positive response of mulching on germination percentage, tiller number and rhizome yield of ginger. Gill *et al.* (1999) reported that application of wheat straw mulch (6 t ha^{-1}) improved growth and yield of turmeric significantly. Palada *et al.* (1999) reported that organic mulches reduced soil temperature in the range of 1 to 6^{o}C in basil. Total plant and leaf fresh weights in plots with compost mulch were higher than all other mulch treatments. Total plant and leaf fresh yields from plots under organic mulches were significantly higher than yields from plots with synthetic mulches.

Shukla *et al.* (2000) reported that in *Emblica officinalis*, among organic mulches, paddy straw was the best, which recorded higher N values, whereas the maximum P, K, Ca and Mg values were recorded for FYM.

The above review shows that mulching is beneficial for the growth and yield of medicinal plants. Organic mulch was found better than synthetic ones.

2.13 QUALITY VARIATIONS ON DOMESTICATION OF WILD PLANTS

With the application of modern chemical pharmacological techniques, it has become possible to evaluate the quality of a particular drug on the basis of the therapeutically active chemical constituents present in them. These chemicals are the result of the physiological activity and biochemical reactions in the plants. The phenology, ecology and chemical conditions play a very active role in determining the occurrence and concentration of various chemical constituents in medicinal plants. The nature and content of both primary and secondary metabolites varied with the change of habitat from wild to domestic (Raj, 1997). Shiva and Mahtolia (1998) reported that the edaphic and climatic conditions of a region affected the quality of medicinal plants.

According to Pusalkar and Aruna (2001) major cultivation of medicinal plants started only after 1980 and the last decade witnessed their large scale cultivation.

Shiva and Mahtolia (1998) reported that total alkaloid content in *Rauvolfia serpentina* roots was highest in the sub-Himalayan tract of Gurhwal and Kumaon and the least in the moist to wet areas of N-E and Western Ghats extending from Goa to Kerala. Total alkaloid content of *Holarrhena antidysenteric*a bark was the highest in Coromandal coast from Vishakhapatanam to Tiruchirappalli. Picrorhizine content of *Picrorhiza kurroa* roots was the highest in Jammu and Kashmir and it declined from W. Himalayas to Nepal and Sikkim.

Shiva and Mahtolia (1998) further recorded that quality of medicinal plants was influenced by seasonal effects and hence they suggested that generally, drugs should be collected in autumn season. Drugs used as emetics and purgatives should be taken after the termination of spring season. Roots should be harvested in winter and summer. Leaves should be collected in spring and rainy season. Barks, bulbs and exudations should be collected in autumn season. Piths should be collected before winter.

Mathur and Kumar (2000) domesticated *Bacopa monnieri* and standardized the technology for cultivation and post harvest processing of the herb. Raj *et al.* (2000) carried out natural habitat analysis and domestication trials and reported that *Piper longum, Naravelia zeylanica, Sida rhombifoila* subsp. *retusa,* *Desmodium velutinum, Baliospermum solanifolium* and *Barieria prattensis* responded well to domestication. Though photosynthesis appeared to be high in the open condition, the enzymatic reactions, which decided the quality of the plant, seemed to be a function of the environment. With respect to the contents of total soluble sugars, starch, total free amino acids, total crude extractables and the number of alkaloids, the species differed greatly between the wild and domestic environments.

Analysis of roots of cultivated *Valeriana wallichii* showed significantly higher contents of valepotriates and patchouli alcohol than those reported in wild plants. A marked difference in terms of percentage of ar-curcumene, beta-patchoulene and gamma-patchoulene was found between the cultivated and wild plants (Singh *et al.*, 2000c).

Pandey and Patra (2001) reported that cultivated ashwagandha yielded better quality roots. Singh *et al.* (2001b) domesticated and cultivated three wild types of *Andrographis paniculata* and reported that the population exhibited wide variation among themselves with respect to growth behaviour, maturity period, dry biomass and leaf yield and per cent andrographolides content and their yield.

The quality of medicinal plants varies with the biotype and the growing environment. Domestication ensures their large scale availability with uniform quality.

2.14 QUALITY VARIATIONS IN CRUDE DRUG IN TRADE

Generally large variations are observed in the quality of crude drugs available in the market thereby affecting the efficacy of the drug formulations. These variations are to be scientifically assessed to develop quality standards for the crude drugs and formulations.

Drying, packing and storage were reported to affect the quality of raw drug in the market. Improper packing and storage might cause the drug to absorb moisture, which might reduce the efficacy of active constituents and expose the raw material to fungal attack. Therefore, appropriate airtight containers or cool dark and well-ventilated places were preferred for storage (Nair *et al.*, 1982).

Vitamin C and total sugar content in *Phyllanthus emblica* decreased when storage period was extended beyond 45 days (Mishra *et al.,* 1996).

Reynolds (1998) recorded the influence of air temperature and moisture content on the colour, major carbohydrates and gingenosides of *Panax quinquifolium*.

Agarawal and Sharma (1999) reported that fennel seeds could be stored in polythene bags or cotton bags for one year without much loss of volatile oil contents. Brantnar and Males (1999) suggested that the flavonoid compounds quercetin 3-O-rhamnoglucoside 7-O- rhamnoside and rutin should be used as markers for the quality assessment of *Paliurus spina-christi.*

Joy *et al*. (1999) observed that the samples of *Alpinia* rhizomes collected from various markets differed morphologically with respect to internodal length, diameter and colour. Large variations were observed in the quality parameters studied. The essential oil content of the rhizomes ranged from 0.30 to 0.50 per cent. Noticeable differences were observed in the case of oleoresin content also (4.6 to 7.78%). In the case of chemical components in the essential oil, Kothamangalam and Angamali samples were more or less similar. However, the former was characterised by a very high content of cineole (40.17%) whereas the latter had a distinctly high level of methyl cinnamate (7.44%). The essential oil in samples collected from Kalady was characterised by high level of ethyl cinnamate (21.82%) typical of oil of *A. calcarata.*

Joy *et al*. (1999) studied the physical characteristics of market samples of *Curcuma zedoaria*. The data on the type of rhizome, length, colour, shape and hardness indicated that market samples obtained from Perumbavoor, Kothamangalam and Muvattupuzha were almost similar. Kalady sample differed considerably in the above physical characters from those collected from other locations.

The essential oils of *C. zedoaria* of the market samples collected from Perumbavoor, Muvattupuzha, Kothamangalam and Kalady were analysed by GLC. The chromatogram of the oils of samples of Perumbavoor, Muvattupuzha and Kothamangalam were similar. Their essential oil yield was 0.75-1.1 per cent and oleoresin content was 9.94-11.38 per cent. The oil and oleoresin contents of

Kalady sample were substantially higher when compared to those of the other three localities (Joy *et al*. 1999).

The quality requirements for herbal medicinal products was concerned with growing and harvest of plant material, drying conditions and the use of pesticides, which were determined by good agricultural practices (Kabelitz, 1999).

Suarez *et al.* (1999) studied the changes occurring in the content and composition of the dietary fibre of white asparagus during storage in different conditions and found that the changes corresponded to xylose and glucose from insoluble dietary fibre and galactose from soluble dietary fibre.

Kamalapurkar *et al.* (2000) developed a method to determine the amount of the crude drug ashwagandha (*Withania somnifera*) present in a formulation based on the presence of active principle withaferin A. Martin and Briones (2000) used reverse phase HPLC techniques to standardize the quality of commercial extracts of quillaja based on the active principle saponins. Roy (2000) observed mould infestation and mycotoxin contamination in a large number of herbal drugs and it was essential that crude or finished herbal drugs should be freed from adulteration and mycotoxin contamination otherwise unwarranted health hazards might be encountered. Sarashwathi (2000) developed HPLC methods, besides physico-chemical standards for the quality assessment of selected crude drugs and herbal medicines which could be used to lay down pharmacopoeial standards for the drugs. Liu *et al.* (2001) suggested to combine DNA probe markers technology with chemical and anatomical analysis to increase the quality and reliability of herbal drugs.

Joy *et al*. (2002a) observed that *Kaempferia rotunda* rhizomes sliced and dried to around 10 per cent moisture could be stored in gunny or polythene bags for two years without deterioration in quality.

Variations occur in the quality of crude drug in the market owing to differences in soil, climate, management practices, maturity, drying, storage, handling, packaging, pests, diseases, substitutions or adulterations. These variations need to be minimized through appropriate quality control measures to ensure the quality of crude drugs and formulations.

3. MATERIALS AND METHODS

3. MATERIALS AND METHODS

Investigations on the agrotechnological practices for quality crude drug production in *nilappana* (*Curculigo orchioides* Gaertn.) were carried out during 2000-’02 at the Aromatic and Medicinal Plants Research Station (AMPRS), Odakkali, Kerala. The details of the materials used and the methods adopted in the conduct of the experiments as well as the evaluation of the results are presented hereunder.

3.1 LOCATION

The Aromatic and Medicinal Plants Research Station, Odakkali functioning under the Kerala Agricultural University lies between 10^{o}5'40" and 10^{o}6'0"N latitude and 76^{o}32'35" and 76^{o}32'55"E longitude in the Asamannoor village of Kunnathunadu taluk in the Ernakulam district of Kerala. The station is located at an elevation of 60 m above MSL.

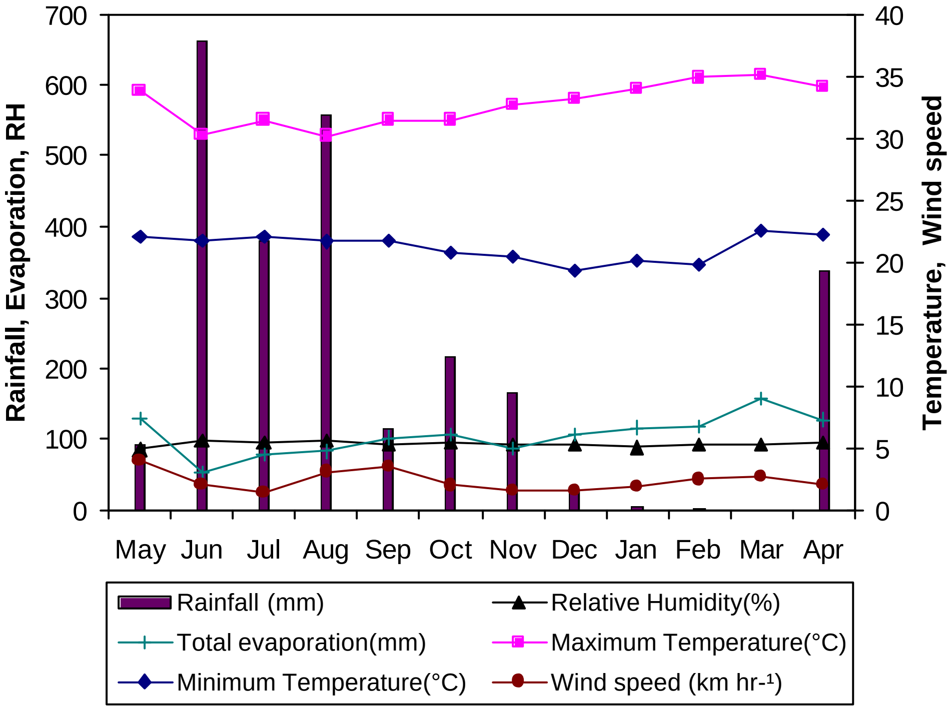
3.2 WEATHER AND CLIMATE

The experimental site represents the typical agroclimatic features of the mid lands of the state. It experiences a warm humid tropical climate. The mean annual rainfall is 3318 mm; with south-west monsoon contributing 57.4 per cent, north-east monsoon 28.8 per cent, summer showers 2.4 per cent and pre-monsoon showers 11.4 per cent. The mean number of rainy days is 166 per annum. The mean maximum and minimum temperatures are 32.6^{o}C and 20^{o}C, respectively. The relative humidity is often as high as 92.2 per cent.

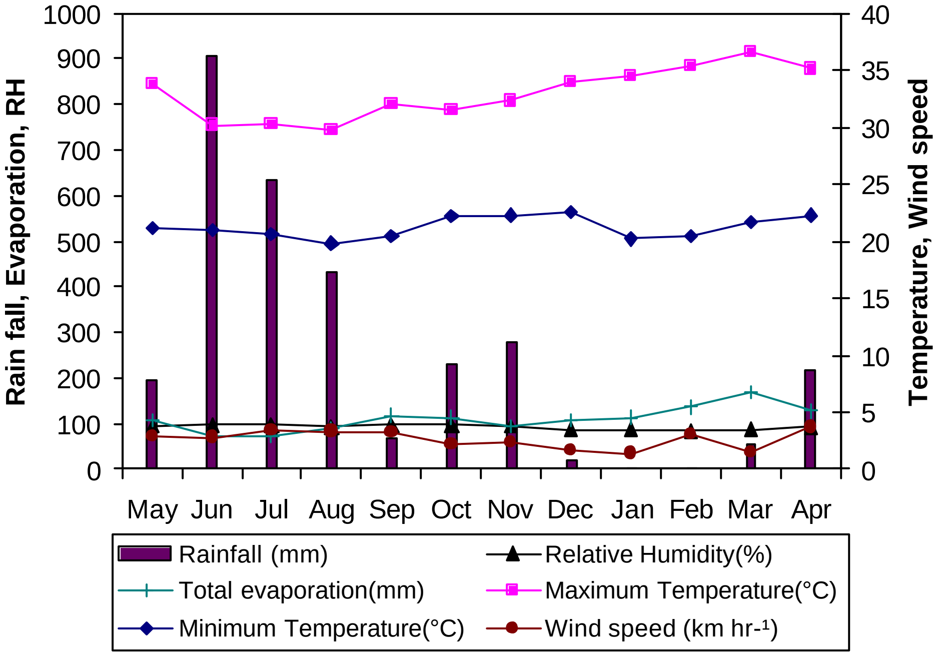
The study was conducted during the period from May 2000 to April 2002. The weather conditions prevailed during the experimental period are presented in Fig. 3.1 and appendix 1 and 2 .

3.3 SOIL

The soil of the experimental site belongs to Odakkali series I. It is gravelly clay loam of the Oxisol group. The physical and chemical characteristics of the soil of the experimental fields are presented in Table 3.1.



During 2000-'01



During 2001-'02

Fig. 3.1. Weather conditions during the experimental period

Table 3.1. Physical and chemical characteristics of the soil prior to the experiment

Chemical characteristic	Experiment 3	Experiment 4	Experiment 5
Texture	Clay loam	Clay loam	Clay loam
Structure	Granular	Granular	Granular
pH	6.09	6.08	6.04
Available N (ppm)	144.48	127.77	127.76
Available P (ppm)	2.90	4.14	6.21
Available K (ppm)	68.00	109.00	94.00
Ca (ppm)	175.80	139.18	139.18
Mg (ppm)	16.07	41.77	38.55
S (ppm)	5.22	39.14	71.75
Fe (ppm)	20.36	29.96	16.44
Mn (ppm)	9.58	13.01	10.64
Zn (ppm)	1.75	1.26	1.38
Cu (ppm)	3.85	3.64	3.01

3.4 CROPPING HISTORY OF EXPERIMENTAL SITE

Field where no experiment was conducted during the three previous seasons was selected for the conduct of the field trials.

3.5 MATERIALS

The details of the various materials used for the study are furnished below.

3.5.1 Biotypes

Two biotypes of the species *C. orchioides*, namely, Panamkuzhi and Vellanikara types were used for the observational trial on developmental physiology of *C. orchioides*. For the field trials only one biotype, namely, Panamkuzhi type was used.

3.5.2 Seed Material

The planting material of Panamkuzhi biotype was collected from Panamkuzhi area of Kodanad forest range in the Ernakulam district. The

Vellanikara biotype was collected from the rubber plantation of the Kerala Agricultural University at Vellanikara in Trichur district

3.5.3 Shade Net

Shade was provided in the experiment on the effect of shade and spacing on the yield and quality of *C. orchioides* using shade nets of varying meshes. Shade nets of 25 per cent, 50 per cent and 75 per cent grades were used for the study.

3.5.4 Manures and Fertilisers

Farmyard manure, compost and poultry manure were used in the study. Farmyard manure was purchased locally. Compost was prepared in the farm from various farm wastes including spent lemongrass. Poultry manure was procured from M/s. Agrobiotech, Kottayam.

3.5.7 Mulch

Spent lemongrass was used as the mulching material and its composition is given in Table 3.2.

Table 3.2. Chemical composition of the experimental materials used in the study

Nutrient	Planting material	FYM	Compost	Poultry manure	Vermi-compost	Mulch
N (%)	0.30	0.89	0.76	1.60	0.66	0.74
P (%)	0.12	0.47	0.09	1.59	0.57	0.07
K (%)	0.51	0.37	2.24	1.64	0.32	2.12
Ca (%)	1.09	0.72	0.43	4.24	1.25	0.36
Mg (%)	0.24	0.39	0.18	0.18	0.15	0.15
S (%)	0.27	0.18	0.19	0.45	0.23	0.19
Fe (ppm)	3344.00	1727.00	145.40	1015.00	1520.00	126.70
Mn (ppm)	188.50	252.90	161.70	249.50	176.60	155.80
Zn (ppm)	72.60	65.90	90.30	121.10	61.50	35.50
Cu (ppm)	22.00	85.10	85.90	102.10	85.60	56.60

3.5.8 Crude Drugs

Crude drugs were purchased directly from the crude drug market representing four agroecological zones of Kerala and from four southern states of India, namely, Tamil Nadu, Karnataka, Andhra Pradesh and Maharashtra.

3.6 METHODS

The research project consisted of 6 independent experiments, the details of which are given below.

3.6.1 Experiment Details

The design and layout of the experiments (Fig. 3.2) are given below along with a brief outline of the technical programme followed. The general views of field experiments are given in Figure 3.3. The plot size was uniform for the field experiments; 9.45 m^2 (6.3m x 1.5m) gross plot and 7.2 m^2 (6m x 1.2m) net plot.

3.6.1.1 Experiment 1

Title: Observational trial on developmental physiology of *C. orchioides*

Two biotypes of *C. orchioides* were planted on 30 April 2000 in standard potting mixture one each in 12 polythene bags each with uniform management, in CRD with 2 replications and harvested at monthly interval till 12 months as per treatments. The production and accumulation of dry matter were noted at monthly intervals. The pattern of growth, development and maturation was studied.

3.6.1.2 Experiment 2

Title: Characterisation of major glycosides in *C. orchioides*

Plant samples of both wild and domesticated types and market raw drug samples were collected during 2001. The major glycoside components were separated and identified following the extraction and identification procedures reported for glycosides. A suitable method was developed for the characterisation of major glycosides.

3.6.1.3 Experiment 3

Title: Effect of shade and spacing on the yield and quality of *C. orchioides*
Design : split plot

M: Mainplot S: Subplot

T3:M1S3	T2:M1S2	T4:M1S4
T1:M1S1	T4:M1S4	T3:M1S3
T2:M1S2	T1:M1S1	T2:M1S2
T4:M1S4	T3:M1S3	T1:M1S1
T6:M2S2	T8:M2S4	T7:M2S3
T5:M2S1	T7:M2S3	T5:M2S1
T8:M2S4	T5:M2S1	T6:M2S2
T7:M2S3	T6:M2S2	T8:M2S4
T13:M4S1	T13:M4S1	T15:M4S3
T15:M4S3	T14:M4S2	T14:M4S2
T16:M4S4	T15:M4S3	T16:M4S4
T14:M4S2	T16:M4S4	T13:M4S1
T12:M3S4	T10:M3S2	T12:M3S4
T9:M3S1	T12:M3S4	T10:M3S2
T10:M3S2	T9:M3S1	T11:M3S3
T11:M3S3	T11:M3S3	T9:M3S1
R1	R2	R3

Experiment 3

F: FYM level P: FYM:Fert. Proportion

N ↑

T11:F2P5	T10:F2P4	T16:F3P5
T9:F2P3	T2:F1P1	T11:F2P5
T12:F3P1	T4:F1P3	T15:F3P4
T8:F2P2	T15:F3P4	T5:F1P4
T4:F1P3	T5:F1P4	T12:F3P1
T10:F2P4	T16:F3P5	T4:F1P3
T16:F3P5	T12:F3P1	T6:F1P5
T15:F3P4	T6:F1P5	T10:F2P4
T5:F1P4	T8:F2P2	T2:F1P1
T3:F1P2	T13:F3P2	T7:F2P1
T6:F1P5	T7:F2P1	T14:F3P3
T2:F1P1	T9:F2P3	T1:Control
T14:F3P3	T11:F2P5	T9:F2P3
T1:Control	T14:F3P3	T3:F1P2
T7:F2P1	T1:Control	T13:F3P2
T13:F3P2	T3:F1P2	T8:F2P2
R1	R2	R3

Experiment 4

M: Mulch S: Source of Nutrients

T11:M1S2	T13:M1S4	T8:M0S7
T15:M1S6	T12:M1S3	T13:M1S4
T1:M0S0	T7:M0S6	T2:M0S1
T10:M1S1	T15:M1S6	T11:M1S2
T4:M0S3	T16:M1S7	T6:M0S5
T9:M1S0	T1:M0S0	T7:M0S6
T16:M1S7	T4:M0S3	T1:M0S0
T14:M1S5	T8:M0S7	T4:M0S3
T3:M0S2	T11:M1S2	T12:M1S3
T6:M0S5	T10:M1S1	T5:M0S4
T2:M0S1	T3:M0S2	T10:M1S1
T8:M0S7	T2:M0S1	T3:M0S2
T13:M1S4	T14:M1S5	T9:M1S0
T12:M1S3	T6:M0S5	T15:M1S6
T5:M0S4	T9:M1S0	T14:M1S5
T7:M0S6	T5:M0S4	T16:M1S7
R1	R2	R3

Experiment 5

Fig. 3.2. Layout of field experiments

General view of the experimental field

Experimental field protected from rodent attack

A view of the shade experiment

Fig. 3.3. General views of field experiments

Replications: 3

Treatments : 4 x 4 =16

Mainplot: Four shades (0, 25, 50, 75 %) (M1 to M4)

Subplot: Four spacings (10x10, 20x10, 20x20, 30x20 cm) (S1 to S4)

Biotype: Panamkuzhi, Date of planting: 28.05.01, Date of harvesting: 28.02.02

FYM was applied as basal dressing at 20 t ha^{-1}

3.6.1.4 Experiment 4

Title: Manurial requirements of *C. orchioides*

Design : RBD

Replications: 3

Treatments: 16

Three levels of FYM (10, 20, 30 t ha^{-1}) (F1 to F3)

Five levels of substitution of FYM with inorganic fertilizers (0, 25, 50, 75, 100%) (P1 to P5)

Control: No FYM and fertilizer

Biotype: Panamkuzhi, Date of planting: 29.05.01, Date of harvesting: 01.03.02

[10 t FYM was considered equivalent to 40:30:20 kg N, P_2O_5 and K_2O based on the content of N, P_2O_5 and K_2O in FYM as per KAU (1996)]

Planting was done at 20 x 10 cm spacing.

3.6.1.5 Experiment 5

Title: Effect of mulch and sources of nutrients on yield and quality of *C. orchioides*

Design : RBD

Replications: 3

Treatments: 8 x 2 = 16

Sources of nutrients (S0 to S7)

Control

FYM 10 t ha^{-1}

Vermicompost 1.3 t ha^{-1}

Poultry manure 2.7 t ha^{-1}

FYM 10 t ha^{-1} + *Azotobacter* 10 kg ha^{-1}

FYM 10 t ha^{-1} + *Phosphobacter* 10 kg ha^{-1}

FYM 10 t ha^{-1} + VAM 10 kg ha^{-1}

Fertiliser N, P_2O_5, K_2O: 40:30:20 kg ha^{-1}

Mulching: With out and with mulching (M0 and M1)

Biotype: Panamkuzhi, Date of planting: 30.05.01, Date of harvesting: 02.03.02

Planting was done at 20 x 10 cm spacing.

3.6.1.6 Experiment 6

Title: Quality variations in *C. orchioides*

Both wild and domesticated plant samples of Panamkuzhi and Vellanikkara types were collected during 2001. Crude drugs were purchased directly from two randomly selected markets representing each of the four agroecological zones of Kerala and from four southern states of India, namely, Tamil Nadu, Karnataka, Andhra Pradesh and Maharashtra. These samples were evaluated for quality variations in terms of primary and secondary metabolites.

3.6.2 Crop Culture

The experimental area was ploughed twice, harrowed, levelled and brought to a good tilth. The field was laid out as per the design of the individual experiment, in raised beds with channels (40 cm) separating the plots.

3.6.2.1 Planting Suckers

The plants collected from Panamkuzhi forest were separated into suckers. Each sucker was cut retaining 2 cm of rhizome and 3-4 cm of shoot portion and was used as the planting material. The suckers were dipped for 10 s in 0.5 per cent calixin solution as a prophylatic measure against the incidence of fungal diseases. Planting of field experiments was done with one sucker per hole on raised beds after the receipt of pre-monsoon showers in the last week of May. Gap filling, wherever necessary, was done 15 days after planting.

3.6.2.2 Shading

The required shade was provided by erecting *pandal* at a height of 2 m using iron poles and shade nets of desired mesh size was hand-stitched to iron wire stretched out between the poles at 2 m height. Buffer plots were maintained between two shade treatments to compensate for the periodical overlapping of shade.

3.6.2.3 Mulching

Uniform mulching with spent lemongrass was given in all the plots, except in non-mulched treatments.

3.6.2.4 Organic Manuring

FYM was applied at 20 t ha^{-1}, half as basal and half three months after planting in Experiment 3. In Experiment 4, FYM was applied basally as per treatments. In Experiment 5, FYM, vermicompost, poultry manure and biofertilisers were applied basally as per treatments. Biofertilisers were applied after thorough mixing with FYM.

3.6.2.5 Fertiliser Application

Urea (46 per cent N), single super phosphate (16 per cent P_2O_5) and muriate of potash (60 per cent K_2O) were used as the sources of nitrogen, phosphorus and potassium respectively in Experiments 4 and 5. Full dose of phosphorus was applied basally at planting. Nitrogen and potassium were applied in two equal split doses after hand weeding at 3 and 6 months after planting.

3.6.2.6 Weed Control

There was heavy weed infestation since the crop was slow growing with limited ground coverage. Hand weeding was carried out at 3 and 6 months after planting.

3.6.2.7 Earthing Up

Earthing up was carried out simultaneously with weeding and topdressing of fertilisers.

3.6.2.8 Plant Protection

In general, plant protection was taken up as and when necessary. Rodent attack was a very serious problem once the rhizome started developing and necessary control measures were taken.

3.6.3 Biometric Observations

The method followed for recording various observations are described below. Biometric observations on five plants were taken and the arithmetic mean was recorded unless otherwise specified. Here plant refers to the whole plant including the suckers originated either from the rhizome or from the leaf of the planted material.

3.6.3.1 Growth Parameters

Plant height

The maximum length of shoot from the soil surface to the tip of the longest leaf was noted in centimetre.

Number of leaves

The total number of leaves present per sucker at the time of observation was counted and recorded.

Canopy spread

The maximum diametrical spread of the leaves in a plant was noted in centimetre.

Number of suckers

The total number of suckers present per hill at the time of observation was counted and recorded.

Leaf area

Length and breadth of all the fully opened leaves in a plant were measured. Leaf area was found out using the formula Y = 2.149 + 0.458 LB where Y is the leaf area in cm^2, L the length and B the breadth of the individual leaf in cm. Leaf area was recorded using graph paper for deriving the linear regression equation (r^2 = 0.997).

Chlorophyll content

Chlorophyll content was estimated colorimetrically in Genesis Spectrophotometer (Yoshida *et al*., 1972) at 3, 6 and 9 months after planting.

Number of roots per plant

The total number of roots originating from the rhizome of the plant was counted and recorded.

Maximum root length

The length of the longest root was measured separately for each plant and expressed in centimetre.

Number of flowers per plant

The total number of flowers present in a plant at the time of observation was counted and recorded.

Number of fruits per plant

The total number of fruits present in a plant at the time of observation was counted and recorded.

Dry matter production and distribution

Five hills were uprooted at random from the destructive sampling area of each plot, cleaned by washing with water, the surface water was allowed to evaporate in shade and the fresh weight was noted. The whole plant was separated into roots, rhizome and shoot and their individual fresh weights were noted. The plant samples were dried in an oven at 70^{o}C to a constant weight and expressed in gram. In the observational trial on developmental physiology, the whole plant in a polybag was uprooted, cleaned and separated into root, rhizome, leaf, flower and fruit and the fresh and dry weights were noted.

Days to emergence, suckering, flowering and maturity

Since suckers of the *nilappana* plant were used as the planting material the number of days to emrgence was not applicable. Suckering was noted when the shoot portion of the sucker was seen above ground. At least a few flowers were noted at random through out the growing season. Maturity was noted when the above ground shoot portion was dried up.

3.6.3.2 Yield Attributes and Yield

Harvesting was carried out 10 months after planting in March-April when the above ground portion had been completely dried up. Plants were dug out taking care to collect the entire rhizomes. The adhering soil particles, leaves and roots were carefully removed.

Length of rhizome

The maximum length of rhizome of the plant was recorded in centimetre.

Breadth of rhizome

The maximum breadth of rhizome of the plant was recorded in centimetre.

Biological yield

The fresh weight of clean whole plant at harvest, comprising the rhizomes and remnants of leaves and roots, expressed in kg ha^{-1}.

Fresh rhizome yield

The fresh weight of clean rhizomes at harvest expressed in kg ha^{-1}.

Dry rhizome yield

The clean fresh rhizomes were sun-dried for a week and the dry weight expressed in kg ha^{-1}.

3.6.3.3 Quality Parameters

The methods used for the proximate analyses are furnished in Table 3.3.

Characterization of major glycosides in *C. orchioides*

An effort was made to characterize the glycosides in *C. orchioides* rhizome on the basis of the benzoic acid derivatives obtained from them on alkali hydrolysis.

Development of an HPLC method to analyse the benzoic acid derivatives formed by the hydrolysis of glycosides in *C. orchioides*

According to Yamasaki *et al*. (1994) the glycosides of benzoyl benzoate in *C. orchioides* were hydrolyzed to release the corresponding benzoic acid residues by treatment with 1 *N* NaOH. The procedure was adopted to hydrolyse the

Table 3.3. Methods used for analysis of soil and plant samples

Sl.No.	Character	Method and equipment	Reference
I.	Soil		
a.	Mechanical composition	International Pipette method	Piper, 1966
b.	Chemical analysis		
	Available N	Alkaline permanganate method	Subbiah and Asija, 1956
	Available P	Ascorbic acid reduced molybdophosphoric blue colour method using Genesys 2PC spectrophotometer	Watanabe and Olsen, 1965
	Available K	Neutral normal NH_4OAC extract method using EEL flame photometer	Jackson, 1958
	Exchangeable Ca, Mg	Neutral normal NH_4OAC extract, titration with EDTA	Jackson, 1958
	Available S	Turbidimetric method using Genesys 2PC spectrophotometer	Bhargava and Raghupathi, 1993
	Available Fe, Mn, Zn, Cu	0.1*N* HCl extract method using Perkin Elmer AAnalyst 300 atomic absorption spectrophotometer	Jackson, 1973
II	Plant		
a.	Proximate analysis		
1.	Glucose	Nelson-Somogy's method	Thimmaiah, 1999
2.	Sucrose	Anthrone method	Thimmaiah, 1999
3.	Starch	Anthrone method	Thimmaiah, 1999
4.	Crude fibre	Acid-alkali treatment	Thimmaiah, 1999
5.	Crude protein	Micro Kjeldahl method	Thimmaiah, 1999
6.	Crude fat	Ether extraction in Soxhlet extractor	Thimmaiah, 1999
7.	Ash	Muffle furnace method	Thimmaiah, 1999
b.	Nutrient analysis		
1.	N	Micro Kjeldahl method	Jackson, 1973
2.	P	Diacid extract estimated in a Genesys 2PC spectrophotometer by vanadomolybdophosphoric yellow color method	Jackson, 1973
3.	K	Diacid extract estimated using EEL flame photometer	Jackson, 1973
4.	Ca	Diacid extraction and complexometric titration with EDTA	Jackson, 1973
5.	Mg	Diacid extraction and complexometric titration with EDTA	Jackson, 1973
6.	S	Turbidimetric method using Genesys 2PC spectrophotometer	Hesse, 1994
7.	Fe, Mn, Zn, Cu	Diacid extract method using Perkin Elmer AAnalyst 300 atomic absorption spectrophotometer	Jackson, 1973
c.	Curculigoside analysis	Extraction with ethyl acetate, alkali hydrolysis and estimation of 2,6-DA with HPLC	

glycosides present in various samples of *C. orchioides* representing biotypes, wild, cultivated and market samples.

A method was also developed to resolve the benzoic acid derivatives in the hydrolysate by high pressure liquid chromatography (HPLC). Two types (C8 and C18) of reversed phase HPLC columns were tried to resolve the peaks in the hydrolysate of a typical sample of *C. orchioides* using water as the eluent.

In order to modify the peak shapes and improve the resolution of compounds, the eluting solvent was changed to 0.01 *M* phosphate buffer pH 6.0. The detection wavelength of the spectrophotometric detector of the HPLC was selected as 205 nm, the characteristic wavelength of carboxylic acids.

The peaks on the chromatogram were identified on the basis of coincidence of retention time with the help of authentic standards of various derivatives of benzoic acids reported to be present in plant materials. The compounds used were 2,6-dimethoxybenzoic acid; 2,4-dimethoxybenzoic acid; 2-methoxy 6-hydroxybenzoic acid; 2-methoxy 4-hydroxybenzoic acid; 4-hydroxy 3-methoxy benzoic acid; 4-hydroxy 6-methoxybenzoic acid and 2,6-dihydroxybenzoic acid.

Estimation of benzoic acid derivatives in different samples of *C. orchioides*

The method developed above was used for characterization of glycosides in *C. orchioides* samples of different origin on the basis of their content of benzoic acid derivatives.

Variations in wild and cultivated biotypes of *C. orchioides*

Samples of mature rhizomes of each of the biotypes collected from the wild and the cultivated source were subjected to extraction of glycosides followed by alkali hydrolysis. The hydrolysate was analysed by HPLC and the peaks were attempted to be identified with the help of authentic standards of benzoic acid derivatives.

Quality variation in market samples of *C. orchioides*

Representative samples of the crude drug were collected from selected markets in Kerala and in the neighboring states. Comparison was made on the quality of this material based on the content of 4-hydroxy 3-methoxybenzoic acid and 2,6-dimethoxybenzoic acid in the hydrolysate.

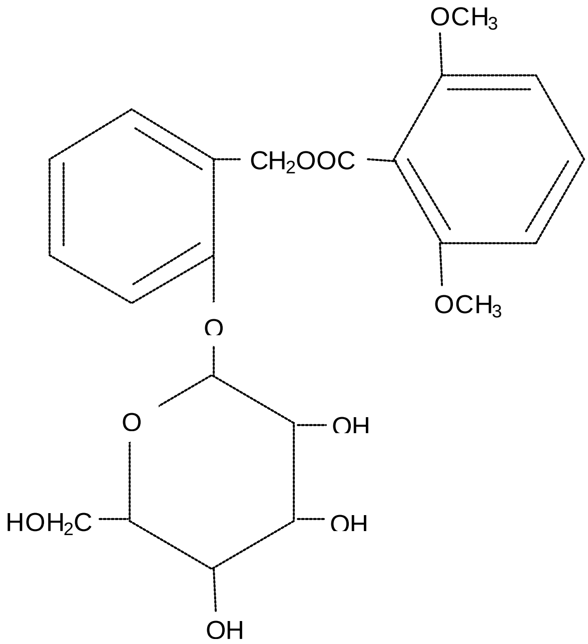
Estimation of curculigoside

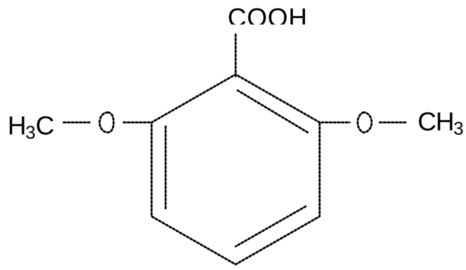
The content of curculigoside, the major glycoside in *C. orchioides* rhizome was estimated by the procedure reported by Yamasaki *et al.* (1994). After extraction with ethyl acetate, curculigoside was quantitatively converted to 2,6-dimethoxybenzoic acid (2,6-DA) by hydrolysis with 1 *N* NaOH (Fig.3.4). The content of curculigoside was estimated indirectly from the content of 2,6-DA determined by HPLC. The quantity of 2,6-DA was multiplied by a constant 2.56, the ratio of molecular weight of curculigoside to 2,6-DA to derive the quantity of curculigoside in the test sample.

The rhizome sample was dried to constant weight at 75-80^{o}C in a hot air oven and ground to fine powder in a Wiley mill. 0.5 g of the sample was extracted three times with 25 ml each of ethyl acetate by refluxing for one hour on a water bath. The extracts were pooled, filtered, solvent evaporated at reduced pressure and residue dissolved in solvent buffer for injection into HPLC column to determine 2,6-dimethoxybenzoic acid. From the peak area obtained for 2,6-DA, its quantity was calculated by comparison with the peak area obtained when known quantity of 2,6-DA was injected. The content of glucoside was calculated by multiplying the concentration of 2,6-DA with the factor 2.56.

3.6.3.4 Uptake Studies

Five plants were carefully uprooted from the net plot area earmarked for destructive sampling at four monthly intervals from each plot. The plants were cleaned and washed thoroughly to remove the adhering soil and other foreign matter. The clean plants were separated into root, rhizome and shoot, noted the fresh weight and then oven dried in a hot air oven at 75^{o}C till constant weights were achieved. After noting the oven dry weight, the dry samples were powdered well in a Wiley Mill and analysed for nutrient contents by methods given in Table 3. Nutrient contents were expressed in per cent on oven dry weight basis. Nutrient ratios and uptake were also worked out. The biomass production in kg ha^{-1} was multiplied by the nutrient content in per cent to get the nutrient uptake in kg ha^{-1}.





Curculigoside (5-hydroxy-2-O-β-D-glucopyranosyl benzyl-2,6-dimethoxy benzoate)		2,6-dimethoxy benzoic acid
$C_{22}H_{26}O_{11}$ (Molecular weight = 446)		$C_9H_{10}O_4$ (Molecular weight = 182)

Fig. 3.4. Chemical structures of curculigoside and 2,6-dimethoxy benzoic acid

3.6.3.5 Soil Characteristics

Aggregate soil samples were collected from each replication of the field experiments to assess the initial nutrient status of the soil of the experimental site. After the harvest of the crop, aggregate soil samples were collected from each plot of the field experiments to assess the post-experimental nutrient status of the soil. Available N, P, K, Ca, Mg, S, Fe, Mn, Zn and Cu were estimated and the nutrient contents were expressed on dry weight basis. The methods used for the soil analyses are given in Table 3.3.

3.6.4 Statistical Analysis

Statistical analysis was done as per the design adopted for each experiment using the analysis of variance technique (Gomez and Gomez, 1984). Microsoft Excel 2002 and MSTAT packages were used for various computations.

4. RESULTS

4. RESULTS

Appropriate agrotechnological practices should be developed to ensure adequate availability of quality crude drug and fetch highest returns for the farmer. In this project entitled 'agrotechnological practices for quality crude drug production in *nilappana* (*Curculigo orchioides* Gaertn.)', six experiments (one observational, two laboratory and three field trials) were conducted at the Aromatic and Medicinal Plants Research Station, Odakkali during 2000-'02. The results of the investigations are presented below.

4.1 EXPERIMENT 1. OBSERVATIONAL TRIAL ON DEVELOPMENTAL PHYSIOLOGY OF *C. ORCHIOIDES*

4.1.1 Growth Parameters

The various growth parameters of the two biotypes of *C. orchioides* at monthly interval are presented in Table 4.1.1 and the interaction effects in Table 4.1.2.

4.1.1.1 Plant Height

The plant height started increasing significantly from 3 MAP onwards. It increased regularly from 9.63 cm at 1 MAP, reached a peak of 21.93 cm at 7 MAP and then started declining. There was a sharp decrease at 9 and 10 MAP. The Panamkuzhi and Vellanikkara biotypes did not differ significantly in plant height. However, the behaviour of the two biotypes significantly varied over the period, as evident from a significant interaction. Panamkuzhi biotype had a lower start (9.00 cm), regular pick up, higher peak at 7 MAP (24.25 cm) and a slower decline. Whereas, Vellanikkara biotype had a higher start (10.50 cm), lower peak at 6 MAP (20.00 cm) and a faster decline.

4.1.1.2 Number of Leaves

The number of leaves per plant significantly increased from 3 MAP onwards. It increased from 2.25 leaves at 1 MAP, reached a peak of 9.75 leaves at 7 MAP and showed no significant variation thereafter, except a slight decline at 11 MAP. The two biotypes had the same number of leaves per plant and there was no significant interaction.

Table 4.1.1. Mean growth parameters of *Curculigo orchioides* at monthly interval

Treatment	Plant height (cm)	Leaves plant^{-1} (No.)	Canopy spread (cm)	Suckers Plant^{-1} (No.)	Leaf sprouts plant^{-1} (No.)	Leaf area plant^{-1} (cm^2)
MAP						
1	9.63	2.25	5.30	1.00	0.00	6.08
2	10.63	3.75	9.85	1.00	0.00	12.90
3	12.00	7.25	12.75	1.00	0.25	28.12
4	14.58	6.25	20.88	1.00	0.00	29.80
5	16.63	6.50	19.38	1.02	0.00	35.38
6	20.38	7.50	24.73	1.24	0.50	51.87
7	21.93	9.75	31.40	1.75	2.00	76.95
8	16.78	8.00	20.73	2.00	0.25	37.80
9	13.73	7.75	17.25	1.75	0.00	15.15
10	12.43	7.25	13.95	1.50	0.00	20.61
11	15.20	6.25	17.70	1.50	0.00	25.27
12	17.70	8.50	17.55	2.00	0.00	26.56
SEm	0.800	0.580	0.913	0.100	0.371	1.885
$CD_{(0.05)}$	2.341	1.696	2.670	0.292	1.086	5.514
Biotype						
Panamkuzhi	15.18	6.75	17.05	1.54	0.29	28.90
Vellanikkara	15.08	6.75	18.19	1.21	0.21	32.18
SEm	0.327	0.237	0.373	0.041	0.151	0.769
Significance	NS	NS	*	**	NS	**
Interaction	**	NS	*	**	NS	**

Table 4.1.1. Mean growth parameters of *Curculigo orchioides* at monthly interval (continued)

Treatment	Chlorophyll content in leaf (mg g^{-1})			Roots plant^{-1} (No.)	Maximum root length (cm)	Flowers plant^{-1} (No.)	Fruits plant^{-1} (No.)
	a	b	a + b				
MAP							
1	0.63	0.32	0.95	3.50	4.50	0.00	0.00
2	0.64	0.24	0.88	4.75	8.63	0.00	0.00
3	0.95	0.33	1.28	6.75	12.88	0.00	0.00
4	0.83	0.60	1.43	7.75	9.65	0.50	0.75
5	0.91	0.69	1.60	9.50	11.65	0.00	0.00
6	1.15	0.83	1.98	10.00	16.38	1.75	0.75
7	0.71	0.51	1.22	26.00	15.58	1.75	3.25
8	0.55	0.24	0.79	21.50	15.65	0.75	1.00
9	0.71	0.28	0.99	15.25	15.15	0.50	0.00
10	0.53	0.26	0.79	14.50	13.53	1.00	1.00
11	1.08	0.42	1.50	13.00	12.33	1.75	0.00
12	0.95	0.37	1.32	8.00	10.90	2.25	1.25
SEm	0.035	0.044	0.063	0.712	1.062	0.630	0.413
$CD_{(0.05)}$	0.104	0.129	0.186	2.084	3.107	NS	1.207
Biotype							
Panamkuzhi	0.76	0.41	1.17	12.21	11.86	0.88	0.29
Vellanikkara	0.85	0.44	1.29	11.21	12.60	0.83	1.04
SEm	0.014	0.018	0.026	0.291	0.434	0.257	0.168
Significance	**	NS	**	*	NS	NS	**
Interaction	*	NS	NS	**	*	NS	*

Table 4.1.2. Mean growth parameters of the two biotypes of *Curculigo orchioides* at monthly interval

MAP	1	2	3	4	5	6	7	8	9	10	11	12
Plant height (cm)												
Panamkuzhi	9.00	9.60	11.80	13.30	15.50	20.75	24.25	16.95	16.30	13.15	16.00	15.60
Vellanikkara	10.50	11.65	12.20	15.85	17.75	20.00	19.60	16.60	11.15	11.70	14.40	19.80
SEm: 1.132 $CD_{(0.05)}$: 3.311												
Canopy spread (cm)												
Panamkuzhi	4.10	6.50	11.75	18.00	19.50	23.45	32.65	20.10	18.70	15.55	17.00	17.30
Vellanikkara	6.50	13.20	13.75	23.75	19.25	26.00	30.15	21.35	15.80	12.35	18.40	17.80
SEm: 1.291 CD(0.05) : 3.776												
Suckers Plant^{-1} (No.)												
Panamkuzhi	1.00	1.00	1.00	1.00	1.00	1.00	2.00	2.00	2.50	2.00	2.00	2.00
Vellanikkara	1.00	1.00	1.00	1.00	1.00	1.00	1.50	2.00	1.00	1.00	1.00	2.00
SEm: 0.141 CD(0.05) : 0.413												
Leaf area plant^{-1} (cm^2)												
Panamkuzhi	3.81	7.37	23.59	23.64	25.22	52.66	74.12	38.04	19.50	25.24	27.69	25.99
Vellanikkara	8.36	18.43	32.65	35.97	45.55	51.09	79.77	37.56	10.80	15.98	22.86	27.13
SEm: 2.665 CD(0.05) : 7.797												
Chlorophyll a (mg g^{-1})												
Panamkuzhi	0.61	0.64	0.96	0.77	0.86	1.08	0.71	0.55	0.56	0.47	1.07	0.80
Vellanikkara	0.65	0.64	0.94	0.80	0.95	1.21	0.71	0.56	0.86	0.58	1.09	1.11
SEm: 0.050 CD(0.05) : 0.147												
Roots plant^{-1} (No.)												
Panamkuzhi	3.50	3.50	6.00	7.50	7.50	10.50	25.00	22.50	22.00	12.50	17.50	8.50
Vellanikkara	3.50	6.00	7.50	8.50	11.50	9.50	27.00	20.50	8.50	16.50	8.50	7.50
SEm: 1.007 CD(0.05) : 2.947												
Maximum root length (cm)												
Panamkuzhi	5.25	6.50	12.40	7.60	10.90	19.70	14.65	17.40	12.35	12.45	12.40	10.75
Vellanikkara	3.75	10.75	13.35	11.70	12.40	13.05	16.50	13.90	17.95	14.60	12.25	11.05
SEm: 1.502 CD(0.05) : 4.395												
Fruits plant-1 (No.)												
Panamkuzhi	0.00	0.00	0.00	0.50	0.00	1.00	1.00	0.50	0.00	0.50	0.00	0.00
Vellanikkara	0.00	0.00	0.00	1.00	0.00	0.50	5.50	1.50	0.00	1.50	0.00	2.50
SEm: 0.584 CD(0.05) : 1.707												

4.1.1.3 Canopy Spread

Canopy spread started increasing significantly early from 2 MAP itself and it reached a peak of 31.40 cm at 7 MAP, declined to 13.95 cm at 10 MAP and then increased. Vellanikkara biotype had a significantly higher canopy spread. The interaction of biotype and period of growth was significant. As in the case of plant height, Panamkuzhi biotype had a lower start (4.10 cm), regular pick up, higher peak at 7 MAP (32.65 cm) and a decline, whereas Vellanikkara biotype showed a higher start (6.50 cm) but a lower peak at 7 MAP (30.15 cm).

4.1.1.4 Number of Suckers

Though sucker production started from 5 MAP, the increase in the number of suckers per plant was statistically significant from 7 MAP only. Panamkuzhi biotype was distinctly superior to Vellanikkara biotype in sucker production. A significant interaction showed that Panamkuzhi biotype produced suckers early and retained two or more suckers per plant from 7 MAP onwards. In Vellanikkara biotype, the sucker production peaked at 8 MAP. However, it could not retain the suckers later on, though there was resurgence at 12 MAP.

4.1.1.5 Number of Leaf Sprouts

Though the plant is well known for vegetative propagation through leaf tips, in practice production of sprouts from leaf tips were very few as evident from the data. It was statistically significant only at 7 MAP (2.00 leaf sprouts per plant). The two biotypes behaved similarly in the production of leaf sprouts and there was no interaction effect.

4.1.1.6 Leaf Area

Leaf area per plant started increasing from 2 MAP onwards. It increased to a highest value of 76.95 cm^2 per plant at 7 MAP and declined thereafter. Vellanikkara biotype was superior to Panamkuzhi biotype in leaf area production. Interaction was significant. Panamkuzhi biotype was more stable in leaf area production. Though initially it had lower leaf area, after the peak production of 74.12 cm^2 at 7 MAP, the decline was less drastic compared to Vellanikkara biotype.

4.1.1.7 Chlorophyll Content in Leaf

In general, chlorophyll a content in leaf was higher than chlorophyll b. Chlorophyll a content started increasing from 3 MAP. There were two peaks, namely at 6 (1.15 mg g^{-1}) and 11 (1.08 mg g^{-1}) MAP. Vellanikkara biotype had significantly higher chlorophyll a content. The interaction effect was marginally significant.

Chlorophyll b content increased significantly from 4 MAP, peaked (0.83 mg g^{-1}) at 6 MAP and decreased thereafter though there was subsequent increase at 11 MAP. The interaction effect was not significant.

Chlorophyll a+b content started increasing from 3 MAP, reached a highest value of 1.98 mg g^{-1} at 6 MAP and declined thereafter with an increase at 11 MAP. Vellanikkara biotype recorded higher chlorophyll a+b content and there was no interaction between period of growth and biotypes.

4.1.1.8 Number of Roots

Number of roots per plant increased significantly from 3 MAP, reached a highest of 26 roots per plant at 7 MAP and decreased subsequently. Panamkuzhi biotype produced more number of roots per plant. The interaction effect indicated that Vellanikkara biotype exhibited wide fluctuation in root production over the period.

4.1.1.9 Root Length

The highest root length varied between 4.50 cm at 1 MAP and 16.38 cm at 6 MAP. There was no significant variation in highest root length after 6 MAP, except at 12 MAP. Though the interaction effect was marginally significant, no definite trend was noticed in the behaviour of the two biotypes in terms of highest root length.

4.1.1.10 Number of Flowers

Though flowers were produced from 4 MAP onwards, 5 MAP being an exception, no peak period of flowering could be noticed. Flowering was at random, neither synchronous nor statistically significant due to biotypes and over the period.

4.1.1.11 Number of Fruits

There was intermittent production of fruits in nilappana. Unlike flower production, there was a peak production of fruits (3.25 fruits per plant) at 7 MAP. Vellanikkara biotype was distinctly superior in fruit production. Interaction data showed that while Panamkuzhi biotype could not produce any significant number of fruits, Vellanikkara biotype showed two peak periods at 7 (5.50 fruits) and 12 (2.50 fruits) MAP.

4.1.2 Biomass Production

The main effects of period of growth and biotypes on fresh biomass production of *C. orchioides* are presented in Table 4.1.3, dry matter production in Table 4.1.4 and the interaction effects in Table 4.1.5.

4.1.2.1 Root

Fresh root biomass per plant increased regularly from 1 MAP, reached a highest value of 5.66 g per plant at 7 MAP and thereafter declined throughout. Biomass accumulation in root was marginally higher in Vellanikkara biotype, but it was not significant. Though Panamkuzhi biotype was slow in biomass accumulation in root initially, with a low peak (4.62 g) compared to Vellanikkara biotype (6.71 g), both types were on par after 9 MAP as seen from the interaction. Dry matter accumulation in root followed a similar trend but Vellanikkara biotype was superior to Panamkuzhi biotype in this respect.

4.1.2.2 Rhizome

Fresh rhizome biomass increased significantly from 5 MAP. The highest accumulation was 3.74 g per plant at 7 MAP. It was reduced to 1.71 g per plant at 10 MAP and then increased again. The interaction showed that though Vellanikkara biotype was superior to Panamkuzhi biotype in fresh rhizome biomass, the latter exhibited a significantly higher peak (4.10 g) at 7 MAP. Dry matter accumulation in rhizome followed a similar trend.

4.1.2.3 Leaf

Fresh leaf biomass accumulation increased significantly from 3 MAP. The highest accumulation was 2.87 g per plant at 7 MAP. Thereafter a drastic

Table 4.1.3. Mean fresh biomass production in *Curculigo orchioides* at monthly interval (g $plant^{-1}$)

Treatment	Root	Rhizome	Leaf	Flower	Fruit	Total
MAP						
1	0.05	0.31	0.37	0.00	0.00	0.73
2	0.49	0.43	0.52	0.00	0.00	1.44
3	1.04	0.46	0.79	0.00	0.00	2.29
4	1.35	0.57	0.85	0.01	0.04	2.82
5	1.36	0.75	1.39	0.00	0.00	3.50
6	2.59	1.80	2.08	0.14	0.07	6.68
7	5.66	3.74	2.87	0.03	0.43	12.73
8	3.15	2.78	0.89	0.09	0.08	6.99
9	2.20	2.23	0.86	0.03	0.00	5.32
10	2.38	1.71	0.76	0.04	0.10	4.99
11	1.95	2.64	0.99	0.06	0.00	5.64
12	1.87	2.66	1.39	0.15	0.12	6.19
SEm	0.218	0.144	0.062	0.030	0.043	0.440
$CD_{(0.05)}$	0.637	0.421	0.180	0.089	0.125	1.288
Biotype						
Panamkuzhi	1.90	1.63	1.02	0.03	0.02	4.60
Vellanikkara	2.12	1.71	1.27	0.05	0.12	5.27
SEm	0.089	0.059	0.025	0.012	0.017	0.180
Significance	NS	NS	**	NS	**	NS
Interaction	**	**	**	NS	**	NS

Table 4.1.4. Mean dry matter production in *Curculigo orchioides* at monthly interval (g $plant^{-1}$)

Treatment	Root	Rhizome	Leaf	Flower	Fruit	Total
MAP						
1	0.01	0.08	0.09	0.00	0.00	0.18
2	0.04	0.14	0.09	0.00	0.00	0.27
3	0.11	0.16	0.19	0.00	0.00	0.46
4	0.17	0.20	0.27	0.00	0.00	0.64
5	0.20	0.35	0.32	0.00	0.00	0.87
6	0.33	0.74	0.47	0.04	0.01	1.59
7	0.85	1.77	0.66	0.01	0.10	3.39
8	0.33	1.14	0.25	0.02	0.02	1.76
9	0.25	0.80	0.18	0.01	0.00	1.24
10	0.33	0.67	0.14	0.01	0.02	1.17
11	0.23	0.77	0.19	0.02	0.00	1.21
12	0.23	0.89	0.25	0.04	0.03	1.44
SEm	0.016	0.052	0.012	0.007	0.009	0.139
$CD_{(0.05)}$	0.045	0.153	0.036	0.020	0.026	0.407
Biotype						
Panamkuzhi	0.24	0.64	0.24	0.01	0.01	1.14
Vellanikkara	0.27	0.64	0.27	0.02	0.02	1.22
SEm	0.006	0.021	0.005	0.003	0.004	0.057
Significance	*	NS	**	**	**	*
Interaction	**	**	**	**	*	NS

Table 4.1.5. Mean biomass production of the two biotypes of *Curculigo orchioides* at monthly interval (g $plant^{-1}$)

MAP	1	2	3	4	5	6	7	8	9	10	11	12
Fresh biomass production												
Root												
Panamkuzhi	0.07	0.08	0.78	1.09	0.77	3.21	4.62	2.89	2.93	2.34	1.97	2.04
Vellanikkara	0.04	0.91	1.30	1.60	1.96	1.97	6.71	3.42	1.47	2.41	1.94	1.70
SEm: 0.308 CD$_{(0.05)}$: 0.902												
Rhizome												
Panamkuzhi	0.26	0.46	0.46	0.55	0.49	1.56	4.10	2.17	2.51	1.51	2.74	2.80
Vellanikkara	0.35	0.41	0.46	0.59	1.01	2.04	3.39	3.39	1.96	1.90	2.55	2.51
SEm: 0.203 CD(0.05) : 0.595												
Leaf												
Panamkuzhi	0.35	0.37	0.72	0.87	0.93	1.94	2.36	0.85	0.83	0.86	1.01	1.22
Vellanikkara	0.39	0.66	0.87	0.84	1.86	2.23	3.29	0.93	0.89	0.65	0.97	1.56
SEm: 0.087 CD(0.05) : 0.255												
Fruit												
Panamkuzhi	0.00	0.00	0.00	0.01	0.00	0.09	0.11	0.02	0.00	0.02	0.00	0.00
Vellanikkara	0.00	0.00	0.00	0.07	0.00	0.05	0.75	0.14	0.00	0.18	0.00	0.23
SEm: 0.060 CD(0.05) : 0.176												
Dry matter production												
Root												
Panamkuzhi	0.01	0.01	0.08	0.17	0.09	0.42	0.63	0.40	0.38	0.29	0.26	0.24
Vellanikkara	0.01	0.07	0.15	0.17	0.32	0.24	1.07	0.27	0.12	0.38	0.20	0.23
SEm: 0.022 CD$_{(0.05)}$: 0.064												
Rhizome												
Panamkuzhi	0.07	0.14	0.14	0.19	0.27	0.75	1.99	0.95	0.83	0.70	0.81	0.89
Vellanikkara	0.10	0.14	0.18	0.21	0.44	0.74	1.56	1.33	0.77	0.64	0.73	0.90
SEm: 0.074 CD(0.05) : 0.217												
Leaf												
Panamkuzhi	0.08	0.09	0.19	0.25	0.25	0.47	0.57	0.25	0.19	0.16	0.18	0.23
Vellanikkara	0.09	0.10	0.20	0.29	0.38	0.48	0.75	0.25	0.17	0.13	0.20	0.28
SEm: 0.017 CD(0.05) : 0.051												
Flower												
Panamkuzhi	0.00	0.00	0.00	0.00	0.00	0.01	0.05	0.01	0.00	0.01	0.00	0.01
Vellanikkara	0.00	0.00	0.00	0.00	0.00	0.01	0.15	0.03	0.00	0.03	0.00	0.03
SEm: 0.010 CD(0.05) : 0.029												
Fruit												
Panamkuzhi	0.00	0.00	0.00	0.00	0.00	0.01	0.05	0.01	0.00	0.01	0.00	0.00
Vellanikkara	0.00	0.00	0.00	0.00	0.00	0.01	0.15	0.03	0.00	0.03	0.00	0.06
SEm: 0.012 CD(0.05) : 0.037												

reduction was observed. Vellanikkara biotype was superior to Panamkuzhi biotype in fresh leaf biomass accumulation. However, the interaction showed that both the biotypes were on par after 7 MAP. Dry matter accumulation in leaf followed a similar trend.

4.1.2.4 Flower

There was no regular pattern in the fresh biomass accumulation in flowers, though there was intermittent significant accumulation at 6, 8 and 12 MAP. The biotypes did not vary significantly in this respect. However, the dry matter accumulation in flower in Vellanikkara biotype was significantly superior.

4.1.2.5 Fruit

As in the case of flowers, there was no regular pattern in the fresh biomass accumulation in fruits and there was significantly higher biomass at 7 MAP only. However, Vellanikkara biotype was distinctly superior in fruit biomass. Dry matter accumulation in fruit also followed a similar trend.

4.1.2.6 Total

The total fresh biomass per plant increased regularly from 1 MAP, reached a highest value of 12.73 g per plant at 7 MAP and thereafter declined with a marginal increase after 10 MAP. Both the biotypes were on par in total fresh biomass. Total dry matter production followed a similar trend but Vellanikkara biotype was superior to Panamkuzhi biotype in this respect with no significant interaction.

4.1.3 Yield parameters

The main effects of period of growth and biotypes on yield parameters of *C. orchioides* are presented in Table 4.1.6 and the interaction effects in Table 4.1.5.

4.1.3.1 Rhizome Length

Rhizome length started increasing significantly from 3 MAP, reached a highest length of 4.45 cm at 8 MAP and no significant variation was observed thereafter. Both biotypes recorded statistically similar rhizome length with no significant interaction.

Table 4.1.6. Mean yield parameters of *Curculigo orchioides* at monthly interval

Treatment	Rhizome length (cm)	Rhizome thickness (cm)	Biological yield (g plant^{-1})	Fresh rhizome (g plant^{-1})	Harvest index (%)	Dry rhizome yield (g plant^{-1})
MAP						
1	0.98	0.45	0.73	0.31	42.47	0.08
2	1.60	0.53	1.44	0.43	29.86	0.14
3	2.48	0.60	2.29	0.46	20.09	0.16
4	2.30	0.63	2.82	0.57	20.21	0.20
5	2.23	0.70	3.50	0.75	21.43	0.35
6	3.65	0.75	6.68	1.80	26.95	0.74
7	3.48	0.85	12.73	3.74	29.38	1.77
8	4.45	1.00	6.99	2.78	39.77	1.14
9	3.83	0.90	5.32	2.23	41.92	0.80
10	3.88	0.85	4.99	1.71	34.27	0.67
11	4.35	1.20	5.64	2.64	46.81	0.77
12	3.93	1.15	6.19	2.66	42.97	0.89
SEm	0.298	0.044	0.440	0.144	-	0.052
$CD_{(0.05)}$	0.871	0.128	1.288	0.421	-	0.153
Biotype						
Panamkuzhi	3.00	0.73	4.60	1.63	35.43	0.64
Vellanikkara	3.18	0.87	5.27	1.71	32.45	0.64
SEm	0.122	0.018	0.180	0.059	-	0.021
Significance	NS	**	NS	NS	-	NS
Interaction	NS	NS	NS	**	-	**

Table 4.1.7. Mean quality parameters of *Curculigo orchioides* root (%)

Treatment	Starch	Crude fibre	Crude protein	Crude fat	Ash
MAP					
0	19.798	19.191	4.648	6.946	11.948
3	20.918	19.878	4.536	6.812	12.487
6	19.973	17.844	4.256	8.782	12.170
9	20.743	21.225	4.928	4.976	12.264
SEm	0.731	0.405	0.046	0.184	0.237
$CD_{(0.05)}$	NS	1.823	0.206	0.830	NS
Biotype					
Panamkuzhi	20.448	20.502	4.536	7.161	12.527
Vellanikkara	20.268	18.568	4.648	6.597	11.907
SEm	0.527	0.400	0.041	0.180	0.212
Significance	NS	*	NS	NS	NS
Interaction	NS	NS	NS	NS	NS

4.1.3.2 Rhizome Thickness

Rhizome thickness also started increasing significantly from 3 MAP, reached a thickness of 1.00 cm at 8 MAP, decreased thereafter and again increased at 11 MAP. Vellanikkara biotype was superior to Panamkuzhi biotype in this respect with no significant interaction.

4.1.3.3 Biological Yield

Biological yield per plant increased regularly from 1 MAP, reached the highest value of 12.73 g per plant at 7 MAP and thereafter declined with a marginal increase after 10 MAP. Both the biotypes were on par in biological yield.

4.1.3.4 Fresh Rhizome Yield

Fresh rhizome yield increased significantly from 5 MAP. The highest fresh rhizome yield was 3.74 g per plant at 7 MAP. It was reduced to 1.71 g per plant at 10 MAP and then increased again. The interaction effect showed that Panamkuzhi biotype exhibited a significantly higher peak (4.10 g) at 7 MAP for fresh rhizome yield.

4.1.3.5 Harvest Index

Harvest index rather decreased initially at 3 MAP and then started increasing regularly with an exception at 10 MAP when it showed a decrease. The highest harvest index value of 46.81 per cent was recorded at 11 MAP. Panamkuzhi biotype recorded marginal increase in harvest index over Vellanikkara biotype.

4.1.3.6 Dry Rhizome Yield

Dry rhizome yield and fresh rhizome yield followed similar trends.

4.1.4 Quality Parameters

Quality parameters such as the contents of glucose, sucrose, starch, crude fibre, crude protein, crude fat, curculigoside and ash were assessed in both the biotypes at planting, 3, 6 and 9 MAP.

4.1.4.1 Root

The main effects of period of growth and biotypes on quality parameters of *C. orchioides* root are presented in Table 4.1.7. The presence of glucose, sucrose and curculigoside could not be detected in the roots of both the biotypes. Starch and ash contents showed no significant variations. Crude fibre in the root was minimum (17.844%) at 6 MAP and highest (21.225%) at 9 MAP. Panamkuzhi biotype recorded significantly higher crude fibre content. Crude protein content followed a similar trend but the two biotypes did not show any variations. Crude fat content was highest (8.782%) at 6 MAP and both the biotypes behaved similarly in this respect. None of the interactions were statistically significant.

4.1.4.2 Rhizome

The main effects of period of growth and biotypes on quality parameters of *C. orchioides* rhizome are presented in Table 4.1.8 and the interaction effects in Table 4.1.9. All the tested parameters were detected in the rhizome. Glucose content was not detected at 3 MAP and later it showed marginal insignificant increase. Sucrose was also not detected at 3 MAP but showed a significant increase at 9 MAP. Rhizome of Panamkuzhi biotype contained significantly higher sucrose content. Rhizome of Vellanikkara biotype contained sucrose only at 9 MAP, which was insignificant. Starch content showed a significantly alternating increase and decrease and the highest starch content was 53.248 per cent at 3 MAP. Vellanikkara biotype contained significantly higher starch content. It followed an alternating trend in Panamkuzhi biotype as against quadratic function in Vellanikkara biotype. Crude fibre was highest at planting (6.388%) which was reduced to 1.968 per cent at 6 MAP and again increased at 9 MAP. Panamkuzhi biotype showed higher crude fibre content in rhizome. Though both the biotypes showed similar trends, Panamkuzhi biotype had distinctly higher crude fibre content at planting. Crude protein content showed an increasing trend through out the period and the highest content was 16.52 per cent at 9 MAP. Vellanikkara biotype had higher crude protein content. Panamkuzhi (1.928%) and Vellanikkara (8.626%) biotype planting materials showed wide variability in crude protein content. In spite of the low initial level, Panamkuzhi biotype recorded the highest value of 17.472 per cent at 9 MAP. Crude fat content rather

Table 4.1.8. Mean quality parameters of *Curculigo orchioides* rhizome

Treatment	Glucose (%)	Sucrose (%)	Starch (%)	Crude fibre (%)	Crude protein (%)	Crude fat (%)	Curculigoside (ppm)	Ash (%)
MAP								
0	2.625	1.052	46.900	6.388	5.277	3.365	345.91	8.547
3	0.000	0.000	53.248	4.105	6.073	1.927	200.78	5.407
6	1.204	0.093	44.813	1.968	8.624	1.708	123.51	3.957
9	0.668	0.580	51.013	3.563	16.520	2.268	164.57	4.901
SEm	0.492	0.169	1.136	0.044	0.214	0.188	-	0.321
$CD_{(0.05)}$	1.644	0.566	3.799	0.146	0.715	0.630	-	1.704
Biotype								
Panamkuzhi	1.616	0.764	47.564	4.366	8.703	2.402	177.77	6.092
Vellanikkara	0.632	0.098	50.423	3.646	9.544	2.232	239.62	5.314
SEm	0.348	0.120	0.803	0.031	0.151	0.133	-	0.227
Significance	NS	**	*	**	**	NS	-	*
Interaction	NS	*	**	**	**	*	208.69	NS

Table 4.1.9. Mean quality parameters of the two biotypes of *Curculigo orchioides* rhizome

MAP	0	3	6	9	SEm	$CD_{(0.05)}$
Sucrose (%)						
Panamkuzhi	2.103	0.000	0.185	0.769	0.239	0.800
Vellanikkara	0.000	0.000	0.000	0.391		
Starch (%)						
Panamkuzhi	49.830	51.005	37.400	52.020	1.607	5.373
Vellanikkara	43.970	55.490	52.225	50.005		
Crude fibre (%)						
Panamkuzhi	7.217	4.037	2.135	4.075	0.062	0.206
Vellanikkara	5.560	4.174	1.802	3.050		
Crude protein (%)						
Panamkuzhi	1.928	7.796	7.616	17.472	0.303	1.012
Vellanikkara	8.626	4.349	9.632	15.568		
Crude fat (%)						
Panamkuzhi	4.006	2.051	1.550	2.002	0.267	0.891
Vellanikkara	2.724	1.804	1.866	2.534		
Curculigoside (ppm)						
Panamkuzhi	310.32	189.42	109.71	101.61	-	-
Vellanikkara	381.50	212.13	137.31	227.52		

showed a decrease after planting and the biotypes were on par, except at the time of planting when Panamkuzhi biotype had a significantly higher content of crude fat. Curculigoside content also showed a decrease after planting but increased at 9 MAP. Vellanikkara biotype was superior to Panamkuzhi biotype in this respect. Ash content in rhizome showed a decreasing trend over the period and Panamkuzhi biotype was superior to Vellanikkara biotype with no significant interaction.

4.1.4.3 Leaf

The main effects of period of growth and biotypes on quality parameters of *C. orchioides* leaf are presented in Table 4.1.10. In the case of leaf no detectable amounts of glucose, sucrose and starch were observed in both the biotypes over the period. Crude fibre and protein contents were significantly higher at 9 MAP, whereas crude fat was higher at 6 MAP. Both the biotypes were on par with respect to crude fibre and crude fat but Panamkuzhi biotype was superior to Vellanikkara biotype in crude protein and ash contents. Curculigoside content showed alternate decrease and increase after planting. Vellanikkara biotype was superior to Panamkuzhi biotype in curculigoside content.

4.2. CHARACTERIZATION OF MAJOR GLYCOSIDES IN *CURCULIGO ORCHIOIDES*

The glycosides in *C. orchioides* was characterized on the basis of the benzoic acid derivatives obtained on alkali hydrolysis of the glycoside fraction of *C. orchioides*.

4.2.1 Development of an HPLC Method to Resolve the Benzoic Acid Derivatives Formed by the Hydrolysis of Glycosides in *C. Orchioides*

The method reported by Yamasaki *et al*. (1994) in *C. orchioides* was adopted to hydrolyse the benzoyl benzoate glycosides present in various samples of *C. orchioides* representing biotypes, wild, cultivated and market samples.

A method was also standardised to separate the benzoic acid derivatives in hydrolysate by high pressure liquid chromatography. Two types of reversed phase HPLC columns (C8 and C18) were tried to resolve the peaks of 4-hydroxy-3-methoxy benzoic acid and 2,6-dimethoxy benzoic acid in the hydrolysate of a typical

Table 4.1.10. Mean quality parameters of *Curculigo orchioides* leaf

Treatment	Crude fibre (%)	Crude protein (%)	Crude fat (%)	Curculigoside (ppm)	Ash (%)
MAP					
0	18.170	10.172	7.427	126.71	10.470
3	18.216	10.340	7.145	74.38	10.273
6	18.794	10.976	8.028	473.13	10.505
9	23.225	12.152	5.369	240.51	10.633
SEm	0.656	0.100	0.169	-	0.153
$CD_{(0.05)}$	2.385	0.362	0.614	-	NS
Biotype					
Panamkuzhi	20.897	11.331	6.983	214.26	11.482
Vellanikkara	19.260	10.981	6.712	243.11	9.458
SEm	0.536	0.081	0.138	-	0.125
Significance	NS	*	NS	-	**
Interaction	NS	NS	NS	228.68	NS

sample of *C. orchioides* using water pH 7.0 as the eluent. Representative chromatograms are given in Figure 4.2.1a and b. It was seen that resolution was not satisfactory in C8 (Lichrospher RP Select B) and better in C18 (Lichrospher RP-18) column. However, it was also noticed that the peaks showed tailing at the hind side. This type of peak tailing is usually observed in the case of compounds possessing ionisable functional groups like the carboxyl group. It is but natural that the benzoic acid residues of glycosides present in the hydrolysate of *C. orchioides* showed peak tailing.

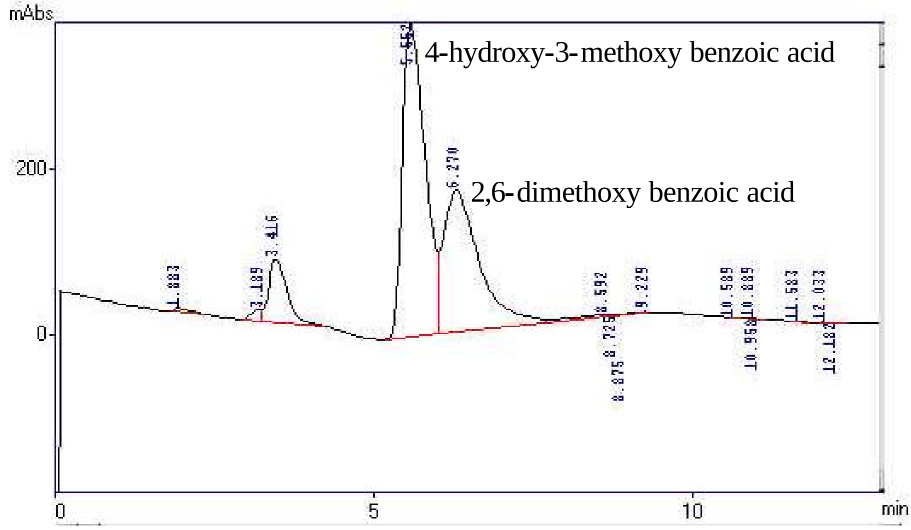
In order to modify the peak shapes and improve the resolution of compounds, the eluting solvent was changed to a buffer wherein the ionization of the polar group was suppressed. 0.01 *M* phosphate buffer pH 6.0 was used as the eluent. Representative chromatogram is given in Figure 4.2.1c. The peaks were symmetrical, narrow and the components were well resolved. Thus a combination of Lichrospher RP-18 column (4.2 mm diameter and 25 cm length) and 0.01 *M* phosphate buffer pH 6.0 at a flow rate of 1 ml minute^{-1} was selected for separation of compounds in the hydrolysate. The detection wavelength of the spectrophotometric detector of the HPLC was set at 205 nm, the characteristic wavelength reported for carboxylic acid derivatives in *Curculigo* species.

4.2.2 Estimation of Benzoic Acid Derivatives in Different Samples of *C. Orchioides*

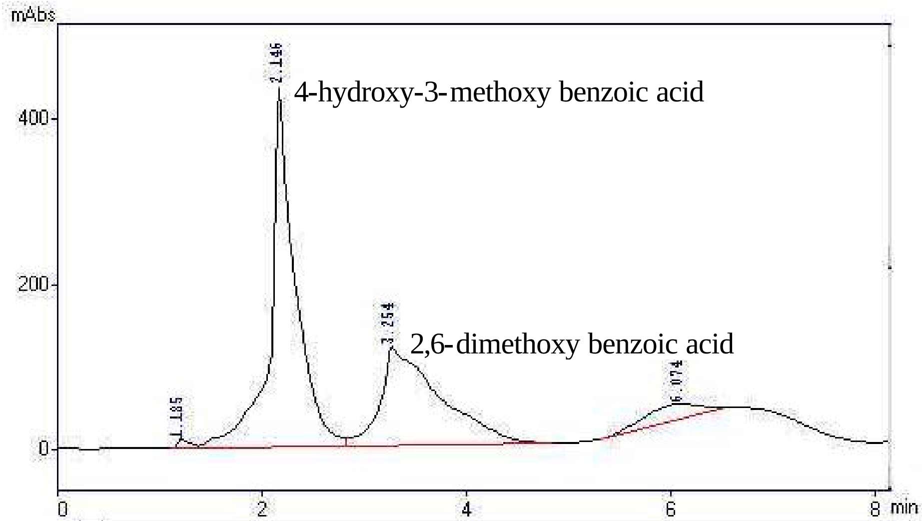
The method developed above was used for characterization of glycosides in *C. orchioides* samples of different origin on the basis of their content of benzoic acid derivatives.

4.2.1.1 Variations in natural habitat and Cultivated Biotypes of C. Orchioides

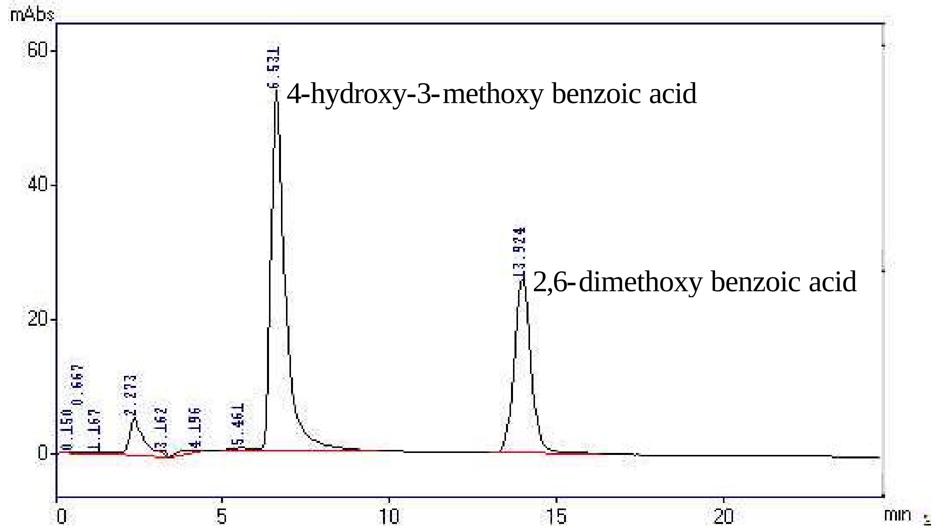
Two biotypes of *C. orchioides* (Panamkuzhi and Vellanikkara biotypes) were subjected to this study. Samples of mature rhizomes of each of the biotypes collected from the natural habitat and the cultivated source were extracted for glycosides and subjected to alkali hydrolysis. The hydrolysate was analysed by HPLC and the peaks were attempted to be identified with the help of authentic standards of benzoic acid derivatives. About 7 peaks developed on the chromatogram. The peaks at Rt 6.531 min and 13.924 min were identified as 4-hydroxy 3-methoxybenzoic acid and 2,6-dimethoxybenzoic acid. The other



(a) Column: C-8 Eluent: Water pH 7.0



(b) Column : C-8 Eluent: 0.01 *M* Phosphate buffer pH 6.0



(c) Column : C-18 Eluent: 0.01 *M* Phosphate buffer pH 6.0

Fig. 4.2.1 High Pressure Liquid Chromatograms of *C. orchioides* rhizome hydrolysate

peaks could not be identified due to want of reference materials. Data obtained are given in Table 4.2.1.

The results showed that the biotypes varied much under natural habitat and cultivated conditions in the contents of benzoyl benzoate derivatives. While Panamkuzhi biotype was superior in 4-hydroxy-3-methoxy benzoic acid, the Vellanikkara biotype was superior in 2,6-dimethoxy benzoic acid, which is an indirect measure of the curculigoside content. The contents of both 4-hydroxy 3-methoxy benzoic acid and 2,6-dimethoxy benzoic acid were reduced on domestication. The highest content of 4-hydroxy-3-methoxy benzoic acid was observed for Panamkuzhi biotype while the highest content of 2,6-dimethoxy benzoic acid was noted for Vellanikkara biotype, both under natural habitat situation.

4.2.1.2 Quality Variation in Market Samples of C. Orchioides

Efforts were made to study the quality differences among samples of *C. orchioides* crude drug available in different markets in south India. Representative samples of the crude drug were collected from selected markets in Kerala and in the neighboring states. Comparison was made on the quality of this material based on the content of 4-hydroxy-3-methoxybenzoic acid and 2,6-dimethoxybenzoic acid. The results furnished in Table 4.2.2 showed a large variability in the market samples in respect of these marker compounds.

In the state of Kerala, 4-hydroxy-3-methoxybenzoic acid was the highest (115.84 ppm) in Malappuram sample followed by Alappuzha sample while it was not detected in the samples from Thiruvananthapuram and Ernakulam. 2,6-dimethoxybenzoic acid was the highest (322.28 ppm) in Alappuzha sample followed by Malappuram and Idukki samples while it was not detected at all in samples from Thrissur.

Among the southern states of India, 4-hydroxy-3-methoxybenzoic acid was the highest (41.19 ppm) in Kerala followed by Maharashtra while it was not detected in the samples from Tamil Nadu and Karnataka. On the other hand, 2,6-dimethoxybenzoic acid was the highest (212.31 ppm) in Tamil Nadu followed by Kerala while it was not detected in samples from Andhra Pradesh.

Table 4.2.1. Content of benzoic acid derivatives in *Curculigo orchioides* rhizome (ppm)

Biotype	4-hydroxy-3-methoxy benzoic acid		2,6-dimethoxy benzoic acid	
	Wild	Cultivated	Wild	Cultivated
Panamkuzhi	145.60	85.49	121.22	42.85
Vellanikkara	36.76	33.83	149.02	88.87

Table 4.2.2. Content of benzoic acid derivatives in market samples of *Curculigo orchioides* crude drug (ppm)

Name of market	4-hydroxy-3-methoxybenzoic acid	2,6-dimethoxybenzoic acid
Thiruvananthapuram	ND	44.66
Alappuzha	96.69	322.28
Ernakulam	ND	20.01
Idukki	52.42	211.96
Thrissur	2.19	ND
Malappuram	115.84	212.31
Kasargod	21.22	10.25
Tamil Nadu	ND	212.31
Karnataka	ND	4.20
Andhra Pradesh	31.40	ND
Maharashtra	38.87	28.25

ND = Not detected

4.3. EXPERIMENT 3. EFFECT OF SHADE AND SPACING ON THE YIELD AND QUALITY OF *C. ORCHIOIDES*

4.3.1 Growth Parameters

4.3.1.1 Plant Height

Effect of shade and spacing on the height of *C. orchioides* is given in Table 4.3.1 and the interaction effect in Table 4.3.2. Plant height was more under shade than under open condition. Among the different shade levels, plants grown at 75 per cent shade exhibited the highest height at the maximum vegetative growth stage (6 MAP) and there was a progressive reduction in plant height with decreasing level of shade. More over, the effect was significant at 4, 6, and 8 MAP. At 4 MAP, the highest plant height of 15.92 cm was observed at 50 per cent shade, which was on par with 75 per cent shade. Both of them were superior to open situation. At 6 MAP, the highest plant height was 23.08 cm at 75 per cent shade, which was on par with 50 per cent shade but superior to 25 per cent shade and open condition. At 8 MAP, all the shade levels recorded significantly higher plant height than the open situation.

The plant height marginally increased with decrease in spacing though it was not significant in most of the months. The effect was, however, significant at 2 MAP wherein the plant height was the highest of 10.16 cm at 20 x 10 cm, which was on par with 9.11 cm at 10 x 10 cm, but significantly higher than the plant heights at 20 x 20 cm and 30 x 20 cm spacings. At 8 MAP, the highest plant height was recorded at 10 x 10 cm spacing, which was on par with 20 x 10 cm but superior to 20 x 20 cm and 30 x 20 cm spacings.

The interaction effect of shade and spacing on plant height at 8 MAP showed that the plant height was the highest of 19.39 cm at 25 per cent shade and 20 x 10 cm spacing followed by 19.10 cm and 19.09 cm at 10 x 10 cm spacing with 75 per cent and 50 per cent shade, respectively and all of them were on par.

4.3.1.2 Number of Leaves

Effect of shade and spacing on leaf production in *C. orchioides* is given in Table 4.3.3 and the interaction effect in Table 4.3.4. In general, number of leaves increased up to 6 MAP and declined thereafter. Variations in number of leaves per

Table 4.3.1. Effect of shade and spacing on height of *Curculigo orchioides* (cm)

MAP	1	2	3	4	5	6	7	8
Shade (%)								
0	9.33	8.54	10.11	11.52	12.19	15.67	11.69	11.24
25	9.28	9.61	12.15	13.79	14.57	18.20	14.41	16.82
50	9.14	8.74	11.81	15.92	14.59	20.14	15.74	16.11
75	9.33	9.19	12.46	15.11	16.27	23.08	13.03	15.99
SEm	0.332	0.53	0.527	0.843	0.901	1.134	0.820	0.393
$CD_{(0.05)}$	NS	NS	NS	2.917	NS	3.924	NS	1.360
Spacing (cm)								
10 x10	9.25	9.11	11.23	14.22	13.52	18.57	15.07	16.81
20 x 10	9.65	10.16	12.11	14.44	14.17	19.91	14.03	15.65
20 x 20	9.32	8.75	11.67	14.38	14.91	20.11	13.40	14.07
30 x 20	8.85	7.98	11.52	13.31	15.02	18.49	12.37	13.64
SEm	0.337	0.377	0.542	0.636	0.840	0.679	0.696	0.516
$CD_{(0.05)}$	NS	1.100	NS	NS	NS	NS	NS	1.505
Interaction	NS	NS	NS	NS	NS	NS	NS	**
G. Mean	9.27	9.00	11.63	14.09	14.40	19.27	13.22	15.04

Table 4.3.2. Interaction effect of shade and spacing on height of *Curculigo orchioides* at 8 MAP (cm)

Shade (%)	Spacing (cm)					
	10x10	20x10	20x20	30x20	SEm	$CD_{(0.05)}$
0	10.23	10.49	12.58	11.68	1.031 [a]	3.011 [a]
25	18.52	19.39	14.39	14.68	0.976 [b]	2.934 [b]
50	19.09	18.45	13.50	13.39		
75	19.10	14.27	15.80	14.79		

[a] Between spacing means at the same level of shade, [b] Between shade means at the same or different levels of spacing

Table 4.3.3. Effect of shade and spacing on leaf production in *Curculigo orchioides* (no. sucker^{-1})

MAP	1	2	3	4	5	6	7	8
Shade (%)								
0	2.65	3.17	4.33	4.28	4.57	5.13	2.42	2.23
25	3.03	3.37	5.40	5.22	5.38	5.95	3.87	2.38
50	2.83	3.45	5.07	5.05	4.82	5.75	3.97	2.24
75	2.75	3.05	5.28	5.05	5.45	5.65	3.75	1.91
SEm	0.196	0.189	0.266	0.332	0.237	0.177	0.154	0.124
$CD_{(0.05)}$	NS	NS	NS	NS	NS	NS	0.534	NS
Spacing (cm)								
10 x10	2.98	3.20	5.28	4.88	5.02	5.48	3.48	2.23
20 x 10	2.92	3.52	4.92	5.07	5.30	5.50	3.40	1.74
20 x 20	2.68	3.23	5.20	4.80	4.87	5.85	3.40	2.44
30 x 20	2.68	3.08	4.68	4.85	5.03	5.65	3.72	2.35
SEm	0.131	0.184	0.219	0.171	0.231	0.199	0.139	0.095
$CD_{(0.05)}$	NS	NS	NS	NS	NS	NS	NS	0.276
Interaction	NS	NS	NS	NS	NS	*	NS	**
G. Mean	2.81	3.26	5.02	4.99	5.05	5.62	3.50	2.19

Table 4.3.4. Interaction effect of shade and spacing on leaf production of *Curculigo orchioides* (leaves suckers^{-1})

Shade (%)	Spacing (cm)				SEm	$CD_{(0.05)}$
	10x10	20x10	20x20	30x20		
	6 MAP					
0	5.60	4.27	5.27	5.40	0.398 [a]	1.161 [a]
25	5.33	6.13	6.80	5.53	0.387 [b]	1.174 [b]
50	5.47	6.27	4.87	6.40		
75	5.53	5.33	6.47	5.27		
	8 MAP					
0	2.30	1.57	2.53	2.50	0.189 [a]	0.552 [a]
25	2.73	1.87	2.87	2.07	0.205 [b]	0.639 [b]
50	2.23	2.00	2.60	2.13		
75	1.67	1.53	1.75	2.70		

[a] Between spacing means at the same level of shade, [b] Between shade means at the same or different levels of spacing

sucker due to shade were statistically significant at 7 MAP and due to spacing at 8 MAP only with significant interaction at 6 and 8 MAP.

Number of leaves per plant was influenced by shade positively but marginally in most of the months. More over the effect was significant at 7 MAP. At 7 MAP, various shade levels (25, 50 and 75%) did not show any significant difference. All the shade levels recorded significantly higher number of leaves per sucker than the open situation. Open condition recorded the lowest number of leaves (2.42) while 50 per cent shade recorded the highest value (3.97 leaves).

The number of leaves per sucker was not influenced by spacing in most of the months, except at 8 MAP when the highest number of leaves (2.44) was noted at 20 x 20 cm spacing which was on par with 10 x 10 cm spacing.

The interaction effect showed that at 6 MAP, the highest number of leaves (6.80) was recorded at 25 per cent shade and 20 x 20 cm spacing. At 8 MAP, 2.87 leaves were the highest recorded at 25 per cent shade and 20 x 20 cm spacing followed by 2.73 leaves produced at 10 x 10 cm spacing at the same shade level.

4.3.1.3 Canopy Spread

Effect of shade and spacing on canopy spread of *C. orchioides* is given in Table 4.3.5 and the interaction effect in Table 4.3.6. In general, canopy spread increased over the period up to 6 MAP and declined thereafter.

The canopy spread was more under shade than under open condition and the effect was significant in most of the months. 75 per cent shade recorded significantly highest canopy spread at maximum vegetative growth stage. At 3 MAP, all shade levels were on par and recorded significantly higher canopy spread than the open situation (9.66 cm). Similar trend was noted at 4 MAP. At 5 MAP, canopy spread was the highest (14.07 cm) at 75 per cent shade, which was on par with 50 per cent and 25 per cent shade but significantly higher than that in open situation (10.97 cm). At 6 MAP, the highest canopy spread of 24.57 cm was recorded at 75 per cent shade, which was superior to all other shade levels including the open situation and all of them were on par. At 7 MAP, 50 per cent shade recorded the highest canopy spread (19.29 cm) which was on par with 25

Table 4.3.5. Effect of shade and spacing on canopy spread of *Curculigo orchioides* (cm)

MAP	1	2	3	4	5	6	7	8
Shade (%)								
0	4.98	6.67	9.66	10.35	10.97	16.30	12.28	8.42
25	5.95	7.43	13.29	12.71	12.45	19.77	16.68	16.06
50	5.14	7.01	12.47	13.87	12.92	19.82	19.29	16.68
75	4.97	6.96	13.68	12.89	14.07	24.57	16.67	15.99
SEm	0.756	0.527	0.751	0.601	0.543	0.784	0.816	0.776
$CD_{(0.05)}$	NS	NS	2.598	2.080	1.878	2.712	2.822	2.684
Spacing (cm)								
10 x10	5.48	7.28	12.25	13.09	12.03	20.30	17.45	16.14
20 x 10	6.10	8.10	13.26	12.48	13.17	19.82	15.80	14.27
20 x 20	4.83	7.18	11.85	12.43	11.67	20.53	17.02	15.01
30 x 20	4.64	5.52	11.73	11.83	13.54	19.82	14.65	12.73
SEm	0.372	0.634	0.761	0.591	0.466	0.709	0.643	0.687
$CD_{(0.05)}$	1.086	1.852	NS	NS	1.359	NS	1.877	2.006
Interaction	NS	NS	NS	NS	*	**	NS	NS
G. Mean	5.26	7.02	12.27	12.46	12.60	20.12	16.23	14.54

Table 4.3.6. Interaction effect of shade and spacing on canopy spread of *Curculigo orchioides* (cm)

Shade (%)	Spacing (cm)				SEm	$CD_{(0.05)}$
	10x10	20x10	20x20	30x20		
	5 MAP					
0	10.73	9.90	12.60	10.63	0.931 [a]	2.718 [a]
25	11.63	13.80	9.40	14.97	0.972 [b]	3.001 [b]
50	12.97	14.00	12.40	12.30		
75	12.77	14.97	12.27	16.27		
	6 MAP					
0	18.79	17.61	11.85	16.95	1.418 [a]	4.139 [a]
25	19.19	20.17	21.73	18.00	1.457 [b]	4.481 [b]
50	21.71	19.03	19.25	19.19		
75	21.43	22.45	29.28	25.13		

[a] Between spacing means at the same level of shade, [b] Between shade means at the same or different levels of spacing

per cent and 75 per cent shade but superior to the open condition. At 8 MAP, the trends were similar to that at 7 MAP.

Canopy spread was significantly influenced by spacing at 1, 2, 5, 7 and 8 MAP. At 1 MAP, the highest canopy spread was 6.10 cm which was on par with that at 10 x 10 cm. At 2 MAP, 20 x 10 cm recorded the highest canopy spread which was on par with that at 10 x 10 and 20 x 20 cm spacing. At 5 MAP among the different spacings, 30 x 20 cm recorded the highest canopy spread (13.54 cm), which was on par with that at 20 x 10 cm. At 7 MAP, among the spacings, 10 x 10 cm and 20 x 20 cm were on par and superior to 30 x 20 cm in canopy spread. At 8 MAP, the trend was similar to that at 7 MAP.

The interaction effect at 5 MAP showed that the highest canopy spread (16.27 cm) was recorded at 75 per cent shade at 30 x 20 cm spacing followed by 14.97 cm both at 75 per cent shade and 20 x 10 cm and at 25 per cent shade and 30 x 20 cm spacing. At 6 MAP, canopy spread was the highest of 29.28 cm at 75 per cent shade at 20 x 20 cm, which was on par with that at the same shade at 30 x 20 cm spacing but superior to all other treatment combinations.

4.3.1.4 Number of Suckers

Effect of shade and spacing on sucker production in *C. orchioides* is furnished in Table 4.3.7 and the interaction effect in Table 4.3.8. In general, the sucker production started from fourth month, reached a peak at 6 MAP and declined thereafter.

Sucker production was marginally higher under shade compared to open condition though the effect was not significant.

Even though the effect of spacing on sucker production was not significant in most of the months, 10 x 10 cm spacing recorded significantly highest number of suckers per plant at 7 and 8 MAP. At 7 MAP, sucker production was the highest of 2.40 suckers at 10 x 10 cm spacing which was superior to all other spacings. At 8 MAP also, sucker production was the highest at 10 x 10 cm spacing which was superior to all other spacings that were on par.

Table 4.3.7. Effect of shade and spacing on sucker production in *Curculigo orchioides* (no. plant^{-1})

MAP	4	5	6	7	8	9
Shade (%)						
0	1.00	1.82	1.92	1.87	1.47	1.17
25	1.10	1.87	1.92	1.78	1.62	1.47
50	1.10	1.87	2.58	1.90	1.53	1.73
75	1.20	1.88	2.47	1.80	1.48	1.68
SEm	0.053	0.124	0.208	0.136	0170	0.146
$CD_{(0.05)}$	NS	NS	NS	NS	NS	NS
Spacing (cm)						
10 x10	1.30	2.03	2.45	2.40	2.00	1.68
20 x 10	1.10	1.98	2.20	1.80	1.35	1.48
20 x 20	1.00	1.77	2.15	1.70	1.33	1.43
30 x 20	1.00	1.65	2.08	1.45	1.42	1.45
SEm	0.042	0.107	0.106	0.179	0.079	0.100
$CD_{(0.05)}$	NS	NS	NS	0.523	0.229	NS
Interaction	NS	NS	**	NS	NS	NS
G. Mean	1.10	1.86	2.22	1.84	1.53	1.51

Table 4.3.8. Interaction effect of shade and spacing on sucker production in *Curculigo orchioides* at 6 MAP (suckers m^{-2})

Shade (%)	Spacing (cm)					
	10x10	20x10	20x20	30x20	SEm	$CD_{(0.05)}$
0	2.00	1.73	2.13	1.80	0.212 [a]	0.619 [a]
25	1.93	2.00	1.73	2.00	0.278 [b]	0.895 [b]
50	2.87	2.73	2.93	1.80		
75	3.00	2.33	1.80	2.73		

[a] Between spacing means at the same level of shade, [b] Between shade means at the same or different levels of spacing.

At 6 MAP, the interaction effect showed that the highest number of suckers was produced at 75 per cent shade and 10 x10 cm spacing, followed by 50 per cent shade and 20 x 20 cm spacing.

4.3.1.5 Chlorophyll Content

Effect of shade and spacing on chlorophyll content of *C. orchioides* leaves is presented in Table 4.3.9. Chlorophyll content at 9 MAP under open condition could not be taken, as there were no green leaves.

Chlorophyll content in leaves was the highest under open condition and it showed a progressive reduction with increase in shade though the effect was not significant in the case of chlorophyll b. As in the case of all other growth parameters, chlorophyll content recorded the peak values at 6 MAP. At 3 MAP, chlorophyll a content in leaves decreased with increase in shade and was the highest (1.851 mg g^{1}) under open condition, which was on par with 25 per cent and 50 per cent shades and all of them were superior to 75 per cent shade. At 6 MAP also, chlorophyll a content in leaves decreased with increase in shade and was the highest (2.118 mg g^{1}) under open condition, but it was superior to all other shade levels, which were on par. On the contrary, at 9 MAP, chlorophyll a content in leaves increased with increase in shade and all values were significantly different from one another. In the case of chlorophyll a+b, the trend was similar to that of chlorophyll a.

Chlorophyll content was not influenced by spacing.

4.3.2 Dry Matter Production

Effect of shade and spacing on total dry matter production in *C. orchioides* is given in Table 4.3.16 and the interaction effect in Table 4.3.17. In general, the total dry matter increased steadily up to 6 MAP and thereafter showed slight fluctuation. Statistically significant increase was noted only from 4 MAP.

The dry matter production was higher under shade though the effect was not significant during most of the months up to maximum growth stage (6 MAP). At 5 MAP, 25 per cent shade produced the highest dry matter (0.58 g $plant^{-1}$) which was superior to that at all other shade levels including the open situation. At 7 MAP, dry matter was the highest of 1.02 g $plant^{-1}$ at 25 per cent shade, which was

Table 4.3.9. Effect of shade and spacing on chlorophyll content of *Curculigo orchioides* (mg g^{-1})

Chlorophyll	a			b			a+b		
MAP	3	6	9	3	6	9	3	6	9
Shade (%)									
0	1.851	2.118	-	0.731	1.089	-	2.581	3.206	-
25	1.672	1.682	0.350	0.801	0.723	0.784	2.470	2.404	1.333
50	1.531	1.431	0.815	0.892	0.574	0.604	2.421	2.004	1.418
75	1.140	1.260	1.275	0.650	0.779	0.655	1.792	2.039	1.930
SEm	0.079	0.082	0.059	0.103	0.092	0.084	0.222	0.187	0.149
$CD_{(0.05)}$	0.357	0.369	0.265	NS	NS	NS	1.000	0.842	0.671
Spacing (cm)									
10 x10	1.461	1.853	0.740	0.751	0.773	0.454	2.210	2.626	1.194
20 x 10	1.510	1.597	0.447	0.791	0.843	0.524	2.311	2.439	0.970
20 x 20	1.621	1.537	0.647	0.640	0.849	0.568	2.261	2.385	1.215
30 x 20	1.602	1.503	0.606	0.892	0.700	0.696	2.492	2.202	1.302
SEm	0.084	0.091	0.063	0.065	0.069	0.054	0.012	0.099	0.114
$CD_{(0.05)}$	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS
G. Mean	1.551	1.622	0.610	0.771	0.791	0.561	2.321	2.413	1.170

Table 4.3.10. Effect of shade and spacing on root dry matter production in *Curculigo orchioides* (g $plant^{-1}$)

MAP	1	2	3	4	5	6	7	8	9
Shade (%)									
0	0.006	0.018	0.022	0.05	0.07	0.21	0.11	0.13	0.12
25	0.002	0.012	0.025	0.04	0.09	0.24	0.17	0.28	0.23
50	0.008	0.016	0.020	0.05	0.07	0.21	0.15	0.22	0.23
75	0.010	0.020	0.027	0.06	0.07	0.23	0.13	0.14	0.18
SEm	0.002	0.002	0.004	0.003	0.005	0.012	0.008	0.014	0.028
$CD_{(0.05)}$	NS	NS	NS	0.010	NS	NS	0.028	0.048	NS
Spacing (cm)									
10 x10	0.008	0.016	0.020	0.05	0.07	0.22	0.21	0.31	0.21
20 x 10	0.002	0.018	0.026	0.05	0.09	0.22	0.16	0.14	0.16
20 x 20	0.006	0.016	0.025	0.04	0.07	0.23	0.11	0.14	0.18
30 x 20	0.008	0.014	0.023	0.06	0.06	0.22	0.08	0.19	0.12
SEm	0.002	0.003	0.003	0.004	0.005	0.014	0.011	0.013	0.014
$CD_{(0.05)}$	NS	NS	NS	0.011	0.014	NS	0.032	0.037	NS
Interaction	NS	NS	NS	**	NS	*	*	**	**
G. Mean	0.006	0.016	0.024	0.05	0.07	0.22	0.14	0.19	0.19

Table 4.3.11. Interaction effect of shade and spacing on root dry matter production in *Curculigo orchioides* (g plant^{-1})

Shade (%)	Spacing (cm)				SEm	$CD_{(0.05)}$
	10x10	20x10	20x20	30x20		
	4 MAP					
0	0.06	0.05	0.04	0.04	0.007 [a]	0.022 [a]
25	0.06	0.04	0.04	0.04	0.007 [b]	0.021 [b]
50	0.03	0.06	0.06	0.05		
75	0.04	0.04	0.03	0.14		
	6 MAP					
0	0.22	0.28	0.19	0.15	0.028 [a]	0.080 [a]
25	0.20	0.20	0.27	0.28	0.027 [b]	0.081 [b]
50	0.21	0.21	0.18	0.24		
75	0.24	0.18	0.29	0.22		
	7 MAP					
0	0.21	0.10	0.04	0.10	0.022 [a]	0.064 [a]
25	0.22	0.23	0.17	0.08	0.021 [b]	0.062 [b]
50	0.22	0.20	0.10	0.07		
75	0.19	0.12	0.14	0.08		
	8 MAP					
0	0.19	0.05	0.13	0.16	0.025 [a]	0.073 [a]
25	0.52	0.18	0.21	0.20	0.026 [b]	0.079 [b]
50	0.37	0.19	0.12	0.20		
75	0.14	0.14	0.10	0.19		
	9 MAP					
0	0.12	0.13	0.10	0.14	0.028 [a]	0.082 [a]
25	0.30	0.16	0.24	0.21	0.037 [b]	0.119 [b]
50	0.18	0.17	0.24	0.34		
75	0.23	0.19	0.16	0.15		

[a] Between spacing means at the same level of shade, [b] Between shade means at the same or different levels of spacing.

Table 4.3.12. Effect of shade and spacing on rhizome dry matter production in *Curculigo orchioides* (g plant^{-1})

MAP	1	2	3	4	5	6	7	8	9
Shade (%)									
0	0.074	0.118	0.139	0.19	0.26	0.60	0.46	0.51	0.43
25	0.062	0.110	0.125	0.18	0.27	0.51	0.65	0.90	0.76
50	0.064	0.122	0.122	0.15	0.15	0.50	0.60	0.74	0.90
75	0.070	0.112	0.139	0.15	0.14	0.50	0.43	0.69	0.69
SEm	0.006	0.011	0.006	0.014	0.009	0.013	0.031	0.033	0.019
$CD_{(0.05)}$	NS	NS	NS	NS	0.030	0.047	0.107	0.115	0.065
Spacing(cm)									
10 x10	0.068	0.120	0.121	0.17	0.22	0.49	0.75	0.93	0.75
20 x 10	0.68	0.120	0.141	0.19	0.19	0.53	0.58	0.60	0.62
20 x 20	0.068	0.112	0.124	0.16	0.24	0.51	0.43	0.64	0.64
30 x 20	0.064	0.110	0.139	0.16	0.17	0.59	0.38	0.66	0.78
SEm	0.006	0.009	0.096	0.009	0.016	0.026	0.023	0.030	0.029
$CD_{(0.05)}$	NS	NS	NS	NS	0.047	NS	0.067	0.087	0.085
Interaction	NS	NS	NS	**	NS	**	**	**	**
G. Mean	0.068	0.116	0.131	0.17	0.20	0.53	0.53	0.71	0.70

Table 4.3.13. Interaction effect of shade and spacing on rhizome dry matter production in *Curculigo orchioides* (g plant^{-1})

Shade (%)	Spacing (cm)				SEm	$CD_{(0.05)}$
	10x10	20x10	20x20	30x20		
	4 MAP					
0	0.20	0.19	0.19	0.19	0.018 [a]	0.052 [a]
25	0.17	0.27	0.18	0.11	0.021 [b]	0.067 [b]
50	0.16	0.15	0.11	0.16		
75	0.16	0.14	0.17	0.16		
	6 MAP					
0	0.51	0.75	0.56	0.59	0.052 [a]	0.152 [a]
25	0.46	0.51	0.53	0.56	0.047 [b]	0.139 [b]
50	0.50	0.56	0.43	0.49		
75	0.48	0.28	0.53	0.72		
	7 MAP					
0	0.75	0.42	0.26	0.42	0.046 [a]	0.134 [a]
25	0.74	0.82	0.55	0.49	0.050 [b]	0.157 [b]
50	0.78	0.75	0.45	0.41		
75	0.73	0.35	0.45	0.20		
	8 MAP					
0	0.49	0.45	0.58	0.53	0.060 [a]	0.175 [a]
25	1.27	0.76	0.87	0.70	0.062 [b]	0.190 [b]
50	1.01	0.61	0.59	0.73		
75	0.96	0.59	0.53	0.69		
	9 MAP					
0	0.53	0.40	0.36	0.43	0.059 [a]	0.171 [a]
25	0.89	0.60	0.56	1.01	0.054 [b]	0.161 [b]
50	0.83	0.73	0.99	1.07		
75	0.74	0.77	0.65	0.62		

[a] Between spacing means at the same level of shade, [b] Between shade means at the same or different levels of spacing.

Table 4.3.14. Effect of shade and spacing on shoot dry matter production in *Curculigo orchioides* (g plant^{-1})

MAP	1	2	3	4	5	6	7	8	9
Shade (%)									
0	0.062	0.050	0.058	0.09	0.16	0.24	0.11	0.13	0.04
25	0.058	0.064	0.86	0.12	0.22	0.35	0.20	0.28	0.13
50	0.058	0.058	0.078	0.12	0.17	0.36	0.19	0.17	0.14
75	0.060	0.056	0.087	0.13	0.16	0.39	0.14	0.12	0.08
SEm	0.003	0.005	0.008	0.006	0.010	0.018	0.010	0.012	0.005
$CD_{(0.05)}$	NS	NS	NS	0.019	0.036	0.065	0.035	0.043	0.017
Spacing (cm)									
10 x10	0.064	0.060	0.077	0.12	0.17	0.39	0.20	0.23	0.09
20 x 10	0.066	0.064	0.082	0.11	0.19	0.31	0.18	0.14	0.11
20 x 20	0.058	0.056	0.078	0.11	0.17	0.33	0.14	0.15	0.10
30 x 20	0.052	0.048	0.073	0.11	0.17	0.30	0.13	0.18	0.10
SEm	0.004	0.004	0.005	0.006	0.009	0.017	0.009	0.012	0.005
$CD_{(0.05)}$	NS	NS	NS	NS	NS	0.050	0.025	0.036	0.014
Interaction	NS	NS	NS	**	**	**	**	*	**
G. Mean	0.060	0.078	0.077	0.11	0.18	0.34	0.16	0.18	0.10

Table 4.3.15. Interaction effect of shade and spacing on shoot dry matter production in *Curculigo orchioides* (g plant^{-1})

Shade (%)	Spacing (cm)				SEm	$CD_{(0.05)}$
	10x10	20x10	20x20	30x20		
	4 MAP					
0	0.11	0.08	0.09	0.06	0.012 [a]	0.036 [a]
25	0.13	0.13	0.12	0.10	0.012 [b]	0.037 [b]
50	0.12	0.14	0.11	0.11		
75	0.11	0.10	0.13	0.17		
	5 MAP					
0	0.16	0.14	0.16	0.17	0.018 [a]	0.053 [a]
25	0.21	0.28	0.20	0.18	0.019 [b]	0.058 [b]
50	0.16	0.22	0.16	0.14		
75	0.15	0.14	0.17	0.17		
	6 MAP					
0	0.28	0.26	0.26	0.15	0.034 [a]	0.099 [a]
25	0.32	0.34	0.36	0.38	0.034 [b]	0.105 [b]
50	0.53	0.39	0.26	0.28		
75	0.44	0.28	0.45	0.40		
	7 MAP					
0	0.15	0.10	0.08	0.10	0.017 [a]	0.050 [a]
25	0.25	0.26	0.16	0.14	0.018 [b]	0.056 [b]
50	0.23	0.23	0.15	0.16		
75	0.16	0.13	0.17	0.11		
	8 MAP					
0	0.15	0.05	0.11	0.20	0.024 [a]	0.071 [a]
25	0.36	0.24	0.30	0.23	0.025 [b]	0.075 [b]
50	0.24	0.18	0.12	0.15		
75	0.18	0.09	0.08	0.14		
	9 MAP					
0	0.04	0.05	0.01	0.05	0.010 [a]	0.028 [a]
25	0.10	0.19	0.14	0.09	0.010 [b]	0.030 [b]
50	0.13	0.10	0.14	0.18		
75	0.07	0.08	0.09	0.10		

[a] Between spacing means at the same level of shade, [b] Between shade means at the same or different levels of spacing.

Table 4.3.16. Effect of shade and spacing on total dry matter production in *Curculigo orchioides* (g plant^{-1})

MAP	1	2	3	4	5	6	7	8	9
Shade (%)									
0	0.142	0.186	0.219	0.33	0.49	1.05	0.68	0.77	0.59
25	0.122	0.186	0.236	0.34	0.58	1.10	1.02	1.46	1.12
50	0.130	0.196	0.220	0.32	0.39	1.07	0.94	1.13	1.27
75	0.140	0.188	0.253	0.34	0.37	1.12	0.70	0.95	0.95
SEm	0.005	0.018	0.032	0.020	0.031	0.051	0.030	0.063	0.072
$CD_{(0.05)}$	NS	NS	NS	NS	0.106	NS	0.103	0.219	0.250
Spacing (cm)									
10 x10	0.140	0.196	0.218	0.34	0.46	1.10	1.16	1.47	1.05
20 x 10	0.136	0.202	0.249	0.35	0.47	1.06	0.92	0.88	0.89
20 x 20	0.132	0.186	0.227	0.31	0.48	1.07	0.68	0.93	0.92
30 x 20	0.124	0.172	0.235	0.29	0.40	1.11	0.59	1.03	1.09
SEm	0.007	0.012	0.028	0.018	0.022	0.033	0.029	0.058	0.032
$CD_{(0.05)}$	NS	NS	NS	0.051	0.063	NS	0.086	0.168	0.094
Interaction	NS	NS	NS	*	*	**	**	*	**
G. Mean	0.134	0.210	0.232	0.33	0.45	1.09	0.83	1.08	0.99

Table 4.3.17. Interaction effect of shade and spacing on total dry matter production in *Curculigo orchioides* (g plant^{-1})

Shade (%)	Spacing (cm)					
	10x10	20x10	20x20	30x20	SEm	$CD_{(0.05)}$
	4 MAP					
0	0.40	0.34	0.32	0.27	0.035 [a]	0.103 [a]
25	0.35	0.44	0.37	0.24	0.036 [b]	0.120 [b]
50	0.28	0.38	0.30	0.29		
75	0.20	0.29	0.34	0.32		
	5 MAP					
0	0.47	0.37	0.55	0.46	0.043 [a]	0.127 [a]
25	0.52	0.74	0.62	0.56	0.049 [b]	0.152 [b]
50	0.41	0.43	0.40	0.34		
75	0.38	0.46	0.48	0.35		
	6 MAP					
0	1.05	1.21	1.13	0.73	0.067 [a]	0.194 [a]
25	0.85	1.04	1.10	1.18	0.077 [b]	0.243 [b]
50	1.18	1.17	0.69	0.92		
75	1.09	0.64	1.34	1.28		
	7 MAP					
0	1.07	0.62	0.34	0.65	0.059 [a]	0.171 [a]
25	1.34	1.28	0.87	0.68	0.059 [b]	0.180 [b]
50	1.14	1.19	0.70	0.70		
75	1.05	0.64	0.87	0.34		
	8 MAP					
0	0.97	0.50	0.88	0.83	0.115 [a]	0.336 [a]
25	1.93	1.30	1.29	1.13	0.118 [b]	0.363 [b]
50	1.55	0.93	0.76	1.16		
75	1.05	0.87	0.75	0.89		
	9 MAP					
0	0.73	0.66	0.49	0.51	0.065 [a]	0.189 [a]
25	1.28	0.73	0.86	1.34	0.092 [b]	0.298 [b]
50	1.11	1.06	1.30	1.67		
75	0.93	0.85	0.92	0.98		

[a] Between spacing means at the same level of shade, [b] Between shade means at the same or different levels of spacing.

on par with 50 per cent shade but superior to 75 per cent shade and open condition. At 8 MAP, the highest dry matter of 1.46 g plant^{-1} was produced at 25 per cent shade, which was superior to all other shade levels, including the open condition. At 9 MAP, 50 per cent shade recorded the highest dry matter (1.27 g plant^{-1}), which was on par with 25 per cent shade but superior to 75 per cent shade and open situation.

Dry matter production was not influenced by spacing in the initial stages. Towards the later stages 10 x 10 cm spacing recorded either the highest dry matter or on par with the highest value. At 4 MAP, the spacing 20 x 10 cm recorded the highest total dry matter of 0.35 g plant^{-1}, which was on par with that at all spacings other than 30 x 20 cm. At 5 MAP, dry matter was the highest (0.48 g plant^{-1}) at 20 x 20 cm, which was on par with all other spacings, except 30 x 20 cm. At 7 MAP, dry matter decreased with increase in spacing and the spacing 10 x 10 cm recorded the highest dry matter of 1.16 g plant^{-1}, which was superior to that at all other spacings. At 8 MAP, total dry matter was the highest (1.47 g plant^{-1}) at 10 x 10 cm spacing, which was superior to all other spacing. At 9 MAP, 10 x 10 cm and 30 x 20 cm were on par, which were superior to the other two spacings.

The superiority of 25 per cent shade and 10 x 10 cm spacing during the later stages of growth is also evident from the interaction effects. The interaction effect at 4 MAP showed the highest dry matter (0.44 g plant^{-1}) at 25 per cent shade and 20 x 10 cm spacing, followed by 10 x 10 cm under open situation. At 5 MAP, the highest dry matter of 0.74 g plant^{-1} was noted at 25 per cent shade and 20 x 10 cm spacing which was on par with that at 25 per cent shade and 20 x 20 cm spacing and superior to all other treatment combinations. At 6 MAP, the highest dry matter (1.34 g plant^{-1}) was recorded by the treatment combination of 75 per cent shade and 20 x 20 cm spacing followed by 75 per cent shade and 30 x 20 cm spacing. The interaction effect at 7 MAP showed the highest dry matter (1.34 g plant^{-1}) at 25 per cent shade and 10 x 10 cm spacing, which was on par with 25 per cent shade and 20 x 10 cm and 50 per cent shade and 20 x 10 cm spacing. At 8 MAP, the dry matter was the highest (1.93 g plant^{-1}) at 25 per cent shade and 10 x 10 cm spacing, which was superior to all other treatment combinations.

4.3.3 Plant Density and Weed Biomass

Effect of shade and spacing on plant density and weed biomass production in *C. orchioides* is presented in Table 4.3.18 and the interaction effect in Table 4.3.19.

4.3.3.1 Plant Density

Plant density and suckers m^{-2} were significantly higher under shade compared to open condition and showed a progressive increase with increase in shade. The plant density was significantly reduced under open condition (22.78 plants m^{-2}) and the densities at other shade levels were on par at 6 MAP.

The effect of spacing alone was significant at 3 MAP. The number of plants m^{-2} steadily decreased with increase in spacing, each being statistically different from one another. Plant density steadily decreased with increase in spacing, the highest (71.18 plants m^{-2}) was at 10 x 10 cm, which was superior to that at all other spacings.

The interaction effect at 6 MAP showed the highest plant density of 92.50 plants m^{-2} at 75 per cent shade and 10 x 10 cm spacing, which were on par with 50 per cent and 25 per cent shades at the same spacing but superior to all other treatment combinations.

The total number of suckers at 6 MAP also was significantly reduced under open condition (48.33 suckers m^{-2}) compared to shaded conditions, which were all on par. The total number of suckers reduced significantly with increase in spacing, each being significantly different from one another, and the highest number (222.75 suckers m^{-2}) was at 10 x 10 cm spacing. A significant interaction showed the highest number of suckers (293.67 suckers m^{-2}) at 75 per cent shade and 10 x 10 cm spacing, which was on par with the other shade levels at the same spacing, except under open condition that was significantly inferior.

4.3.3.2 Fresh Weed Biomass

The main effect of shade alone was significant on weed biomass production. Weed infestation was significantly higher under open condition and there was a progressive reduction with increase in shade. At 2 MAP, fresh weed biomass was the highest (0.91 kg m^{-2}) under open condition, which was significantly higher

Table 4.3.18. Effect of shade and spacing on plant density and weed biomass production in *Curculigo orchioides*

Treatment	Plants m^{-2}		Suckers m^{-2}	Fresh weed biomass (kg m^{-2})			Dry weed biomass (kg m^{-2})		
	3MAP	6MAP	6MAP	2MAP	4MAP	6MAP	2MAP	4MAP	6MAP
Shade (%)									
0	52.00	22.78	48.33	0.91	2.16	2.81	0.131	0.311	0.405
25	49.17	41.46	128.17	0.16	1.13	1.32	0.023	0.163	0.190
50	47.83	41.81	130.58	0.08	0.32	0.45	0.012	0.046	0.065
75	51.17	47.57	150.92	0.08	0.26	0.31	0.012	0.037	0.045
SEm	1.178	2.084	10.544	0.160	0.146	0.152	0.023	0.021	0.022
$CD_{(0.05)}$	NS	7.211	36.486	0.553	0.507	0.684	0.080	0.073	0.098
Spacing (cm)									
10 x10	100.83	71.18	222.75	0.28	0.92	1.21	0.040	0.132	0.174
20 x 10	51.67	37.78	116.33	0.38	1.01	1.22	0.055	0.145	0.176
20 x 20	29.00	26.39	74.25	0.25	0.98	1.23	0.036	0.141	0.177
30 x 20	18.58	18.26	44.67	0.33	0.96	1.23	0.048	0.138	0.177
SEm	1.968	3.140	10.930	0.074	0.086	0.103	0.011	0.012	0.015
$CD_{(0.05)}$	5.744	9.166	31.901	NS	NS	NS	NS	NS	NS
Interaction	NS	*	**	NS	NS	NS	NS	NS	NS
G. Mean	50.04	38.40	114.50	0.31	0.97	1.223	0.45	0.140	0.176

Table 4.3.19. Interaction effect of shade and spacing on plant density of *Curculigo orchioides*

Shade (%)	Spacing (cm)				SEm	$CD_{(0.05)}$
	10x10	20x10	20x20	30x20		
	Plant density at 6 MAP (plants m^{-2})					
0	35.00	24.44	18.89	12.78	6.281 [a]	18.332 [a]
25	80.83	40.00	25.56	19.44	5.825 [b]	17.405 [b]
50	76.39	41.39	31.11	18.33		
75	92.50	45.20	30.00	22.50		
	Sucker production at 6 MAP (suckers m^{-2})					
0	79.00	48.33	43.33	22.67	21.859 [a]	63.803 [a]
25	251.00	134.67	79.67	47.33	21.669 [b]	66.026 [b]
50	267.33	108.33	96.00	50.67		
75	293.67	174.00	78.00	58.00		

[a] Between spacing means at the same level of shade, [b] Between shade means at the same or different levels of spacing.

than that at other shade levels that were on par. At 4 MAP, fresh weed biomass reduced with increase in shade level and the highest was 2.16 kg m^{-2} under open condition which was significantly higher than that at other shade levels. The same trend was followed at 6 MAP.

Weed biomass was not significantly influenced by spacing but a lesser value was observed at 10 x 10 cm spacing at 4 and 6 MAP.

4.3.3.3 Dry Weed Biomass

Fresh and dry weed biomass followed similar trends.

4.3.4 Yield Parameters

Effect of shade and spacing on yield of *C. orchioides* is presented in Table 4.3.20 and the interaction effect in Table 4.3.21.

4.3.4.1 Biological Yield

Biological yield at each shade level was significantly different from one another. More over, it was significantly higher under shade compared to open condition. It was the highest (2621.17 kg ha^{-1}) at 25 per cent shade, followed by 75 per cent and 50 per cent shades and least under open situation (627.77 kg ha^{-1}). Among the shade levels, 25 per cent shade recorded 76.05 per cent higher yield than under open condition.

Biological yield was significantly influenced by spacing and it steadily decreased with increase in spacing. The highest yield was 3512.84 kg ha^{-1} at 10 x 10 cm spacing and the lowest 712.84 kg ha^{-1} at 30 x 20 cm spacing.

The interaction effect showed the highest biological yield of 4715.27 kg ha^{-1} at 25 per cent shade and 10 x 10 cm spacing which was on par with 75 per cent shade at the same spacing but superior to all other treatment combinations.

4.3.4.2 Fresh Rhizome Yield

Fresh rhizome yield followed the trend of the biological yield in the main effect of shade and spacing with a slight deviation in the interaction effect.

Fresh rhizome yield was significantly higher under shade compared to open condition. It was the highest (1482.81 kg ha^{-1}) at 25 per cent shade, followed by 75 per cent and 50 per cent shades and least under open situation (420.33 kg ha^{-1}).

Table 4.3.20. Effect of shade and spacing on yield and harvest index of *Curculigo orchioides*

Treatment	Yield (kg ha^{-1})			Harvest index (%)
	Biological	Fresh rhizome	Dry rhizome	
Shade (%)				
0	627.77	420.33	129.19	66.96
25	2621.17	1482.81	643.33	56.57
50	1925.34	965.85	419.93	50.17
75	2450.69	1166.63	509.93	47.60
SEm	101.913	39.005	9.874	–
$CD_{(0.05)}$	352.665	134.973	34.169	–
Spacing (cm)				
10 x10	3512.84	1896.32	796.60	53.98
20 x 10	2135.76	1137.65	499.53	53.27
20 x 20	1263.54	648.62	259.88	51.33
30 x 20	712.84	353.03	146.36	49.52
SEm	116.581	37.759	9.770	–
$CD_{(0.05)}$	340.276	110.211	28.517	–
Interaction	**	**	**	
G. Mean	1906.24	1008.91	425.59	52.93

Table 4.3.21. Interaction effect of shade and spacing on yield of *Curculigo orchioides* (kg ha^{-1})

Shade (%)	Spacing (cm)				SEm	$CD_{(0.05)}$
	10x10	20x10	20x20	30x20		
	Biological yield					
0	1506.94	615.27	241.66	147.22	233.162 [a]	680.553 [a]
25	4715.27	3301.38	1881.94	586.10	226.185 [b]	685.061 [b]
50	3784.72	1891.66	1037.50	987.49		
75	4044.44	2734.72	1893.05	1130.55		
	Fresh rhizome yield					
0	1155.88	322.40	142.17	60.88	75.518 [a]	220.423 [a]
25	2736.74	1899.11	957.82	337.58	76.149 [b]	233.084 [b]
50	1836.76	980.10	594.69	451.83		
75	1855.90	1349.00	899.81	561.82		
	Dry rhizome yield					
0	324.22	127.38	41.94	23.21	19.540 [a]	57.035 [a]
25	1208.29	836.24	379.76	149.03	19.593 [b]	59.883 [b]
50	810.03	403.43	275.00	191.25		
75	843.88	631.10	342.79	221.97		

[a] Between spacing means at the same level of shade, [b] Between shade means at the same or different levels of spacing.

Among the shade levels, 25 per cent shade recorded 71.65 per cent higher yield than under open condition.

Fresh rhizome yield was significantly influenced by spacing and it steadily decreased with increase in spacing. The highest yield was 1896.32 kg ha^{-1} at 10 x 10 cm spacing and the lowest 353.03 kg ha^{-1} at 30 x 20 cm spacing.

The interaction effect recorded the highest (2736.74 kg ha^{-1}) yield at 25 per cent shade and 10 x 10 cm spacing, which was superior to all other treatment combinations.

4.3.4.3 Dry Rhizome Yield

Dry rhizome yield at each shade level was significantly different from one another. It was significantly higher under shade compared to open condition. It was the highest (643.33 kg ha^{-1}) at 25 per cent shade, followed by 75 per cent and 50 per cent shades. Among the shade levels, 25 per cent shade recorded 79.92 per cent higher yield than under open condition.

Dry rhizome yield was significantly influenced by spacing and it steadily decreased with increase in spacing. The highest yield was 796.60 kg ha^{-1} at 10 x 10 cm spacing and the lowest 146.36 kg ha^{-1} at 30 x 20 cm spacing.

The interaction effect showed the highest dry rhizome yield of 1208.29 kg ha^{-1} at 25 per cent shade and 10 x 10 cm spacing, which was superior to all other treatment combinations.

4.3.4.4 Harvest Index

Harvest index steadily decreased with increase in shade level. The highest harvest index value (66.96%) was recorded under open condition and the least value (47.60%) at 75 per cent shade. Among spacings, though the harvest index values decreased steadily with increase in spacing, the decrease was marginal. The highest harvest index value (53.98%) was recorded at 10 x 10 cm and the least value (49.52%) at 30 x 20 cm spacing.

4.3.5 Quality Parameters

Effect of shade and spacing on quality parameters of *C. orchioides* is furnished in Table 4.3.22 and the interaction effect in Table 4.3.23.

Table 4.3.22. Effect of shade and spacing on quality parameters of *Curculigo orchioides*

Treatment	Quality parameters of dry rhizome at harvest (%)							
	Glucose	Sucrose	Starch	Fibre	Protein	Fat	Curculigoside	Ash
Shade (%)								
0	0.592	0.549	53.838	2.908	11.475	1.880	0.000	4.424
25	1.275	1.061	59.880	2.615	10.719	1.767	0.137	3.782
50	1.353	0.908	53.385	2.350	9.856	1.587	0.094	3.418
75	1.243	1.003	55.578	2.462	10.244	1.581	0.125	3.668
SEm	0.006	0.005	0.437	0.010	0.106	0.010	-	0.019
$CD_{(0.05)}$	0.025	0.021	1.969	0.046	0.481	0.042	-	0.085
Spacing (cm)								
10 x10	1.241	0.994	59.409	2.746	10.581	1.674	0.093	4.015
20 x 10	1.289	1.036	53.304	2.806	10.613	1.736	0.097	3.838
20 x 20	0.994	0.721	55.238	2.395	10.888	1.722	0.084	3.644
30 x 20	0.937	0.771	54.730	2.387	10.219	1.682	0.083	3.795
SEm	0.008	0.008	0.235	0.024	0.075	0.010	-	0.022
$CD_{(0.05)}$	0.023	0.025	0.725	0.073	0.231	0.039	-	0.067
Interaction	**	**	**	**	**	NS	-	**
G. Mean	1.116	0.881	55.670	2.584	10.575	1.704	0.089	3.823

Table 4.3.23. Interaction effect of shade and spacing on quality of *Curculigo orchioides* (%)

Shade (%)	Spacing (cm)				SEm	$CD_{(0.05)}$
	10x10	20x10	20x20	30x20		
	Glucose					
0	1.147	1.220	0.000	0.000	0.015 [a]	0.047 [a]
25	1.299	1.323	1.310	1.168	0.014 [b]	0.047 [b]
50	1.211	1.445	1.401	1.356		
75	1.306	1.169	1.267	1.232		
	Sucrose					
0	1.100	1.098	0.000	0.000	0.016 [a]	0.050 [a]
25	1.039	1.089	1.002	1.115	0.015 [b]	0.048 [b]
50	0.968	0.883	0.815	0.968		
75	0.871	1.074	1.067	0.999		
	Starch					
0	54.57	51.47	52.33	56.97	0.470 [a]	1.450 [a]
25	66.08	59.46	59.77	54.19	0.598 [b]	2.296 [b]
50	53.24	52.15	55.35	52.79		
75	63.73	50.13	53.49	54.96		
	Fibre					
0	2.945	3.191	2.807	2.688	0.047 [a]	0.146 [a]
25	3.216	2.616	2.089	2.540	0.042 [b]	0.134 [b]
50	2.458	2.621	2.158	2.162		
75	2.367	2.798	2.526	2.156		
	Protein					
0	11.869	11.869	12.319	9.856	0.150 [a]	0.463 [a]
25	9.856	10.975	11.869	10.188	0.169 [b]	0.613 [b]
50	10.525	9.519	9.181	10.188		
75	10.075	10.075	10.188	10.638		
	Ash					
0	4.317	4.844	3.394	5.141	0.043 [a]	0.134 [a]
25	4.529	3.586	3.312	3.700	0.042 [b]	0.141 [b]
50	3.270	3.382	3.972	3.049		
75	3.943	3.540	3.897	3.292		

[a] Between spacing means at the same level of shade, [b] Between shade means at the same or different levels of spacing.

Glucose, sucrose and starch were higher under shade compared to open condition whereas, crude protein, crude fat, crude fibre and ash were higher under open condition. Among the shade levels, 25 per cent shade recorded the highest value of all the above, except glucose.

4.3.5.1 Glucose

The glucose content in dry rhizome at harvest was significantly different at each shade level. It was the highest (1.353%) at 50 per cent shade, followed by 25 per cent and 75 per cent shades and the least under open condition (0.592%).

The glucose content in dry rhizome was significantly different at each spacing. The highest glucose content (1.289%) was at 20 x 10 cm spacing, followed by 10 x 10 cm and the least at 30 x 20 cm spacing.

The interaction effect showed the highest glucose content (1.445%) at 50 per cent shade and 20 x 10 cm spacing, which was on par with 20 x 20 cm at the same shade and superior to all other treatment combinations. Glucose could not be detected at 20 x 20 cm and 30 x 20 cm spacing under open condition.

4.3.5.2 Sucrose

The sucrose content in dry rhizome at harvest was significantly different at each shade level. It was the highest (1.061%) at 25 per cent shade, followed by 75 per cent and 50 per cent shades and the least under open condition (0.549%).

It was also significantly different at each spacing. The highest sucrose content (1.036%) was at 20 x 10 cm spacing, followed by 10 x 10 cm spacing.

However, the interaction effect showed the highest sucrose content at 25 per cent shade and 30 x 20 cm spacing. Sucrose could not be detected at 20 x 20 cm and 30 x 20 cm spacing under open condition.

4.3.5.3 Starch

The starch content in dry rhizome was the highest (59.880%) at 25 per cent shade, which was superior to all other shade levels including the open situation. It was followed by 75 per cent shade.

The starch content was significantly different at each spacing. The spacing 10 x 10 cm recorded the highest value (59.409%), followed by 20 x 20 cm.

The interaction effect showed the highest starch content of 66.08 per cent at 25 per cent shade and 10 x 10 cm spacing, which was superior to all other treatment combinations.

4.3.5.4 Fibre

The fibre content in dry rhizome at harvest was significantly different at each shade level. It was the highest (2.908%) under open condition, followed by 25 per cent and 75 per cent shades and the least (2.350%) at 50 per cent shade.

Among spacings, 20 x 10 cm recorded the highest value (2.806%), which was on par with that at 10 x 10 cm spacing but superior to that at the other two spacings.

The interaction effect showed the highest fibre content of 3.216 per cent at 25 per cent shade and 10 x 10 cm spacing, which was on par with 20 x 10 cm under open condition but superior to all other treatment combinations.

4.3.5.5 Protein

The protein content in dry rhizome was the highest (11.475%) under open condition, which was superior to all other shade levels. It was followed by 25 per cent and 75 per cent shades.

The protein content was significantly different at each spacing. The highest protein content (10.888%) was at 20 x 20 cm spacing, followed by 20 x 10 cm and 10 x 10 cm spacing.

The interaction effect showed the highest protein content of 12.319 per cent under open at 20 x 20 cm, which was on par with the other spacings, except 30 x 20 cm under open and same spacing at 25 per cent shade but superior to all other treatment combinations.

4.3.5.6 Fat

The fat content in dry rhizome steadily decreased with increase in shade. It was the highest (1.880%) under open condition, which was superior to all other shade levels. It was followed by 25 per cent and 75 per cent shades.

Among spacings, 20 x 10 cm and 20 x 20 cm recorded significantly higher fat content in dry rhizome than the other two spacings.

The interaction effect was not significant.

4.3.5.7 Curculigoside

Curculigoside was not detected under open condition. It was the highest of 0.014 per cent in dry rhizome at 25 per cent shade, followed by 75 per cent and 50 per cent shades.

Among spacings, closer spacings recorded higher curculigoside contents than wider spacings and the highest was 0.009 per cent at 10 x 10 cm spacing.

4.3.5.8 Ash

The ash content in dry rhizome at harvest was significantly different at each shade level. It was the highest (4.424%) under open condition, followed by 25 per cent and 75 per cent shades and the least (3.418%) at 50 per cent shade.

Among spacings, 10 x 10 cm recorded the highest value (4.015%), which was superior to all other spacings.

However, the interaction effect showed the highest ash content of 5.141 per cent under open condition at 30 x 20 cm spacing, which was superior to all other treatment combinations.

4.3.6 Nutrient Contents

4.3.6.1 Rhizome

4.3.6.1.1 Major nutrients

Effect of shade and spacing on the content of major nutrients in *C. orchioides* rhizome is given in Table 4.3.24 and the interaction effect in Table 4.3.25.

Nitrogen

Nitrogen content increased with increase in age of the plant up to 9 MAP. It was highest under open condition though not significant at 3 MAP. Among the shade levels, 25 per cent recorded the highest value. At 6 MAP, the highest N content in rhizome of 1.456 per cent was recorded under open condition, and among the shade levels, 25 per cent shade recorded the highest N content in rhizome. At 9 MAP, N content in rhizome was the highest (2.057%) under open

Table 4.3.24. Effect of shade and spacing on the content of major nutrients in *Curculigo orchioides* rhizome (%)

Treatment	N				P				K			
	3 MAP	6 MAP	9 MAP	Harvest	3 MAP	6 MAP	9 MAP	Harvest	3 MAP	6 MAP	9 MAP	Harvest
Shade (%)												
0	0.453	1.456	2.057	1.836	0.121	0.178	0.254	0.250	0.670	0.728	0.594	0.903
25	0.453	1.138	1.822	1.715	0.102	0.167	0.167	0.211	0.728	0.624	0.447	0.772
50	0.407	1.129	1.621	1.577	0.122	0.136	0.114	0.172	0.749	0.682	0.466	0.722
75	0.538	1.120	1.652	1.639	0.124	0.156	0.137	0.144	0.789	0.744	0.488	0.739
SEm	0.006	0.013	0.013	0.017	0.001	0.001	0.006	0.001	0.091	0.027	0.013	0.010
$CD_{(0.05)}$	NS	0.060	0.059	0.077	NS	0.004	0.028	0.003	NS	NS	0.059	0.043
Spacing (cm)												
10 x10	0.427	1.259	1.687	1.693	0.124	0.161	0.177	0.192	0.706	0.694	0.544	0.796
20 x 10	0.446	1.223	1.833	1.698	0.106	0.154	0.159	0.206	0.736	0.682	0.481	0.763
20 x 20	0.499	1.205	1.806	1.742	0.115	0.165	0.169	0.192	0.735	0.713	0.513	0.797
30 x 20	0.479	1.156	1.825	1.635	0.123	0.158	0.166	0.186	0.759	0.690	0.456	0.782
SEm	0.008	0.017	0.009	0.012	0.001	0.002	0.004	0.003	0.082	0.022	0.014	0.019
$CD_{(0.05)}$	NS	0.052	0.029	0.037	NS	0.007	NS	0.008	NS	NS	0.042	NS
Interaction	NS	**	**	**	NS	**	**	**	NS	NS	*	NS
G. Mean	0.463	1.211	1.788	1.692	0.117	0.159	0.168	0.194	0.734	0.694	0.498	0.784

Table 4.3.25. Interaction effect of shade and spacing on the content of major nutrients in *Curculigo orchioides* rhizome (%)

Shade (%)	Spacing (cm)					
	10x10	20x10	20x20	30x20	SEm	$CD_{(0.05)}$
	N at 6 MAP					
0	1.613	1.541	1.416	1.254	0.034 [a]	0.104 [a]
25	1.129	1.075	1.308	1.039	0.032 [b]	0.107 [b]
50	1.129	1.183	1.057	1.147		
75	1.165	1.093	1.039	1.183		
	N at 9 MAP					
0	1.976	2.173	2.099	2.023	0.019 [a]	0.058 [a]
25	1.791	1.930	1.852	1.714	0.021 [b]	0.076 [b]
50	1.482	1.621	1.667	1.714		
75	1.498	1.652	1.605	1.852		
	N at harvest					
0	1.899	1.899	1.971	1.577	0.024 [a]	0.074 [a]
25	1.577	1.756	1.899	1.630	0.027 [b]	0.098 [b]
50	1.684	1.523	1.469	1.630		
75	1.612	1.612	1.630	1.702		
	P at 6 MAP					
0	0.184	0.187	0.186	0.154	0.004 [a]	0.014 [a]
25	0.193	0.158	0.154	0.162	0.004 [b]	0.013 [b]
50	0.120	0.127	0.148	0.149		
75	0.146	0.143	0.171	0.165		
	P at 9 MAP					
0	0.257	0.243	0.273	0.241	0.008 [a]	0.025 [a]
25	0.153	0.171	0.240	0.140	0.010 [b]	0.035 [b]
50	0.093	0.114	0.090	0.157		
75	0.205	0.109	0.109	0.124		
	P at harvest					
0	0.245	0.252	0.251	0.252	0.005 [a]	0.016 [a]
5	0.198	0.222	0.210	0.213	0.004 [b]	0.014 [b]
50	0.192	0.178	0.173	0.148		
75	0.135	0.173	0.136	0.131		
	K at 9 MAP					
0	0.588	0.575	0.700	0.513	0.027 [a]	0.084 [a]
25	0.488	0.425	0.450	0.425	0.027 [b]	0.092 [b]
50	0.513	0.488	0.425	0.438		
75	0.588	0.438	0.475	0.450		

[a] Between spacing means at the same level of shade, [b] Between shade means at the same or different levels of spacing.

condition, which was on par with 25 per cent shade but superior to other two shade levels.

Nitrogen content was not influenced by spacing at 3 MAP. At 6 MAP, the N content decreased with increase in spacing. The highest N content of 1.259 per cent was recorded at 10 x 10 cm spacing, which was on par with 20 x 10 cm and superior to the other two spacings. At 9 MAP, the spacing 10 x 10 cm recorded significantly lower N content than the other three spacings that were on par. At harvest, the spacing 20 x 20 cm recorded the highest N content of 1.742 per cent, which was superior to all other spacings.

At 6 MAP, a significant interaction showed the highest N content of 1.613 per cent under open condition at 10 x 10 cm spacing which was on par with 20 x 10 cm at the same shade level and superior to all other treatment combinations. However, the interaction effect showed the highest N content at 20 x 10 cm at 9 MAP while at 20 x 20 cm spacing at harvest, both under open condition.

Phosphorus

Phosphorus content in rhizome increased throughout the period and the highest content was noted under open condition. Moreover, it was significant at 6 and 9 MAP and at harvest. Among the shade levels, 25 per cent recorded the highest. At 6 MAP, P content was significantly different at each shade level. It was the highest under open condition followed by 25 per cent shade at 6 and 9 MAP. P content in rhizome at harvest decreased significantly with increase in shade.

Phosphorus content was not influenced by spacing at 3 MAP. At 6 MAP, P content was the highest of 0.165 per cent at 20 x 20 cm which was on par with 10 x 10 cm. At 9 MAP, it was numerically the highest at 10 x 10 cm spacing though the variation was not significant. It was the highest of 0.206 per cent at 20 x 10 cm spacing at harvest, followed by 10 x 10 cm and superior to all other spacings.

The interaction effect showed the highest P content (0.193%) at 25 per cent shade and 10 x 10 cm spacing, which was on par with all spacings, except 30 x 20 cm under open condition and superior to all other treatment combinations at 6

MAP. However, at 9 MAP, the interaction showed the highest P content of 0.273 per cent at 20 x 20 cm under open, which was on par with 10 x 10 cm under open and 20 x 20 cm at 25 per cent shade and superior to all other treatment combinations.

Potassium

Potassium content did not show much variation up to 6 MAP, thereafter a reduction at 9 MAP was followed by an increase at harvest. The highest value was noted under open condition at 9 MAP and at harvest. At 9 MAP, the K content was the highest of 0.594 per cent under open condition, which was superior to all other shade levels. Among the shade levels, 25 per cent recorded the highest at harvest.

Effect of spacing was significant only at 9 MAP wherein 10 x 10 cm spacing recorded the highest K content of 0.544 per cent compared to the other spacings.

4.3.6.1.2 Secondary nutrients

Effect of shade and spacing on the content of secondary nutrients in *C. orchioides* rhizome is given in Table 4.3.26 and the interaction effect in Table 4.3.27.

Calcium

Calcium content decreased with increase in age up to 9 MAP with a slight increase at harvest. At 6 MAP, 75 per cent shade recorded significantly highest value whereas at 9 MAP and at harvest it was highest under open condition. Among shade levels, 25 per cent recorded the highest at 9 MAP and at harvest. At harvest, the Ca content decreased with increase in shade. It was the highest of 0.666 per cent under open condition, which was on par with 25 per cent shade and superior to all other shade levels.

Calcium content was the highest at 10 x 10 cm spacing at 3 and 6 MAP while it was on par with the highest at 9 MAP and at harvest at the same spacing.

The interaction effect at 6 MAP, recorded the highest Ca content of 1.358 per cent at 75 per cent and 10 x 10 cm spacing which was on par with 20 x 20 cm

Table 4.3.26. Effect of shade and spacing on the content of secondary nutrients in *Curculigo orchioides* rhizome (%)

Nutrient	Ca				Mg				S		
	3 MAP	6 MAP	9 MAP	Harvest	3 MAP	6 MAP	9 MAP	Harvest	6 MAP	9 MAP	Harvest
Shade (%)											
0	1.306	0.955	0.637	0.666	0.388	0.116	0.191	0.314	0.475	0.180	0.128
25	1.253	0.915	0.486	0.621	0.342	0.141	0.142	0.238	0.604	0.142	0.106
50	1.526	0.807	0.606	0.587	0.445	0.299	0.148	0.225	0.422	0.169	0.138
75	1.467	1.172	0.533	0.582	0.376	0.320	0.160	0.233	1.043	0.158	0.141
SEm	0.136	0.034	0.013	0.012	0.049	0.005	0.002	0.003	0.054	0.003	0.001
$CD_{(0.05)}$	NS	0.153	0.059	0.053	NS	0.023	0.009	0.013	0.241	0.013	0.005
Spacing (cm)											
10 x10	1.433	1.049	0.591	0.569	0.421	0.255	0.172	0.238	0.599	0.169	0.138
20 x 10	1.380	1.003	0.566	0.689	0.376	0.226	0.153	0.254	0.604	0.171	0.139
20 x 20	1.373	0.898	0.600	0.546	0.396	0.197	0.152	0.281	0.760	0.156	0.124
30 x 20	1.366	0.897	0.506	0.652	0.408	0.198	0.165	0.236	0.581	0.152	0.112
SEm	0.069	0.015	0.011	0.009	0.040	0.008	0.002	0.003	0.046	0.003	0.002
$CD_{(0.05)}$	NS	0.046	0.035	0.028	NS	0.024	0.007	0.009	NS	0.009	0.006
Interaction	NS	**	**	*	NS	**	**	*	**	**	**
G. Mean	1.388	0.962	0.566	0.614	0.400	0.219	0.160	0.253	0.636	0.162	0.128

Table 4.3.27. Interaction effect of shade and spacing on the content of secondary nutrients in *Curculigo orchioides* rhizome (%)

Shade (%)	Spacing (cm)				SEm	$CD_{(0.05)}$
	10x10	20x10	20x20	30x20		
	Ca at 6 MAP					
0	0.946	1.110	1.012	0.751	0.030[a]	0.092[a]
25	0.916	0.881	0.949	0.914	0.043[b]	0.170[b]
50	0.977	0.914	0.424	0.914		
75	1.358	1.110	1.208	1.012		
	Ca at 9 MAP					
0	0.647	0.710	0.643	0.549	0.023[a]	0.070[a]
25	0.523	0.402	0.603	0.415	0.024[b]	0.084[b]
50	0.683	0.590	0.590	0.563		
75	0.509	0.563	0.563	0.496		
	Ca at harvest					
0	0.613	0.773	0.586	0.693	0.018[a]	0.057[a]
25	0.598	0.746	0.440	0.701	0.020[b]	0.071[b]
50	0.546	0.586	0.626	0.588		
75	0.520	0.650	0.533	0.626		
	Mg at 6 MAP					
0	0.164	0.167	0.050	0.081	0.016[a]	0.049[a]
25	0.082	0.158	0.208	0.116	0.015[b]	0.048[b]
50	0.316	0.041	0.369	0.471		
75	0.458	0.536	0.164	0.123		
	Mg at 9 MAP					
0	0.185	0.178	0.211	0.192	0.005[a]	0.014[a]
25	0.192	0.145	0.126	0.105	0.004[b]	0.015[b]
50	0.165	0.145	0.119	0.165		
75	0.145	0.145	0.152	0.198		
	Mg at harvest					
0	0.278	0.331	0.337	0.311	0.006[a]	0.017[a]
25	0.238	0.218	0.298	0.198	0.006[b]	0.020[b]
50	0.200	0.232	0.245	0.225		
75	0.238	0.237	0.245	0.212		
	S at 6 MAP					
0	1.049	0.463	0.118	0.269	0.093[a]	0.286[a]
25	0.741	0.639	0.581	0.455	0.097[b]	0.340[b]
50	0.110	0.826	0.436	0.317		
75	0.498	0.487	1.904	1.284		
	S at 9 MAP					
0	0.165	0.194	0.171	0.189	0.006[a]	0.019[a]
25	0.159	0.151	0.147	0.112	0.006[b]	0.021[b]
50	0.164	0.204	0.151	0.156		
75	0.186	0.137	0.155	0.153		
	S at harvest					
0	0.147	0.135	0.115	0.115	0.004[a]	0.012[a]
25	0.089	0.160	0.092	0.083	0.004[b]	0.012[b]
50	0.141	0.115	0.166	0.132		
75	0.174	0.146	0.125	0.120		

[a] Between spacing means at the same level of shade, [b] Between shade means at the same or different levels of spacing.

at the same shade level but superior to all other treatment combinations. At 9 MAP, the significant interaction showed the highest Ca content of 0.710 per cent at 20 x 20 cm under open condition, which was on par with 50 per cent shade at 10 x 10 cm spacing and superior to all other treatment combinations. At harvest, the interaction effect showed the highest Ca content of 0.773 per cent at 20 x 10 cm spacing under open condition which was on par with the same spacing at 25 per cent shade and superior to all other treatment combinations.

Magnesium

Magnesium content decreased over the period with an exception at harvest where it showed an increase. It was more under shade up to 6 MAP but more under open condition at 9 MAP and at harvest. Among shade levels, 25 per cent recorded the highest Mg content.

At 6 MAP, as in the case of Ca, Mg content increased with increase in shade level and the highest content of 0.320 per cent was recorded at 75 per cent shade which was on par with 50 per cent shade and superior to 25 per cent shade and open condition. At 9 MAP and at harvest, the open condition recorded the highest Mg content which was superior to all other shade levels.

In the case of spacing, at 6 MAP, 10 x 10 cm and 20 x 10 cm recorded significantly higher Mg content than the other two wider spacings. At 9 MAP, the spacing 10 x 10 cm recorded the highest Mg content of 0.172 per cent which was on par with that at 30 x 20 cm but superior to the other two spacings. At harvest, the spacing 20 x 20 cm recorded the highest Mg content of 0.281 per cent, which was significantly higher than that at any other spacing.

The interaction effect at 6 MAP showed the highest Mg content of 0.536 per cent at 75 per cent shade and 20 x 10 cm spacing, which was superior to all other treatment combinations. At harvest, the interaction effect showed that Mg content was the highest under open condition at 20 x 20 cm spacing which was on par with 20 x 10 cm spacing under open condition and superior to all other treatment combinations.

Sulphur

Sulphur content decreased with increase in age and it was more under shade up to 6 MAP but under open condition at 9 MAP. At 6 MAP, S content was the highest of 1.043 per cent at 75 per cent shade which was superior to all other shade levels including the open situation that were on par. At 9 MAP, the open condition recorded the highest S content of 0.180 per cent, which was on par with that at 50 per cent shade but superior to the other two shade levels. At harvest, S content was the highest of 0.141 per cent at 75 per cent shade which was on par with 50 per cent shade but superior to the other shade levels.

Sulphur content was the highest at 20 x 10 cm spacing, which was on par with 10 x 10 cm spacing and superior to the other two spacings at 9 MAP and at harvest while it was not significant at 6 MAP.

The interaction effect at 6 MAP, showed the highest S content of 1.904 per cent at 75 per cent shade and 20 x 20 cm spacing, which was superior to all other treatment combinations. At 9 MAP, the interaction effect showed the highest S content of 0.204 per cent at 50 per cent shade and 20 x 10 cm spacing. At harvest, the interaction effect showed that S content was the highest of 0.174 per cent at 75 per cent shade and 10 x 10 cm spacing, which was superior to all other treatment combinations.

4.3.6.1.3 Micronutrients

Effect of shade and spacing on the content of micronutrients in *C. orchioides* rhizome is given in Table 4.3.28.

Iron

Iron content was the highest at maximum vegetative growth stage (6 MAP), followed by a decrease at 9 MAP and again an increase at harvest. It was higher under open condition at 9 MAP and at harvest. Among shade levels, it was the lowest at 25 per cent shade at 6 and 9 MAP and at harvest. At 6 MAP, Fe content in rhizome was the highest at 50 per cent shade level. At 9 MAP, the open condition recorded the highest Fe content (677.55 ppm) in rhizome which was superior to that at all other shade levels that were on par. At harvest, Fe content

Table 4.3.28. Effect of shade and spacing on the content of micronutrients in *Curculigo orchioides* rhizome (ppm)

Treatment	Fe				Mn				Zn				Cu			
	3 MAP	6 MAP	9 MAP	Harvest	3 MAP	6 MAP	9 MAP	Harvest	3 MAP	6 MAP	9 MAP	Harvest	3 MAP	6 MAP	9 MAP	Harvest
Shade (%)																
0	414.60	1645.7	677.55	1824.0	98.65	81.22	83.10	94.07	51.02	64.35	85.55	157.37	12.78	27.52	66.38	34.32
25	436.08	1203.0	331.08	802.8	94.17	73.82	63.63	65.80	45.90	74.30	58.93	71.60	27.25	31.25	47.00	42.30
50	563.93	1713.3	355.85	825.0	105.78	76.60	65.40	76.72	54.53	55.87	49.43	61.10	40.35	29.15	55.55	45.05
75	373.65	1442.7	338.48	917.7	104.78	76.55	64.93	89.65	37.23	80.55	45.60	60.27	37.00	27.52	60.20	33.47
SEm	31.296	79.41	55.457	71.62	2.508	2.312	4.651	2.508	2.013	2.942	5.112	1.891	6.109	4.182	4.234	2.789
$CD_{(0.05)}$	NS	357.41	170.87	322.36	NS	NS	NS	11.285	NS	NS	15.752	NS	18.495	NS	NS	NS
Spacing (cm)																
10x10	435.48	1566.0	458.28	1034.7	97.55	71.60	73.33	79.12	47.43	65.32	61.25	79.52	36.57	34.85	62.00	48.15
20x10	349.65	1797.0	395.88	1120.7	98.10	78.52	68.33	85.47	47.83	64.82	60.65	68.00	19.57	27.37	56.03	42.15
20x20	495.33	1297.3	441.58	1055.7	105.83	79.37	69.25	84.35	46.33	77.62	61.15	109.50	34.75	29.17	56.00	30.47
30x20	477.80	1344.5	407.23	1158.3	101.90	78.70	66.15	77.30	47.10	67.30	56.45	93.32	26.47	24.05	55.10	34.37
SEm	48.323	94.21	42.143	147.32	2.925	2.183	2.538	2.625	1.978	2.713	4.147	1.958	2.784	3.142	3.942	2.784
$CD_{(0.05)}$	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	8.578	NS	NS	8.578
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
G. Mean	447.06	1501.2	425.74	1092.3	100.84	77.05	69.26	81.563	47.17	68.769	59.88	87.588	29.34	28.863	57.28	38.788

was the highest of 1824.00 ppm under open condition, which was superior to all other shade levels that were on par.

Though 10 x 10 cm spacing recorded numerically higher value, Fe content was not influenced by spacing and there was no significant interaction.

Manganese

Manganese content decreased with increase in age. A marginally higher content was noted under open condition at 6 and 9 MAP and it was significant at harvest. Among shade levels, it was the lowest at 25 per cent shade throughout the growth period.

At 9 MAP, Mn content was influenced by neither spacing nor interaction. However at harvest, Mn content was the highest of 94.07 ppm under open condition which was on par with 75 per cent shade and superior to the other two shade levels.

Zinc

Zinc content increased over the period and it was constantly higher under open condition. But under shade it showed an increase at 6 MAP then decreased and again increased at harvest. Zn content showed a progressive reduction with increase in shade at 9 MAP and at harvest.

Zinc content in rhizome was not influenced by spacing and the interaction was not significant.

Copper

Copper content increased with increase in age under open and 25 per cent shade but a reduction was noticed at 6 MAP at 50 per cent and 75 per cent shades and a further reduction both under open and under shade. At 3 MAP, Cu content was the highest of 40.35 ppm at 50 per cent shade, which was on par with the other two shade levels but superior to open condition.

At 6 MAP, among spacings, 10 x 10 cm and 20 x 20 cm recorded significantly higher Cu content than the other two spacings. At 9 MAP, Cu content was significantly highest at 10 x 10 cm spacing. At harvest, Cu content was significantly higher at 10 x 10 cm and 20 x 10 cm spacings than at other spacings. The highest Cu content was 48.15 ppm recorded at 10 x 10 cm spacing.

The interaction effect was not significant.

4.3.6.2 Shoot

4.3.6.2.1 Major nutrients

Effect of shade and spacing on the content of major nutrients in *C. orchioides* shoot is given in Table 4.3.29 and the interaction effect in Table 4.3.30.

Nitrogen

Nitrogen content increased with increase in age up to maximum vegetative growth stage (6 MAP) then decreased at 9 MAP. At 3 MAP, N content was more under shade than under open condition. At 6 MAP, the N content in the shoot was the highest (2.239%) at 25 per cent shade, which was on par with that under open condition and superior to 50 per cent and 75 per cent shades. At 9 MAP, N content was the highest under open condition, which was superior to all other shade levels.

Among spacings, 30 x 20 cm recorded the highest N content of 2.24 per cent, which was superior to that at all other spacings at 6 MAP. At 9 MAP, the spacing 20 x 10 cm and 30 x 20 cm recorded significantly higher N content (1.671 per cent each) than the other two spacings

The interaction effect at 6 MAP, showed the highest N content of 2.294 per cent at 25 per cent shade and 10 x 10 cm spacing. At 9 MAP, it showed the highest N content of 1.883 per cent at 10 x 10 cm spacing under open condition, which was superior to all other treatment combinations.

Phosphorus

Phosphorus content increased up to 6 MAP and then decreased at 9 MAP under open condition. At 3 MAP, it was more under shade than under open condition. At 6 MAP it was less under shade than under open condition. Among shade levels, 25 per cent recorded the highest. At 9 MAP, it was significantly the highest at 75 per cent shade followed by open condition. At 6 MAP, The P

Table 4.3.29. Effect of shade and spacing on the content of major nutrients in *Curculigo orchioides* shoot (%)

Treatment	N			P			K		
	3 MAP	6 MAP	9 MAP	3 MAP	6 MAP	9 MAP	3 MAP	6 MAP	9 MAP
Shade (%)									
0	1.499	2.227	1.787	0.261	0.267	0.148	2.860	2.144	1.766
25	1.753	2.239	1.617	0.273	0.262	0.119	2.980	2.394	1.691
50	1.969	2.168	1.567	0.268	0.231	0.098	3.050	2.494	1.734
75	2.127	2.137	1.667	0.276	0.221	0.276	2.880	2.369	1.897
SEm	0.472	0.009	0.005	0.012	0.003	0.009	0.029	0.115	0.049
$CD_{(0.05)}$	NS	0.038	0.025	NS	0.016	0.041	NS	NS	NS
Spacing(cm)									
10x10	1.792	2.159	1.640	0.280	0.250	0.137	3.020	2.306	1.819
20x10	1.806	2.174	1.671	0.255	0.245	0.144	2.850	2.250	1.675
20x20	1.917	2.199	1.656	0.271	0.239	0.170	2.940	2.413	1.831
30x20	1.833	2.240	1.671	0.274	0.246	0.188	2.960	2.431	1.763
SEm	0.452	0.013	0.005	0.006	0.002	0.005	0.027	0.075	0.060
$CD_{(0.05)}$	NS	0.039	0.016	NS	0.007	0.015	NS	NS	NS
Interaction	NS	**	**	NS	*	**	NS	NS	*
G. Mean	1.837	2.193	1.660	0.270	0.245	0.160	2.943	2.350	1.772

Table 4.3.30. Interaction effect of shade and spacing on the content of major nutrients in *Curculigo orchioides* shoot (%)

Shade (%)	Spacing (cm)					
	10x10	20x10	20x20	30x20	SEm	$CD_{(0.05)}$
	N at 6 MAP					
0	2.204	2.258	2.276	2.170	0.026^{a}	0.079^{a}
25	2.294	2.222	2.204	2.236	0.024^{b}	0.077^{b}
50	2.097	2.065	2.290	2.222		
75	2.043	2.150	2.025	2.330		
	N at 9 MAP					
0	1.883	1.807	1.714	1.745	0.010^{a}	0.032^{a}
25	1.667	1.529	1.544	1.729	0.011^{b}	0.037^{b}
50	1.529	1.574	1.652	1.513		
75	1.482	1.776	1.714	1.698		
	P at 6 MAP					
0	0.270	0.288	0.257	0.254	0.004^{a}	0.014^{a}
25	0.271	0.259	0.250	0.265	0.005^{b}	0.019^{b}
50	0.233	0.219	0.232	0.241		
75	0.227	0.216	0.218	0.224		
	P at 9 MAP					
0	0.162	0.163	0.093	0.176	0.010^{a}	0.031^{a}
25	0.140	0.163	0.111	0.062	0.013^{b}	0.049^{b}
50	0.070	0.031	0.104	0.187		
75	0.175	0.218	0.374	0.327		
	K at 9 MAP					
0	1.913	1.700	1.588	1.863	0.120^{a}	0.370^{a}
25	1.663	1.538	1.863	1.700	0.115^{b}	0.384^{b}
50	1.913	1.888	1.613	1.525		
75	1.788	1.575	2.263	1.963		

[a] Between spacing means at the same level of shade, [b] Between shade means at the same or different levels of spacing.

content was significantly higher under open and at 25 per cent shade than at 50 per cent and 75 per cent shades. However, at 9 MAP, P content was the highest at 75 per cent shade, which was superior to all other shade levels including the open condition.

Phosphorus content at 6 MAP was the highest of 0.250 per cent at 10 x 10 cm spacing and least at 20 x 20 cm spacing, which were significantly different. At 9 MAP, The P content increased steadily with increase in spacing. The highest P content was 0.188 per cent at 30 x 20 cm spacing which was superior to that at all other spacings.

The interaction effect at 6 MAP showed the highest P content of 0.288 per cent at 20 x 20 cm spacing under open condition, which was on par with 25 per cent shade and 10 x 10 cm spacing and superior to all other treatment combinations. However, At 9 MAP, The interaction effect showed the highest P content of 0.374 per cent at 75 per cent shade and 20 x 20 cm spacing superior to all other treatment combinations.

Potassium

Potassium content decreased with increase in age. It was marginally higher under shade than under open condition at 3 and 6 MAP. Among shade levels, it was the highest at 50 per cent followed by 25 per cent. At 9 MAP it was less at 25 per cent and 50 per cent than under open condition.

The interaction effect at 9 MAP alone was significant which showed the highest K content of 2.263 per cent at 75 per cent shade and 20 x 20 cm spacing.

4.3.6.2.2 Secondary nutrients

Effect of shade and spacing on the content of secondary nutrients in *C. orchioides* shoot is given in Table 4.3.31 and the interaction effect in Table 4.3.32.

Calcium

Calcium content increased with increase in age. At 3 and 6 MAP, it was less under open condition than under shade. At 9 MAP, it was more under 50 per cent and 75 per cent shades but less under 25 per cent shade. At 9 MAP, the Ca content

Table 4.3.31. Effect of shade and spacing on the content of secondary nutrients in *Curculigo orchioides* shoot (%)

Treatment	Ca			Mg			S	
	3 MAP	6 MAP	9 MAP	3 MAP	6 MAP	9 MAP	6 MAP	9 MAP
Shade (%)								
0	0.946	1.137	1.172	0.404	0.557	0.392	0.305	0.179
25	1.026	1.097	1.041	0.407	0.509	0.360	0.271	0.162
50	0.933	1.136	1.397	0.445	0.577	0.312	0.401	0.143
75	1.080	1.106	1.269	0.429	0.538	0.314	0.411	0.129
SEm	0.048	0.028	0.012	0.014	0.013	0.006	0.015	0.005
$CD_{(0.05)}$	NS	NS	0.052	NS	NS	0.025	0.068	0.025
Spacing (cm)								
10x10	0.979	1.166	1.145	0.421	0.552	0.324	0.404	0.162
20x10	1.026	1.073	1.313	0.438	0.590	0.352	0.319	0.156
20x20	0.993	1.159	1.142	0.384	0.494	0.377	0.370	0.146
30x20	0.986	1.078	1.279	0.442	0.544	0.325	0.295	0.151
SEm	0.049	0.030	0.008	0.026	0.009	0.006	0.008	0.004
$CD_{(0.05)}$	NS	NS	0.025	NS	0.027	0.018	0.024	NS
Interaction	NS	**	**	NS	**	**	**	**
G. Mean	0.996	1.119	1.220	0.421	0.545	0.344	0.347	0.153

Table 4.3.32. Interaction effect of shade and spacing on the content of secondary nutrients in *Curculigo orchioides* shoot (%)

Shade (%)	Spacing (cm)					
	10x10	20x10	20x20	30x20	SEm	$CD_{(0.05)}$
	Ca at 6 MAP					
0	1.025	1.077	1.273	1.172	0.060[a]	0.059[a]
25	1.175	1.223	0.979	1.012	0.185[b]	0.201[b]
50	1.110	0.979	1.371	1.084		
75	1.355	1.012	1.012	1.044		
	Ca at 9 MAP					
0	1.166	1.420	0.911	1.193	0.017[a]	0.051[a]
25	0.978	1.085	0.951	1.152	0.018[b]	0.067[b]
50	1.447	1.420	1.353	1.367		
75	0.991	1.327	1.353	1.040		
	Mg at 6 MAP					
0	0.573	0.653	0.450	0.550	0.017[a]	0.053[a]
25	0.469	0.410	0.626	0.532	0.020[b]	0.072[b]
50	0.594	0.614	0.516	0.582		
75	0.573	0.685	0.385	0.510		
	Mg at 9 MAP					
0	0.364	0.436	0.476	0.291	0.011[a]	0.035[a]
25	0.396	0.350	0.324	0.370	0.011[b]	0.039[b]
50	0.256	0.324	0.317	0.350		
75	0.278	0.298	0.390	0.291		
	S at 6 MAP					
0	0.299	0.248	0.308	0.366	0.015[a]	0.047[a]
25	0.344	0.226	0.248	0.266	0.020[b]	0.078[b]
50	0.355	0.326	0.652	0.269		
75	0.618	0.476	0.271	0.279		
	S at 9 MAP					
0	0.184	0.218	0.144	0.173	0.008[a]	0.026[a]
25	0.220	0.161	0.148	0.122	0.009[b]	0.033[b]
50	0.131	0.110	0.145	0.186		
75	0.113	0.134	0.146	0.123		

[a] Between spacing means at the same level of shade, [b] Between shade means at the same or different levels of spacing.

was the highest of 1.397 per cent at 50 per cent shade, which was superior to all other shade levels.

Spacing significantly influenced Ca content only at 9 MAP and it was the highest of 1.313 per cent at 20 x 10 cm spacing.

The interaction effect at 6 MAP showed the highest Ca content of 1.371 per cent at 50 per cent shade and 20 x 20 cm spacing which was on par with 75 per cent shade and 10 x 10 cm spacing, 25 per cent shade and 20 x 10 cm and 20 x 20 cm under open condition and superior to all other treatment combinations. At 9 MAP, it showed the highest Ca content of 1.447 per cent at 50 per cent shade and 10 x 10 cm spacing, which was on par with 20 x 10 cm spacing at the same shade level and under open condition but superior to all other treatment combinations.

Magnesium

Magnesium content increased up to 6 MAP and then decreased. Open condition recorded a lesser Mg content compared to shade at 3 MAP. 25 per cent shade recorded the least Mg at 6 MAP. It was highest under open condition followed by 25 per cent shade at 9 MAP. At 9 MAP, Mg content was the highest of 0.392 per cent under open, which was superior to all other shade levels.

At 6 MAP, Mg content was the highest (0.590%) at 20 x 10 cm spacing, which was superior to all other spacings. At 9 MAP, it was the highest of 0.377 per cent at 20 x 20 cm spacing, which was superior to all other spacings.

The interaction effect at 6 MAP showed the highest Mg content of 0.685 per cent at 75 per cent shade and 20 x 10 cm spacing which was on par with 25 per cent shade and 20 x 20 cm spacing and 20 x 10 cm spacing under open condition but superior to all other treatment combinations. At 9 MAP, a significant interaction showed the highest Mg content of 0.476 per cent at 20 x 20 cm spacing under open condition, which was superior to all other treatment combinations.

Sulphur

The Sulphur content at 6 MAP was significantly higher at 75 per cent and 50 per cent shades than at 25 per cent shade and under open condition. At 9 MAP, the S content steadily decreased with increase in shade level. It was the highest of 0.179 per cent under open condition, which was superior to all other shade levels.

At 6 MAP, it was the highest of 0.404 per cent at 10 x 10 cm spacing, which was significantly higher than that at all other spacings.

The interaction effect at 6 MAP showed the highest S content of 0.652 per cent at 50 per cent shade and 20 x 20 cm spacing, which was on par with 75 per cent shade and 10 x 10 cm spacing and superior to all other treatment combinations. At 9 MAP, a significant interaction showed the highest S content of 0.220 per cent at 25 per cent shade and 10 x 10 cm spacing which was on par with 20 x 10 cm spacing under open condition and superior to all other treatment combinations.

4.3.6.2.3 Micronutrients

Effect of shade and spacing on the content of micronutrients in *C. orchioides* shoot is given in Table 4.3.33.

Iron content increased drastically up to 6 MAP and then decreased at 9 MAP. Least content was noticed at 25 per cent shade at all stages. Fe content was the highest at 75 per cent shade, which was superior to all other shade levels including the open condition both at 6 and 9 MAP.

Manganese content increased with increase in age. Among shade levels, 25 per cent shade recorded a lower Mn content especially at 3 and 9 MAP though it was not significant.

Among shade levels, 25 per cent shade recorded the lowest Zinc content at 9 MAP and highest under open condition. At 3 MAP, the content of Zn varied significantly with shade alone. Fifty per cent shade recorded the highest (52.800 ppm) Zn content in the shoot and 75 per cent shade showed the lowest of 17.150 ppm, which were significantly different.

Though copper content was not significantly influenced by any of the treatments, it was the least under open condition up to 6 MAP but highest at 9 MAP.

Table 4.3.33. Effect of shade and spacing on the content of micronutrients in *Curculigo orchioides* shoot (ppm)

Treatment	Fe			Mn			Zn			Cu		
	3 MAP	6 MAP	9 MAP	3 MAP	6 MAP	9 MAP	3 MAP	6 MAP	9 MAP	3 MAP	6 MAP	9 MAP
Shade (%)												
0	456.625	3527.5	2434.50	163.050	265.375	349.83	38.825	48.825	85.88	73.725	91.825	536.55
25	412.725	3315.5	2101.50	156.625	267.965	324.18	37.100	49.500	47.73	115.575	116.775	180.80
50	894.475	4085.0	2712.75	160.850	291.900	360.70	52.800	48.025	51.88	39.875	119.900	304.68
75	932.925	4496.2	3463.75	162.525	267.250	326.88	17.150	47.100	53.30	51.925	117.400	163.78
SEm	29.878	53.12	74.958	6.467	7.532	6.369	7.116	6.913	7.143	15.240	18.776	61.039
$CD_{(0.05)}$	NS	374.10	337.355	NS	NS	NS	32.028	NS	NS	NS	NS	NS
Spacing (cm)												
10 x10	736.325	3675.7	2425.50	165.550	258.425	341.13	42.825	47.850	58.80	77.675	128.025	452.58
20 x 10	654.550	3964.0	2943.25	144.625	289.350	353.48	33.325	47.475	57.93	80.575	100.150	302.28
20 x 20	550.275	4108.7	2827.25	160.325	278.725	334.70	42.675	52.600	67.18	58.275	111.600	149.38
30 x 20	755.600	3675.7	2516.50	172.550	266.500	332.28	27.050	45.525	54.88	64.575	106.125	281.58
SEm	32.142	132.21	144.239	8.041	7.124	11.439	4.117	5.213	6.642	10.213	13.463	54.172
$CD_{(0.05)}$	NS	NS	NS	NS	NS	NS	12.691	NS	NS	NS	NS	NS
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
G. Mean	674.188	3856.06	2678.13	160.763	273.250	340.39	36.469	48.363	59.69	70.275	111.475	296.45

4.3.7 Nutrient Ratios

4.3.7.1 Rhizome

Effect of shade and spacing on nutrient ratios of *C. orchioides* rhizome at 6 MAP is given in Table 4.3.34. Shade levels showed considerable influence on the nutrient ratios. The ratio of (Ca+Mg)/K was higher at all shade levels compared to open condition (1.47) and the highest was 2.01 at 75 per cent shade. It was higher at closer spacings than at wider spacings. Fe/K ratio was the highest of 0.251 at 50 per cent shade, followed by open condition. It was higher at closer spacings than at wider spacings. Mn/K ratio was the highest of 0.012 at 25 per cent shade, followed by 50 per cent shade and open situation and the least under 75 per cent shade. Mn/K ratio was the least of 0.010 at 10 x 10 cm spacing and the values ranged between 0.011 and 0.012 at other spacings. Zn/K ratio was the highest of 0.012 at 25 per cent shade followed by 75 per cent shade. It was the highest of 0.011 at 20 x 20 cm spacing and the values ranged between 0.009 and 0.010 at other spacings. Cu/K ratio was the highest of 0.005 at 25 per cent shade, followed by 50 per cent shade. This ratio was the highest of 0.005 at 10 x 10 cm spacing and it decreased with increase in spacing.

4.3.7.2 Shoot

Effect of shade and spacing on nutrient ratios of *C. orchioides* shoot at 6 MAP is given in Table 4.3.35. In general, the ratios of (Ca+Mg)/K, Fe/K and Zn/K were lower in shoot than in rhizome while Mn/K and Cu/K were relatively higher in the shoot. The ratio of (Ca+Mg)/K was the highest (0.79) under open and the values ranged between 0.67 and 0.69 at other shade levels. It was higher at closer spacings than at wider spacings. Fe/K ratio was the lowest at 25 per cent shade and it increased with increase in shade level. It was the lowest of 0.151 at 30 x 20 cm spacing, followed by 10 x 10 cm spacing. Mn/K ratio was the lowest of 0.011 at 25 per cent shade and the highest (0.012) under open condition. It was the lowest of 0.011 at 30 x 20 cm spacing, followed by 10 x 10 cm spacing. Zn/K ratio did not show much variation due to shade and spacing and the values ranged between 0.002 and 0.002. Cu/K ratio was the highest at 75 per cent shade and lowest under open condition. It was the highest at 10 x 10 cm spacing and the values ranged between 0.004 and 0.005 at other spacings.

Table 4.3.34. Effect of shade and spacing on nutrient ratios of *Curculigo orchioides* rhizome at 6 MAP

Treatment	(Ca+Mg)/K	Fe/K	Mn/K	Zn/K	Cu/K
Shade (%)					
0	1.47	0.226	0.011	0.009	0.004
25	1.69	0.193	0.012	0.012	0.005
50	1.62	0.251	0.011	0.008	0.004
75	2.01	0.194	0.010	0.011	0.004
Spacing (cm)					
10 x10	1.88	0.226	0.010	0.009	0.005
20 x 10	1.80	0.264	0.012	0.010	0.004
20 x 20	1.54	0.182	0.011	0.011	0.004
30 x 20	1.59	0.195	0.011	0.010	0.003
G. Mean	1.70	0.216	0.011	0.009	0.004

Table 4.3.35. Effect of shade and spacing on nutrient ratios of *Curculigo orchioides* shoot at 6 MAP

Treatment	(Ca+Mg)/K	Fe/K	Mn/K	Zn/K	Cu/K
Shade (%)					
0	0.79	0.165	0.012	0.002	0.004
25	0.67	0.138	0.011	0.002	0.005
50	0.69	0.164	0.012	0.002	0.005
75	0.69	0.190	0.011	0.002	0.005
Spacing (cm)					
10 x10	0.75	0.159	0.011	0.002	0.006
20 x 10	0.74	0.176	0.013	0.002	0.004
20 x 20	0.69	1.702	0.012	0.002	0.005
30 x 20	0.67	0.151	0.011	0.002	0.004
G. Mean	0.71	0.165	0.012	0.002	0.004

4.3.8 Nutrient Uptake

Effect of shade and spacing on uptake of nutrients by *C. orchioides* at 6 MAP is presented in Table 4.3.36. In general, the main effects of shade and spacing alone significantly influenced the uptake of nutrients by *C. orchioides* and it was higher under shade and at closer spacing.

The uptake of N was significantly higher under shade than under open condition. It was the highest (6.629 kg ha^{-1}) at 75 per cent shade and least under open condition. The highest uptake of N was 10.385 kg ha^{-1} at 10 x 10 cm and the least was 2.473 kg ha^{-1} at 30 x 20 cm spacing.

Phosphorus uptake was the highest of 0.781 kg ha^{-1} at 75 per cent shade, followed by 25 per cent and 50 per cent shades and least (0.389 kg ha^{-1}) under open condition. It was the highest (1.186 kg ha^{-1}) at 10 x 10 cm and least (0.305 kg ha^{-1}) at 30 x 20 cm spacing.

The uptake of K significantly increased with each increase in shade level. It was the highest of 6.165 kg ha^{-1} at 75 per cent shade and the least (2.167 kg ha^{-1}) under open condition. The highest uptake of K was 8.822 kg ha^{-1} at 10 x 10 cm and the least was 2.075 kg ha^{-1} at 30 x 20 cm spacing.

Calcium uptake was the highest of 4.839 kg ha^{-1} at 75 per cent shade, followed by 25 per cent and 50 per cent shades and least (1.927 kg ha^{-1}) under open condition. It was the highest (6.896 kg ha^{-1}) at 10 x 10 cm and least (1.557 kg ha^{-1}) at 30 x 20 cm spacing.

The uptake of Mg significantly increased with each increase in shade level. It was the highest of 1.759 kg ha^{-1} at 75 per cent shade and the least (0.463 kg ha^{-1}) under open condition. The highest uptake of Mg was 2.422 kg ha^{-1} at 10 x 10 cm and the least was 0.511 kg ha^{-1} at 30 x 20 cm spacing.

Sulphur uptake was the highest of 3.243 kg ha^{-1} at 75 per cent shade, followed by 25 per cent and 50 per cent shades and least (0.816 kg ha^{-1}) under open condition. It was the highest (3.211 kg ha^{-1}) at 10 x 10 cm and least (0.788 kg ha^{-1}) at 30 x 20 cm spacing.

The uptake of Fe significantly increased with each increase in shade level. It was the highest of 1.177 kg ha^{-1} at 75 per cent shade and the least (0.418 kg ha^{-1})

Table 4.3.36. Effect of shade and spacing on uptake of nutrients by *Curculigo orchioides* at 6 MAP (kg ha^{-1})

Nutrient	N	P	K	Ca	Mg	S	Fe	Mn	Zn	Cu
Shade (%)										
0	3.208	0.389	2.167	1.927	0.463	0.816	0.418	0.026	0.011	0.009
25	5.655	0.733	4.793	3.527	1.037	1.670	0.735	0.054	0.023	0.024
50	5.623	0.632	5.180	3.397	1.494	1.486	0.973	0.060	0.019	0.024
75	6.629	0.781	6.165	4.839	1.759	3.243	1.177	0.068	0.028	0.028
SEm	0.031	0.002	0.038	0.020	0.010	0.013	0.006	0.001	0.001	0.001
$CD_{(0.05)}$	0.092	0.007	0.113	0.061	0.029	0.039	0.019	0.003	0.002	0.002
Spacing (cm)										
10 x10	10.385	1.186	8.822	6.896	2.422	3.211	1.567	0.097	0.036	0.048
20 x 10	4.995	0.595	4.001	3.265	1.144	1.583	0.824	0.050	0.019	0.017
20 x 20	3.537	0.430	3.061	2.218	0.695	1.345	0.532	0.035	0.015	0.014
30 x 20	2.472	0.305	2.075	1.557	0.511	0.788	0.346	0.023	0.010	0.008
SEm	0.051	0.005	0.059	0.049	0.012	0.014	0.008	0.001	0.001	0.001
$CD_{(0.05)}$	0.154	0.015	0.177	0.147	0.035	0.043	0.023	0.003	0.002	0.002
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
G. Mean	5.328	0.643	4.481	3.419	1.157	1.747	0.809	0.051	0.020	0.020

Table 4.3.37. Effect of shade and spacing on soil characteristics after the harvest of *Curculigo orchioides*

Treatment	pH	N (ppm)	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	S (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)
Shade (%)											
0	6.26	172.13	16.77	75.25	141.01	47.39	11.42	23.56	11.41	1.71	4.73
25	5.95	186.25	21.58	85.75	172.14	24.10	25.10	26.50	12.06	1.47	4.73
50	6.07	184.98	15.47	100.37	164.82	37.75	27.06	29.05	13.37	1.73	4.81
75	6.12	178.96	15.65	106.00	181.30	40.96	35.88	23.59	14.26	2.23	4.88
SEm	0.007	0.849	0.802	1.359	1.058	0.769	0.411	5.217	3.014	0.324	0.714
$CD_{(0.05)}$	0.030	3.822	3.609	6.118	4.760	3.462	1.851	NS	NS	NS	NS
Spacing	(cm)										
10 x10	6.16	174.40	16.78	89.63	179.46	27.31	23.15	25.70	12.56	1.62	4.95
20 x 10	6.10	175.86	17.92	89.00	155.66	36.15	21.85	23.20	12.30	1.81	4.48
20 x 20	6.03	182.42	16.55	95.50	168.48	42.57	26.73	24.07	13.23	1.85	4.53
30 x 20	6.11	192.64	18.23	93.25	155.66	44.18	27.72	29.73	13.01	1.85	5.18
SEm	0.005	0.510	0.072	1.408	2.479	1.811	1.209	4.328	2.987	0.309	0.698
$CD_{(0.05)}$	NS	1.573	NS	4.339	7.639	5.582	3.725	NS	NS	NS	NS
Interaction	NS	**	**	**	**	**	**	NS	NS	NS	NS
G. Mean	6.10	181.33	17.37	91.84	164.81	37.55	24.86	25.68	12.77	1.78	4.789

under open condition. The highest uptake of Fe was 1.567 kg ha^{-1} at 10 x 10 cm and the least was 0.346 kg ha^{-1} at 30 x 20 cm spacing.

The uptake of Mn significantly increased with each increase in shade level. It was the highest of 0.068 kg ha^{-1} at 75 per cent shade and the least (0.026 kg ha^{-1}) under open condition. The highest uptake of Mn was 0.097 kg ha^{-1} at 10 x 10 cm and the least was 0.023 kg ha^{-1} at 30 x 20 cm spacing.

Zinc uptake was the highest of 0.028 kg ha^{-1} at 75 per cent shade, followed by 25 per cent and 50 per cent shades and least (0.011 kg ha^{-1}) under open condition. It was the highest (0.036 kg ha^{-1}) at 10 x 10 cm and least (0.010kg ha^{-1}) at 30 x 20 cm spacing.

The uptake of Cu significantly increased with each increase in shade level. It was the highest of 0.028 kg ha^{-1} at 75 per cent shade and the least (0.009 kg ha^{-1}) under open condition. The highest uptake of Cu was 0.048 kg ha^{-1} at 10 x 10 cm and the least was 0.008 kg ha^{-1} at 30 x 20 cm spacing.

4.3.9 Soil Characteristics

Effect of shade and spacing on soil characteristics after the harvest of *C. orchioides* is given in Table 4.3.37 and the interaction effect in Table 4.3.38. In general, shade and spacing significantly influenced the available major and secondary nutrients but not the available micronutrients in the soil.

Shade alone significantly affected the pH of the soil. It was the highest of 6.26 under open condition. However, the pH increased with increase in shade.

The available N in the soil was the highest of 186.25 ppm at 25 per cent shade, which was on par with 50 per cent shade but superior to other shade levels. It was the least (172.13 ppm) under open condition. The available N increased with increase in spacing, recording the highest of 192.64 ppm at 30 x 20 cm spacing, which was superior to all other spacings. A significant interaction showed the highest available N content of 197.75 ppm at 25 per cent shade and 20 x 10 cm spacing, which was superior to all other treatment combinations.

The available P content was the highest of 21.58 ppm at 25 per cent shade, which was superior to all other shade levels. The interaction effect showed the

Table 4.3.38. Interaction effect of shade and spacing on soil characteristics after the harvest of *Curculigo orchioides* (ppm)

Shade (%)	Spacing (cm)				SEm	$CD_{(0.05)}$
	10x10	20x10	20x20	30x20		
	N					
0	165.34	142.29	175.85	216.72	1.021 [a]	3.146 [a]
25	168.56	197.75	188.26	190.45	1.225 [b]	4.612 [b]
50	175.13	188.26	189.72	186.80		
75	188.26	175.13	175.85	176.58		
	P					
0	11.46	12.35	22.11	21.17	1.403 [a]	4.323 [a]
25	27.66	34.63	9.29	14.75	1.456 [b]	5.113 [b]
50	12.94	10.00	20.35	18.60		
75	15.05	14.70	14.46	18.40		
	K					
0	81.00	66.00	79.00	75.00	2.816 [a]	8.678 [a]
25	66.00	90.00	107.00	80.00	2.792 [b]	9.543 [b]
50	106.50	99.00	88.00	108.00		
75	105.00	101.00	108.00	110.00		
	Ca					
0	183.13	146.50	109.88	124.53	4.959 [a]	15.279 [a]
25	175.80	168.48	212.43	131.85	4.423 [b]	13.986 [b]
50	168.48	161.15	146.51	183.13		
75	190.45	146.51	205.10	183.13		
	Mg					
0	32.13	35.35	70.68	51.40	3.630 [a]	11.163 [a]
25	19.28	25.71	16.07	35.35	3.230 [b]	10.214 [b]
50	35.35	32.13	44.98	38.56		
75	22.49	51.40	38.56	51.40		
	S					
0	10.44	11.74	10.44	13.05	2.418 [a]	7.450 [a]
25	15.66	15.66	40.39	28.70	2.134 [b]	6.688 [b]
50	23.46	24.77	23.48	36.53		
75	43.05	35.22	32.62	32.62		

[a] Between spacing means at the same level of shade, [b] Between shade means at the same or different levels of spacing.

highest available P content of 34.63 ppm at 25 per cent shade and 20 x 10 cm spacing, which was superior to all other treatment combinations.

The available K content increased with increase in shade recording the highest of 106.00 ppm at 75 per cent shade, which was on par with 50 per cent shade, but superior to all other shade levels. Among spacings, 20 x 20 cm recorded the highest available K content of 95.50 ppm, which was on par with that at 30 x 20 cm but superior to that at the other two spacings. The interaction effect showed the highest available K content of 110.00 ppm at 75 per cent shade and 30 x 20 cm spacing.

The available Ca content in soil was the highest of 181.30 ppm at 75 per cent shade, followed by 25 per cent and 50 per cent shades and the least (141.01 ppm) under open condition, each being significantly different from one another. It was the highest (179.46 ppm) at 10 x 10 cm, which was superior to all other spacings. A significant interaction showed the highest available Ca content of 212.43 ppm at 25 per cent shade and 20 x 20 cm spacing, which was superior to all other treatment combinations.

The available Mg content was the highest of 47.39 ppm under open condition, which was superior to all other shade levels. However, it increased with increase in shade levels and increase in spacing. The spacing 30 x 20 cm recorded the highest available Mg content of 44.18 ppm, which was on par with that at 20 x 20 cm but superior to the other two spacings. A significant interaction showed the highest available Mg content of 70.68 ppm under open condition and 20 x 20 cm spacing, which was superior to all other treatment combinations.

The available S significantly increased with each increase in shade level. It was the highest of 35.88 ppm at 75 per cent shade and the least (11.42 ppm) under open condition. The highest available S was 27.72 ppm at 30 x 20 cm spacing, which was on par with 20 x 20 cm but superior to the other two spacings. A significant interaction showed the highest available S content of 43.05 ppm at 75 per cent shade and 10 x 10 cm spacing, which was on par with 25 per cent shade and 20 x 20 cm spacing, but superior to all other treatment combinations.

The available Fe, Mn, Zn and Cu contents were not significantly influenced by shade and spacing. The interaction effects were also not significant.

4.4 EXPERIMENT 4 MANURIAL REQUIREMENTS OF *CURCULIGO ORCHIOIDES*

4.4.1 Growth Parameters

4.4.1.1 Plant Height

Effect of FYM and proportion of FYM and fertiliser on plant height of *C. orchioides* is given in Table 4.4.1 and the interaction effect in Table 4.4.2. In general, the plant height increased till maximum vegetative growth stage (6 MAP) and decreased thereafter. The effect of FYM levels was statistically significant at 4, 6 and 7 MAP, the proportion of FYM and fertilizer at 6 MAP and the interaction at 8 MAP.

The plant height increased with increase in the level of FYM in most of the months with significance at 4, 6 and 7 MAP. At 4 MAP, plant height increased with increase in the level of FYM and it was the highest (11.44 cm) at 30 t ha^{-1}, which was on par with 20 t ha^{-1} but superior to 10 t ha^{-1} (9.33 cm). At 6 and 7 MAP, plant height was the highest at 30 t ha^{-1}, which was superior to the other two lower levels that were on par.

The substitution of FYM with fertilizer in different proportions had little influence on height of *C. orchioides*, except at 6 MAP. At 6 MAP, plant height was the highest (17.61 cm) at 100:0 proportion of FYM and fertiliser, which was on par with 75:25 and 0:100 but superior to 50:50 and 25:75 proportions.

The interaction effect was significant at 8 MAP alone while control *vs* rest was not so at any month. At 8 MAP, the interaction effect of FYM and its substitution with fertilizer in different proportions showed the highest plant height of 16.65 cm at 20 t ha^{-1} of FYM and 50:50 proportion, followed by 16.31 cm at 30 t ha^{-1} and 25:75 proportion and the least (9.49 cm) at 30 t ha^{-1} and 100:0 proportion.

4.4.1.2 Number of Leaves

Effect of FYM and proportion of FYM and fertiliser on leaf production in *C. orchioides* is furnished in Table 4.4.3 and the interaction effect in Table 4.4.2. In general, number of leaves per sucker increased up to 6 MAP and diminished thereafter. It was not significantly influenced by FYM and its substitution with

Table 4.4.1. Effect of FYM and proportion of FYM and fertiliser on height of *Curculigo orchioides* (cm)

MAP	1	2	3	4	5	6	7	8
FYM ($t\ ha^{-1}$)								
10	8.10	11.23	8.67	9.33	10.18	15.15	11.21	12.67
20	8.74	11.58	9.27	10.97	11.13	15.69	11.14	13.64
30	8.79	11.70	8.91	11.44	10.81	17.30	13.72	13.09
SEm	0.364	0.411	0.437	0.547	0.345	0.454	0.487	0.517
$CD_{(0.05)}$	NS	NS	NS	1.579	NS	1.311	1.407	NS
FYM:Fert								
100:0	8.90	10.66	9.50	9.77	10.93	17.61	12.24	11.78
75:25	9.08	11.72	7.98	11.30	10.83	16.40	10.71	13.66
50:50	8.26	11.77	8.75	10.24	11.33	14.40	13.07	13.48
25:75	7.93	11.78	8.96	10.33	9.82	15.24	11.73	14.04
0:100	8.54	11.51	9.57	11.28	10.63	16.57	12.36	12.69
SEm	0.469	0.530	0.564	0.706	0.446	0.586	0.629	0.667
$CD_{(0.05)}$	NS	NS	NS	NS	NS	1.693	NS	NS
Interaction	NS	NS	NS	NS	NS	NS	NS	*
Control	8.90	12.26	10.73	9.39	10.41	15.85	12.11	11.45
Rest	8.54	11.49	8.95	10.58	10.71	16.05	12.02	13.13
Control x Rest	NS	NS	NS	NS	NS	NS	NS	NS
G. Mean	8.54	11.49	8.95	10.58	10.69	16.04	12.03	13.03

Table 4.4.2. Interaction effect of FYM and proportion of FYM and fertiliser on growth parameters of *Curculigo orchioides*

FYM (t/ha)	Proportion of FYM:Fertiliser (%)						
	100:0	75:25	50:50	25:75	0:100	SEm	$CD_{(0.05)}$
	Plant height at 8 MAP (cm)						
10	12.11	14.11	11.88	13.59	11.67	1.155	3.337
20	13.74	13.04	16.65	12.22	12.55		
30	9.49	13.84	11.92	16.31	13.87		
	Leaf production at 5 MAP (Leaves $sucker^{-1}$)						
10	4.47	4.07	4.27	3.73	4.07	0.295	0.852
20	4.40	4.13	4.87	4.47	4.33		
30	4.87	5.60	4.00	3.93	3.87		
	Canopy spread at 1 MAP (cm)						
10	1.83	2.53	3.40	1.80	4.41	0.819	2.366
20	2.93	3.20	2.57	3.77	3.03		
30	6.04	3.97	1.77	2.30	1.97		
	Canopy spread at 8 MAP (cm)						
10	5.79	6.49	10.08	11.43	6.65	1.065	3.076
20	8.68	4.49	11.03	5.32	8.30		
30	6.65	6.62	5.34	12.23	8.02		

Table 4.4.3. Effect of FYM and proportion of FYM and fertiliser on leaf production in *Curculigo orchioides* (no. sucker^{-1})

MAP	1	2	3	4	5	6	7	8
FYM(t ha^{-1})								
10	1.83	3.23	4.63	4.15	4.12	5.24	2.63	2.11
20	2.03	3.19	4.88	4.52	4.44	5.35	2.68	2.09
30	1.92	3.25	5.12	4.47	4.45	5.48	2.87	2.14
SEm	0.127	0.186	0.213	0.176	0.132	0.200	0.170	0.127
$CD_{(0.05)}$	NS	NS	NS	NS	NS	NS	NS	NS
FYM:Fert								
100:0	1.82	3.00	4.73	4.53	4.58	5.78	2.33	2.14
75:25	1.93	3.20	4.82	4.53	4.60	5.44	2.98	1.92
50:50	1.80	3.13	4.80	3.98	4.38	5.02	2.96	2.21
25:75	1.98	3.56	5.16	4.18	4.04	5.16	2.51	2.06
0:100	2.10	3.22	4.87	4.67	4.09	5.38	2.84	2.25
SEm	0.165	0.240	0.276	0.227	0.170	0.258	0.219	0.164
$CD_{(0.05)}$	NS	NS	NS	NS	NS	NS	NS	NS
Interaction	NS	NS	NS	NS	*	NS	NS	NS
Control	2.13	2.80	3.73	4.13	3.80	4.67	2.60	2.02
Rest	1.93	3.22	4.88	4.38	4.34	5.36	2.73	2.11
Con x Rest	NS	NS	*	NS	NS	NS	NS	NS
G. Mean	1.93	3.22	4.88	4.38	4.30	5.31	2.72	2.11

Table 4.4.4. Effect of FYM and proportion of FYM and fertiliser on canopy spread of *Curculigo orchioides* (cm)

MAP	1	2	3	4	5	6	7	8
FYM(t ha^{-1})								
10	2.74	6.79	10.31	8.64	10.42	18.99	10.80	10.09
20	3.10	6.34	11.57	9.96	11.11	19.29	10.22	7.56
30	3.21	6.58	12.33	9.73	10.48	21.10	14.23	7.77
SEm	0.366	0.548	0.699	0.566	0.456	0.740	0.624	0.476
$CD_{(0.05)}$	NS	NS	NS	NS	NS	NS	1.802	NS
FYM:Fert								
100:0	3.60	7.14	10.78	9.36	11.20	20.06	12.83	7.04
75:25	3.23	7.14	12.16	9.95	11.29	19.48	10.31	5.87
50:50	2.58	6.40	11.53	9.38	11.10	20.11	12.41	8.82
25:75	2.62	6.34	11.19	8.35	9.60	18.82	10.99	9.66
0:100	3.14	5.84	11.35	10.16	10.17	20.51	13.03	7.66
SEm	0.473	0.708	0.903	0.731	0.589	0.956	0.806	0.615
$CD_{(0.05)}$	NS	NS	NS	NS	NS	NS	NS	1.776
Interaction	*	NS	NS	NS	NS	NS	NS	**
Control	3.63	6.56	12.2	8.05	8.57	19.66	10.10	7.11
Rest	3.03	6.57	11.40	9.44	10.67	19.80	11.92	7.81
Control x Rest	NS	NS	NS	NS	NS	NS	NS	NS
G. Mean	3.03	6.57	11.40	9.44	10.54	19.79	11.80	7.76

fertiliser in different proportions at any month. However, 30 t ha^{-1} of FYM recorded a marginally higher leaf production though the effect was not significant.

The interaction of FYM and its substitution with fertilizer in different proportions were statistically significant at 3 and 5 MAP, respectively. The interaction effect at 5 MAP showed the highest number of leaves (5.60) per sucker at 30 t FYM and 75:25 proportion, which was on par with 30 t and 100:0 and 20 t and 50:50 proportion but superior to all other treatment combinations. Supply of nutrients either through FYM or fertilizer alone or both in different proportions recorded marginally higher value compared to no application of manures and fertilizers and the effect was significant at 3 MAP.

4.4.1.3 Canopy Spread

Effect of FYM and proportion of FYM and fertiliser on canopy spread of *C. orchioides* is presented in Table 4.4.4 and the interaction effect in Table 4.4.2. On an average, canopy spread increased from 3.03 cm to 11.40 cm at 3 MAP, then decreased to 9.44 cm at 4 MAP, again increased to 19.79 cm at 6 MAP and decreased thereafter.

Canopy spread was the highest at 30 t FYM at 1, 3 and 6 MAP and the effect was significant at 7 MAP. Canopy spread was significantly influenced by substitution of FYM with fertiliser in different proportions at 8 MAP alone wherein it was the highest at 25:75 proportion, which was on par with 50:50 proportion but superior to all other proportions. It was the highest at 75:25 proportion at 2, 3 and 5 MAP.

Interaction of FYM and its substitution with fertiliser in different proportions was significant at 1 and 8 MAP while control *vs* rest was not significant at any month. At 1 MAP, the interaction effect showed the highest canopy spread of 6.04 cm at 30 t FYM and 100:0 proportion, which was on par with 30 t and 75:25 and 10 t and 0:100 proportion but superior to all other treatment combinations. The interaction effect at 8 MAP showed the highest canopy spread of 12.23 cm at 30 t and 25:75 proportion, followed by 11.43 cm at 10 t at the same proportion. Application of FYM alone or its substitution with fertilizer in different proportions recorded a slightly higher canopy spread compared to no application of manures and fertilizers.

4.4.1.4 Number of Suckers

Effect of FYM and proportion of FYM and fertiliser on sucker production in *C. orchioides* is given in Table 4.4.5. In general, sucker production started at 4 MAP, reached the highest (1.933 suckers plant^{-1}) at the peak vegetative stage (6 MAP) and declined thereafter. The number of suckers per plant was influenced by none of the treatments or interaction, except FYM at 8 MAP. At 8 MAP, number of suckers per plant was the highest of 1.533 at 30 t FYM, which was significantly higher than that at 20 t FYM. It was marginally higher at 30 t FYM at 4 and 5 MAP. Similarly, 75:25 proportion recorded the highest number of suckers per plant at most of the months though not significant.

4.4.2 Dry Matter Production

Effect of FYM and proportion of FYM and fertiliser on total dry matter production of *C. orchioides* is presented in Table 4.4.10 and the interaction effect in Table 4.4.7. In general, the total dry matter production increased up to 6 MAP and decreased later on. The highest mean whole plant dry matter was 1.182 g plant^{-1}. It was significantly influenced by FYM at 6 and 7 MAP, FYM:fertiliser proportion at 7 MAP and by the interaction of FYM and its substitution with fertiliser in different proportions at 2, 7 and 8 MAP. Control (no manure or fertiliser) recorded a lower dry matter production compared to application of FYM or fertiliser either alone or in combinations though the effect was not significant.

The dry matter production was the highest at 30 t FYM in most of the months and it was significant at 6 and 7 MAP. At 6 MAP, 30 t FYM produced significantly higher total dry matter than 20 t FYM. At 7 MAP, total dry matter was the highest of 0.854 g plant^{-1} at 30 t FYM, which was superior to the other two lower levels that were on par.

The substitution of FYM with fertilizer in different proportions had no significant influence on the dry matter production in most of the months though it was the highest (1.036 g plant^{-1}) at 50:50 proportion, which was superior to all other proportions at 6 MAP.

The interaction effect at 2 MAP showed the highest total dry matter of 0.246 g plant^{-1} at 10 t ha^{-1} FYM and 25:75 proportion, followed by 30 t and 75:25

Table 4.4.5. Effect of FYM and proportion of FYM and fertiliser on sucker production in *Curculigo orchioides* (no. plant^{-1})

MAP	4	5	6	7	8	9
FYM (t ha^{-1})						
10	1.090	1.653	2.000	1.427	1.413	1.467
20	1.000	1.493	1.853	1.360	1.240	1.493
30	1.210	1.667	1.933	1.360	1.533	1.467
SEm	0.054	0.086	0.109	0.081	0.077	0.074
$CD_{(0.05)}$	NS	NS	NS	NS	0.222	NS
FYM:Fert						
100:0	1.146	1.578	1.911	1.467	1.244	1.422
75:25	1.148	1.689	2.111	1.489	1.511	1.467
50:50	1.124	1.733	1.867	1.356	1.422	1.489
25:75	1.010	1.378	1.867	1.267	1.467	1.422
0:100	1.073	1.644	1.889	1.333	1.333	1.578
SEm	0.062	0.111	0.140	0.104	0.099	0.095
$CD_{(0.05)}$	NS	NS	NS	NS	NS	NS
Interaction	NS	NS	NS	NS	NS	NS
Control	1.082	1.933	2.000	1.600	1.667	1.267
Rest	1.121	1.604	1.929	1.382	1.396	1.476
Control x Rest	NS	NS	NS	NS	NS	NS
G. Mean	1.101	1.625	1.933	1.396	1.413	1.463

Table 4.4.6. Effect of FYM and proportion of FYM and fertiliser on root dry matter production in *Curculigo orchioides* (g plant^{-1})

MAP	1	2	3	4	5	6	7	8	9
FYM (t ha^{-1})									
10	0.004	0.016	0.030	0.023	0.044	0.238	0.113	0.138	0.109
20	0.006	0.018	0.033	0.035	0.044	0.204	0.097	0.145	0.124
30	0.002	0.018	0.033	0.034	0.060	0.316	0.139	0.173	0.149
SEm	0.002	0.003	0.003	0.003	0.004	0.021	0.011	0.012	0.012
$CD_{(0.05)}$	NS	NS	NS	0.009	0.012	0.061	0.031	NS	NS
FYM:Fert									
100:0	0.004	0.022	0.030	0.030	0.054	0.214	0.098	0.135	0.139
75:25	0.004	0.016	0.031	0.032	0.061	0.238	0.121	0.166	0.120
50:50	0.004	0.012	0.031	0.031	0.048	0.265	0.162	0.156	0.134
25:75	0.004	0.020	0.034	0.023	0.044	0.262	0.109	0.148	0.120
0:100	0.004	0.016	0.032	0.037	0.038	0.286	0.092	0.156	0.124
SEm	0.002	0.004	0.004	0.004	0.005	0.027	0.014	0.015	0.015
$CD_{(0.05)}$	NS	NS	NS	NS	NS	NS	0.040	NS	NS
Interaction	NS	NS	NS	*	*	NS	**	*	NS
Control	0.002	0.010	0.019	0.027	0.035	0.120	0.051	0.117	0.145
Rest	0.004	0.016	0.032	0.030	0.049	0.253	0.116	0.152	0.128
ConxRest	NS	NS	NS	NS	NS	**	**	NS	NS
G. Mean	0.004	0.016	0.031	0.029	0.048	0.245	0.112	0.150	0.129

Table 4.4.7. Interaction effect of FYM and proportion of FYM and fertiliser on dry matter production in *Curculigo orchioides* (g plant^{-1})

FYM (t/ha)	Proportion of FYM:Fertiliser (%)					SEm	$CD_{(0.05)}$
	100:0	75:25	50:50	25:75	0:100		
	Root at 4 MAP						
10	0.023	0.009	0.036	0.025	0.019	0.007	0.021
20	0.034	0.039	0.024	0.033	0.045		
30	0.033	0.046	0.033	0.011	0.048		
	Root at 5 MAP						
10	0.037	0.041	0.046	0.058	0.039	0.009	0.027
20	0.044	0.045	0.054	0.049	0.026		
30	0.082	0.097	0.045	0.026	0.050		
	Root at 7 MAP						
10	0.070	0.104	0.211	0.057	0.123	0.024	0.068
20	0.067	0.103	0.152	0.114	0.047		
30	0.156	0.157	0.122	0.155	0.107		
	Root at 8 MAP						
10	0.135	0.147	0.133	0.149	0.126	0.027	0.077
20	0.144	0.121	0.209	0.143	0.110		
30	0.125	0.230	0.125	0.152	0.231		
	Rhizome at 2 MAP						
10	0.148	0.078	0.090	0.142	0.104	0.021	0.063
20	0.144	0.090	0.138	0.078	0.110		
30	0.082	0.136	0.106	0.140	0.130		
	Rhizome at 7 MAP						
10	0.393	0.281	0.829	0.294	0.397	0.064	0.184
20	0.356	0.519	0.403	0.499	0.331		
30	0.337	0.518	0.501	0.512	0.553		
	Rhizome at 8 MAP						
10	0.587	0.748	0.873	0.633	0.463	0.089	0.257
20	0.652	0.621	0.924	0.695	0.507		
30	0.583	0.926	0.594	0.829	0.809		
	Shoot at 7 MAP						
10	0.117	0.153	0.279	0.089	0.133	0.025	0.072
20	0.120	0.190	0.103	0.151	0.137		
30	0.190	0.221	0.138	0.171	0.205		
	Shoot at 8 MAP						
10	0.160	0.180	0.129	0.141	0.175	0.024	0.070
20	0.171	0.143	0.228	0.215	0.134		
30	0.102	0.146	0.149	0.190	0.169		
	Total at 2 MAP						
10	0.220	0.128	0.162	0.246	0.174	0.029	0.084
20	0.236	0.152	0.206	0.146	0.194		
30	0.162	0.238	0.170	0.228	0.201		
	Total at 7 MAP						
10	0.579	0.425	1.293	0.449	0.711	0.092	0.266
20	0.545	0.663	0.917	0.768	0.574		
30	0.872	0.732	0.899	0.833	0.933		
	Total at 8 MAP						
10	0.886	1.084	1.146	0.927	0.897	0.139	0.400
20	0.971	0.885	1.299	1.049	0.744		
30	0.713	1.345	1.002	1.247	1.329		

Table 4.4.8. Effect of FYM and proportion of FYM and fertiliser on rhizome dry matter production in *Curculigo orchioides* (g plant^{-1})

MAP	1	2	3	4	5	6	7	8	9
FYM (t ha^{-1})									
10	0.054	0.112	0.167	0.145	0.149	0.710	0.439	0.661	0.653
20	0.060	0.112	0.178	0.181	0.188	0.595	0.422	0.680	0.688
30	0.054	0.118	0.165	0.171	0.193	0.619	0.484	0.748	0.692
SEm	0.005	0.010	0.016	0.015	0.015	0.040	0.028	0.040	0.003
$CD_{(0.05)}$	NS	NS	NS	NS	NS	NS	NS	NS	NS
FYM:Fert									
100:0	0.046	0.124	0.172	0.167	0.198	0.665	0.362	0.607	0.620
75:25	0.060	0.102	0.155	0.157	0.186	0.643	0.439	0.765	0.761
50:50	0.058	0.112	0.183	0.174	0.194	0.636	0.578	0.797	0.703
25:75	0.060	0.120	0.188	0.148	0.141	0.614	0.435	0.719	0.673
0:100	0.054	0.014	0.152	0.184	0.165	0.649	0.427	0.593	0.631
SEm	0.006	0.013	0.021	0.020	0.020	0.052	0.037	0.051	0.044
$CD_{(0.05)}$	NS	NS	NS	NS	NS	NS	0.106	0.148	NS
Interaction	NS	*	NS	NS	NS	NS	*	*	NS
Control	0.052	0.070	0.122	0.106	0.153	0.487	0.559	0.681	0.656
Rest	0.056	0.114	0.170	0.166	0.177	0.641	0.448	0.696	0.678
Control x Rest	NS	NS	NS	NS	NS	NS	NS	NS	NS
G. Mean	0.056	0.112	0.167	0.162	0.175	0.632	0.455	0.695	0.676

Table 4.4.9. Effect of FYM and proportion of FYM and fertiliser on shoot dry matter production in *Curculigo orchioides* (g plant^{-1})

MAP	1	2	3	4	5	6	7	8	9
FYM (t ha^{-1})									
10	0.048	0.054	0.089	0.071	0.102	0.328	0.154	0.157	0.103
20	0.054	0.054	0.094	0.095	0.124	0.291	0.140	0.178	0.093
30	0.054	0.062	0.102	0.100	0.114	0.340	0.185	0.151	0.092
SEm	0.004	0.004	0.006	0.007	0.010	0.022	0.011	0.011	0.009
$CD_{(0.05)}$	NS	NS	NS	0.020	NS	NS	0.032	NS	NS
FYM:Fert									
100:0	0.056	0.062	0.097	0.089	0.121	0.295	0.142	0.144	0.089
75:25	0.054	0.052	0.090	0.104	0.120	0.305	0.188	0.156	0.097
50:50	0.048	0.052	0.097	0.078	0.131	0.325	0.173	0.169	0.085
25:75	0.052	0.064	0.102	0.071	0.096	0.311	0.137	0.182	0.096
0:100	0.050	0.056	0.089	0.100	0.099	0.363	0.159	0.159	0.113
SEm	0.005	0.006	0.008	0.009	0.013	0.028	0.014	0.014	0.012
$CD_{(0.05)}$	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction	NS	NS	NS	NS	NS	NS	**	*	NS
Control	0.062	0.058	0.081	0.066	0.087	0.251	0.149	0.071	0.118
Rest	0.052	0.058	0.095	0.089	0.113	0.320	0.160	0.162	0.096
Control x Rest	NS	NS	NS	NS	NS	NS	NS	**	NS
G. Mean	0.052	0.058	0.094	0.087	0.112	0.315	0.159	0.156	0.097

Table 4.4.10. Effect of FYM and proportion of FYM and fertiliser on total dry matter production in *Curculigo orchioides* (g plant^{-1})

MAP	1	2	3	4	5	6	7	8	9
FYM (t ha^{-1})									
10	0.108	0.186	0.289	0.240	0.293	1.248	0.691	0.988	0.893
20	0.122	0.186	0.284	0.300	0.360	1.033	0.693	0.990	0.957
30	0.110	0.200	0.303	0.306	0.367	1.306	0.854	1.127	0.925
SEm	0.007	0.013	0.021	0.022	0.027	0.061	0.041	0.062	0.046
$CD_{(0.05)}$	NS	NS	NS	NS	NS	0.177	0.119	NS	NS
FYM:Fert									
100:0	0.108	0.206	0.266	0.291	0.367	1.114	0.665	0.857	0.873
75:25	0.118	0.172	0.302	0.291	0.368	1.164	0.607	1.105	1.016
50:50	0.110	0.180	0.291	0.278	0.385	1.187	1.036	1.149	0.957
25:75	0.120	0.206	0.321	0.249	0.269	1.206	0.683	1.074	0.936
0:100	0.110	0.190	0.279	0.302	0.312	1.307	0.739	0.990	0.843
SEm	0.009	0.017	0.027	0.028	0.035	0.079	0.053	0.080	0.060
$CD_{(0.05)}$	NS	NS	NS	NS	NS	NS	0.154	NS	NS
Interaction	NS	*	NS	NS	NS	NS	*	*	NS
Control	0.116	0.138	0.217	0.199	0.281	0.973	0.592	0.897	0.899
Rest	0.114	0.190	0.292	0.282	0.340	1.196	0.746	1.035	0.925
Con x Rest	NS	NS	NS	NS	NS	NS	NS	NS	NS
G. Mean	0.114	0.188	0.287	0.277	0.336	1.182	0.737	1.026	0.923

Table 4.4.11. Effect of FYM and proportion of FYM and fertiliser on plant density and weed biomass production in *Curculigo orchioides*

Treatment	Plants m^{-2}		Suckers m^{-2}	Fresh weed biomass (kg m^{-2})			Dry weed biomass (kg m^{-2})		
	3 MAP	6 MAP	6 MAP	2 MAP	4 MAP	6 MAP	2 MAP	4 MAP	6 MAP
FYM (t ha^{-1})									
10	47.16	33.06	62.27	0.063	0.764	0.801	0.009	0.110	0.115
20	44.66	31.23	65.93	0.068	0.929	0.972	0.010	0.134	0.141
30	46.92	31.00	61.07	0.069	0.982	1.028	0.010	0.142	0.148
SEm	0.958	1.180	3.864	0.008	0.036	0.037	0.001	0.005	0.006
$CD_{(0.05)}$	NS	NS	NS	NS	0.103	0.108	NS	0.014	0.016
FYM:Fert									
100:0	45.58	32.13	63.78	0.088	0.851	0.890	0.013	0.122	0.128
75:25	44.25	33.70	66.11	0.068	0.907	0.949	0.009	0.131	0.137
50:50	45.80	31.48	64.33	0.062	0.949	0.993	0.009	0.137	0.143
25:75	49.92	29.53	59.44	0.066	1.051	1.100	0.009	0.152	0.159
0:100	46.75	31.94	61.78	0.049	0.703	0.739	0.007	0.101	0.106
SEm	1.237	1.524	4.988	0.010	0.046	0.048	0.001	0.007	0.008
$CD_{(0.05)}$	NS	NS	NS	NS	0.133	0.139	NS	0.019	0.020
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS
Control	46.11	35.00	58.67	0.029	0.264	0.276	0.004	0.038	0.040
Rest	46.26	31.76	63.09	0.067	0.892	0.933	0.009	0.129	0.135
Control x Rest	NS	NS	NS	*	**	**	*	**	**
G. Mean	46.25	31.960	62.813	0.065	0.853	0.892	0.009	0.123	0.129

proportion. The interaction effect at 7 MAP showed the highest total dry matter of 1.293 g plant^{-1} at 10 t FYM and 50:50 proportion, which was superior to all other treatment combinations. The interaction effect at 8 MAP showed the highest total dry matter of 1.345 g plant^{-1} at 30 t FYM and 75:25 proportion followed by 1.329 g plant^{-1} at 0:100 proportion at the same level of FYM.

4.4.3 Plant Density and Weed Biomass

Effect of FYM and proportion of FYM and fertiliser on plant density and weed biomass production of *C. orchioides* is presented in Table 4.4.11.

4.4.3.1 Plant Density

The number of plants m^{-2} as well as the total number of suckers m^{-2} were not significantly influenced by any of the treatments or their interaction at any month.

4.4.3.2 Fresh Weed Biomass

The weed biomass increased with increase in the level of FYM and it was significant at 4 and 6 MAP. At 4 MAP, fresh weed biomass was the highest (0.982 kg m^{-2}) at 30 t FYM, which was on par with 20 t but significantly higher than 10 t FYM. It was the highest of 1.051 kg m^{-2} at 25:75 proportion which was on par with 50:50 proportion and the significantly lowest of all was 0.703 kg m^{-2} at 0:100 proportion. Similar trend was noted at 6 MAP also. The interaction of FYM and its substitution with fertiliser in different proportions was not significant at any month. However, the weed biomass was significantly lower in the control than the rest of the treatments at all the months.

4.4.3.3 Dry Weed Biomass

Dry weed biomass followed the trend of fresh weed biomass.

4.4.4 Yield Parameters

Effect of FYM and proportion of FYM and fertiliser on yield and harvest index of *C. orchioides* is presented in Table 4.4.12 and the interaction effect in Table 4.4.13.

Table 4.4.12. Effect of FYM and proportion of FYM and fertiliser on yield and harvest index of *Curculigo orchioides*

Treatment	Yield (kg ha^{-1})			Harvest index (%)
	Biological	Fresh rhizome	Dry rhizome	
FYM (t ha^{-1})				
10	661.94	405.27	151.34	61.22
20	736.39	518.95	201.62	70.47
30	806.66	490.22	191.95	60.77
SEm	20.132	7.324	2.500	–
$CD_{(0.05)}$	58.147	21.152	7.221	–
FYM:Fert				
100:0	686.57	448.39	167.29	65.31
75:25	1093.98	736.45	293.37	67.32
50:50	794.44	567.99	222.93	71.50
25:75	486.11	340.75	130.47	70.10
0:100	613.89	363.82	135.80	59.26
SEm	25.991	9.455	3.228	–
$CD_{(0.05)}$	75.068	27.308	9.322	–
Interaction	**	**	**	–
Control	408.33	305.08	109.35	74.71
Rest	734.99	491.48	189.97	66.87
Control x Rest	**	**	**	–
G. Mean	734.99	479.830	184.931	65.28

Table 4.4.13. Interaction effect of FYM and proportion of FYM and fertiliser on yield of *Curculigo orchioides*

FYM (t/ha)	Proportion of FYM:Fertiliser (%)						
	100:0	75:25	50:50	25:75	0:100	SEm	$CD_{(0.05)}$
	Biological yield (kg ha^{-1})						
10	658.33	781.94	830.55	426.38	612.50	45.017	130.021
20	934.72	695.83	850.00	513.89	687.50		
30	466.66	1804.16	702.78	518.05	541.66		
	Fresh rhizome yield (kg ha^{-1})						
10	459.33	476.01	449.14	288.22	353.63	16.376	47.298
20	633.72	673.03	777.48	361.07	449.46		
30	252.13	1060.31	471.33	372.96	288.39		
	Dry rhizome yield (kg ha^{-1})						
10	161.06	192.32	176.03	103.92	123.38	5.590	16.146
20	246.52	264.90	303.00	136.40	177.29		
30	94.32	422.89	189.76	151.08	106.71		

4.4.4.1 Biological Yield

The biological yield increased with increase in the level of FYM and it was significantly different at each level. It was the highest of 806.66 kg ha^{-1} at 30 t FYM and the least of 661.94 kg ha^{-1} at 10 t FYM. Biological yield was the highest of 1093.98 kg ha^{-1} at 75:25 proportion followed by 50:50 proportion. The proportion of FYM and fertiliser 25:75 recorded significantly lowest of all yields. The interaction effect showed the highest biological yield of 1804.16 kg ha^{-1} at 30 t FYM and 75:25 proportion, which was superior to all other treatment combinations. The control was significantly inferior to the rest of the treatments.

4.4.4.2 Fresh Rhizome Yield

Fresh rhizome yield was the highest at 20 t ha^{-1} FYM, which was superior to the other two levels. 30 t ha^{-1} produced the next higher yield and 10 t the least. fresh rhizome yield was the highest of 736.45 kg ha^{-1} of FYM at 75:25 proportion followed by 50:50 proportion. The proportion of FYM and fertiliser 25:75 and 0:100 recorded significantly lowest of all yields. The interaction effect showed the highest fresh rhizome yield of 1060.31 kg ha^{-1} at 30 t FYM and 75:25 proportion, which was superior to all other treatment combinations. The control was significantly inferior to the rest of the treatments.

4.4.4.3 Dry Rhizome Yield

Dry rhizome yield followed the trend of fresh rhizome yield.

4.4.4.4 Harvest Index

Harvest index was the highest of 70.47 per cent at 20 t ha^{-1} FYM, which was much higher than that at other two levels. Similarly, the proportions 50:50 and 25:75 recorded higher harvest index values than other proportions. However, the control recorded higher harvest index than the rest of the treatments.

4.4.5 Quality Parameters

Effect of FYM and proportion of FYM and fertiliser on quality parameters of *C. orchioides* is given in Table 4.4.14 and the interaction effect in Table 4.4.15.

Table 4.4.14. Effect of FYM and proportion of FYM and fertiliser on quality parameters of *Curculigo orchioides*

Treatment	Glucose (%)	Sucrose (%)	Starch (%)	Fibre (%)	Protein (%)	Fat (%)	Curculigoside (ppm)	Ash (%)
FYM (t ha^{-1})								
10	1.268	0.821	50.636	2.655	11.286	1.561	7.232	3.979
20	1.253	0.892	50.336	2.656	11.578	1.704	7.266	3.875
30	1.387	0.770	51.830	2.530	11.973	1.576	9.154	3.819
SEm	0.007	0.013	0.281	0.026	0.118	0.057	-	0.045
$CD_{(0.05)}$	0.020	0.039	0.847	0.079	0.357	NS	-	0.136
FYM:Fert								
100:0	1.348	0.835	48.835	2.860	11.533	1.498	7.417	4.132
75:25	1.247	0.764	51.423	2.695	11.609	1.457	8.033	3.836
50:50	1.307	0.915	52.647	2.585	11.494	1.733	7.480	4.013
25:75	1.283	0.810	51.408	2.232	11.197	1.823	8.163	3.529
0:100	1.328	0.813	50.357	2.698	12.227	1.557	8.327	3.946
SEm	0.008	0.017	0.363	0.034	0.153	0.073	-	0.058
$CD_{(0.05)}$	0.026	0.050	1.094	0.102	0.461	0.220	-	0.176
Interaction	**	**	**	**	**	NS	-	**
Control	1.333	0.845	49.435	2.911	10.975	1.266	3.700	3.864
Rest	1.303	0.828	50.934	2.614	11.612	1.614	7.884	3.891
Conx Rest	NS	NS	*	*	*	*	-	NS
G. Mean	1.305	0.829	50.840	2.632	11.572	1.592	7.623	3.889

Table 4.4.15. Interaction effect of FYM and proportion of FYM and fertiliser on quality parameters of *Curculigo orchioides* dry rhizome at harvest

FYM	Proportion of FYM:Fertiliser (%)						
(t/ha)	100:0	75:25	50:50	25:75	0:100	SEm	$CD_{(0.05)}$
	Glucose (%)						
10	1.327	1.168	1.232	1.263	1.351	0.015	0.044
20	1.374	1.366	1.235	1.157	1.131		
30	1.344	1.208	1.454	1.429	1.503		
	Sucrose (%)						
10	0.904	0.865	0.980	0.682	0.675	0.029	0.087
20	0.925	0.682	1.026	0.900	0.925		
30	0.678	0.746	0.740	0.847	0.838		
	Starch (%)						
10	50.935	49.310	53.875	50.880	48.180	0.629	1.895
20	46.825	49.885	51.815	52.040	51.115		
30	48.745	55.075	52.250	51.305	51.775		
	Fibre (%)						
10	3.086	2.816	2.685	2.053	2.635	0.059	0.177
20	2.673	2.672	2.510	2.111	3.317		
30	2.820	2.597	2.560	2.531	2.143		
	Protein (%)						
10	10.188	11.309	11.419	11.419	12.094	0.265	0.798
20	12.206	11.200	11.419	11.422	11.644		
30	12.206	12.319	11.644	10.750	12.944		
	Ash(%)						
10	3.979	3.824	4.153	3.680	4.260	0.101	0.305
20	4.150	4.066	4.097	3.201	3.858		
30	4.266	3.617	3.790	3.705	3.720		

4.4.5.1 Glucose

The glucose content of dry rhizome at harvest was the highest of 1.387 per cent at 30 t ha^{-1} FYM which was superior to the other two lower levels. It was the highest (1.348%) at 100:0 proportion, which was on par with 0:100 proportion but superior to all other proportions. The interaction effect showed the highest glucose content of 1.503 per cent at 30 t FYM and 0:100 proportion which was superior to all other treatment combinations.

4.4.5.2 Sucrose

The sucrose content of rhizome at harvest was the highest of 0.892 per cent at 20 t ha^{-1} of FYM, which was superior to the other two levels. It was the highest of 0.915 per cent at 50:50 proportion, which was superior to all other proportions. This was followed by 100:0 proportion. The interaction of FYM and its substitution with fertiliser in different proportions showed the highest sucrose content of 1.026 per cent at 20 t FYM and 50:50 proportion, which was on par with 0.980 per cent at 10 t and the same proportion but superior to all other treatment combinations.

4.4.5.3 Starch

The starch content of dry rhizome at harvest was the highest of 51.830 per cent at 30 t FYM, which was superior to the other two lower levels that were on par. It was the highest of 52.647 per cent at 50:50 proportion, which was superior to all other proportions and the least was 48.835 per cent at 100:0 proportion. The interaction effect showed the highest starch content of 55.075 per cent at 30 t FYM and 75:25 proportion, which was on par with 53.875 per cent at 10 t and 50:50 proportion but superior to all other treatment combinations. The control was significantly inferior to the rest of the treatments.

4.4.5.4 Fibre

The fibre content of dry rhizome at harvest was significantly higher at 10 t and 20 t FYM than 30 t FYM (2.530%). It was the highest of 2.860 per cent at 100:0 proportion, which was superior to all other proportions and the least was 2.232 per cent at 25:75 proportion. The interaction of FYM and its substitution with fertiliser in different proportions showed the highest fibre content of 3.317

per cent at 20 t FYM and 0:100 proportion but superior to all other treatment combinations. The control was superior to the rest of the treatments in fibre content.

4.4.5.5 Protein

The protein content of dry rhizome at harvest increased with increase in the level of FYM. It was the highest of 11.973 per cent at 30 t FYM, which was superior to the other two lower levels that were on par. It was the highest of 12.227 per cent at 0:100 proportion which was superior to all other proportions that were on par. The interaction effect showed the highest protein content of 12.944 per cent at 30 t FYM and 0:100 proportion, followed by 12.319 per cent at 30 t and 75:25 proportion. The control was significantly inferior to the rest of the treatments.

4.4.5.6 Fat

The fat content of dry rhizome at harvest was the highest (1.823%) at 25:75 proportion which was on par with 50:50 proportion but superior to all other proportions. It was not significantly influenced by the FYM levels and the interaction effect of FYM and proportion of FYM and fertiliser. The control was significantly inferior to the rest of the treatments.

4.4.5.7 Curculigoside

The curculigoside content of dry rhizome at harvest increased with increase in the level of FYM and the highest was 9.154 ppm at 30 t ha^{-1}. The proportion of FYM and fertilizer had very little effect on the curculigoside content. The control had the lowest value of 3.700 ppm, as against 7.884 ppm recorded by the rest of the treatments.

4.4.5.8 Ash

The ash content decreased with increase in the level of FYM and the extreme levels (10 t and 30 t ha^{-1}) were significantly different from each other but statistically on par with the adjacent level. It was the highest (4.132%) at 100:0 proportion which was on par with 50:50 proportion but superior to all other proportions. The interaction effect showed the highest ash content of 4.266 per cent at 30 t FYM and 100:0 proportion, followed by 4.260 per cent at 10 t and 0:100 proportion of FYM and fertiliser.

4.4.6 Nutrient Contents

4.4.6.1 Rhizome

4.4.6.1.1 Major nutrients

Effect of FYM and proportion of FYM and fertiliser on the content of major nutrients in *C. orchioides* rhizome is presented in Table 4.4.16 and the interaction effect in Table 4.4.17.

Nitrogen

Nitrogen content of *C. orchioides* rhizome, in general, increased up to 9 MAP and then decreased. At 3 and 6 MAP, N content in rhizome increased with increase in the level of FYM and it was significantly different at each level, the highest being recorded at 30 t ha^{-1}. At 9 MAP, N content was the highest of 2.312 per cent at 20 t FYM, which was superior to the other two levels of FYM. At harvest, N content in rhizome was the highest of 1.916 per cent at 30 t ha^{-1} FYM which was superior to the other two lower levels that were on par.

The substitution of FYM with fertiliser in different proportions had little influence on N content at 3 MAP. However, at 6 and 9 MAP and at harvest N content was the highest at 0:100 proportion which was superior to all other proportions.

The interaction effect of FYM and its substitution with fertiliser in different proportions was significant at 6 and 9 MAP and at harvest wherein the highest N content was noted at 30 t FYM and 0:100 proportion.

The control was significantly inferior to the rest of the treatments in N content at all stages.

Phosphorus

Phosphorus content of *C. orchioides* rhizome, in general, increased up to 9 MAP and then decreased slightly. At 3 and 9 MAP, P content increased with increase in the level of FYM and it was the highest at 30 t ha^{-1}, which was superior to the other two lower levels that were on par. At 6 MAP, P content was

Table 4.4.16. Effect of FYM and proportion of FYM and fertiliser on the content of major nutrients in *Curculigo orchioides* rhizome (%)

Treatment	N				P				K			
	3 MAP	6 MAP	9 MAP	Harvest	3 MAP	6 MAP	9 MAP	Harvest	3 MAP	6 MAP	9 MAP	Harvest
FYM (t ha^{-1})												
10	0.504	1.172	2.248	1.806	0.108	0.177	0.204	0.231	0.694	0.680	0.605	0.713
20	0.641	1.258	2.312	1.853	0.113	0.188	0.227	0.219	0.708	0.619	0.548	0.739
30	0.756	1.308	2.235	1.916	0.139	0.166	0.279	0.209	0.750	0.630	0.493	0.879
SEm	0.037	0.008	0.006	0.019	0.006	0.003	0.005	0.001	0.046	0.013	0.017	0.022
$CD_{(0.05)}$	0.112	0.025	0.017	0.057	0.019	0.010	0.016	0.005	NS	0.040	0.052	0.067
FYM:Fert												
100:0	0.560	1.254	2.264	1.845	0.140	0.189	0.233	0.236	0.731	0.661	0.554	0.725
75:25	0.639	1.165	2.254	1.858	0.114	0.182	0.253	0.243	0.716	0.619	0.600	0.736
50:50	0.735	1.177	2.151	1.839	0.128	0.193	0.227	0.228	0.753	0.656	0.546	0.838
25:75	0.639	1.284	2.218	1.792	0.116	0.170	0.251	0.212	0.691	0.615	0.521	0.738
0:100	0.595	1.350	2.439	1.956	0.103	0.151	0.220	0.180	0.697	0.665	0.521	0.848
SEm	0.048	0.011	0.007	0.024	0.008	0.004	0.007	0.002	0.052	0.017	0.022	0.029
$CD_{(0.05)}$	NS	0.033	0.022	0.074	0.024	0.012	0.021	0.006	NS	NS	NS	0.087
Interaction	NS	**	**	**	NS	**	**	**	NS	NS	NS	NS
Control	0.473	0.932	2.069	1.756	0.110	0.117	0.154	0.172	0.748	0.713	0.600	0.769
Rest	0.634	1.246	2.265	1.858	0.120	0.177	0.237	0.220	0.718	0.643	0.548	0.777
Control x Rest	*	**	**	*	**	**	**	**	NS	*	NS	NS
G. Mean	0.624	1.226	2.253	1.852	0.119	0.173	0.232	0.217	0.720	0.648	0.552	0.776

Table 4.4.17. Interaction effect of FYM and proportion of FYM and fertiliser on the content of major nutrients in *Curculigo orchioides* rhizome (%)

FYM (t/ha)	Proportion of FYM:Fertiliser (%)					SEm	$CD_{(0.05)}$
	100:0	75:25	50:50	25:75	0:100		
	N at 6 MAP						
10	1.183	1.057	1.111	1.201	1.308	0.019	0.057
20	1.236	1.183	1.236	1.308	1.326		
30	1.344	1.254	1.183	1.344	1.416		
	N at 9 MAP						
10	2.347	2.161	2.146	2.115	2.470	0.013	0.039
20	2.470	2.470	2.145	2.130	2.347		
30	1.976	2.130	2.161	2.408	2.501		
	N at harvest						
10	1.630	1.810	1.827	1.827	1.935	0.042	0.128
20	1.953	1.792	1.827	1.827	1.863		
30	1.953	1.971	1.863	1.720	2.071		
	P at 6 MAP						
10	0.171	0.170	0.197	0.167	0.177	0.007	0.021
20	0.204	0.208	0.213	0.189	0.128		
30	0.191	0.169	0.169	0.155	0.146		
	P at 9 MAP						
10	0.238	0.198	0.192	0.204	0.187	0.012	0.037
20	0.257	0.272	0.226	0.226	0.156		
30	0.203	0.288	0.264	0.323	0.318		
	P at harvest						
10	0.218	0.260	0.240	0.231	0.209	0.003	0.010
20	0.260	0.258	0.224	0.190	0.158		
30	0.232	0.210	0.221	0.210	0.174		

also significantly different at each level of FYM. The highest (0.188%) was recorded at 20 t, followed by 10 t and 30 t FYM. At harvest, P content significantly decreased with each increase in the level of FYM and it was the highest of 0.231 per cent at 10 t ha^{-1} FYM.

At 3 MAP, P content was the highest of 0.140 per cent at 100:0 proportion, followed by 50:50 and 25:75 proportions which were on par and the least at 0:100 proportion. At 6 MAP, P content was the highest of 0.193 per cent at 50:50 proportion which was on par with 100:0 and 75:25 proportions and superior to 0:100 and 25:75 proportions. At 9 MAP, P content was the highest of 0.253 per cent at 75:25 proportion which was on par with 25:75 and 100:0 proportions but superior to 50:50 and 0:100 proportions. At harvest, P content was the highest of 0.243 per cent at 75:25 proportion which was superior to all other proportions.

At 6 MAP, the interaction of FYM and its substitution with fertiliser in different proportions showed highest P content of 0.213 per cent at 20 t FYM and 50:50 proportion which was on par with 75:25 and 100:0 proportions at the same level of FYM but superior to all other treatment combinations. At 9 MAP, The interaction effect showed the highest P content of 0.323 per cent at 30 t FYM and 25:75 proportion which was on par with 0:100 and 75:25 proportions at the same level of FYM but superior to all other treatment combinations. At harvest, the interaction effect showed the highest P content of 0.260 per cent both at 20 t and 100:0 proportion and 10 t and 75:25 proportion which were on par with 20 t and 75:25 proportion.

The control was significantly inferior to the rest of the treatments in P content at all stages.

Potassium

Potassium content of *C. orchioides* rhizome, in general, decreased up to 9 MAP and then increased. At 6 MAP, K content was the highest of 0.680 per cent at 10 t FYM, which was superior to the other two higher levels that were on par. At 9 MAP, K content significantly decreased at each level of FYM and it was the highest of 0.605 per cent at 10 t FYM. At harvest, K content increased with increase in FYM level and it was the highest of 0.879 per cent at 30 t FYM, which was superior to the other two lower levels.

The substitution of FYM with fertiliser in different proportions had little influence on K content in most of the stages. However, at harvest K content was the highest of 0.848 per cent at 0:100 proportion which was on par with 50:50 but superior to all other proportions.

The interaction effect of FYM and its substitution with fertiliser in different proportions was not significant at any stage. K content was lower in plots supplied with manure or fertiliser alone or in combination compared to no application.

4.4.6.1.2 Secondary nutrients

Effect of FYM and proportion of FYM and fertiliser on the content of secondary nutrients in *C. orchioides* rhizome is presented in Table 4.4.18 and the interaction effect in Table 4.4.19.

Calcium

Calcium content of *C. orchioides* rhizome, in general, decreased up to 9 MAP and then increased slightly.

FYM levels, though had little influence initially, the effect was significant at later stages. At 9 MAP, Ca content significantly increased with increase in each level of FYM and it was the highest (0.582%) at 30 t ha^{-1} FYM. At harvest, Ca content was significantly different at each level of FYM. It was the highest of 0.756 per cent at 20 t FYM followed by 30 t and 10 t FYM.

At 6 MAP, Ca content was the highest of 1.033 per cent at 75:25 proportion which was on par with the proportions where both FYM and fertiliser were present but superior to FYM or fertiliser alone. At 9 MAP, it was the highest of 0.607 per cent at 0:100 proportion which was superior to all other proportions. At harvest, Ca content was the highest at 50:50 proportion, which was on par with proportions involving more FYM but superior to proportions involving lesser FYM.

At 6 MAP, the interaction effect showed highest Ca content of 1.110 per cent both at 10 t and 25:75 proportion and at 30 t and 100:0 proportion. At 9 MAP, The interaction effect showed the highest Ca content of 0.670 per cent at 30 t FYM and 50:50 proportion which was on par with 0:100 proportion at the same FYM level but superior to all other treatment combinations. At harvest, the

Table 4.4.18. Effect of FYM and proportion of FYM and fertiliser on the content of secondary nutrients in *Curculigo orchioides* rhizome (%)

Treatment	Ca				Mg				S		
	3 MAP	6 MAP	9 MAP	Harvest	3 MAP	6 MAP	9 MAP	Harvest	6 MAP	9 MAP	Harvest
FYM ($t\ ha^{-1}$)											
10	0.954	0.999	0.509	0.652	0.343	0.121	0.227	0.220	0.139	0.283	0.101
20	1.034	0.979	0.541	0.756	0.379	0.122	0.210	0.231	0.141	0.216	0.118
30	0.890	0.927	0.582	0.687	0.375	0.160	0.190	0.222	0.163	0.158	0.114
SEm	0.050	0.025	0.005	0.008	0.022	0.008	0.003	0.003	0.014	0.006	0.006
$CD_{(0.05)}$	NS	NS	0.014	0.025	NS	0.025	0.009	NS	NS	0.019	NS
FYM:Fert											
100:0	1.084	0.968	0.527	0.698	0.394	0.178	0.225	0.245	0.105	0.153	0.101
75:25	0.809	1.033	0.540	0.716	0.415	0.074	0.227	0.197	0.120	0.264	0.099
50:50	1.013	1.001	0.549	0.721	0.383	0.102	0.207	0.245	0.157	0.165	0.116
25:75	0.880	1.001	0.496	0.662	0.345	0.160	0.194	0.220	0.202	0.267	0.112
0:100	1.013	0.838	0.607	0.694	0.291	0.157	0.194	0.217	0.154	0.247	0.130
SEm	0.064	0.032	0.006	0.011	0.028	0.011	0.004	0.004	0.018	0.008	0.007
$CD_{(0.05)}$	NS	0.096	0.018	0.033	NS	0.033	0.012	0.012	0.055	0.024	0.022
Interaction	NS	**	**	**	NS	**	**	**	NS	**	*
Control	1.360	1.044	0.536	0.657	0.372	0.078	0.218	0.190	0.183	0.153	0.138
Rest	0.960	0.968	0.544	0.698	0.366	0.134	0.209	0.225	0.148	0.219	0.112
Control x Rest	**	NS	NS	*	NS	**	NS	**	NS	**	NS
G. Mean	0.985	0.973	0.544	0.696	0.366	0.131	0.210	0.223	0.150	0.216	0.113

Table 4.4.19. Interaction effect of FYM and proportion of FYM and fertiliser on the content of secondary nutrients in *Curculigo orchioides* rhizome (%)

FYM (t/ha)	Proportion of FYM:Fertiliser (%)						
	100:0	75:25	50:50	25:75	0:100	SEm	$CD_{(0.05)}$
	Ca at 6 MAP						
10	0.783	1.077	1.044	1.110	0.979	0.055	0.165
20	1.012	1.044	0.946	0.946	0.946		
30	1.110	0.979	1.012	0.946	0.587		
	Ca at 9 MAP						
10	0.429	0.536	0.469	0.563	0.549	0.010	0.031
20	0.590	0.576	0.509	0.415	0.616		
30	0.563	0.509	0.670	0.509	0.657		
	Ca at harvest						
10	0.575	0.630	0.698	0.712	0.643	0.019	0.056
20	0.712	0.780	0.821	0.767	0.698		
30	0.808	0.739	0.643	0.507	0.739		
	Mg at 6 MAP						
10	0.246	0.041	0.123	0.092	0.102	0.019	0.056
20	0.184	0.078	0.082	0.164	0.102		
30	0.104	0.102	0.102	0.225	0.266		
	Mg at 9 MAP						
10	0.258	0.251	0.251	0.172	0.205	0.007	0.020
20	0.225	0.231	0.165	0.212	0.218		
30	0.192	0.198	0.205	0.198	0.159		
	Mg at harvest						
10	0.251	0.204	0.224	0.177	0.251	0.007	0.021
20	0.347	0.184	0.190	0.197	0.238		
30	0.137	0.204	0.319	0.285	0.163		
	S at 9 MAP						
10	0.159	0.439	0.174	0.186	0.459	0.014	0.042
20	0.152	0.194	0.142	0.451	0.143		
30	0.148	0.159	0.180	0.164	0.141		
	S at harvest						
10	0.070	0.055	0.115	0.125	0.138	0.013	0.038
20	0.119	0.130	0.120	0.099	0.124		
30	0.115	0.113	0.112	0.112	0.129		

interaction effect showed the highest Ca content of 0.821 per cent at 20 t FYM and 50:50 proportion followed by 0.808 per cent at 30 t and 100:0 proportion.

At 3 MAP, The control was inferior to the rest of the treatments in Ca till 6 MAP but later the trend reversed and the effect was significant at 3 MAP and at harvest.

Magnesium

At 6 MAP, Mg content increased with increase in FYM level and it was the highest of 0.160 per cent at 30 t FYM, which was superior to the other two lower levels that were on par. At 9 MAP, Mg content significantly reduced with each addition of FYM and it was the highest of 0.227 per cent at 10 t FYM.

At 6 MAP, Mg content was the highest of 0.178 per cent at 100:0 proportion which was on par with 25:75 and 0:100 proportions but superior to 75:25 and 50:50 proportions. At 9 MAP, The proportions 100:0 and 75:25 recorded higher Mg contents than other proportions. At harvest, Mg content was the highest both at 100:0 and 50:50 proportion, which were superior to all other proportions.

At 6 MAP, The interaction effect showed the highest Mg content of 0.266 per cent at 30 t FYM and 0:100 proportion which was on par with 10 t and 100:0 and 30 t and 25:75 proportion but superior to all other treatment combinations. At 9 MAP, The interaction effect showed the highest Mg content of 0.258 per cent at 10 t FYM and 100:0 proportion which was on par with 75:25 and 50:50 proportions at the same FYM level but superior to all other treatment combinations. At harvest, the interaction effect showed the highest Mg content of 0.347 per cent at 20 t FYM and 100:0 proportion which was superior to all other treatment combinations.

At 6 MAP and at harvest, the control was significantly inferior to the rest of the treatments in Mg.

Sulphur

At 9 MAP, S significantly reduced with increase in the level of FYM and it was the highest (0.283%) at 10 t FYM.

At 6 MAP, S content was the highest of 0.202 per cent at 25:75 proportion which was on par with 50:50 and 0:100 proportions and superior to the other two proportions. At 9 MAP, S was the highest of 0.267 per cent at 25:75 proportion, which was on par with 75:25 and 0:100 proportions but superior to 100:0 and 50:50 proportions. At harvest, S content was the highest of 0.130 per cent at 0:100 proportion which was on par with 50:50 and 25:75 proportions but superior to 75:25 and 100:0 proportions.

At 9 MAP, The interaction effect showed the highest S content of 0.459 per cent at 10 t FYM and 0:100 proportion which was on par with 75:25 proportion at the same FYM level and 20 t and 25:75 proportion but superior to all other treatment combinations. At harvest, the interaction effect showed the highest S content of 0.138 per cent at 10 t FYM and 0:100 proportion followed by 0.130 per cent at 20 t and 75:25 proportion.

At 9 MAP, The control was significantly inferior to the rest of the treatments in S content.

4.4.6.1.3 Micronutrients

Effect of FYM and proportion of FYM and fertiliser on the content of micronutrients in *C. orchioides* rhizome is presented in Table 4.4.20.

Iron

Iron content in rhizome exhibited alternate increase and decrease. At 9 MAP, Fe content significantly increased with increase in the level of FYM and it was the highest of 734.02 ppm at 30 t FYM.

At 9 MAP, Fe content was the highest of 745.40 ppm at 0:100 proportion which was on par with all other proportions, except 100:0 proportion.

The interaction effect of FYM and its substitution with fertiliser in different proportions as well as control *vs* rest was not statistically significant at any stage.

Manganese

Mn content decreased till 6 MAP and increased later. It decreased with increase in the level of FYM in most of the stages and it was significant at 3 and 6 MAP and at harvest. At 3 MAP, the extreme levels (10 t and 30 t ha^{-1}) were

Table 4.4.20. Effect of FYM and proportion of FYM and fertiliser on the content of micronutrients in *Curculigo orchioides* rhizome (ppm)

Nutrient	Fe				Mn				Zn				Cu			
	3 MAP	6 MAP	9 MAP	Harvest	3 MAP	6 MAP	9 MAP	Harvest	3 MAP	6 MAP	9MAP	Harvest	3 MAP	6 MAP	9 MAP	Harvest
FYM (t ha^{-1})																
10	307.38	1299.5	374.42	1452.2	119.14	93.96	80.68	110.90	59.40	56.24	61.68	77.78	77.68	19.60	57.22	69.00
20	282.02	1302.1	545.82	1107.9	110.92	90.74	97.22	106.12	47.74	66.52	65.86	65.06	102.54	20.88	51.76	65.90
30	367.74	1067.0	734.02	1016.4	108.10	53.44	96.64	97.52	53.10	59.12	73.42	95.50	72.38	27.22	69.26	108.32
SEm	29.288	120.32	59.162	123.16	2.306	2.096	3.488	2.096	5.085	7.349	3.748	7.493	9.283	3.892	3.623	14.17
$CD_{(0.05)}$	NS	NS	178.32	NS	6.951	6.319	NS	6.319	NS	NS	NS	22.584	NS	NS	NS	NS
FYM:Fert																
100:0	340.50	1266.1	371.72	1537.3	111.87	80.63	82.03	100.23	63.20	54.73	66.23	61.13	69.33	26.93	58.20	96.23
75:25	329.13	1266.5	551.40	906.1	113.00	81.13	86.40	99.30	43.56	56.07	61.60	73.83	66.93	15.53	49.47	57.37
50:50	423.13	1234.0	534.20	1071.7	116.47	95.57	94.47	108.43	75.80	64.40	62.57	121.80	122.17	25.13	48.07	68.11
25:75	322.43	1343.5	554.40	1136.3	109.40	92.40	88.07	104.63	47.20	71.07	66.33	68.43	85.37	16.26	61.40	100.23
0:100	278.03	1004.1	745.40	1309.3	112.87	97.17	106.60	110.63	37.30	56.87	78.23	73.03	77.20	28.97	79.93	83.40
SEm	32.361	155.32	76.377	153.18	2.977	2.704	4.503	2.706	7.495	9.156	4.838	9.673	12.156	4.467	4.214	19.43
$CD_{(0.05)}$	NS	NS	230.22	NS	NS	8.152	13.573	8.158	22.591	NS	NS	29.156	NS	NS	NS	NS
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Control	238.40	1767.0	417.80	1061.0	131.50	99.10	77.40	98.10	62.20	78.80	57.00	59.70	45.60	49.60	58.60	180.70
Rest	319.05	1222.9	551.42	1192.2	112.72	89.38	91.51	104.85	83.41	60.63	66.99	79.45	84.20	22.57	59.41	81.07
Control x Rest	NS	NS	NS	NS	*	*	NS	NS	NS	*	NS	*	**	**	NS	**
G. Mean	314.01	1256.9	543.07	1183.9	113.89	89.99	90.63	104.43	53.96	61.76	66.36	78.21	81.71	23.94	59.36	87.30

significantly different from each other but statistically on par with the adjacent level. At 6 MAP, it was significantly lower (53.44 ppm) at 30 t FYM than at the lower levels of FYM.

At 6 and 9 MAP and at harvest, Mn content was the highest at 0:100 proportion followed by 50:50 proportion.

None of the interaction of FYM and its substitution with fertiliser in different proportions was statistically significant. However, the control was inferior to the rest of the treatments till 6 MAP and the reverse afterwards in Mn content.

Zinc

At harvest, Zn content was the highest of 95.50 ppm at 30 t FYM, which was superior to 20 t FYM.

At 3 MAP, Zn content was the highest of 75.80 ppm at 50:50 proportion, followed by 100:0 and 25:75 proportions, which were on par. At harvest, Zn content was the highest of 121.80 ppm at 50:50 proportion, which was superior to all other proportions.

The interaction effect of FYM and its substitution with fertiliser in different proportions was not significant at any stage. At harvest, the control was significantly inferior to the rest of the treatments in Zn.

Copper

Copper content in rhizome was little influenced by the treatments. However at 3 MAP and at harvest, the control was significantly inferior to the rest of the treatments in Cu content.

4.4.6.2 Shoot

4.4.6.2.1 Major nutrients

Effect of FYM and proportion of FYM and fertiliser on the content of major nutrients in *C. orchioides* shoot is presented in Table 4.4.21 and the interaction effect in Table 4.4.23.

Table 4.4.21. Effect of FYM and proportion of FYM and fertiliser on the content of major nutrients in *Curculigo orchioides* shoot (%)

Treatment	N			P			K		
	3MAP	6 MAP	9 MAP	3 MAP	6 MAP	9 MAP	3 MAP	6 MAP	9 MAP
FYM	(t ha^{-1})								
0	1.759	1.959	1.791	0.220	0.183	0.342	2.800	2.175	1.413
10	1.723	2.064	1.658	0.246	0.220	0.275	2.792	2.310	1.508
20	2.048	2.147	1.729	0.264	0.232	0.248	2.880	2.315	1.640
30	2.076	2.110	1.686	0.207	0.232	0.301	2.504	2.330	1.750
SEm	0.049	0.020	0.005	0.011	0.005	0.005	0.721	0.058	0.052
$CD_{(0.05)}$	0.147	0.061	0.016	0.034	NS	0.016	NS	NS	0.157
FYM:Fert									
100:0	1.922	2.132	1.796	0.246	0.254	0.254	2.467	2.417	1.488
75:25	2.109	2.138	1.611	0.297	0.240	0.293	2.880	2.167	1.671
50:50	1.879	2.109	1.677	0.207	0.236	0.281	2.440	2.317	1.608
25:75	1.759	2.055	1.636	0.240	0.214	0.279	2.880	2.317	1.713
0:100	2.075	2.103	1.734	0.200	0.197	0.266	2.960	2.375	1.683
SEm	0.063	0.026	0.007	0.015	0.006	0.007	0.263	0.075	0.067
$CD_{(0.05)}$	0.189	NS	0.020	0.044	0.019	0.021	NS	NS	NS
Interaction	NS	NS	**	NS	NS	**	NS	NS	NS
Control	1.759	1.959	1.791	0.220	0.183	0.342	2.800	2.175	1.413
Rest	1.949	2.107	1.691	0.238	0.228	0.275	2.725	2.318	1.633
ConxRest	*	**	**	NS	*	**	NS	NS	NS
G. Mean	1.937	2.098	1.697	0.237	0.222	0.279	2.730	2.309	1.619

Table 4.4.22. Effect of FYM and proportion of FYM and fertiliser on the content of secondary nutrients in *Curculigo orchioides* shoot (%)

Treatment	Ca			Mg			S	
	3 MAP	6 MAP	9 MAP	3 MAP	6 MAP	9 MAP	6 MAP	9 MAP
FYM (t ha^{-1})								
0	0.667	0.946	0.964	0.437	0.532	0.271	0.344	0.189
10	0.890	0.979	1.082	0.447	0.549	0.335	0.288	0.153
20	0.912	0.868	1.152	0.498	0.508	0.324	0.302	0.169
30	0.974	0.973	1.128	0.495	0.455	0.309	0.220	0.192
SEm	0.050	0.043	0.006	0.032	0.024	0.003	0.020	0.003
$CD_{(0.05)}$	NS	NS	0.019	NS	0.072	0.008	0.062	0.011
FYM:Fert								
100:0	0.971	0.827	1.192	0.511	0.642	0.319	0.252	0.169
75:25	0.968	0.914	1.058	0.491	0.526	0.365	0.325	0.181
50:50	0.972	0.968	1.156	0.487	0.526	0.315	0.247	0.160
25:75	0.889	0.979	1.063	0.469	0.457	0.302	0.290	0.158
0:100	0.826	1.012	1.134	0.442	0.369	0.312	0.236	0.189
SEm	0.064	0.056	0.008	0.041	0.031	0.003	0.026	0.005
$CD_{(0.05)}$	NS	NS	0.024	NS	0.093	0.010	0.079	0.014
Interaction	NS	NS	**	NS	**	**	**	**
Control	0.667	0.946	0.964	0.437	0.532	0.271	0.344	0.189
Rest	0.925	0.940	1.121	0.480	0.504	0.323	0.270	0.171
Con x Rest	*	NS	**	NS	NS	**	NS	*
G. Mean	0.909	0.934	1.111	0.477	0.514	0.319	0.275	0.172

Table 4.4.23. Interaction effect of FYM and proportion of FYM and fertiliser on the content of nutrients in *Curculigo orchioides* shoot (%)

FYM (t/ha)	Proportion of FYM:Fertiliser (%)					SEm	$CD_{(0.05)}$
	100:0	75:25	50:50	25:75	0:100		
	N at 9 MAP						
10	1.667	1.544	1.683	1.652	1.745	0.012	0.035
20	1.961	1.574	1.776	1.559	1.776		
30	1.760	1.714	1.574	1.698	1.683		
	P at 9 MAP						
10	0.319	0.319	0.350	0.187	0.202	0.012	0.036
20	0.194	0.296	0.275	0.264	0.210		
30	0.249	0.264	0.218	0.387	0.387		
	Ca at 9 MAP						
10	1.085	0.938	1.112	1.286	0.991	0.014	0.042
20	1.179	1.246	1.273	0.951	1.112		
30	1.313	0.991	1.085	0.951	1.300		
	Mg at 6 MAP						
10	0.594	0.573	0.512	0.532	0.532	0.053	0.161
20	0.635	0.369	0.635	0.430	0.471		
30	0.696	0.635	0.430	0.410	0.102		
	Mg at 9 MAP						
10	0.350	0.370	0.343	0.271	0.343	0.006	0.018
20	0.317	0.383	0.298	0.291	0.330		
30	0.291	0.343	0.304	0.343	0.264		
	S at 6 MAP						
10	0.287	0.224	0.253	0.412	0.264	0.046	0.138
20	0.277	0.524	0.248	0.290	0.172		
30	0.193	0.227	0.240	0.170	0.272		
	S at 9 MAP						
10	0.140	0.159	0.150	0.138	0.180	0.008	0.024
20	0.178	0.161	0.162	0.172	0.172		
30	0.191	0.223	0.167	0.164	0.215		

Nitrogen

Nitrogen content in shoot, in general, increased first and then decreased. It increased with increase in FYM level. At 3 MAP, It was the highest of 2.076 per cent at 30 t FYM which was on par with 20 t but superior to 10 t FYM. At 6 MAP, N content was the highest of 2.147 per cent at 20 t FYM which was on par with 30 t but superior to 10 t FYM. At 9 MAP, the N content in shoot was the highest of 1.729 per cent at 20 t FYM, which was superior to the other two lower levels.

At 3 MAP, N content was the highest of 2.109 per cent at 75:25 proportion which was on par with 0:100 and 100:0 proportions but superior to 50:50 and 25:75 proportions. At 6 MAP, P content in shoot decreased with increase in the proportion of fertiliser and it was the highest of 0.254 per cent at 100:0 proportion which was on par with 75:25 and 50:50 proportions but superior to 25:75 and 0:100 proportions. At 9 MAP, N content was the highest of 1.796 per cent at 100:0 proportion, which was superior to all other proportions.

The interaction effect was significant at 9 MAP alone wherein it showed the highest N content of 1.961 per cent at 20 t FYM and 100:0 proportion, which was superior to all other treatment combinations.

The control was significantly inferior to the rest of the treatments in N at 3 and 6 MAP.

Phosphorus

Phosphorus content increased with increasing level of FYM and it was significantly evident at 9 MAP. At 3 MAP, P content in shoot was the highest of 0.264 per cent at 20 t FYM which was on par with 10 t but superior to 30 t FYM. At 9 MAP, The P content in shoot was the highest of 0.301 per cent at 30 t FYM, which was superior to the other two lower levels.

P content was the highest at 75:25 proportion at 3 and 9 MAP while it was on par with the highest value at 6 MAP.

The interaction effect was significant at 9 MAP alone wherein it showed the highest P content of 0.387 per cent both at 25:75 and 0:100 proportions at 30 t FYM that were superior to all other treatment combinations.

The control was significantly inferior to the rest of the treatments in P at 3 and 6 MAP and the reverse at 9 MAP.

Potassium

K content increased with increase in the FYM level and it was significant at 9 MAP wherein the highest K content was 1.750 per cent at 30 t FYM.

K content in shoot at any stage was not influenced by the substitution of FYM with fertiliser in different proportions or the interaction of FYM and proportion of FYM and fertiliser.

4.4.6.2.2 Secondary nutrients

Effect of FYM and proportion of FYM and fertiliser on the content of secondary nutrients in *C. orchioides* shoot is presented in Table 4.4.22 and the interaction effect in Table 4.4.23.

Calcium

Calcium content increased with advancement in growth stage of the plant. FYM significantly influenced Ca content at 9 MAP alone when it was the highest of 1.152 per cent at 20 t FYM which was superior to the other two levels.

At 9 MAP, Ca was the highest of 1.192 per cent at 100:0 proportion which was superior to all other proportions.

The interaction effect at 9 MAP, showed the highest Ca content of 1.313 per cent at 30 t and 100:0 proportion followed by 1.300 per cent at 0:100 proportion at the same FYM level.

The control was significantly inferior to the rest of the treatments in Ca at 3 and 9 MAP.

Magnesium

Magnesium content in the shoot first increased and then decreased. It significantly decreased with increase in the level of FYM at 6 and 9 MAP. At 6 MAP, the extreme levels (10 t and 30 t) of FYM were significantly different but on par with the adjacent level. At 9 MAP, Mg content in the shoot significantly decreased with each increase in the FYM level and it was the highest of 0.335 per cent at 10 t FYM.

At 6 MAP, Mg content in shoot was the highest of 0.642 per cent at 100:0 proportion, which was superior to all other proportions. At 9 MAP, Mg content was the highest of 0.365 per cent at 75:25 proportion which was superior to all other proportions.

The interaction effect at 6 MAP, showed the highest Mg content of 0.696 per cent at 30 t FYM and 100:0 proportion followed by 0.635 per cent recorded by three treatment combinations (30 t and 75:25; 20 t and 100:0 and 20 t and 50:50 proportions) which were on par.

At 9 MAP, The control was significantly inferior to the rest of the treatments in Mg.

Sulphur

At 6 MAP, S content was the highest of 0.302 per cent at 20 t FYM which was on par with 10 t FYM but superior to 30 t FYM. At 9 MAP, S content increased significantly at each level of FYM and it was the highest of 0.192 per cent at 30 t FYM.

S content was the highest or on par with the highest value at 75:25 proportion at 6 and 9 MAP.

The interaction effect at 6 MAP, showed the highest S content of 0.524 per cent at 20 t FYM and 75:25 proportion which was on par with 10 t and 25:75 proportions but superior to all other treatment combinations. At 9 MAP, The interaction effect showed the highest S content of 0.223 per cent at 30 t FYM and 75:25 proportion which was on par with 0:100 proportion at the same FYM level but superior to all other treatment combinations.

At 9 MAP, The control was significantly inferior to the rest of the treatments in S.

4.4.6.2.3 Micronutients

Effect of FYM and proportion of FYM and fertiliser on the content of micronutrients in *C. orchioides* shoot is presented in Table 4.4.24.

Table 4.4.24. Effect of FYM and proportion of FYM and fertiliser on the content of micronutrients in *Curculigo orchioides* shoot (ppm)

Nutrient	Fe			Mn			Zn			Cu		
	3 MAP	6 MAP	9 MAP	3 MAP	6 MAP	9 MAP	3 MAP	6 MAP	9 MAP	3 MAP	6 MAP	9 MAP
FYM (t ha^{-1})												
0	651.00	3230.0	2646.00	224.80	348.30	404.00	60.50	56.20	70.90	66.00	85.10	146.20
10	839.30	3587.8	3020.40	230.50	355.86	447.70	17.48	47.38	72.34	73.20	81.62	129.90
20	844.44	3799.0	2839.20	243.04	378.66	464.96	21.06	46.60	71.72	72.80	80.42	95.60
30	913.00	3691.8	3056.40	194.92	359.42	457.46	21.86	44.82	68.58	101.14	60.04	138.02
SEm	26.571	100.57	142.84	10.685	11.214	5.199	1.492	2.282	3.373	11.642	10.556	12.159
$CD_{(0.05)}$	NS	NS	NS	32.206	NS	NS	NS	NS	NS	NS	NS	NS
FYM:Fert												
100:0	839.16	3617.2	3122.66	203.40	309.97	399.23	24.13	43.97	83.20	77.80	76.73	149.10
75:25	857.80	3731.0	2584.66	224.50	320.87	404.47	26.00	46.13	57.37	75.33	84.63	87.87
50:50	821.77	4054.0	3203.66	220.30	394.80	488.90	17.90	48.50	72.57	119.70	70.73	110.73
25:75	925.57	3710.3	3164.33	241.37	375.60	477.00	14.67	47.97	69.50	65.50	72.43	121.13
0:100	883.00	3297.0	2784.66	224.53	422.00	513.93	17.97	44.77	71.77	70.57	65.60	137.03
SEm	39.841	129.84	184.41	12.147	13.794	6.712	3.849	3.946	4.354	13.627	12.124	15.697
$CD_{(0.05)}$	NS	391.36	NS	NS	41.578	20.231	11.603	NS	NS	41.076	NS	NS
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Control	651.00	3230.0	2646.00	224.80	348.30	404.00	60.50	56.20	70.90	66.00	85.10	146.20
Rest	865.58	3692.9	2972.00	222.82	364.65	456.71	20.13	46.27	70.88	82.38	74.03	121.17
Control x Rest	*	*	NS	NS	NS	*	**	*	NS	NS	NS	NS
G. Mean	852.17	3663.9	2951.63	22.94	363.62	453.41	22.66	46.89	70.88	81.36	74.72	122.74

Iron

Iron content was the highest at 30 t FYM in most of the stages though not significant.

At 6 MAP, Fe content was the highest of 4054 ppm at 50:50 proportion which was on par with 75:25 and 25:75 proportions but superior to 0:100 and 100:0 proportions.

The interaction effect of FYM and its substitution with fertiliser in different proportions was not significant at any stage. The control was significantly inferior to the rest of the treatments in Fe.

Manganese

Manganese content in the shoot increased over the period. It was the highest at 20 t FYM and it was significant at 3 MAP.

Mn content was the highest at 0:100 proportion at 6 and 9 MAP.

The interaction effect of FYM and its substitution with fertiliser in different proportions was not significant at any stage. At 9 MAP, The control was significantly inferior to the rest of the treatments in Mn.

Zinc

Zinc content in the shoot increased over the period. FYM had little effect on Zn content.

At 3 MAP, Zn content was the highest of 26.00 per cent at 75:25 proportion followed by 24.13 per cent at 100:0 proportion which were superior to 25:75 proportion.

The interaction effect of FYM and its substitution with fertiliser in different proportions was not significant at any stage. The control was superior to the rest of the treatments in Zn at all stages.

Copper

Copper content in shoot was not significantly influenced by FYM levels at any stage. The substitution of FYM with fertiliser in different proportions was significant at 3 MAP alone wherein 50:50 proportion recorded the highest Cu content. The interaction effect of FYM and its substitution with fertiliser in different proportions as well as control *vs* rest was not significant at any stage.

4.4.7 Nutrient Ratios

4.4.7.1 Rhizome

Effect of FYM and proportion of FYM and fertiliser on nutrient ratios of *C. orchioides* rhizome at 6 MAP is furnished in Table 4.4.25. The nutrient ratios showed considerable variations due to FYM levels and proportion of FYM and fertilizer. All ratios were the highest at 20 t FYM, except Cu/K which showed little variation. In the case of proportion of FYM and fertilizer 25:75 proportion recorded the highest values for (Ca+Mg)/K and Fe/K. The ratios of Mn/K and Zn/K slightly increased with increase in the proportion of fertilizer while Cu/K ratio showed little variation. The control values were higher for the ratios of Fe/K, Zn/K and Cu/K than the rest of the treatments and the reverse for (Ca+Mg)/K.

4.4.7.2 Shoot

Effect of FYM and proportion of FYM and fertiliser on nutrient ratios of *C. orchioides* shoot at 6 MAP is furnished in Table 4.4.26. In general, nutrient ratios showed less variation in the shoot. The ratios Fe/K and Mn/K showed highest values at 20 t FYM, while (Ca+Mg)/K and Cu/K ratios were highest at 10 t FYM. Zn/K ratio showed no variation. The ratio (Ca+Mg)/K was the highest of 0.66 at 75:25 proportion while Fe/K was the highest at 50:50 proportion. Mn/K ratio slightly increased with increase in the proportion of fertilizer while Zn/K and Cu/K ratios showed little variation due the proportion of FYM and fertilizer. The control value was higher for (Ca+Mg)/K ratio, lower for Fe/K and similar with the rest of the treatments for Mn/K, Zn/K and Cu/K.

4.4.8 Nutrient Uptake

Effect of FYM and proportion of FYM and fertiliser on uptake of nutrients by *C. orchioides* at 6 MAP is presented in Table 4.4.27. FYM levels significantly influenced K and Mg uptake while the substitution of FYM with fertiliser in different proportions affected Mg and S uptake with no significant interactions for any of the nutrients. K uptake was the highest of 3.972 kg ha^{-1} at 10 t ha^{-1} FYM that was superior to the other two higher levels. Mg uptake was the highest of

Table 4.4.25. Effect of FYM and proportion of FYM and fertiliser on nutrient ratios of *Curculigo orchioides* rhizome at 6 MAP

Treatment	(Ca+Mg)/K	Fe/K	Mn/K	Zn/K	Cu/K
FYM (t ha^{-1})					
10	1.65	0.191	0.014	0.008	0.003
20	1.78	0.210	0.015	0.011	0.003
30	1.73	0.169	0.008	0.009	0.004
FYM:Fert					
100:0	1.73	0.192	0.012	0.008	0.004
75:25	1.79	0.205	0.013	0.009	0.003
50:50	1.68	0.188	0.015	0.010	0.004
25:75	1.89	0.218	0.015	0.012	0.003
0:100	1.50	0.151	0.015	0.009	0.004
Control	1.57	0.248	0.014	0.011	0.007
Rest	1.71	0.191	0.014	0.008	0.003
G.Mean	1.70	0.210	0.015	0.011	0.003

Table 4.4.26. Effect of FYM and proportion of FYM and fertiliser on nutrient ratios of *Curculigo orchioides* shoot at 6 MAP

Treatment	(Ca+Mg)/K	Fe/K	Mn/K	Zn/K	Cu/K
FYM (t ha^{-1})					
10	0.66	0.155	0.015	0.002	0.004
20	0.59	0.164	0.016	0.002	0.003
30	0.61	0.158	0.015	0.002	0.003
FYM:Fert					
100:0	0.61	0.150	0.013	0.002	0.003
75:25	0.66	0.172	0.015	0.002	0.004
50:50	0.64	0.175	0.017	0.002	0.003
25:75	0.62	0.160	0.016	0.002	0.003
0:100	0.58	0.139	0.018	0.002	0.003
Control	0.68	0.149	0.016	0.003	0.004
Rest	0.62	0.159	0.016	0.002	0.003
G. Mean	0.63	0.155	0.015	0.002	0.004

Table 4.4.27. Effect of levels of FYM and proportions of FYM and fertiliser on uptake of nutrients at 6 MAP (kg ha^{-1})

Treatment	N	P	K	Ca	Mg	S	Fe	Mn	Zn	Cu
FYM (t ha^{-1})										
10	482.92	63.31	397.18	329.73	85.11	61.81	67.18	5.87	1.78	1.30
20	439.45	57.40	333.43	267.23	70.53	54.97	60.17	5.25	1.70	1.15
30	488.66	58.12	378.29	289.48	81.20	56.22	61.30	4.97	1.66	1.19
SEm	2.430	0.742	5.754	3.235	1.271	0.320	0.225	0.011	0.011	0.012
$CD_{(0.05)}$	NS	NS	*	NS	*	NS	NS	NS	NS	NS
FYM:Fert										
100:0	468.11	64.20	368.83	284.06	98.48	46.13	61.09	4.64	1.58	1.30
75:25	448.38	60.87	338.86	301.76	66.56	56.41	62.47	4.80	1.60	1.15
50:50	458.88	63.82	374.48	304.40	75.46	57.64	67.28	6.05	1.82	1.25
25:75	456.79	54.70	351.42	294.11	76.92	68.55	63.32	5.55	1.87	1.04
0:100	524.65	54.24	413.99	291.59	75.47	59.40	59.15	6.92	1.70	1.36
SEm	4.163	1.204	9.554	6.347	1.461	0.532	0.375	0.017	0.019	0.018
$CD_{(0.05)}$	NS	NS	NS	NS	4.389	1.598	NS	NS	NS	NS
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Control	302.59	32.93	285.81	238.68	54.89	56.15	53.48	4.34	1.68	1.46
Rest	471.34	59.65	369.26	294.81	79.10	58.01	62.90	5.57	1.72	1.22
Control x Rest	**	**	*	*	**	NS	*	NS	NS	NS
G.Mean	459.42	57.37	363.80	290.93	78.30	58.06	62.35	5.49	1.72	1.24

0.851 kg ha^{-1} at 10 t FYM that was superior to the other two levels of FYM. It was the highest of 98.48 kg ha^{-1} at 100:0 proportion, which was superior to all other proportions. S uptake was the highest of 0.685 kg ha^{-1} at 25:75 proportion, which was superior to all other proportions. The control was significantly inferior to the rest of the treatments in N, P, K, Ca, Mg and Fe uptake.

4.4.9 Soil Characteristics

Effect of FYM and proportion of FYM and fertiliser on soil characteristics after the harvest of *C. orchioides* is furnished in Table 4.4.28 and the interaction effect in Table 4.4.29. While the pH and available major and secondary nutrients were influenced by the treatments none of the available micronutrients were significantly affected.

The soil pH after the harvest of the crop decreased with increase in the level of FYM. Soil pH was the highest of 5.79 at 30 t ha^{-1} FYM which was superior to the other two lower levels that were on par. It was the highest of 6.00 at 25:75 proportion which was on par with 75:25 proportion but superior to the other proportions.

The available N content in soil significantly decreased with each increase in the FYM level and it was the highest of 198.04 ppm at 10 t FYM. It was the highest of 178.76 ppm at 75:25 proportion, which was superior to all other proportions. The interaction effect showed the highest available N content of 217.45 ppm, which was superior to all other treatment combinations.

The available P content in soil increased significantly with increase in FYM level. It was the highest of 16.82 ppm at 30 t FYM. It was the highest of 16.11 ppm which was on par with 100:0 and 75:25 proportions but superior to 25:75 and 0:100 proportions. The interaction effect showed the highest available P content of 24.46 ppm at 20 t FYM and 50:50 proportion which was on par with 100:0 proportion both at 20 t and 30 t FYM but superior to all other treatment combinations.

The available K content in soil was the highest of 134.67 ppm at 0:100 proportion which was superior to all other proportions that were on par. The interaction effect showed the highest available K content of 136.00 ppm at 20 t

Table 4.4.28. Effect of FYM and proportion of FYM and fertiliser on soil characteristics after the harvest of *Curculigo orchioides*

Treatment	pH	N (ppm)	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	S (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)
FYM (t ha^{-1})											
10	5.95	198.04	7.07	116.60	142.04	39.84	67.32	22.63	13.43	1.39	4.10
20	5.92	165.25	15.76	120.20	149.43	43.05	78.80	22.40	13.01	1.95	4.29
30	5.79	151.39	16.82	117.80	159.69	46.23	77.23	16.23	14.00	2.53	4.46
SEm	0.002	0.598	0.463	1.779	2.925	2.029	1.707	1.970	1.023	0.008	0.019
$CD_{(0.05)}$	0.006	1.802	1.395	NS	8.815	NS	5.146	NS	NS	NS	NS
FYM : Fert											
100:0	5.86	170.14	15.53	111.33	190.45	28.92	64.79	21.83	12.87	1.83	4.10
75:25	5.94	178.76	14.86	112.67	161.15	52.49	69.14	19.34	14.53	1.87	4.57
50:50	5.87	172.54	16.11	110.67	139.06	51.40	71.32	20.94	14.35	2.22	4.29
25:75	6.00	172.82	11.27	112.00	136.73	39.62	83.06	23.23	13.31	1.77	4.15
0:100	5.79	163.55	8.31	134.67	124.53	42.77	83.93	16.75	12.34	2.080	4.30
SEm	0.003	0.772	0.598	2.297	3.776	2.620	2.204	2.149	1.089	0.012	0.021
$CD_{(0.05)}$	0.008	2.327	1.801	6.924	11.380	7.897	6.644	NS	NS	NS	NS
Int	NS	**	**	**	**	**	**	NS	NS	NS	NS
Control	5.94	178.05	4.13	106.00	117.20	32.13	40.39	23.36	16.92	1.29	4.91
Rest	5.89	171.56	13.22	118.07	150.38	43.04	74.45	20.42	13.48	1.95	4.28
Cx Rest	**	**	**	**	**	**	**	NS	NS	NS	NS
Mean	5.89	171.96	12.65	117.31	148.31	41.36	72.32	20.60	13.70	1.91	4.32

Table 4.4.29. Interaction effect of FYM and proportion of FYM and fertiliser on soil characteristics after the harvest of *Curculigo orchioides* (ppm)

FYM (t/ha)	Proportion of FYM:Fertiliser (%)					SEm	$CD_{(0.05)}$
	100:0	75:25	50:50	25:75	0:100		
	N						
10	197.75	217.45	200.66	195.56	178.78	1.337	4.030
20	180.23	156.16	162.67	193.38	133.83		
30	132.44	162.67	154.29	129.52	178.05		
	P						
10	2.82	7.65	8.24	8.05	8.58	1.035	3.120
20	21.76	16.94	24.46	9.76	5.88		
30	21.99	19.99	15.64	16.00	10.47		
	K						
10	109.00	104.00	126.00	126.00	116.00	3.979	11.992
20	114.00	136.00	106.00	111.00	134.00		
30	111.00	98.00	100.00	126.00	154.00		
	Ca						
10	146.50	183.13	124.18	146.50	109.88	6.539	19.712
20	234.40	146.50	131.85	109.88	124.53		
30	190.45	153.83	161.15	153.83	139.18		
	Mg						
10	35.34	35.34	44.98	38.55	44.98	4.538	13.678
20	16.06	48.19	44.98	64.25	41.77		
30	35.34	73.95	64.25	16.07	41.57		
	S						
10	53.49	69.15	74.36	66.54	73.06	3.818	11.507
20	83.49	82.19	83.49	82.19	62.62		
30	57.40	56.10	56.10	100.45	116.11		

FYM and 75:25 proportion which was followed by 134.00 ppm at 20 t and 0:100 proportions which were on par.

The available Ca content in soil increased with increase in FYM level. It was the highest of 159.69 ppm at 30 t FYM that was superior to the other two lower levels that were on par. It was the highest of 190.45 ppm at 100:0 proportion, which was superior to all other proportions. The interaction effect showed the highest available Ca content of 234.40 ppm at 20 t FYM and 100:0 proportion that was superior to all other treatment combinations.

The available Mg content was the highest of 52.49 ppm at 75:25 proportion which was on par with 50:50 proportion but superior to all other proportions. The interaction effect showed the highest available Mg content of 73.95 ppm at 30 t FYM and 75:25 proportion which was on par with 50:50 proportion at the same FYM level and 25:75 at 20 t FYM but superior to all other treatment combinations.

The available S content was the highest of 78.80 ppm at 20 t FYM which was on par with 30 t FYM but superior to 10 t FYM. It was the highest of 83.93 ppm at 0:100 proportion which was on par with 25:75 proportion but superior to all other proportions. The interaction effect showed the highest available S content of 116.11 ppm at 30 t and 0:100 proportion, which was superior to all other treatment combinations.

The control was significantly inferior to the rest of the treatments in available P, K, Ca, Mg and S contents but the reverse in the case of available N and pH.

4.5 EXPERIMENT 5 EFFECT OF MULCH AND SOURCES OF NUTRIENTS ON YIELD AND QUALITY OF *CURCULIGO ORCHIOIDES*

4.5.1 Growth Parameters

4.5.1.1 Plant Height

Effect of mulch and nutrient sources on plant height of *C. orchioides* is furnished in Table 4.5.1. In general, the plant height steadily increased from 8.18 cm to 15.11 cm at maximum vegetative growth phase and decreased thereafter. The height of *C. orchioides* was higher in mulched plots and the effect was

Table 4.5.1. Effect of mulch and nutrient sources on height of *Curculigo orchioides* (cm)

MAP	1	2	3	4	5	6	7	8
Mulch								
No mulch	8.17	8.68	9.78	10.33	10.31	14.26	13.07	9.09
Mulch	8.20	9.26	11.46	11.45	12.34	15.96	15.37	11.36
SEm	0.206	0.291	0.269	0.286	0.449	0.356	0.328	0.415
Significance	NS	NS	**	**	**	**	**	**
Nutrient source								
Control	8.48	9.16	9.06	10.53	10.48	14.13	12.70	8.91
FYM	8.13	8.23	10.77	11.32	10.16	15.69	14.42	11.79
Vermicompost	9.30	8.44	9.81	9.89	10.50	15.15	14.18	10.05
Poultry Manure	7.05	7.97	10.35	11.26	10.96	16.18	15.51	10.25
FYM+Azotobacter	8.20	9.10	9.75	10.48	11.63	15.39	14.21	10.16
FYM+Phosphobacter	8.25	9.86	10.89	11.36	11.46	10.01	15.47	10.77
FYM+VAM	7.80	8.66	11.75	11.63	13.28	15.53	13.33	10.32
NPK	7.73	9.06	10.64	10.26	12.08	13.80	13.92	9.59
SEm	0.438	0.617	0.571	0.606	0.898	0.711	0.655	0.830
$CD_{(0.05)}$	NS	NS	1.642	NS	NS	NS	NS	NS
Interaction	NS	NS	NS	NS	NS	NS	NS	NS
G. Mean	8.18	8.97	10.62	10.89	11.32	15.11	14.22	10.23

Table 4.5.2. Effect of mulch and nutrient sources on leaf production in *Curculigo orchioides* (no. $sucker^{-1}$)

MAP	1	2	3	4	5	6	7	8
Mulch								
No mulch	1.69	3.45	4.61	4.22	4.43	5.16	3.22	1.86
Mulch	1.81	3.72	4.31	4.04	4.71	5.29	3.12	1.79
SEm	0.068	0.117	0.123	0.135	0.127	0.147	0.116	0.098
Significance	NS	NS	NS	NS	NS	NS	NS	NS
Nutrient source								
Control	1.83	3.23	4.47	3.90	4.17	4.90	2.57	1.74
FYM	1.50	3.53	4.23	4.53	3.93	5.13	3.23	1.98
Vermicompost	1.97	3.03	4.60	4.20	4.57	5.50	2.93	2.00
Poultry Manure	1.40	3.43	4.37	3.83	4.83	5.13	3.40	2.16
FYM+Azotobacter	1.93	3.67	4.20	4.03	4.93	5.24	2.93	1.40
FYM+Phosphobacter	1.70	3.33	3.97	4.27	4.73	5.60	3.60	1.64
FYM+VAM	1.90	3.40	4.43	4.10	4.57	5.37	3.23	2.04
NPK	1.53	3.83	4.87	4.13	4.83	4.93	3.43	1.65
SEm	0.144	0.249	0.261	0.285	0.255	0.294	0.232	0.196
$CD_{(0.05)}$	NS	NS	NS	NS	NS	NS	NS	NS
Interaction	NS	NS	NS	NS	NS	NS	NS	NS
G. Mean	1.75	3.59	4.46	4.13	4.57	5.23	3.17	1.83

significant during most of the months. It was not influenced by nutrient sources except at 3 MAP. At 3 MAP, plant height was the maximum of 11.75 cm in FYM + VAM, followed by 10.89 cm in FYM + phosphobacter and the least in the control (9.06 cm). Interaction of mulch and nutrient sources was not significant.

4.5.1.2 Number of Leaves

Effect of mulch and nutrient sources on leaf production in *C. orchioides* is presented in Table 4.5.2. In general, the number of leaves per sucker increased from 1.75 to 5.23 at 6 MAP and decreased later. The number of leaves per sucker in *C. orchioides* was not significantly influenced by mulch, nutrient sources or their interaction.

4.5.1.3 Canopy Spread

Effect of mulch and nutrient sources on canopy spread of *C. orchioides* is given in Table 4.5.3. In general, canopy spread increased from 2.21 cm to 15.43 cm at 7 MAP and drastically reduced afterwards. It was significantly influenced by mulch at 5, 6 and 7 MAP and by nutrient sources at 3 MAP but not by the interaction of mulch and nutrient sources at any month. Mulch increased the canopy spread in most of the months and the increase was significant at 5, 6 and 7 MAP. At 3 MAP, FYM + VAM resulted in the highest canopy spread which was on par with all other nutrient sources but superior to the control.

4.5.1.4 Number of Suckers

Effect of mulch and nutrient sources on sucker production in *C. orchioides* is furnished in Table 4.5.4. Suckers were produced in *C. orchioides* from 4 MAP only. Number of suckers per plant increased to 1.82 at 6 MAP and later decreased to 1.52 at 8 MAP and then reached a maximum of 2.03 at 9 MAP. Number of suckers per plant was higher in mulch treatment in most of the months and the increase was significant at 5 and 8 MAP. Nutrient sources did not influence sucker production. Interaction of mulch and nutrient sources was not significant.

4.5.2 Dry Matter Production

Effect of mulch and nutrient sources on total dry matter production in *C. orchioides* is presented in Table 4.5.9 and the interaction effect in Table 4.5.6. In general, total dry matter increased till 7 MAP and decreased thereafter. It was

Table 4.5.3. Effect of mulch and nutrient sources on canopy spread of *Curculigo orchioides* (cm)

MAP	1	2	3	4	5	6	7	8
Mulch								
No mulch	2.14	6.32	9.58	9.89	10.78	14.18	14.77	6.28
Mulch	2.29	6.70	10.56	10.51	12.52	15.58	16.09	5.04
SEm	0.131	0.420	0.394	0.363	0.496	0.473	0.456	0.464
Significance	NS	NS	NS	NS	*	*	*	NS
Nutrient source								
Control	2.25	6.35	7.77	10.07	10.65	13.75	14.17	4.61
FYM	1.80	5.21	10.29	10.33	9.49	15.72	15.36	5.89
Vermicompost	2.55	6.79	8.95	9.62	11.20	17.54	15.22	6.42
Poultry Manure	1.70	5.16	10.38	10.84	11.47	15.75	16.31	7.31
FYM+Azotobacter	2.43	6.45	9.27	9.66	13.31	13.57	16.05	3.59
FYM+Phosphobacter	2.25	6.66	10.56	10.47	12.52	14.58	16.65	4.60
FYM+VAM	1.98	6.45	11.00	11.15	10.78	14.77	15.89	6.88
NPK	2.32	6.92	10.03	9.94	13.78	13.38	13.77	6.02
SEm	0.278	0.892	0.837	0.77	0.991	0.946	0.912	0.929
$CD_{(0.05)}$	NS	NS	2.404	NS	NS	NS	NS	NS
Interaction	NS	NS	NS	NS	NS	NS	NS	NS
G. Mean	2.21	6.51	10.07	10.20	11.65	14.88	15.43	5.66

Table 4.5.4. Effect of mulch and nutrient sources on sucker production in *Curculigo orchioides* (no. $plant^{-1}$)

MAP	4	5	6	7	8	9
Mulch						
No mulch	1.23	1.47	1.76	1.61	1.41	2.09
Mulch	1.31	1.70	1.88	1.69	1.63	1.97
SEm	0.052	0.061	0.102	0.067	0.064	0.085
Significance	NS	*	NS	NS	*	NS
Nutrient source						
Control	1.24	1.47	1.80	1.67	1.70	1.90
FYM	1.32	1.73	1.80	1.60	1.33	2.10
Vermicompost	1.24	1.50	1.57	1.73	1.50	1.10
Poultry Manure	1.27	1.63	2.00	1.70	1.53	2.10
FYM+Azotobacter	1.07	1.37	1.71	1.70	1.47	1.97
FYM+Phosphobacter	1.30	1.70	2.00	1.47	1.70	2.37
FYM+VAM	1.31	1.70	1.50	1.60	1.47	2.10
NPK	1.25	1.57	2.20	1.73	1.47	1.77
SEm	0.089	0.120	0.201	0.135	0.127	0.171
$CD_{(0.05)}$	NS	NS	NS	NS	NS	NS
Interaction	NS	NS	NS	NS	NS	NS
G. Mean	1.27	1.58	1.82	1.65	1.52	2.03

Table 4.5.5. Effect of mulch and nutrient sources on root dry matter production in *Curculigo orchioides* (g plant^{-1})

MAP	1	2	3	4	5	6	7	8	9
Mulch									
No mulch	0.010	0.02	0.05	0.047	0.075	0.251	0.274	0.179	0.215
Mulch	0.008	0.02	0.03	0.045	0.085	0.268	0.303	0.201	0.229
SEm	0.002	0.002	0.003	0.003	0.006	0.014	0.017	0.014	0.018
Significance	NS	NS	**	NS	NS	NS	NS	NS	NS
Nutrient source									
Control	0.006	0.01	0.03	0.041	0.064	0.184	0.268	0.143	0.214
FYM	0.004	0.02	0.04	0.054	0.070	0.301	0.289	0.224	0.189
Vermicompost	0.004	0.02	0.04	0.051	0.075	0.226	0.229	0.148	0.193
Poultry Manure	0.008	0.02	0.04	0.045	0.115	0.280	0.356	0.212	0.316
FYM+Azotobacter	0.008	0.02	0.03	0.038	0.087	0.253	0.321	0.197	0.237
FYM+Phosphobacter	0.010	0.02	0.04	0.047	0.090	0.317	0.352	0.246	0.261
FYM+VAM	0.012	0.01	0.04	0.053	0.064	0.270	0.261	0.193	0.201
NPK	0.012	0.02	0.05	0.039	0.075	0.248	0.229	0.159	0.168
SEm	0.004	0.004	0.006	0.007	0.012	0.027	0.033	0.028	0.035
$CD_{(0.05)}$	NS	NS	0.018	NS	NS	0.078	NS	NS	NS
Interaction	NS	*	NS	NS	NS	NS	NS	NS	NS
G. Mean	0.010	0.02	0.04	0.046	0.080	0.260	0.288	0.190	0.222

Table 4.5.6. Interaction effect of mulch and nutrient sources on dry matter production in *Curculigo orchioides* (g plant^{-1})

Mulch	Nutrient source									
	Control	FYM	Vermi compost	Poultry Manure	FYM+ Azoto bacter	FYM+ Phosph obacter	FYM+ VAM	NPK	SEm	$CD_{(0.05)}$
	Root at 2 MAP									
No mulch	0.01	0.01	0.03	0.02	0.02	0.02	0.01	0.02	0.005	0.015
Mulch	0.01	0.03	0.01	0.02	0.02	0.02	0.01	0.02		
	Shoot at 2 MAP									
No mulch	0.08	0.05	0.05	0.05	0.08	0.07	0.04	0.07	0.008	0.023
Mulch	0.05	0.06	0.06	0.06	0.08	0.06	0.08	0.06		
	Total at 6 MAP									
No mulch	0.92	1.39	0.98	1.57	1.17	1.34	1.02	1.16	0.103	0.298
Mulch	1.06	1.17	1.13	1.30	1.04	1.44	1.52	1.31		

Table 4.5.7. Effect of mulch and nutrient sources on rhizome dry matter production in *Curculigo orchioides* (g plant^{-1})

MAP	1	2	3	4	5	6	7	8	9
Mulch									
No mulch	0.096	0.15	0.150	0.192	0.245	0.638	0.770	0.670	0.775
Mulch	0.104	0.14	0.16	0.179	0.284	0.656	0.816	0.870	0.895
SEm	0.008	0.007	0.006	0.123	0.018	0.020	0.029	0.027	0.042
Significance	NS	NS	NS	NS	NS	NS	NS	**	NS
Nutrient source									
Control	0.084	0.14	0.16	0.187	0.278	0.564	0.779	0.650	0.686
FYM	0.086	0.12	0.15	0.204	0.217	0.660	0.818	0.859	0.800
Vermicompost	0.088	0.11	0.15	0.166	0.183	0.541	0.672	0.531	0.692
Poultry Manure	0.092	0.16	0.14	0.165	0.290	0.733	0.915	0.806	0.927
FYM+Azotobacter	0.104	0.15	0.15	0.157	0.322	0.584	0.777	0.884	0.924
FYM+Phosphobacter	0.076	0.16	0.14	0.180	0.239	0.697	0.799	0.930	1.120
FYM+VAM	0.098	0.11	0.14	0.212	0.247	0.721	0.813	0.769	0.902
NPK	0.100	0.16	0.17	0.211	0.340	0.675	0.771	0.730	0.626
SEm	0.018	0.016	0.013	0.025	0.035	0.039	0.057	0.054	0.084
$CD_{(0.05)}$	NS	NS	NS	NS	NS	0.114	NS	0.157	0.244
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS
G. Mean	0.100	0.14	0.16	0.185	0.264	0.647	0.793	0.770	0.835

Table 4.5.8. Effect of mulch and nutrient sources on shoot dry matter production in *Curculigo orchioides* (g plant^{-1})

MAP	1	2	3	4	5	6	7	8	9
Mulch									
No mulch	0.060	0.06	0.08	0.092	0.128	0.297	0.255	0.141	0.124
Mulch	0.060	0.07	0.09	0.096	0.164	0.320	0.269	0.165	0.162
SEm	0.004	0.003	0.004	0.006	0.010	0.017	0.014	0.014	0.010
$CD_{(0.05)}$	NS	NS	NS	NS	*	NS	NS	NS	*
Nutrient source									
Control	0.064	0.07	0.07	0.085	0.115	0.238	0.241	0.114	0.157
FYM	0.052	0.05	0.09	0.094	0.123	0.317	0.269	0.178	0.119
Vermicompost	0.062	0.06	0.07	0.089	0.132	0.291	0.257	0.131	0.144
Poultry Manure	0.048	0.06	0.07	0.105	0.151	0.363	0.279	0.137	0.152
FYM+Azotobacter	0.064	0.08	0.09	0.84	0.167	0.292	0.245	0.214	0.144
FYM+Phosphobacter	0.064	0.06	0.08	0.099	0.169	0.345	0.297	0.146	0.185
FYM+VAM	0.062	0.06	0.09	0.102	0.152	0.310	0.247	0.171	0.130
NPK	0.052	0.06	0.09	0.093	0.158	0.310	0.258	0.134	0.115
SEm	0.008	0.006	0.009	0.011	0.021	0.033	0.028	0.028	0.020
$CD_{(0.05)}$	NS	0.016	NS	NS	NS	NS	NS	NS	NS
Interaction	NS	**	NS	NS	NS	NS	NS	NS	NS
G. Mean	0.060	0.07	0.09	0.094	0.146	0.308	0.262	0.153	0.143

Table 4.5.9. Effect of mulch and nutrient sources on total dry matter production in *Curculigo orchioides* (g plant^{-1})

MAP	1	2	3	4	5	6	7	8	9
Mulch									
No mulch	0.168	0.22	0.286	0.321	0.454	1.194	1.291	0.990	1.102
Mulch	0.172	0.23	0.275	0.322	0.586	1.245	1.388	1.225	1.245
SEm	0.010	0.011	0.010	0.020	0.033	0.037	0.051	0.050	0.046
Significance	NS	NS	NS	NS	**	NS	NS	**	*
Nutrient source									
Control	0.156	0.23	0.245	0.318	0.455	0.989	1.257	0.904	1.059
FYM	0.144	0.20	0.265	0.379	0.502	1.279	1.303	1.263	1.115
Vermicompost	0.154	0.18	0.272	0.300	0.412	1.056	1.157	0.797	1.065
Poultry Manure	0.150	0.24	0.253	0.312	0.584	1.435	1.555	1.191	1.398
FYM+Azotobacter	0.176	0.24	0.273	0.279	0.582	1.104	1.345	1.296	1.146
FYM+Phosphobacter	0.142	0.24	0.267	0.311	0.536	1.391	1.447	1.204	1.368
FYM+VAM	0.162	0.19	0.266	0.329	0.532	1.269	1.389	1.178	1.242
NPK	0.168	0.25	0.300	0.344	0.558	1.234	1.263	1.024	0.993
SEm	0.022	0.023	0.022	0.041	0.066	0.073	0.101	0.099	0.093
$CD_{(0.05)}$	NS	NS	NS	NS	NS	0.211	NS	0.287	0.268
Interaction	NS	NS	NS	NS	NS	*	NS	NS	NS
G. Mean	0.170	0.23	0.281	0.321	0.520	1.219	1.339	1.107	1.173

Table 4.5.10. Effect of mulch and nutrient sources on plant density and weed biomass production in *Curculigo orchioides*

Treatment	Plants m^{-2} (no.)		Suckers m^{-2}	Fresh weed biomass (kg m^{-2})			Dry weed biomass (kg m^{-2})		
	3 MAP	6 MAP	6 MAP	2 MAP	4 MAP	6 MAP	2 MAP	4 MAP	6 MAP
Mulch									
No mulch	46.63	38.75	66.29	0.058	0.283	0.340	0.008	0.041	0.051
Mulch	46.35	39.68	74.37	0.024	0.412	0.512	0.003	0.059	0.071
SEm	0.760	0.936	1.298	0.004	0.016	0.019	0.001	0.002	0.002
Significance	NS	NS	**	**	**	**	**	**	**
Nutrient source									
Control	47.78	39.44	63.33	0.018	0.214	0.257	0.003	0.031	0.037
FYM	48.33	38.06	67.33	0.036	0.417	0.501	0.005	0.060	0.071
Vermicompost	46.66	38.33	71.17	0.030	0.302	0.361	0.004	0.044	0.053
Poultry Manure	44.73	40.83	82.33	0.096	0.341	0.410	0.013	0.049	0.059
FYM+Azotobacter	42.35	39.03	70.67	0.039	0.437	0.521	0.005	0.063	0.076
FYM+Phosphobacter	47.50	40.97	70.50	0.046	0.388	0.464	0.006	0.056	0.067
FYM+VAM	47.23	36.39	65.17	0.043	0.398	0.478	0.006	0.057	0.068
NPK	46.94	40.69	72.17	0.020	0.284	0.339	0.003	0.041	0.049
SEm	1.613	1.872	3.595	0.008	0.031	0.037	0.001	0.005	0.006
$CD_{(0.05)}$	NS	NS	10.384	0.023	0.090	0.108	0.003	0.013	0.016
Interaction	NS	NS	NS	*	NS	NS	*	NS	NS
G. Mean	46.50	39.22	70.33	0.041	0.348	0.417	0.006	0.050	0.060

significantly influenced by mulch at 5, 8 and 9 MAP and by nutrient sources at 6, 8 and 9 MAP with a significant interaction of mulch and nutrient sources at 6 MAP. The total dry matter was higher in mulch treatment in most of the months and the increase was significant at 5, 8 and 9 MAP. At 6 MAP, the total dry matter was the maximum of 1.435 g plant^{-1} in poultry manure applied plots which was on par with FYM + phosphobacter, FYM + VAM, FYM alone and inorganic NPK but superior to FYM + azotobacter and vermicompost, besides the control. The interaction of mulch and nutrient sources at 6 MAP showed the maximum dry matter production of 1.569 g plant^{-1} with poultry manure and no mulch followed by 1.519 g plant^{-1} with FYM + VAM and mulch as against 0.923 g plant^{-1} in the control with no mulch. At 8 MAP, it was the maximum of 1.296 g plant^{-1} in FYM + azotobacter which was on par with all other nutrient sources, except vermicompost and control. At 9 MAP, it was the highest of 1.398 g plant^{-1} in poultry manure which was on par with FYM + biofertilizers but superior to all other sources, besides the control.

4.5.3 Plant Density and Weed Biomass

Effect of mulch and nutrient sources on plant density and weed biomass production in *C. orchioides* is given in Table 4.5.10 and the interaction effect in Table 4.5.11.

4.5.3.1 Plant Density

Though the number of plants m^{-2} was not significantly influenced by mulch, nutrient sources or their interaction, the number of suckers m^{-2} at 6 MAP was significantly higher in mulch treatment. It was the highest of 82.33 suckers m^{-2} in poultry manure applied plots which was on par with inorganic NPK application but superior to all other nutrient sources.

4.5.3.2 Fresh Weed Biomass

Weed biomass was significantly influenced by mulch and nutrient sources but not by their interaction. The fresh weed biomass was significantly lower in mulch treatment at 2 MAP and the reverse at 4 and 6 MAP. Among the nutrient sources at 2 MAP, poultry manure recorded the maximum weed biomass of 0.096 kg m^{-2}, which was significantly the highest of all the treatments. The least weed

Table 4.5.11. Interaction effect of mulch and nutrient sources on weed biomass production in *Curculigo orchioides* (kg m^{-2})

Mulch	Nutrient source									
	Control	FYM	Vermi compost	Poultry Manure	FYM+ Azoto bacter	FYM+ Phosph obacter	FYM+ VAM	NPK	SEm	$CD_{(0.05)}$
	Weed fresh weight at 2 MAP									
No mulch	0.125	0.271	0.281	0.927	0.315	0.320	0.392	0.126	0.069	0.199
Mulch	0.091	0.154	0.074	0.219	0.153	0.235	0.127	0.116		
	Weed dry weight at 2 MAP									
No mulch	0.017	0.037	0.038	0.125	0.043	0.043	0.053	0.017	0.009	0.027
Mulch	0.012	0.021	0.010	0.030	0.021	0.032	0.017	0.016		

Table 4.5.12. Effect of mulch and nutrient sources on yield and harvest index of *Curculigo orchioides*

Treatment	Yield (kg ha^{-1})			Harvest index (%)
	Biological	Fresh rhizome	Dry rhizome	
Mulch				
No mulch	1201.73	630.75	239.01	52.49
Mulch	1173.78	612.10	238.99	52.15
SEm	26.806	18.041	7.455	-
Significance	NS	NS	NS	-
Nutrient source				-
Control	977.77	429.69	160.01	43.95
FYM	1081.25	600.81	228.44	55.57
Vermicompost	880.55	454.41	168.91	51.61
Poultry Manure	1851.39	982.72	382.63	53.08
FYM+Azotobacter	921.52	602.77	238.29	65.41
FYM+Phosphobacter	1602.78	781.67	308.99	48.77
FYM+VAM	973.61	541.36	213.66	55.60
NPK	1101.39	577.94	211.04	52.47
SEm	53.612	36.073	14.911	-
$CD_{(0.05)}$	154.846	104.187	43.065	-
Interaction	**	**	**	-
G. Mean	1173.78	621.422	238.995	52.94

biomass was in the control, which was on par with NPK, vermicompost, FYM and FYM + azotobacter. The interaction of mulch and nutrient sources at 2 MAP showed the maximum fresh weed biomass of 0.927 kg m^{-2} in poultry manure with no mulch, which was significantly the highest of all the treatment combinations. Vermicompost with mulch recorded the least biomass of 0.074 kg m^{-2}. At 4 MAP, fresh weed biomass was the maximum of 0.437 kg m^{-2} in FYM + azotobacter which was on par with FYM, FYM + VAM and FYM + phosphobacter but significantly higher than that in other nutrient sources. At 6 MAP, the trend was similar to that of 4 MAP.

4.5.3.3 Dry Weed Biomass

Dry weed biomass followed the trend of fresh weed biomass.

4.5.4 Yield Parameters

Effect of mulch and nutrient sources on yield and harvest index of *C. orchioides* is given in Table 4.5.12 and the interaction effect in Table 4.5.13.

4.5.4.1 Biological Yield

Biological yield was significantly influenced by the nutrient sources and interaction of mulch and nutrient sources but not by mulch. It was the maximum of 1851.39 kg ha^{-1} in poultry manure, which was superior to all other nutrient sources. It was followed by 1602.78 kg ha^{-1} in FYM + phosphobacter. The lowest yield of 880.55 kg ha^{-1} was recorded by vermicompost which was on par with FYM + azotobacter, FYM + VAM and the control. The interaction effect showed the highest biological yield of 2002.78 kg ha^{-1} in poultry manure with no mulch which was on par with FYM + phosphobacter with no mulch and superior to all other treatment combinations.

4.5.4.2 Fresh Rhizome Yield

As in the case of biological yield, fresh rhizome yield also was significantly influenced by nutrient sources and the interaction of mulch and nutrient source. It was the highest of 982.72 kg ha^{-1} in poultry manure which was superior to all other nutrient sources. It was followed by 781.67 kg ha^{-1} in FYM + phosphobacter. The interaction effect showed the highest fresh rhizome yield of 1069.90 kg ha^{-1} in

Table 4.5.13. Interaction effect of mulch and nutrient sources on yield of *Curculigo orchioides*

Mulch	Nutrient source									
	Control	FYM	Vermi compost	Poultry Manure	FYM+ Azoto bacter	FYM+ Phosph obacter	FYM+ VAM	NPK	SEm	$CD_{(0.05)}$
	Biological yield (kg ha^{-1})									
No mulch	831.94	1287.50	869.44	2002.78	920.83	1920.83	970.83	809.72	75.819	218.986
Mulch	1123.61	875.00	891.66	1700.00	922.22	1284.72	976.39	1393.05		
	Fresh rhizome yield (kg ha^{-1})									
No mulch	276.45	679.71	464.21	1069.90	655.13	903.92	552.47	442.21	51.015	147.343
Mulch	582.93	421.92	444.61	895.54	550.42	659.43	530.25	711.67		
	Dry rhizome yield (kg ha^{-1})									
No mulch	90.63	255.42	162.70	407.39	261.02	353.78	212.97	164.15	21.087	60.904
Mulch	229.39	201.47	171.11	351.86	215.57	264.19	214.35	257.93		

Table 4.5.14. Effect of mulch and nutrient sources on quality parameters of *Curculigo orchioides*

Treatment	Quality parameters								
	Glucose (%)	Sucrose (%)	Starch (%)	Fibre (%)	Protein (%)	Fat (%)	Curculigoside (ppm)	Curculigoside yield (kgha^{-1})	Ash (%)
Mulch									
No mulch	1.120	0.926	56.642	3.160	12.254	1.839	11.138	0.266	3.747
Mulch	1.173	0.882	53.621	3.009	12.023	1.662	4.930	0.118	3.745
SEm	0.017	0.010	0.302	0.014	0.086	0.007	8.034	0.006	0.020
Significance	*	**	**	**	NS	**	-	-	NS
Nutrient source									
Control	1.186	0.883	58.995	3.363	12.822	1.964	5.105	0.082	4.022
FYM	1.090	0.942	51.610	2.737	11.478	1.634	10.855	0.248	3.779
Vermicompost	1.161	0.872	52.338	3.253	11.981	1.899	15.570	0.263	4.108
Poultry Manure	1.84	0.803	57.898	3.040	11.756	1.609	9.010	0.345	3.868
FYM+Azotobacter	1.162	1.003	56.515	3.217	11.422	1.639	11.450	0.273	3.681
FYM+Phosphobacter	1.148	0.883	53.233	2.748	11.894	1.862	4.265	0.132	3.355
FYM+VAM	1.141	0.979	53.785	3.178	13.158	1.470	2.855	0.061	3.316
NPK	1.104	0.866	56.780	3.142	12.547	1.925	5.160	0.109	3.839
SEm	0.033	0.120	0.604	0.028	0.172	0.014	-	-	0.040
$CD_{(0.05)}$	NS	0.054	1.820	0.085	0.517	0.041	-	-	0.120
Interaction	NS	**	**	**	**	**	-	-	**
G. Mean	1.147	0.904	55.132	3.085	12.138	1.750	8.034	0.192	3.746

poultry manure with no mulch, which was superior to all other treatment combinations.

4.5.4.3 Dry Rhizome Yield

Dry rhizome yield followed the trend of fresh rhizome yield.

4.5.4.4 Harvest Index

Harvest index values did not show much variation and they ranged from 43.95 (control) to 65.41 per cent (FYM + azotobacter).

4.5.5 Quality Parameters

Effect of mulch and nutrient sources on quality parameters of *C. orchioides* is given in Table 4.5.14 and the interaction effect in Table 4.5.15.

4.5.5.1 Glucose

Glucose content in *C. orchioides* rhizome at harvest was significantly higher in mulch treatment. It was not significantly influenced by nutrient sources and the interaction of mulch and nutrient source.

4.5.5.2 Sucrose

Unlike glucose, sucrose content in rhizome at harvest was significantly lower in the mulch treatment. It was the highest of 1.003 per cent in FYM + azotobacter which was on par with FYM + VAM but superior to all other nutrient sources. It was the lowest of 0.803 per cent in poultry manure, which was significantly inferior to all other nutrient sources including the control. The interaction effect showed the highest sucrose content of 1.025 per cent in FYM + azotobacter with mulch which was followed by 0.985 per cent in FYM + VAM without mulch.

4.5.5.3 Starch

Starch content of rhizome was significantly reduced in mulch treatment. It was the maximum of 58.995 per cent in the control which was on par with poultry manure but superior to all other nutrient sources. The least was recorded by FYM which was on par with vermicompost and FYM + phosphobacter. The interaction effect showed the highest starch content of 59.45 per cent in NPK without mulch which was on par with FYM + VAM and poultry manure without mulch and control with mulch but superior to all other treatment combinations.

Table 4.5.15. Interaction effect of mulch and nutrient sources on quality parameters of *Curculigo orchioides*

Mulch	Nutrient source									
	Control	FYM	Vermi compos	Poultry Manure	FYM+ Azoto bacter	FYM+ Phosph obacter	FYM+ VAM	NPK	SEm	$CD_{(0.05)}$
	Sucrose (%)									
No mulch	0.944	0.922	0.862	0.826	0.980	0.981	0.985	0.906	0.028	0.083
Mulch	0.822	0.962	0.883	0.780	1.025	0.785	0.974	0.827		
	Starch (%)									
No mulch	58.92	52.75	54.77	59.11	56.71	54.04	57.41	59.45	0.854	2.574
Mulch	59.08	50.47	49.91	56.69	56.13	52.43	50.17	54.11		
	Fibre (%)									
No mulch	3.395	2.943	3.366	3.035	3.168	2.735	3.256	3.383	0.040	0.120
Mulch	3.332	2.530	3.141	3.045	3.266	2.760	3.100	2.902		
	Protein (%)									
No mulch	13.55	11.87	11.64	11.87	11.42	11.81	13.66	12.21	0.243	0.731
Mulch	12.09	11.09	12.32	11.64	11.42	11.98	12.65	12.99		
	Fat (%)									
No mulch	2.520	1.865	2.040	1.710	1.565	1.815	1.384	1.813	0.019	0.058
Mulch	1.408	1.403	1.757	1.509	1.713	1.910	1.557	2.037		
	Curculigoside (ppm)									
No mulch	6.75	16.63	26.02	11.32	14.14	8.53	5.71	0	-	-
Mulch	3.46	5.08	5.12	6.70	8.76	0	0	10.32		
	Ash (%)									
No mulch	3.860	3.800	4.197	3.884	3.299	3.319	3.528	4.091	0.056	0.170
Mulch	4.185	3.758	4.019	3.853	4.064	3.391	3.104	3.587		

4.5.5.4 Crude Fibre

The crude fibre content of the rhizome significantly decreased in mulch treatment. It was the highest of 3.363 per cent in the control, which was superior to all other nutrient sources. It was the lowest of 2.737 per cent in FYM which was on par with FYM + phosphobacter. The interaction effect showed the highest crude fibre content of 3.395 per cent in control with no mulch which was on par with NPK and vermicompost without mulch and the control with mulch but superior to all other treatment combinations.

4.5.5.5 Crude Protein

Effect of mulch on crude protein content was not significant. Crude protein content was the maximum of 13.158 per cent in FYM + VAM which was on par with the control but superior to all other nutrient sources. The interaction effect showed the highest protein content of 13.66 per cent in FYM + VAM without mulch which was on par with the control without mulch and NPK with mulch but superior to all other treatment combinations.

4.5.5.6 Crude Fat

Crude fat content was significantly decreased in the mulch treatment. It was the highest of 1.964 per cent in the control which was on par with NPK application but superior to all other nutrient sources. It was the lowest of 1.470 per cent in FYM + VAM which was significantly inferior to all other nutrient sources. The interaction effect showed the highest crude fat content of 2.52 per cent in the control without mulch, which was superior to all other treatment combinations.

4.5.5.7 Curculigoside

The curculigoside content of the rhizome was much higher (11.138 ppm) in no mulch treatment than the mulch treatment. Among the nutrient sources, vermicompost application recorded the highest curculigoside content of 15.570 ppm, followed by FYM+Azotobacter and FYM, as against 5.105 ppm in the control and 2.855 ppm in FYM+VAM treatment.

4.5.5.8 Ash

Effect of mulch on ash content was not significant. The ash content of the rhizome was the highest of 4.108 per cent in vermicompost which was on par with the control but superior to all other nutrient sources. It was the lowest of 3.316 per cent in FYM + VAM which was on par with FYM + phosphobacter. The interaction effect showed the highest ash content of 4.197 per cent in vermicompost without mulch followed by 4.185 per cent in the control with mulch.

4.5.6 Nutrient Contents

4.5.6.1 Rhizome

4.5.6.1.1 Major nutrients

Effect of mulch and nutrient sources on the content of major nutrients in *C. orchioides* rhizome is presented in Table 4.5.16 and the interaction effect in Table 4.5.17.

Nitrogen

In general, N content of the rhizome increased up to 2.294 per cent at 9 MAP and decreased thereafter. Mulching decreased the N content at all stages and the decrease was significant at 6 and 9 MAP.

In respect of nutrient sources, the variation in N content was not significant at 3 MAP. At 6 MAP, the N content of the rhizome was the highest of 2.249 per cent in FYM + VAM which was superior to all other nutrient sources. At 9 MAP, the N content was the highest of 2.408 per cent in the FYM which was superior to all other nutrient sources. The N content of rhizome at harvest was the highest of 2.106 per cent in NPK which was on par with FYM + VAM and the control but superior to the other nutrient sources that were on par except vermicompost.

The interaction effect was not significant at 3 MAP. At 6 MAP, the interaction effect showed the highest N content of 1.523 per cent in FYM without mulch, which was superior to all other treatment combinations. At 9 MAP, it showed the highest N content of 2.532 per cent in poultry manure and the control without mulch which were superior to all other treatment combinations. At harvest,

Table 4.5.16. Effect of mulch and nutrient sources on the content of major nutrients in *Curculigo orchioides* rhizome (%)

Treatment	N				P				K			
	3 MAP	6 MAP	9 MAP	Harvest	3 MAP	6 MAP	9 MAP	Harvest	3 MAP	6 MAP	9 MAP	Harvest
Mulch												
No mulch	0.630	2.179	2.337	1.961	0.11	0.224	0.291	0.199	0.529	0.478	0.227	0.658
Mulch	0.542	2.119	2.252	1.924	0.12	0.239	0.277	0.198	0.713	0.607	0.441	0.774
SEm	0.035	0.013	0.005	0.014	0.006	0.001	0.008	0.002	0.041	0.011	0.017	0.014
Significance	NS	**	**	NS	NS	**	NS	NS	NS	**	**	**
Nutrient source												
Control	0.486	2.159	2.347	2.052	0.11	0.188	0.288	0.145	0.5965	0.578	0.306	0.744
FYM	0.394	2.151	2.408	1.837	0.12	0.264	0.327	0.216	0.590	0.510	0.319	0.650
Vermicompost	0.683	2.159	2.169	1.917	0.13	0.221	0.303	0.175	0.602	0.560	0.419	0.679
Poultry Manure	0.749	2.069	2.347	1.881	0.13	0.252	0.350	0.233	0.670	0.560	0.381	0.794
FYM+Azotobacter	0.631	2.168	2.208	1.828	0.13	0.241	0.311	0.215	0.636	0.529	0.344	0.688
FYM+Phosphobacter	0.604	2.105	2.292	1.903	0.12	0.261	0.244	0.211	0.622	0.522	0.325	0.685
FYM+VAM	0.539	2.249	2.261	2.105	0.12	0.238	0.230	0.220	0.606	0.497	0.281	0.691
NPK	0.604	2.132	2.324	2.106	0.08	0.188	0.221	0.170	0.652	0.585	0.294	0.797
SEm	0.071	0.025	0.010	0.027	0.11	0.063	0.016	0.004	0.048	0.022	0.033	0.028
$CD_{(0.05)}$	NS	0.076	0.029	0.083	0.034	0.009	0.049	0.012	NS	NS	NS	0.084
Interaction	NS	**	**	**	NS	**	**	**	NS	NS	NS	NS
G. Mean	0.586	2.149	2.294	1.942	0.12	0.232	0.284	0.198	0.621	0.543	0.334	0.716

Table 4.5.17. Interaction effect of mulch and nutrient sources on the content of nutrients in *Curculigo orchioides* rhizome (%)

Mulch	Nutrient source									
	Control	FYM	Vermi compost	Poultry Manure	FYM+ Azoto bacter	FYM+ Phosph obacter	FYM+ VAM	NPK	SEm	$CD_{(0.05)}$
	N at 6 MAP									
No mulch	1.308	1.523	1.290	1.326	1.201	1.236	1.272	1.362	0.015	0.045
Mulch	1.057	1.111	1.165	1.237	1.47	1.237	1.237	1.129		
	N at 9 MAP									
No mulch	2.532	2.424	2.161	2.532	2.146	2.408	2.146	2.347	0.014	0.041
Mulch	2.161	2.393	2.177	2.161	2.270	2.177	2.377	2.301		
	N at harvest									
No mulch	2.168	1.899	1.863	1.899	1.828	1.889	2.186	1.953	0.034	0.117
Mulch	1.935	1.774	1.971	1.863	1.828	1.917	2.025	2.078		
	P at 6 MAP									
No mulch	0.121	0.186	0.150	0.188	0.154	0.174	0.136	0.113	0.003	0.010
Mulch	0.085	0.163	0.145	0.173	0.162	0.168	0.151	0.106		
	P at 9 MAP									
No mulch	0.257	0.273	0.257	0.350	0.303	0.257	0.281	0.350	0.023	0.070
Mulch	0.319	0.381	0.349	0.349	0.319	0.230	0.179	0.092		
	P at harvest									
No mulch	0.155	0.219	0.178	0.240	0.255	0.208	0.205	0.161	0.006	0.018
Mulch	0.135	0.214	0.173	0.227	0.205	0.214	0.235	0.179		
	Ca at 9 MAP									
No mulch	0.683	0.616	0.737	0.469	0.536	0.576	0.657	0.670	0.015	0.004
Mulch	0.657	0.683	0.630	0.630	0.603	0.616	0.562	0.643		
	Ca at harvest									
No mulch	0.794	0.767	0.780	0.835	0.575	0.616	0.711	0.862	0.040	0.122
Mulch	0.671	0.616	0.726	0.643	0.766	0.725	0.561	0.694		
	Mg at 6 MAP									
No mulch	0.471	0.418	0.450	0.409	0.696	0.614	0.491	0.512	0.053	0.158
Mulch	0.491	0.532	0.307	0.512	0.512	0.450	0.327	0.471		
	Mg at 9 MAP									
No mulch	0.218	0.132	0.205	0.218	0.185	0.218	0.139	0.198	0.008	0.025
Mulch	0.132	0.145	0.191	0.132	0.224	0.224	0.190	0.192		
	Mg at harvest									
No mulch	0.272	0.306	0.313	0.292	0.271	0.258	0.290	0.210	0.007	0.022
Mulch	0.217	0.238	0.263	0.244	0.251	0.278	0.278	0.278		
	S at 6 MAP									
No mulch	0.185	0.174	0.175	0.190	0.154	0.138	0.149	0.119	0.021	0.063
Mulch	0.182	0.122	0.255	0.138	0.271	0.119	0.128	0.292		
	S at 9 MAP									
No mulch	0.183	0.153	0.278	0.188	0.193	0.215	0.183	0.221	0.007	0.021
Mulch	0.205	0.239	0.129	0.104	0.410	0.222	0.177	0.202		
	S at harvest									
No mulch	0.162	0.169	0.120	0.120	0.184	0.122	0.120	0.120	0.006	0.019
Mulch	0.117	0.124	0.107	0.125	0.127	0.133	0.152	0.128		

the interaction effect showed the highest N content of 2.186 per cent in FYM + VAM without mulch which was on par with control without mulch and NPK with mulch but superior to all other treatment combinations.

Phosphorus

In general, P content of the rhizome increased up to 0.284 per cent at 9 MAP and decreased thereafter. Mulch treatment had little effect on P content of rhizome at most of the stages, except a significant increase at 6 MAP.

However, P content of rhizome was significantly influenced by nutrient sources at all the stages. It was the highest of 0.13 per cent in vermicompost, poultry manure and FYM + azotobacter which were on par with all other nutrient sources, except NPK application at 3 MAP. At 6 MAP, P content in rhizome was the highest of 0.264 per cent in FYM which was on par with FYM + phosphobacter but superior to all other treatment combinations. At 9 MAP, it was the highest of 0.350 per cent in poultry manure which was on par with FYM, vermicompost and FYM + azotobacter but superior to the other nutrient sources. At harvest, P content was the maximum of 0.233 per cent in poultry manure, which was superior to all other nutrient sources.

The interaction effect at 6 MAP, showed the highest P content of 0.188 per cent in poultry manure without mulch which was on par with FYM without mulch but superior to all other treatment combinations. At 9 MAP, it showed the highest P content of 0.381 per cent in FYM with mulch followed by 0.350 per cent in NPK and poultry manure without mulch. At harvest, the interaction effect showed the highest P content of 0.255 per cent in FYM + azotobacter without mulch which was on par with poultry manure without mulch but superior to all other treatment combinations.

Potassium

Unlike N and P, K content of rhizome, in general, decreased to 0.334 per cent at 9 MAP and increased thereafter. Mulching increased the N content at all stages and the increase was significant at 6 and 9 MAP and at harvest.

Potassium content at 3, 6 and 9 MAP was not significantly influenced by the nutrient sources and the interaction of mulch and nutrient source. K content in rhizome after harvest was the maximum of 0.797 per cent in NPK, which was on par with poultry manure and the control but superior to all other nutrient sources that were on par.

4.5.6.1.2 Secondary nutrients

Effect of mulch and nutrient sources on the content of secondary nutrients in *C. orchioides* rhizome at 6 MAP is furnished in Table 4.5.18 and the interaction effect in Table 4.5.17.

Calcium

In general, Ca content of rhizome decreased over the period from 1.128 per cent at 3 MAP to 0.090 per cent at harvest. Mulch significantly decreased Ca content at 6 MAP and at harvest.

Nutrient sources had little influence on the Ca content at 3 and 6 MAP. At 9 MAP Ca content was the maximum of 0.683 per cent in vermicompost which was on par with NPK and the control but superior to other nutrient sources. At harvest, Ca content was the highest of 0.778 per cent in NPK which was on par with vermicompost, poultry manure and the control but superior to all other nutrient sources.

The interaction effect at 9 MAP showed the highest Ca content of 0.737 per cent in vermicompost without mulch, which was superior to all other treatment combinations. At harvest, the interaction effect showed the highest Ca content of 0.862 per cent in NPK without mulch followed by 0.835 per cent in poultry manure without mulch.

Magnesium

Magnesium content of rhizome showed alternate increase and decrease over the period. Mulch significantly decreased Mg content of rhizome at 6 and 9 MAP and at harvest.

In respect of nutrient source, the variation in Mg content was not significant at 3 MAP. At 6 MAP Mg content of rhizome was the highest of 0.758 per cent in FYM + azotobacter which was superior to all other nutrient sources. It was the least of 0.286 per cent in the control, which was significantly inferior to all other

Table 4.5.18. Effect of mulch and nutrient sources on the content of secondary nutrients in *Curculigo orchioides* rhizome (%)

Treatment	Ca				Mg				S		
	3 MAP	6 MAP	9 MAP	Harvest	3 MAP	6 MAP	9 MAP	Harvest	6 MAP	9 MAP	Harvest
Mulch											
No mulch	1.076	1.146	0.618	0.742	0.318	0.637	0.189	0.276	0.203	0.201	0.139
Mulch	1.179	1.056	0.628	0.675	0.366	0.465	0.179	0.256	0.385	0.177	0.127
SEm	0.032	0.029	0.005	0.014	0.023	0.014	0.003	0.003	0.017	0.003	0.002
Significance	NS	*	NS	**	NS	**	*	**	**	**	**
Nutrient source											
Control	1.026	1.158	0.670	0.732	0.316	0.286	0.175	0.244	0.304	0.194	0.139
FYM	1.106	1.066	0.650	0.691	0.324	0.532	0.139	0.272	0.252	0.196	0.146
Vermicompost	0.989	1.158	0.683	0.753	0.429	0.553	0.198	0.288	0.325	0.203	0.114
Poultry Manure	1.160	1.142	0.549	0.739	0.324	0.512	0.175	0.268	0.296	0.146	0.123
FYM+Azotobacter	1.316	1.077	0.569	0.670	0.340	0.758	0.205	0.261	0.246	0.167	0.155
FYM+Phosphobacter	1.346	1.028	0.596	0.670	0.307	0.614	0.221	0.268	0.281	0.218	0.127
FYM+VAM	0.946	1.060	0.609	0.636	0.324	0.645	0.164	0.284	0.292	0.180	0.136
NPK	1.133	1.127	0.656	0.778	0.372	0.512	0.195	0.244	0.358	0.211	0.124
SEm	0.065	0.058	0.010	0.029	0.046	0.028	0.006	0.005	0.033	0.005	0.005
$CD_{(0.05)}$	NS	NS	0.031	0.086	NS	0.084	0.018	0.016	NS	0.015	0.014
Interaction	NS	NS	**	**	NS	**	**	**	NS	**	**
G. Mean	1.128	1.101	0.623	0.090	0.342	0.555	0.184	0.266	0.294	0.189	0.133

nutrient sources. At 9 MAP, Mg content was the highest of 0.221 per cent in FYM + phosphobacter which was on par with FYM + azotobacter but superior to the other nutrient sources. At harvest, Mg content was the maximum of 0.288 per cent in vermicompost which was on par with FYM + VAM and FYM but superior to all other nutrient sources.

The interaction effect at 6 MAP showed the highest Mg content of 0.696 per cent in FYM + azotobacter without mulch which was on par with FYM + phosphobacter without mulch but superior to all other treatment combinations. At 9 MAP, the interaction effect showed the highest Mg content of 0.224 per cent both in FYM + azotobacter and FYM + phosphobacter with mulch followed by 0.218 per cent recorded by three treatment combinations (control, poultry manure, and FYM + phosphobacter without mulch). At harvest, the interaction effect showed the highest Mg content of 0.313 per cent in vermicompost without mulch which was on par with FYM and poultry manure without mulch but superior to all other treatment combinations.

Sulphur

In general, S content of rhizome decreased over the period. Mulch significantly increased S content at 6 MAP but decreased at 9 MAP and at harvest.

Nutrient sources had little influence on S content at 3 MAP. At 9 MAP, it was the maximum of 0.218 per cent in FYM + phosphobacter which was on par with NPK and vermicompost but superior to the other nutrient sources. At harvest, S content was the maximum of 0.155 per cent in FYM + azotobacter which was on par with FYM but superior to all other nutrient sources.

The interaction effect at 6 MAP showed the highest S content of 0.292 per cent in NPK with mulch which was on par with FYM + azotobacter and vermicompost with mulch but superior to all other treatment combinations. The interaction effect at 9 MAP showed the highest S content of 0.278 per cent in vermicompost without mulch, which was superior to all other treatment combinations. At harvest, the interaction effect showed the highest S content of 0.184 per cent in FYM + azotobacter without mulch which was on par with FYM without mulch but superior to all other treatment combinations.

4.5.6.1.3 Micronutrients

Effect of mulch and nutrient sources on the content of micronutrients in *C. orchioides* rhizome is furnished in Table 4.5.19.

Iron

In general, Fe content of rhizome showed alternate increase and decrease over the period and the increase at maximum vegetative growth phase (6 MAP) was very high to the tune of 3314.13 ppm. Mulch and interaction of mulch and nutrient sources had little influence on Fe content of rhizome at any stage.

Nutrient sources had significant influence only at harvest wherein Fe content was the maximum of 1171.50 ppm in the control, which was on par with vermicompost but significantly higher than that in all other nutrient sources.

Manganese

In general, Mn content of rhizome showed alternate increase and decrease over the period Mulch decreased the Mn content at all stages and the decrease was significant at 6 MAP and at harvest.

Manganese content in rhizome at 6 MAP was the highest of 444.30 ppm in the control which was on par with NPK and vermicompost but superior to all other nutrient sources. At 9 MAP the micronutrient Mn was the maximum of 100.30 ppm in NPK, which was significantly higher than that in all other nutrient sources that were on par except poultry manure. At harvest, Mn content was the highest of 124.10 ppm in the control, which was on par with NPK but significantly higher than that in all other nutrient sources.

The interaction of mulch and nutrient sources on Mn content was not significant at any stage.

Zinc

Zinc content of rhizome, in general, increased over the period. Mulch as well as the interaction effect had little influence on Zn content at any stage.

At harvest, Zn content was the highest of 125.50 ppm in the control which was on par with FYM and vermicompost but superior to all other nutrient sources.

Table 4.5.19. Effect of mulch and nutrient sources on the content of micronutrients in *Curculigo orchioides* rhizome (ppm)

Treatment	Fe				Mn				Zn				Cu			
	3 MAP	6 MAP	9 MAP	Harvest	3 MAP	6 MAP	9 MAP	Harvest	3 MAP	6 MAP	9 MAP	Harvest	3 MAP	6 MAP	9MAP	Harvest
Mulch																
No mulch	201.56	3307.75	693.62	977.86	126.34	427.45	84.81	108.53	51.17	55.37	61.44	92.15	113.47	112.93	56.69	34.01
Mulch	465.68	3320.50	645.99	804.70	130.19	353.56	77.35	101.55	62.85	51.03	57.35	81.55	86.50	98.81	61.70	29.25
SEm	27.154	83.622	43.124	52.597	4.942	5.974	2.190	1.874	4.617	2.551	6.272	7.756	5.747	11.543	3.280	2.213
Significance	NS	NS	NS	NS	NS	**	NS	*	NS	NS	NS	NS	NS	NS	NS	NS
Nutrient source																
Control	304.10	3025.00	693.45	1171.50	134.15	444.30	83.85	124.10	58.20	58.65	65.70	125.50	92.080	100.60	54.85	44.55
FYM	122.70	3757.00	624.30	367.40	120.40	388.50	73.75	101.35	22.05	60.80	49.80	118.55	78.40	124.85	45.65	29.65
Vermicompost	156.00	3277.00	635.45	1166.10	134.15	433.55	81.45	111.75	61.20	43.00	60.80	109.75	110.60	74.05	59.75	35.50
Poultry Manure	453.35	3610.00	641.65	772.30	118.95	375.15	85.05	97.40	47.20	48.45	53.90	57.20	147.25	101.40	51.20	37.30
FYM+Azotobacter	532.00	3370.00	752.20	679.10	122.70	378.15	81.05	98.10	53.15	53.15	60.20	69.35	89.05	56.65	73.10	28.35
FYM+Phosphobacter	401.30	3576.50	508.75	833.30	132.75	391.45	71.75	95.70	61.85	49.10	55.85	90.70	99.95	100.65	60.10	26.30
FYM+VAM	337.05	2768.00	674.45	785.75	119.25	391.55	71.45	92.00	49.25	51.30	58.55	57.95	99.10	78.15	58.35	24.20
NPK	362.50	3129.54	828.20	853.60	140.75	443.40	100.30	119.90	53.20	61.20	70.35	65.80	82.25	180.10	69.95	27.20
SEm	44.308	167.243	86.248	115.92	7.129	11.949	4.380	3.921	5.412	5.102	12.544	11.152	11.495	21.144	6.56	4.914
$CD_{(0.05)}$	NS	NS	NS	347.76	NS	36.011	13.204	11.763	NS	NS	NS	33.456	34.642	NS	NS	NS
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
G. Mean	333.63	3314.13	669.81	891.13	128.26	405.51	81.08	105.04	57.01	53.20	59.39	86.85	99.98	105.86	59.19	31.63

Copper

Copper content of rhizome, in general, decreased over the period. Mulch as well as the interaction effect had little influence on Cu content at any stage.

Effect of nutrient sources was significant at 3 MAP alone wherein Cu content was the maximum of 147.25 ppm in poultry manure, which was superior to all other nutrient sources.

4.5.6.2 Shoot

4.5.6.2.1 Major nutrients

Effect of mulch and nutrient sources on the content of major nutrients in *C. orchioides* shoot is furnished in Table 4.5.20 and the interaction effect in Table 4.5.22.

Nitrogen

In general, N content of shoot increased up to maximum vegetative phase (6 MAP) and decreased later. The mulch treatment significantly decreased the content of N in the shoot at 6 and 9 MAP.

Nutrient sources had little influence on N content at 3 MAP. At 6 MAP, The N content in the shoot was the maximum of 2.249 per cent in FYM + VAM which was superior to all other nutrient sources. At 9 MAP, N content was the highest of 1.845 per cent in the control which was on par with FYM + phosphobacter but superior to all other nutrient sources.

The interaction effect at 6 MAP, showed the highest N content of 2.275 per cent in vermicompost without mulch followed by 2.258 per cent in FYM + VAM with mulch. The interaction effect at 9 MAP, showed the highest N content 2.161 per cent in the control without mulch, which was superior to all other treatment combinations.

Phosphorus

In general, P content of shoot decreased up to maximum vegetative phase (6 MAP) and increased later. The mulch treatment significantly increased the content of P in the shoot at 6 and 9 MAP.

Table 4.5.20. Effect of mulch and nutrient sources on the content of major nutrients in *Curculigo orchioides* shoot (%)

Treatment	N			P			. K		
	3 MAP	6 MAP	9 MAP	3 MAP	6 MAP	9 MAP	3 MAP	6 MAP	9 MAP
Mulch									
No mulch	1.809	2.179	1.810	0.288	0.224	0.267	2.245	1.691	0.895
Mulch	1.858	2.119	1.654	0.270	0.239	0.383	3.015	2.272	0.952
SEm	0.036	0.013	0.004	0.008	0.001	0.005	0.289	0.051	0.034
Significance	NS	**	**	NS	**	**	NS	**	NS
Nutrient source									
Control	1.629	2.159	1.845	0.247	0.188	0.275	2.640	1.813	0.919
FYM	1.641	2.151	1.690	0.282	0.264	0.245	2.480	1.988	1.013
Vermicompost	2.075	2.159	1.768	0.282	0.221	0.291	2.540	2.075	0.888
Poultry Manure	1.983	2.069	1.698	0.302	0.262	0.341	2.820	2.088	0.881
FYM+Azotobacter	1.865	2.168	1.567	0.333	0.241	0.426	2.600	2.025	0.838
FYM+Phosphobacter	1.839	2.105	1.837	0.297	0.261	0.299	2.690	1.963	1.006
FYM+VAM	1.681	2.249	1.783	0.271	0.238	0.335	2.540	1.850	1.025
NPK	1.957	2.132	1.667	0.219	0.188	0.389	2.780	2.050	0.819
SEm	0.072	0.025	0.008	0.016	0.063	0.010	0.391	0.102	0.069
$CD_{(0.05)}$	NS	0.076	0.023	0.049	0.009	0.031	NS	NS	NS
Interaction	NS	**	**	NS	**	**	NS	NS	**
G. Mean	1.833	2.149	1.732	0.28	0.232	0.325	2.630	1.981	0.923

Table 4.5.21. Effect of mulch and nutrient sources on the content of secondary nutrients in *Curculigo orchioides* shoot (%)

Treatment	Ca			Mg			S	
	3 MAP	6 MAP	9 MAP	3 MAP	6 MAP	9 MAP	6 MAP	9 MAP
Mulch								
No mulch	0.846	1.146	1.542	0.534	0.637	0.343	0.203	0.195
Mulch	0.940	1.056	1.216	0.433	0.465	0.264	0.385	0.294
SEm	0.035	0.029	0.003	0.032	0.014	0.002	0.017	0.006
Significance	NS	*	**	*	**	**	**	**
Nutrient source								
Control	0.787	1.158	1.306	0.494	0.286	0.268	0.304	0.276
FYM	0.800	1.066	1.407	0.615	0.532	0.333	0.252	0.237
Vermicompost	0.866	1.158	1.373	0.437	0.553	0.344	0.325	0.225
Poultry Manure	1.013	1.142	1.380	0.437	0.512	0.330	0.296	0.208
FYM+Azotobacter	0.907	1.077	1.520	0.550	0.758	0.294	0.246	0.194
FYM+Phosphobacter	1.000	1.028	1.400	0.437	0.614	0.300	0.281	0.293
FYM+VAM	0.880	1.060	1.457	0.461	0.645	0.264	0.292	0.280
NPK	0.893	1.127	1.192	0.437	0.512	0.297	0.358	0.245
SEm	0.070	0.058	0.006	0.064	0.028	0.003	0.033	0.012
$CD_{(0.05)}$	NS	NS	0.018	NS	0.084	0.010	NS	0.036
Interaction	NS	**	**	NS	**	**	NS	**
G. Mean	0.893	1.101	1.379	0.483	0.551	0.304	0.294	0.245

Table 4.5.22. Interaction effect of mulch and nutrient sources on the content of nutrients in *Curculigo orchioides* shoot (%)

Mulch	Nutrient source									
	Control	FYM	Vermi compos	Poultry Manure	FYM+ Azoto bacter	FYM+ Phosph obacter	FYM+ VAM	NPK	SEm	$CD_{(0.05)}$
	N at 6 MAP									
No mulch	2.114	2.240	2.275	2.114	2.114	2.168	2.240	2.168	0.036	0.108
Mulch	2.204	2.063	2.043	2.025	2.222	2.043	2.258	2.096		
	N at 9 MAP									
No mulch	2.161	1.852	1.776	1.961	1.467	1.852	1.760	1.652	0.011	0.033
Mulch	1.529	1.529	1.760	1.435	1.667	1.822	1.807	1.683		
	P at 6 MAP									
No mulch	0.204	0.266	0.218	0.239	0.236	0.244	0.220	0.171	0.004	0.013
Mulch	0.173	0.263	0.225	0.265	0.246	0.278	0.257	0.205		
	P at 9 MAP									
No mulch	0.224	0.202	0.257	0.280	0.402	0.264	0.241	0.264	0.015	0.044
Mulch	0.327	0.288	0.325	0.402	0.450	0.335	0.428	0.514		
	K at 9 MAP									
No mulch	1.225	0.938	0.900	0.950	0.800	0.825	0.925	0.600	0.098	0.294
Mulch	0.613	1.088	0.875	0.813	0.875	1.188	1.125	1.038		
	Ca at 6 MAP									
No mulch	1.077	1.240	1.338	1.077	1.044	1.109	1.273	1.012	0.082	0.248
Mulch	1.240	0.881	0.979	1.207	1.109	0.946	0.848	1.242		
	Ca at 9 MAP									
No mulch	1.353	1.702	1.568	1.634	1.514	1.621	1.527	1.420	0.008	0.025
Mulch	1.259	1.112	1.179	1.125	1.527	1.179	1.386	0.964		
	Mg at 6 MAP									
No mulch	0.327	0.491	0.594	0.635	0.799	0.778	0.696	0.778	0.040	0.119
Mulch	0.245	0.573	0.512	0.389	0.717	0.450	0.594	0.245		
	Mg at 9 MAP									
No mulch	0.298	0.337	0.423	0.343	0.350	0.337	0.343	0.317	0.004	0.013
Mulch	0.238	0.330	0.264	0.317	0.238	0.264	0.185	0.277		
	S at 9 MAP									
No mulch	0.156	0.156	0.197	0.193	0.211	0.187	0.242	0.223	0.017	0.052
Mulch	0.396	0.317	0.253	0.224	0.177	0.398	0.319	0.267		

Nutrient sources exerted significant influence on P content at all stages. At 3 MAP, The P content in shoot was the maximum of 0.333 per cent in FYM + azotobacter which was on par with poultry manure and FYM + phosphobacter but superior to all other nutrient sources. At 6 MAP, P content was the maximum of 0.264 per cent in FYM which was on par with poultry manure and FYM + phosphobacter but superior to all other nutrient sources. At 9 MAP, P content was the maximum of 0.426 per cent in FYM + azotobacter which was superior to all other nutrient sources.

The interaction effect at 6 MAP, showed the highest P content of 0.278 per cent in FYM + phosphobacter with mulch, which was on par with FYM without mulch and poultry manure with mulch but superior to all other treatment combinations. At 9 MAP, The interaction effect showed the highest P content of 0.514 per cent in NPK with mulch, which was superior to all other treatment combinations.

Potassium

In general, K content of shoot decreased over the period. The mulch treatment increased the content of K in the shoot at all stages and the increase was significant at 6 MAP. The effect of nutrient sources was not significant at any stage.

At 9 MAP, Interaction of mulch and nutrient sources showed the maximum K content of 1.225 per cent in the control without mulch followed by 1.188 per cent in FYM + phosphobacter with mulch.

4.5.6.2.2 Secondary nutrients

Effect of mulch and nutrient sources on the content of secondary nutrients in *C. orchioides* shoot at 6 MAP is furnished in Table 4.5.21 and the interaction effect in Table 4.5.22.

Calcium

Calcium content of shoot increased over the period. In general, the mulch treatment significantly increased the content of Ca in the shoot at 6 and 9 MAP.

Nutrient sources significantly influenced at 9 MAP alone wherein Ca content was the maximum of 1.52 per cent in FYM + azotobacter which was superior to all other nutrient sources.

The interaction effect at 6 MAP, showed the highest Ca content of 1.338 per cent in vermicompost without mulch followed by 1.273 per cent in FYM + VAM without mulch. At 9 MAP, the interaction effect showed the highest Ca content of 1.702 per cent in FYM without mulch, which was superior to all other treatment combinations.

Magnesium

Magnesium content first increased and then decreased over the period. The mulch treatment significantly decreased the content of Mg in the shoot at all the stages.

Nutrient sources had little influence on Mg content in the shoot at 3 MAP. At 6 MAP, it was the highest of 0.758 per cent in FYM + azotobacter which was superior to all other nutrient sources. At 9 MAP, Mg was the highest of 0.344 per cent in vermicompost, which was superior to all other nutrient sources.

The interaction effect at 6 MAP, showed the highest Mg content of 0.799 per cent in FYM + azotobacter without mulch followed by 0.778 per cent both in FYM + phosphobacter and NPK without mulch. At 9 MAP, it showed the highest Mg content of 0.423 per cent in vermicompost without mulch, which was superior to all other treatment combinations.

Sulphur

In general, sulphur content decreased after 6 MAP. Mulch significantly increased S content of shoot at 6 and 9 MAP.

Nutrient sources and interaction significantly influenced S content at 9 MAP alone. At 9 MAP, S content was the highest of 0.293 per cent in FYM + phosphobacter which was on par with FYM + VAM and the control but superior to all other nutrient sources.

The interaction effect at 9 MAP, showed the highest S content of 0.398 per cent in FYM + phosphobacter with mulch which was on par with the control with mulch but superior to all other treatment combinations.

4.5.6.2.3 Micronutients

Effect of mulch and nutrient sources on the content of micronutrients in *C. orchioides* shoot is furnished in Table 4.5.23.

Iron

Mulch, nutrient sources or their interaction had little influence on the Fe content of shoot at any stage.

Manganese

Manganese content of shoot increased over the period. The mulch treatment significantly decreased the content of Mn in the shoot at all stages.

Nutrient sources also significantly influenced Mn content of shoot at all stages. At 3 MAP, Mn content was the maximum of 251.50 ppm in the control which was on par with FYM and vermicompost but superior to all other nutrient sources. At 6 MAP, it was the maximum of 444.30 ppm in the control which was on par with NPK and vermicompost but superior to all other nutrient sources. At 9 MAP, Mn content was the highest of 636.90 ppm in the control which was on par with NPK, vermicompost and FYM + azotobacter but significantly higher than that in all other nutrient sources.

The interaction of mulch and nutrient sources was not significant at any stage.

Zinc

Zinc content of shoot was not significantly influenced by any treatment or interaction at any stage, except by nutrient sources at 3 MAP. At 3 MAP, Zn content was the maximum of 32.90 ppm in FYM + azotobacter followed by 29.65 ppm in FYM + phosphobacter as against 28.10 ppm in the control.

Copper

Mulch, nutrient sources or their interaction had little influence on the Cu content of shoot at any stage.

Table 4.5.23. Effect of mulch and nutrient sources on the content of micronutrients in *Curculigo orchioides* shoot (ppm)

Treatment	Fe			Mn			Zn			Cu		
	3 MAP	6 MAP	9 MAP	3 MAP	6 MAP	9 MAP	3 MAP	6 MAP	9 MAP	3 MAP	6 MAP	9 MAP
Mulch												
No mulch	834.25	3307.75	3084.00	230.88	427.45	631.34	26.71	55.37	64.47	87.42	112.93	72.42
Mulch	848.55	3320.50	2984.63	195.93	383.56	571.86	23.87	51.03	65.44	91.88	98.81	67.19
SEm	23.142	83.622	92.625	3.849	5.974	6.588	1.875	2.551	3.690	10.491	11.543	4.326
Significance	NS	NS	NS	**	**	**	NS	NS	NS	NS	NS	NS
Nutrient source												
Control	829.25	3025.00	2711.50	251.50	444.30	636.90	28.10	88.65	88.15	95.05	100.60	62.30
FYM	762.30	3757.00	3451.00	225.20	388.50	564.10	22.35	60.80	58.05	78.85	124.85	67.00
Vermicompost	786.50	3277.00	2949.50	225.65	431.55	622.25	27.60	43.00	56.10	95.40	74.05	65.15
Poultry Manure	891.15	3610.00	3603.00	187.45	375.15	584.00	27.60	48.45	55.70	83.15	101.40	65.15
FYM+Azotobacter	827.40	3370.00	2833.50	190.10	378.15	610.80	32.90	53.15	59.60	84.65	86.65	70.85
FYM+Phosphobacter	910.80	3576.50	2828.50	224.50	391.45	574.90	29.65	49.10	60.45	94.25	100.65	66.75
FYM+VAM	971.30	2768.00	3273.50	194.40	391.55	589.05	17.90	51.30	65.90	86.05	78.15	69.05
NPK	752.50	3129.50	2624.00	208.45	443.40	630.80	16.25	61.20	75.65	97.05	180.10	92.15
SEm	47.14	167.243	185.250	8.931	11.949	13.177	3.112	5.102	6.138	15.720	21.144	8.653
$CD_{(0.05)}$	NS	NS	NS	26.791	36.011	39.718	9.336	NS	NS	NS	NS	NS
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
G. Mean	841.40	3314.13	3034.31	213.41	405.51	601.60	25.29	53.20	64.95	89.30	105.86	69.80

4.5.7 Nutrient Ratios

4.5.7.1 Rhizome

Effect of mulch and nutrient sources on nutrient ratios of *C. orchioides* rhizome at 6 MAP is presented in Table 4.5.24. The nutrient ratios of (Ca+Mg)/K, Fe/K, Mn/K, Zn/K and Cu/K were higher in no mulch treatment than the mulch treatment in the case of rhizome. Among the nutrient sources, FYM recorded the highest values for Fe/K, Zn/K and Cu/K ratios. (Ca+Mg)/K was highest for FYM+Azotobacter while Mn/K for FYM+VAM.

4.5.7.2 Shoot

Effect of mulch and nutrient sources on nutrient ratios of *C. orchioides* shoot at 6 MAP is presented in Table 4.5.25. As in the case of rhizome, the nutrient ratios of (Ca+Mg)/K, Fe/K, Mn/K, Zn/K and Cu/K were higher in no mulch treatment than the mulch treatment for shoot. Among the nutrient sources, FYM + VAM recorded the highest (Ca+Mg)/K ratio while FYM recorded the highest Fe/K ratio. Cu/K was highest for NPK while Mn/K and Zn/K for the control.

4.5.8 Nutrient Uptake

Effect of mulch and nutrient sources on uptake of nutrients by *C. orchioides* at 6 MAP is furnished in Table 4.5.26. The mulch treatment significantly increased K and S uptake and decreased Mn uptake while the uptake of other nutrients were unaffected.

Nitrogen uptake was the maximum of 7.420 kg ha^{-1} in FYM + VAM which was on par with poultry manure but superior to all other nutrient sources. It was the lowest in the control (5.541 kg ha^{-1}), which was significantly the lowest uptake of all. P uptake was the highest of 0.895 kg ha^{-1} in poultry manure which was on par with FYM + phosphobacter but superior to all other nutrient sources. The control recorded 0.483 kg ha^{-1} which was significantly the lowest. K uptake was the maximum of 3.739 kg ha^{-1} in poultry manure, which was superior to all other nutrient sources. K uptake was significantly the lowest in the control.

Calcium uptake was the highest of 4.005 kg ha^{-1} in poultry manure, which was superior to all other nutrient sources. It was the lowest in the control and it was

Table 4.5.24. Effect of mulch and nutrient sources on nutrient ratios of *Curculigo orchioides* rhizome at 6MAP

Treatment	(Ca+Mg)/K	Fe/K	Mn/K	Zn/K	Cu/K
Mulch					
No mulch	3.73	0.692	0.089	0.012	0.024
Mulch	2.51	0.547	0.058	0.008	0.016
Nutrient source					
Control	2.50	0.523	0.077	0.010	0.017
FYM	3.13	0.737	0.076	0.012	0.024
Vermicompost	3.06	0.585	0.077	0.008	0.013
Poultry Manure	2.95	0.645	0.067	0.009	0.018
FYM+Azotobacter	3.47	0.637	0.071	0.010	0.011
FYM+Phosphobacter	3.15	0.685	0.075	0.009	0.019
FYM+VAM	3.43	0.557	0.079	0.010	0.016
NPK	2.80	0.535	0.076	0.010	0.031
G. Mean	3.05	0.692	0.089	0.012	0.024

Table 4.5.25. Effect of mulch and nutrient sources on nutrient ratios of *Curculigo orchioides* shoot at 6 MAP

Treatment	(Ca+Mg)/K	Fe/K	Mn/K	Zn/K	Cu/K
Mulch					
No mulch	1.05	0.196	0.025	0.003	0.007
Mulch	0.67	0.146	0.017	0.002	0.004
Nutrient source					
Control	0.80	0.167	0.025	0.005	0.006
FYM	0.80	0.189	0.020	0.003	0.006
Vermicompost	0.82	0.158	0.021	0.002	0.004
Poultry Manure	0.79	0.173	0.018	0.002	0.005
FYM+Azotobacter	0.91	0.166	0.019	0.003	0.004
FYM+Phosphobacter	0.84	0.182	0.020	0.003	0.005
FYM+VAM	0.92	0.150	0.021	0.003	0.004
NPK	0.80	0.153	0.022	0.003	0.009
G. Mean	0.83	0.196	0.025	0.003	0.007

Table 4.5.26. Effect of mulch and nutrient sources on uptake of nutrients by *Curculigo orchioides* at 6 MAP (kg ha^{-1})

Nutrient	N	P	K	Ca	Mg	S	Fe	Mn	Zn	Cu
Mulch										
No mulch	651.96	67.02	258.30	342.88	190.59	60.74	98.97	12.79	1.66	3.38
Mulch	661.81	74.64	360.07	329.81	145.23	120.24	103.71	11.35	1.59	3.09
SEm	1.541	0.120	3.487	3.434	1.667	0.201	0.997	0.071	0.003	0.014
$CD_{(0.05)}$	NS	NS	*	NS	*	**	NS	NS	NS	NS
Nutrient source										
Control	554.09	48.25	242.40	297.19	73.40	78.02	77.63	8.36	1.73	2.58
FYM	672.49	82.54	309.37	333.27	166.32	78.79	117.46	12.15	1.90	3.90
Vermicompost	574.81	58.84	290.17	308.31	147.23	86.53	87.25	11.52	1.14	1.97
Poultry Manure	725.64	89.54	373.90	400.52	179.57	103.81	126.61	13.16	1.70	3.56
FYM+Azotobacter	607.73	67.56	288.08	301.90	212.48	68.96	94.47	10.60	1.49	1.87
FYM+Phosphobacter	701.89	87.03	333.14	342.78	204.73	93.70	119.25	13.05	1.64	3.36
FYM+VAM	741.99	78.52	298.19	349.72	212.80	96.34	91.32	12.92	1.69	2.58
NPK	672.01	59.26	329.72	355.23	161.38	112.84	98.64	13.98	1.93	5.68
SEm	5.761	1.452	3.520	3.362	2.645	1.760	3.851	0.028	0.012	0.049
$CD_{(0.05)}$	17.283	4.365	10.569	10.084	7.932	5.310	11.550	0.843	NS	0.147
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
G. Mean	656.73	70.90	307.67	336.47	169.21	89.85	101.28	12.39	1.63	3.24

on par with FYM + azotobacter. Mg uptake was the maximum of 2.128 kg ha^{-1} in FYM + VAM which was on par with FYM + azotobacter but superior to all other nutrient sources. Mg uptake was significantly the lowest in the control. S uptake was the maximum of 1.128 kg ha^{-1} in NPK, which was superior to all other nutrient sources. It was the lowest in FYM + azotobacter.

Iron uptake was the maximum of 1.266 kg ha^{-1} in poultry manure which was on par with FYM + phosphobacter and FYM alone but superior to all other nutrient sources. It was the lowest in the control, which was on par with vermicompost. Mn uptake was the maximum of 0.140 kg ha^{-1} in NPK which was on par with poultry manure but superior to all other nutrient sources. It was significantly the lowest in the control. Cu uptake was the maximum of 0.057 kg ha^{-1} in NPK, which was superior to all other nutrient sources. It was the lowest in FYM + azotobacter which was on par with vermicompost. None of the interactions were statistically significant.

4.5.9 Soil Characteristics

Effect of mulch and nutrient sources on soil characteristics after the harvest of *C. orchioides* is given in Table 4.5.27 and the interaction effect in Table 4.5.28. The mulch treatment significantly increased the pH and the available K, Ca and S contents but decreased available Mg content while other available nutrients were unaffected. Soil pH was the maximum of 6.17 in FYM + azotobacter which was superior to all other nutrient sources.

Available N content in the soil was the maximum of 173.67 ppm in FYM + phosphobacter which was on par with FYM + other biofertilisers but superior to all other nutrient sources. The interaction effect showed the highest available N content of 183.88 ppm in FYM + azotobacter without mulch which was on par with poultry manure, vermicompost and FYM + phosphobacter with mulch and FYM + phosphobacter without mulch but superior to all other treatment combinations. The available P content was the maximum of 17.58 ppm in poultry manure which was on par with FYM + azotobacter but superior to all other nutrient sources. The available K content in the soil was the maximum of 101.00 ppm in NPK which was on par with poultry manure and FYM + azotobacter but superior to all other nutrient sources. The interaction effect showed the highest available K

Table 4.5.27. Effect of mulch and nutrient sources on soil characteristics after the harvest of *Curculigo orchioides*

Treatment	pH	N (ppm)	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	S (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)
Mulch											
No mulch	5.94	164.99	11.49	68.38	154.76	37.35	90.99	19.82	14.11	1.82	4.25
Mulch	5.98	163.85	12.21	100.75	188.62	27.31	97.52	21.86	14.21	1.42	3.84
SEm	0.002	1.275	0.699	1.459	2.16	1.116	1.675	2.041	1.104	0.007	0.017
Significance	**	NS	NS	**	**	**	*	NS	NS	NS	NS
Nutrient source											
Control	5.91	162.72	8.85	82.00	142.84	32.13	89.73	19.82	12.78	1.53	4.09
FYM	5.92	156.65	10.45	74.00	139.18	40.16	90.96	21.37	13.46	1.76	4.02
Vermicompost	5.94	164.99	8.17	78.00	124.54	44.97	86.10	20.80	13.01	1.75	4.22
Poultry Manure	5.91	163.97	17.58	97.50	212.45	30.52	88.06	19.65	14.04	1.70	4.37
FYM+Azotobacter	6.17	169.65	17.53	96.00	212.43	27.31	93.28	19.55	16.38	1.67	3.60
FYM+Phosphobacter	6.05	173.67	10.74	69.00	208.78	14.44	95.88	21.55	15.13	1.56	4.56
FYM+VAM	5.91	167.92	10.63	79.00	194.13	48.20	101.11	22.54	14.20	1.45	3.67
NPK	5.88	155.78	10.82	101.00	139.19	20.88	108.93	21.43	14.28	1.53	3.86
SEm	0.004	2.550	1.398	2.918	4.321	2.232	3.350	2.321	1.217	0.032	0.019
$CD_{(0.05)}$	0.011	7.685	4.214	8.796	13.023	6.729	10.098	NS	NS	NS	NS
Interaction	NS	**	NS	**	**	**	**	NS	NS	NS	NS
G. Mean	5.96	164.42	11.85	84.563	171.69	32.33	94.26	20.84	14.16	1.69	4.05

Table 4.5.28. Interaction effect of mulch and nutrient sources on soil characteristics after the harvest of *Curculigo orchioides*

Mulch	Nutrient source									
	Control	FYM	Vermi compost	Poultry Manure	FYM+ Azoto bacter	FYM+ Phosph obacter	FYM+ VAM	NPK	SEm	$CD_{(0.05)}$
	N (ppm)									
No mulch	167.83	170.75	155.43	152.81	183.88	173.67	164.18	151.35	3.606	10.868
Mulch	157.61	142.54	174.56	175.13	155.43	173.67	171.65	160.21		
	K (ppm)									
No mulch	65.00	58.00	57.00	92.00	77.00	57.00	68.00	73.00	4.127	12.439
Mulch	99.00	90.00	99.00	103.00	115.00	81.00	90.00	129.00		
	Ca (ppm)									
No mulch	117.20	117.20	109.90	190.50	205.10	183.15	205.10	109.90	6.110	18.418
Mulch	168.48	161.15	139.18	234.40	219.75	234.40	183.15	168.48		
	Mg (ppm)									
No mulch	32.13	48.19	54.60	25.70	25.70	19.25	57.85	35.34	3.157	9.516
Mulch	32.13	32.13	35.34	35.34	28.92	9.64	38.55	6.43		
	S (ppm)									
No mulch	82.19	61.32	88.71	91.32	86.10	92.63	105.67	120.03	4.738	14.280
Mulch	97.27	120.60	83.49	84.80	100.45	99.15	96.54	98.84		

content of 129.00 ppm in NPK with mulch, which was superior to all other treatment combinations.

The available Ca content was the maximum of 212.45 ppm in poultry manure which was on par with FYM + azotobacter and FYM + phosphobacter but superior to all other nutrient sources. The interaction effect showed the highest available Ca content of 234.40 ppm both in poultry manure and in FYM + phosphobacter with mulch which were on par with FYM + azotobacter with mulch but superior to all other treatment combinations. The available Mg content was the maximum of 48.20 ppm in FYM + VAM which was on par with vermicompost but superior to all other nutrient sources. The interaction effect showed the highest available Mg content of 57.85 ppm in FYM + VAM without mulch which was on par with vermicompost without mulch but superior to all other treatment combinations. The available S content was the maximum of 108.93 ppm in NPK which was on par with FYM + VAM but superior to all other nutrient sources. The interaction effect showed the highest available S content of 120.6 ppm in FYM with mulch which was on par with NPK without mulch but superior to all other treatment combinations.

The available micronutrients in soil such as Fe, Mn, Zn and Cu were not significantly influenced by mulch, nutrient sources or their interaction.

4.6 EXPERIMENT 6. QUALITY VARIATIONS IN *CURCULIGO ORCHIOIDES*

Efforts were made to study the quality variations in crude drug due to biotypes and ecology and among the samples available in different markets in south India. Representative samples of the crude drug were collected from selected habitats and markets in Kerala and in the neighbouring states and studied in detail. The quality parameters of *C. orchioides* rhizome from various ecology and markets are presented in Table 4.6.1.

4.6.1 Biotype Variation

In general, natural habitat types recorded higher content of curculigoside, most of the primary metabolites and ash. The Panamkuzhi and Vellanikkara biotypes showed quality variations in all the parameters tested. In the natural

Table 4.6.1. Quality parameters of *Curculigo orchioides* rhizome from various ecology and markets (%)

Location	Dry matter	Ash	Crude protein	Crude fat	Crude fibre	Starch	Glucose	Sucrose	Curculigoside
Wild									
Panamkuzhi	93.15	9.110	1.928	4.006	7.217	49.83	4.120	2.103	0.031
Vellanikkara	92.47	7.985	8.626	2.724	5.560	43.97	1.130	ND	0.038
Cultivated									
Panamkuzhi	93.40	5.282	17.472	2.049	4.075	52.02	0.569	0.769	0.011
Vellanikkara	92.70	4.520	15.568	1.367	3.050	50.01	0.767	0.391	0.014
Market samples									
Kerala									
South zone	90.47	6.471	6.121	1.500	3.326	48.53	1.436	0.745	0.007
Central zone	89.75	8.523	4.720	1.579	2.823	52.91	0.772	0.000	0.005
North zone	91.13	6.523	6.105	1.616	3.153	54.31	1.063	0.755	0.029
High ranges	90.75	22.206	5.040	1.623	3.975	52.04	0.743	ND	0.054
Tamil Nadu	90.40	8.026	6.127	1.742	3.082	52.81	1.115	ND	0.045
Karnataka	92.05	8.607	6.160	1.717	3.050	53.20	1.195	ND	0.001
Andhra Pradesh	87.51	17.299	7.304	1.855	3.675	35.16	ND	ND	ND
Maharashtra	89.40	8.545	6.832	1.727	2.851	52.54	0.810	ND	0.007
SEm	2.674	0.265	0.233	0.161	0.128	0.936	0.491	0.170	-
$CD_{(0.05)}$	NS	0.799	0.703	0.485	0.385	2.823	1.479	0.513	-
G. Mean	90.94	8.818	7.192	1.856	3.654	50.10	1.152	0.438	0.020

ND = Not detected

habitat, Panamkuzhi biotype was superior to Vellanikkara biotype in the content of ash, crude fat, crude fibre, starch, glucose and sucrose while the reverse in the case of crude protein. In the cultivated situation, Panamkuzhi biotype was superior in all the parameters except glucose and curculigoside.

4.6.2 Market Samples

Among the different zones in the state of Kerala, the market samples showed considerable variation in the content of ash, crude protein, crude fibre, starch and sucrose. The ash content was the maximum of 22.206 per cent in High Ranges while it ranged between 6.471 per cent and 8.523 per cent in the other zones. Crude protein content was the maximum of 6.121 per cent in the south zone which was on par with the north zone but superior to Central zone and High Ranges. The crude fibre content was the maximum of 3.975 per cent in High Ranges, which was superior to all other zones and the least was 2.823 per cent in Central zone. The starch content was the maximum of 54.31 per cent in the north zone which was on par with Central zone and High Ranges but superior to the South zone (48.53%). The sucrose content was detected only in the market samples collected from south and north zones. Among the market samples collected from various zones of Kerala, those from High Ranges recorded higher curculigoside content.

Among the southern states, the ash content was higher in Andhra Pradesh (17.299%) while there was no significant variation in the market samples of Tamil Nadu, Karnataka and Maharashtra in ash content. There was no significant variation in crude protein content though Andhra Pradesh samples recorded a numerically higher value of 7.304 per cent. The crude fibre content was the maximum of 3.675 per cent in Andhra Pradesh samples, which was superior to all other states that were on par. The starch content was the lowest of 35.16 per cent in Andhra Pradesh samples whereas those from all other states recorded significantly higher starch content. Sucrose content was not detected in the market samples from other states.

On an average over various ecology and markets, *C. orchioides* crude drug contained crude protein 7.192 per cent, crude fat 1.856 per cent, crude fibre 3.654

per cent, starch 50.10 per cent, glucose 1.152 per cent, sucrose 0.438 per cent, curculigoside 0.020 per cent and ash 8.818 per cent.

5. DISCUSSION

5. DISCUSSION

The results of the various experiments under the project entitled 'agrotechnological practices for quality crude drug production in *nilappana* (*Curculigo orchioides* Gaertn.)'conducted at the Aromatic and Medicinal Plants Research Station, Odakkali during 2000-'02 are discussed in this chapter.

5.1 EXPERIMENT 1. OBSERVATIONAL TRIAL ON DEVELOPMENTAL PHYSIOLOGY OF *C. ORCHIOIDES*

This experiment was aimed at studying the growth and development pattern of *C. orchioides* and characterizing the primary and secondary metabolites in the plant. In this experiment, the growth and development pattern, dry matter production and yield and quality parameters of two biotypes of *C. orchioides*, namely, Panamkuzhi and Vellanikkara biotypes were studied. The results are discussed hereunder.

5.1.1 Growth Parameters

The general features of the plant along with the two biotypes, Panamkuzhi and Vellanikkara used for the study are depicted in Figure 5.1.1.

In general, over the period of 12 months, the height of *C. orchioides* increased from 9.63 cm to 21.93 cm at 7 MAP, decreased to 12.43 cm at 10 MAP and again increased to 17.70 cm at 12 MAP. Leaves per plant also followed similar trend with a peak at 7 MAP (9.75 leaves), a decrease thereafter and again an increase at 12 MAP. Canopy spread also peaked at 7 MAP (31.40 cm) with a decrease at 10 MAP and again an increase. Sucker production reached the highest at 8 MAP and 12 MAP with a slight reduction in between. Production of leaf sprouts was mainly confined to 7 MAP. Leaf area per plant increased steadily till 7 MAP with a decline at 9 MAP and later a marginal increase. Number of roots steadily increased till 7 MAP and later decreased progressively. Root length was the highest at 6 MAP and later there was a progressive decrease. Though there was no significant variation in the production of flowers over the period, the production of fruits was highest at 7 MAP. The chlorophyll content increased till 6 MAP4 and later decreased with a lower peak at 11 MAP.

Panamkuzhi biotype with leaf sprout

Vellanikkara biotype with fruits

Growth stages of the plant up to 6 months

In bloom

Rhizome

Crude drug in trade

Fig. 5.1.1. The plant *nilappana* (*Curculigo orchioides* Gaertn.)

Among the growth parameters studied, Panamkuzhi biotype was superior to Vellanikkara biotype in number of suckers per plant and number of roots per plant and the reverse in the case of canopy spread, leaf area per plant, chlorophyll content in leaf and number of fruits per plant while there was no significant variation in plant height, the number of leaves per plant, leaf sprouts per plant, chlorophyll b content, maximum root length and number of flowers per plant.

Both the biotypes varied significantly over the period in plant height, canopy spread, suckers per plant, leaf area, number of roots and fruits per plant, maximum root length and chlorophyll a content as evident from the corresponding significant interactions (Fig. 5.1.2). Vellanikkara biotype though had higher plant height till 6 MAP, it became shorter after with an exception at 12 MAP. In the case of canopy spread, Vellanikkara biotype had higher canopy spread till 4 MAP but later there was not much variation between the biotypes. Sucker production started from 6 MAP and Panamkuzhi biotype had a consistently higher number of suckers per plant while Vellanikkara biotype fluctuated very much in this respect. Leaf area expansion was much higher in Vellanikkara biotype till 5 MAP and later Panamkuzhi biotype showed not much variation. In the case of chlorophyll a content both the biotypes behaved similarly except at 9 and 12 MAP when Vellanikkara biotype recorded higher content of chlorophyll a. The number of roots per plant was slightly higher in Panamkuzhi biotype till 5 MAP and later there was wide fluctuation in both the biotypes. The highest root length showed wide fluctuation in Panamkuzhi biotype whereas it was more or less stable in the case of Vellanikkara biotype. The Vellanikkara biotype showed a higher fruit bearing ability with a peak at 7 MAP whereas Panamkuzhi biotype was a shy bearer.

In general in both the biotypes, various growth parameters peaked around 7 MAP indicating that the maximum growth of the plant was attained in a period of 7 MAP. There was a sharp decline in most of the growth parameters after 7 months probably because of the onset of dry season from December (Fig. 3.1a). The leaf sprout production coincided with the peak south-west monsoon during July and north-east monsoon during November-December. The growth and development of the plant seemed to be dependent on the climatic factors

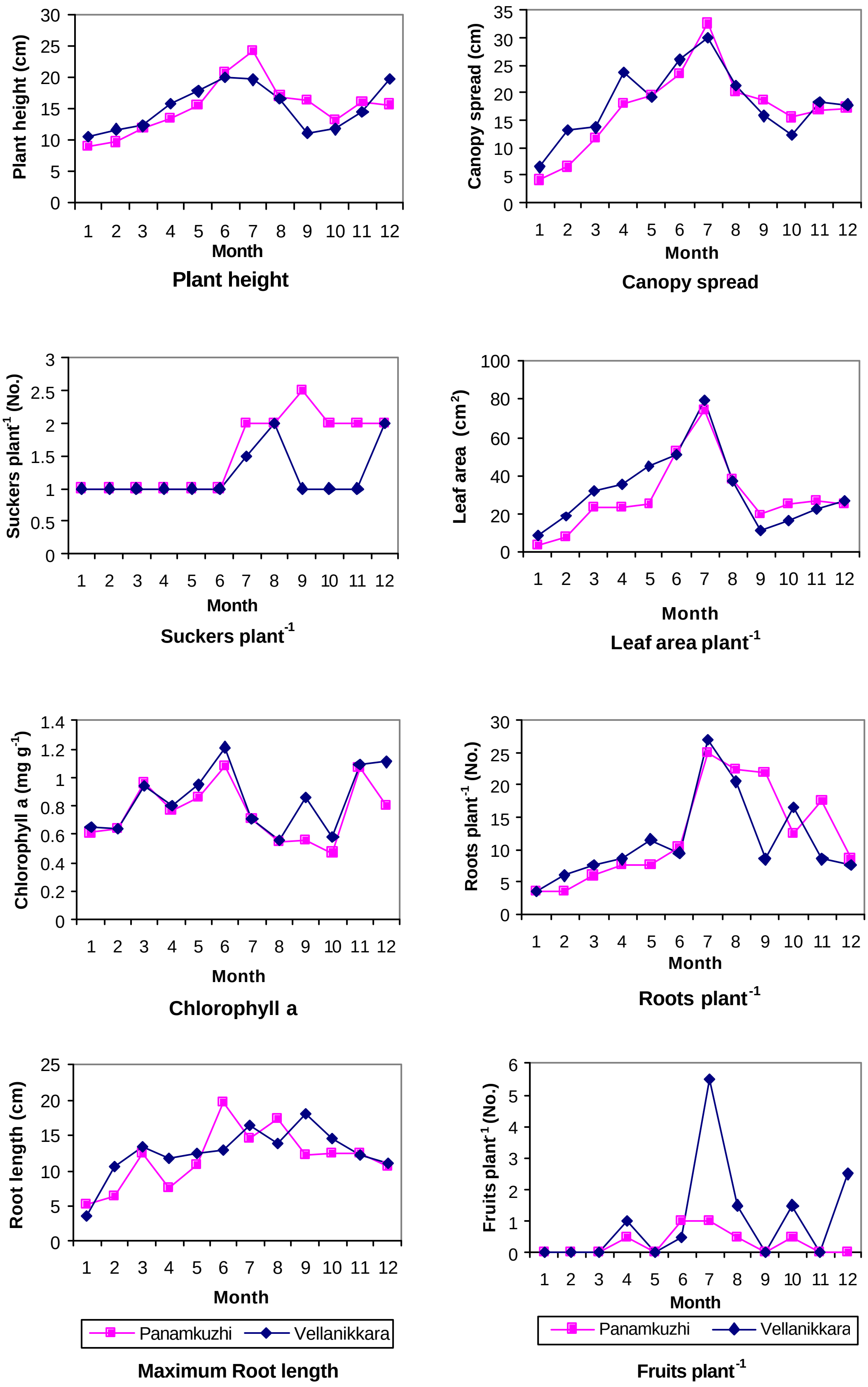


Fig. 5.1.2. ***Curculigo orchioides*** **biotype variation in growth**

particularly the rainfall. The production of leaves, suckers and leaf sprouts was favoured by the availability of adequate moisture through rainfall and the flowering and fruit production especially in Vellanikkara biotype was the result of culmination of growth and development of the crop. Flowering and fruiting might have utilized the reserve food in the plant leading to a sharp decline in the growth parameters in Vellanikkara biotype after 7 months (Fig. 5.1.2). Since flowering and fruiting were very meagre in Panamkuzhi biotype, greater availability of reserve food could sustain the growth and development in Panamkuzhi biotype better than Vellanikkara biotype.

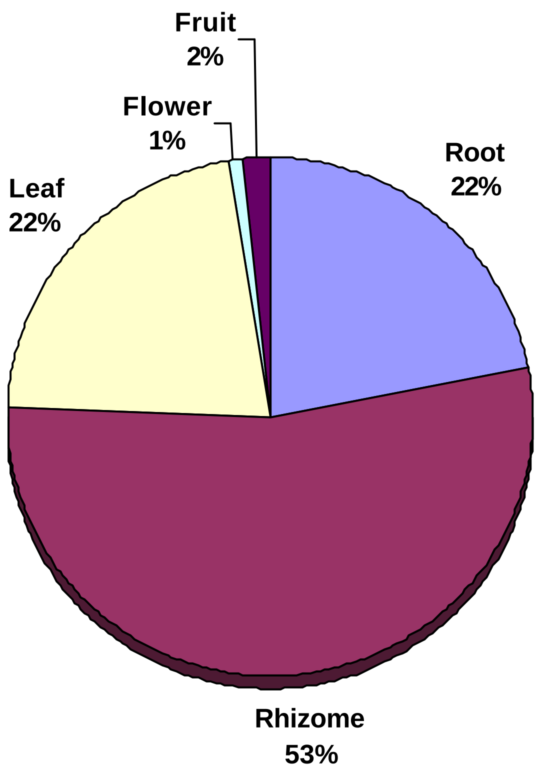
5.1.2 Dry Matter Production

The dry matter accumulation in root, rhizome, leaf and fruit steadily increased up to 7 MAP and decreased thereafter. The increase in dry matter production was the result of an increase in vegetative growth parameters such as the number of roots, root length, leaves, leaf area and suckers as evident from their positive correlations (Appendix 3).

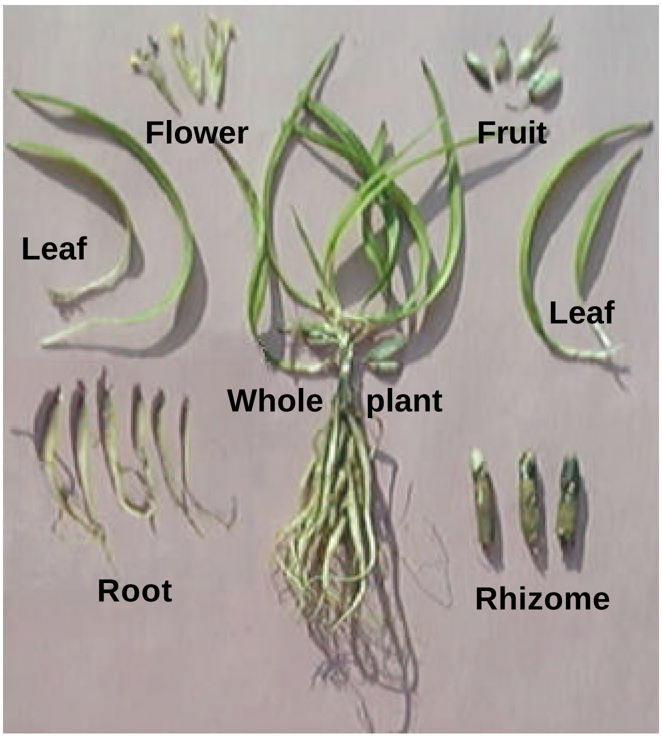
On an average over the period and biotype, the dry matter distribution was 21.94 per cent in root, 54.01 per cent in rhizome, 21.94 per cent in leaf, 0.84 per cent in flower and 1.69 per cent in fruit. Vellanikkara biotype recorded significantly higher dry matter accumulation in root, leaf, flower, fruit and total dry matter production while there was no variation in rhizome dry matter production compared to Panamkuzhi biotype (Table 4.1.4). Vellanikkara biotype recorded significantly higher peak values for root, leaf, flower and fruit dry matter production whereas Panamkuzhi biotype was distinctly superior to Vellanikkara biotype in dry matter accumulation in rhizome (Fig. 5.1.3). In other words, Panamkuzhi biotype is the better choice for cultivation as the rhizome is the economic part and a better partitioning of the dry matter into the rhizome is obtained in this biotype. In Vellanikkara biotype a higher partitioning of the dry matter into flower and fruit at the expense of rhizome is a negative attribute.

5.1.3 Yield Parameters

The rhizome length did not vary significantly after 6 months whereas the rhizome thickness showed two peaks, at 8 and 11 MAP respectively, the latter being higher. The Vellanikkara biotype was superior to Panamkuzhi biotype in



Dry matter distribution



Different parts of the plant

Fig. 5.1.3. Partitioning of dry matter in *Curculigo orchioides*

rhizome thickness (Table 4.1.6). It was observed that, unlike in other tuberous or rhizomatous crops, the rhizome development in *C. orchioides* is upwards (neither downwards nor horizontal) and it continues until the rhizome is exposed over the soil when it starts suckering for continued development of the plant. This type of rhizome development has got special agronomic significance in that the crop requires occasional earthing up for realization of higher rhizome yield.

The biological yield and fresh rhizome yield peaked at 7 MAP. The harvest index was the highest at 11 MAP. Panamkuzhi biotype was superior in harvest index. Higher rhizome yield per plant and a higher harvest index were noticed in Panamkuzhi biotype indicating its superiority over Vellanikkara biotype for cultivation. The higher rhizome yield in Panamkuzhi biotype was the result of a better partitioning of dry matter into the rhizome with a higher harvest index value due to negligible diversion of reserve food for reproductive growth.

5.1.4 Quality Parameters

Over the period, crude fibre and crude protein content of root decreased up to 6 MAP but reached the highest at 9 MAP. However, the crude fat showed an opposite trend, which indicated the possibility of their inter-conversion or translocation to other parts. Between the biotypes, there was no significant difference in quality, except in crude fibre content wherein Panamkuzhi biotype was superior (Table 4.1.7).

In the case of rhizome, the two biotypes differed significantly in sucrose, starch, crude fibre, crude protein, crude fat and ash contents (Table 4.1.8 and Fig. 5.1.4). Panamkuzhi biotype initially had much higher sucrose content, which reduced drastically at 3 MAP and marginally higher later on. Starch content remained similar throughout, except for a significant decrease at 6 MAP recorded by Panamkuzhi biotype. Crude fibre content decreased steadily till 6 MAP and then increased. Panamkuzhi biotype had higher crude fibre content both initially and at 9 MAP. Crude protein content increased in both the biotypes over the period, except a slight decrease for Vellanikkara biotype at 3 MAP. Crude fat content decreased initially and later showed a marginal increase in both the biotypes. Though Panamkuzhi biotype had higher crude fat content in rhizome

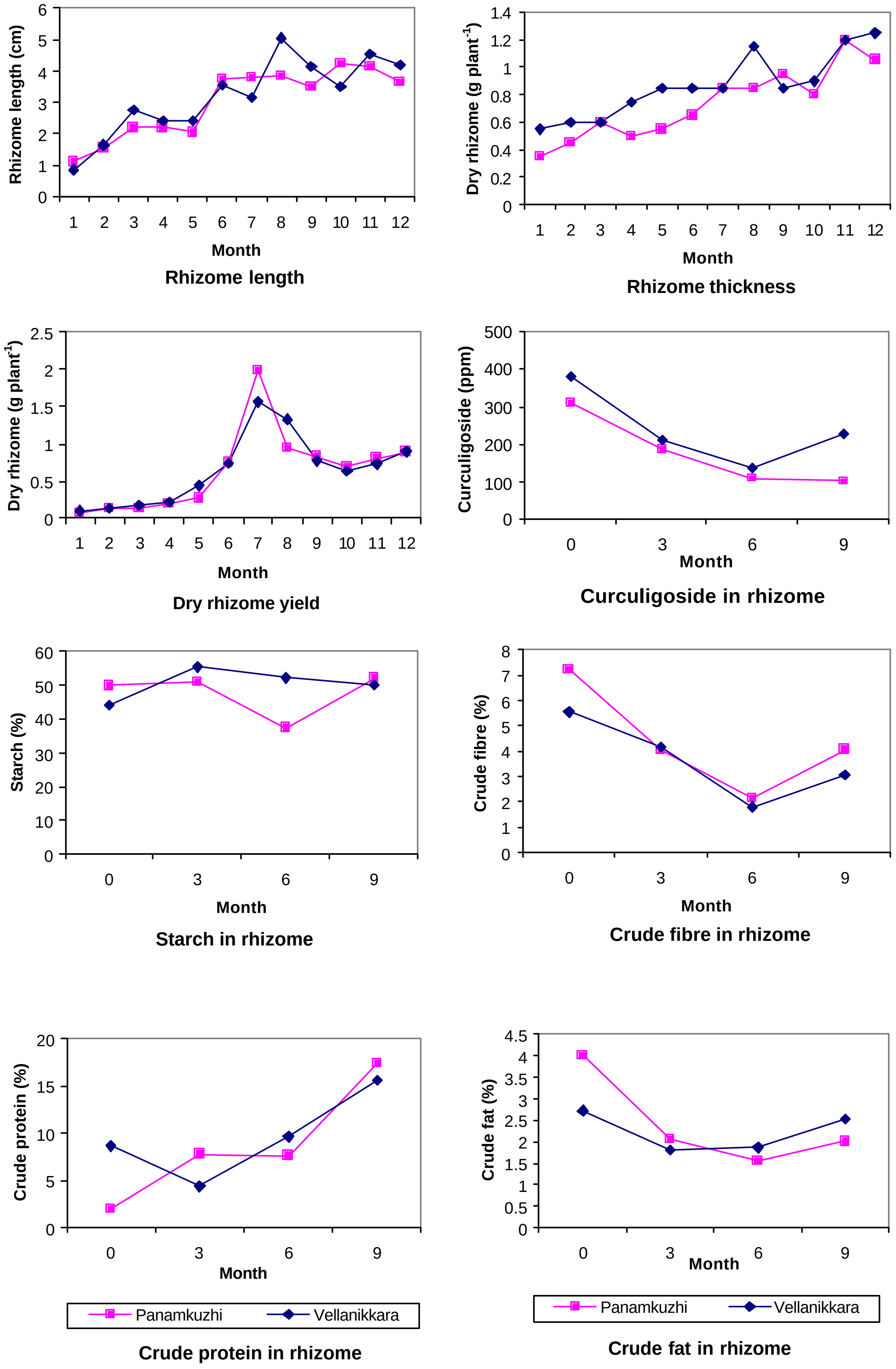


Fig. 5.1.4. ***Curculigo orchioides*** **biotype variation in yield and quality**

initially, it was taken over by Vellanikkara biotype during later phases. Panamkuzhi biotype was superior in ash content.

In leaf quality, the biotypes varied significantly in crude protein and ash contents and Panamkuzhi biotype was distinctly superior in this respect (Table 4.1.10).

5.1.4 General Discussion

The observational trial on developmental physiology of *C. orchioides* revealed that the plant is characterized by an active vegetative phase till 7 MAP under irrigated condition which is culminated by reproductive phase. In general, it grew to a maximum height of 22 cm with 31 cm canopy spread, 10 leaves, 2 suckers, 2 leaf sprouts, 26 roots per plant and producing 2-3 flowers and fruits, asynchronously. The highest rhizome length was attained in 8 MAP and there was not much variation in rhizome length afterwards (Table 4.1.6). However the rhizome thickness increased progressively though marginally throughout the growth period. In spite of this increase in rhizome thickness, there was no increase in rhizome yield after 7 months. The leaf production and consequently the leaf area were drastically reduced after 7 months reducing the photosynthetic efficiency resulting in the stagnation of the rhizome yield. The little starch produced through photosynthesis might have been used for the physiological activity of the plant. The highest growth and yield of the crop was achieved in a period of 7 months when it could be harvested for the highest yield of rhizome. As a rainfed crop it could be planted with the onset of south-west monsoon during May-June. Bhaskaran and Padmanabhan (1983) and Dong and Zhang (1998) reported that *C. orchioides* was grown during the monsoon season in India.

On an average (at 6 MAP), the contents of starch, crude fibre, crude protein, crude fat, curculigoside and ash were 19.97, 17.84, 4.26, 8.78, 0 and 12.17 per cent in root, 44.81, 1.97, 8.62, 1.71, 0.01 and 3.96 per cent in rhizome and 0, 18.79, 10.98, 8.03, 0.05 and 10.51 per cent in leaf of *C. orchioides,* respectively.

The primary metabolites like sucrose, crude fibre, crude fat and curculigoside contents decreased initially probably due to their utilisation by the plant for its establishment in the field. However, they increased substantially with the onset of active physiological activity in the plant. On the contrary, the crude protein content in the rhizome progressively increased through out the growth period, which might have resulted from inter-conversion from other metabolites during early phase and active synthesis during the later growth phase of the plant. More over, a negative relation was reflected between quantity and quality as indicated by their negative correlations (Appendix 4).

The two biotypes significantly differed in growth, yield and quality parameters. Panamkuzhi biotype had good vegetative growth but poor reproductive growth enabling a better diversion of reserve food for the production of rhizome, the economic part. This resulted in a higher harvest index for the biotype. The Vellanikkara biotype though had good vegetative growth its characteristic reproductive phase resulted in a greater diversion of reserve food for fruit production leading to lesser rhizome yield. This clearly indicated that Panamkuzhi biotype is a better choice for cultivation. Biotype variation in growth, yield and quality parameters has also been reported by Paly *et al*. (1989) in medicinal plants, Menon (1996) in *njavara* rice, Joy *et al*. (1999) in *Alpinia calcarata*, Kurian *et al*. (2000) in *Ocimum sanctum*, Sreevalli *et al*. (2000) in periwinlkle and Krishnamoorthy and Madalageri (2002) in ajowan.

5.2. EXPERIMENT 2. CHARACTERIZATION OF MAJOR GLYCOSIDES IN *CURCULIGO ORCHIOIDES*

The rhizome of *C. orchioides* is reported to contain glycosides (Oru and Kogyo, 1983; Dhawan and Saxena, 1958; Xu *et al*., 1992b; Mamta *et al*., 1995). Glycosides are considered to be one of the major pharmacologically active components of the drug. Kubo *et al*. (1983) reported the presence of curculigoside (5-hydroxy-2-O-β-D-glucopyranosyl benzoyl-2,6-dimethoxy benzoate) in *C. orchioides* and Yamasaki *et al*. (1994) reported that the rhizome contained 0.2 per cent curculigoside. The glycosides in *C. orchioides* which are considered to be pharmacologically important are the glucosides of benzoyl benzoate. In view of the importance of these compounds in the therapeutical activity of the drug, an effort was made to characterize them on the basis of the benzoic acid derivatives obtained on alkali hydrolysis of the glucoside fraction of *C. orchioides*.

5.2.1 Development of an HPLC Method to Resolve the Benzoic Acid Derivatives Formed by the Hydrolysis of Glycosides in *C. Orchioides*

According to Yamasaki *et al*. (1994) the glycosides of benzoyl benzoate in *C. orchioides* can be hydrolyzed to release the corresponding benzoic acid residues by treatment with 1 *N* NaOH. The method was closely followed to hydrolyse the benzoyl benzoate glycosides present in various samples of *C. orchioides* representing biotypes, natural habitat, cultivated and market samples.

A method was developed to analyse the benzoic acid derivatives in hydrolysate by high pressure liquid chromatography. A combination of Lichrospher RP-18 column (4.2 mm diameter and 25 cm length) and 0.01 *M* phosphate buffer pH 6.0 at a flow rate of 1 ml minute^{-1} was optimum for the separation of benzoic acid derivatives.

5.2.2 Estimation of Benzoic Acid Derivatives in Different Samples of *C. Orchioides*

The method developed above was used for the characterization of *C. orchioides* samples of different origin on the basis of their content of benzoic acid derivatives.

5.2.1.1 Natural Habitat and Cultivated Biotypes of C. Orchioides

Efforts were made to study the difference between biotypes in their chemical composition taking 4-hydroxy 3-methoxy benzoic acid and 2,6-dimethoxy benzoic acid as indicator compounds. The content of 4-hydroxy 3-methoxy benzoic acid was higher in the rhizome of Panamkuzhi biotype under both natural habitat and cultivated situations (Table 4.2.1). On the contrary, the reverse was true when the content of 2,6-dimethoxy benzoic acid was taken into consideration. The results clearly demonstrate that biotypes of the same species show wide variations in respect of their chemical composition. The relative importance of the two marker compounds in the medicinal effect of the drug is not clearly known. Further *C. orchioides* possesses a number of therapeutical properties like aphrodisiac, uterine stimulatory, nerve tonic and diuretic and the association of each of the chemical compounds with these widely different properties is also not known. Hence it is difficult to establish the superiority of one biotype over the other in this case.

5.2.1.2 Quality Variation in Market Samples of C. Orchioides

Efforts were also made to study the quality difference among samples of *C. orchioides* crude drug available in different markets in south India. Representative samples of the crude drug were collected from selected markets in Kerala and in the neighboring states. Comparison was made on the quality of this material based on the content of 4-hydroxy 3-methoxybenzoic acid and 2,6-dimethoxybenzoic acid.

The key attribute of the data (Table 4.2.2) is the wide variation in the level of the marker compounds. Sampling locations are situated far apart and hence the source of the material can be expected to be different. This clearly demonstrates that a large variation exists among the *C. orchioides* plant types sourced from different parts of south India. This wide variation in quality as indicated by these marker compounds proposes a large variation in the therapeutical efficiency as well. Two important aspects that emerge from this study are:

(1) A large natural variability exists among the natural habitat population of *C. orchioides* in the subcontinent, which offers the breeder wide scope for improvement of the crop by selection and hybridization.

(2) There is a dire need for developing methods for identification of quality crude drugs of *C. orchioides* and imposing strict quality control to ensure the efficiency of the drug formulations manufactured using the drug.

5.3 EXPERIMENT 3. EFFECT OF SHADE AND SPACING ON THE YIELD AND QUALITY OF *C. ORCHIOIDES*

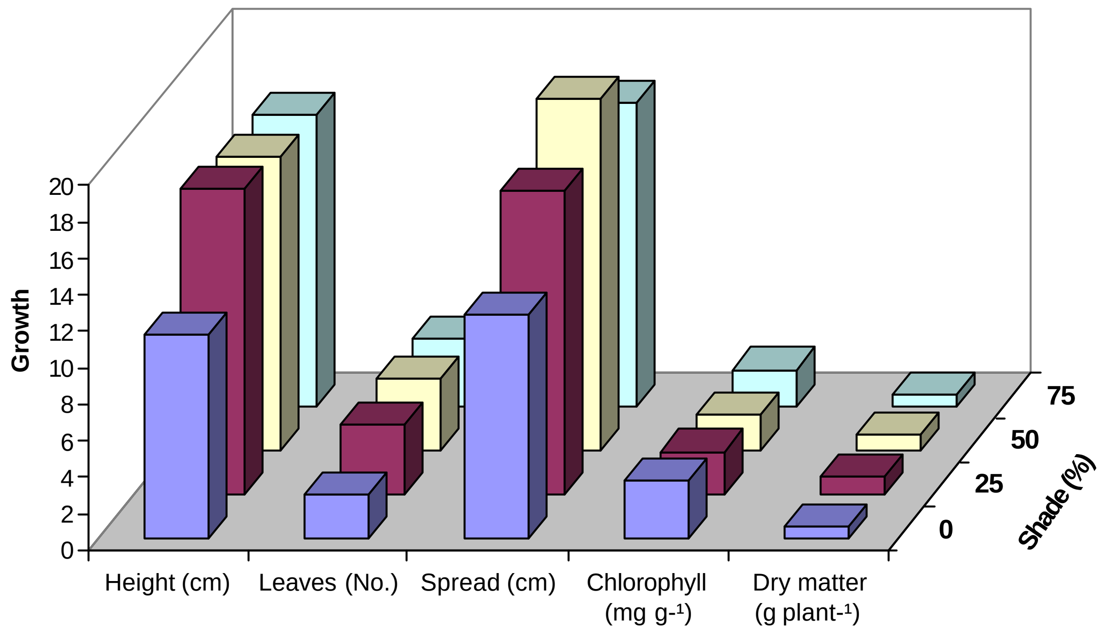
A field experiment was conducted to study the effect of shade and spacing on the growth, yield and quality of *C. orchioides* and to ascertain the optimum requirement of shade and spacing for maximizing quality crude drug production in *C. orchioides*. The main and interaction effects of shade and spacing on growth, yield, quality and on soil characteristics were studied and are discussed hereunder.

5.3.1 Growth Parameters

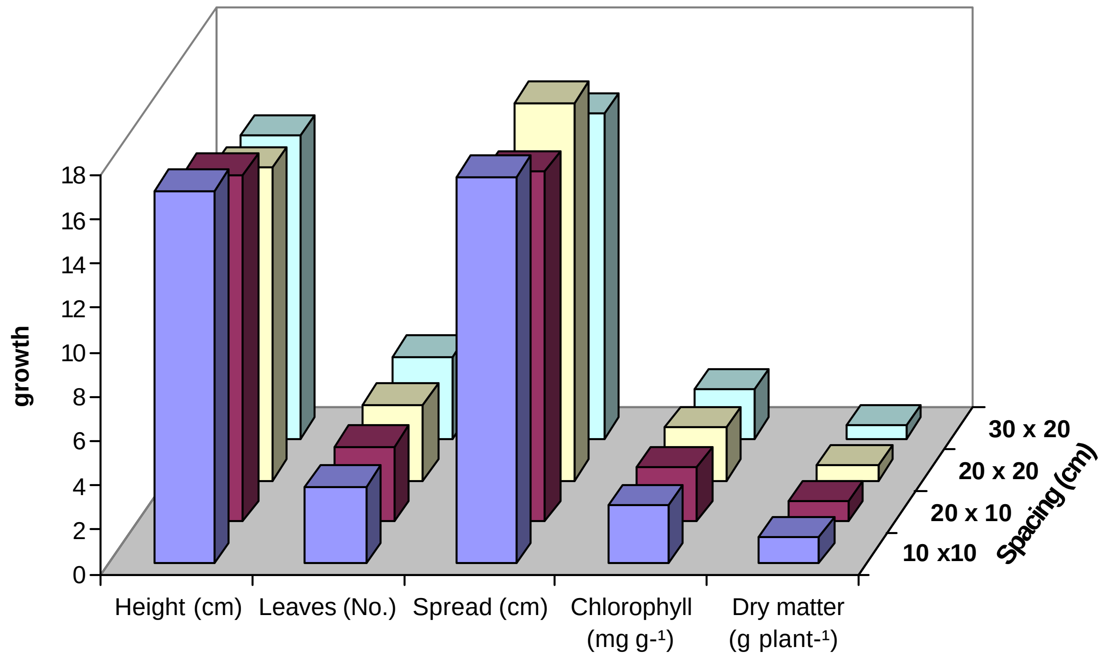
Plant height was more under shade than under open condition and it increased with increase in shade (Fig. 5.3.1). More over, the effect was significant at 4, 6, and 8 MAP. A higher plant height under shaded condition is a general characteristic exhibited by many plants. It is due to an increase in the content of gibberellins in plants grown under shade (Jones and Millan, 1992; Vyas and Nein, 1999). Among the different shade levels, plants grown under 75 per cent shade exhibited the highest height at the maximum vegetative growth stage (6 MAP) and there was a progressive reduction in plant height with decreasing levels of shade (Table 4.3.1). Number of leaves per plant was influenced by shade positively but marginally in most of the months (Table 4.3.3). More over the effect was significant at 7 MAP. Increasing levels of shade also increased the canopy spread after two months. Sucker production was marginally higher under shade compared to open condition though the effect was not significant (Table 4.3.7). Increase in growth parameters due to shade has also been reported by Nizam and Jayachandran (1997) in Zingiberaceous crops like ginger, turmeric and mango ginger; Vyas and Nein (1999) in *Cassia angustifolia;* Thanuja (2001) in spice crops and Korikanthimath *et al.* (2002) in cardamom.

The chlorophyll a and a+b contents decreased with increasing level of shade at 3 and 6 MAP but decreased at 9 MAP while chlorophyll b content remained unchanged. Among the shade levels 25 per cent shade recorded the highest chlorophyll a and a+b contents. Korikanthimath *et al.* (2002) reported that cardamom was morphologically and anatomically suited to the shade situation because full sunlight caused scorching in cardamom leaves due to break down of chlorophyll.

The dry matter production was higher under shade though the effect was not significant during most of the period up to maximum growth stage (6 MAP) (Table 4.3.16). This is due to the higher plant height, number of leaves, canopy spread and sucker production under shade compared to open condition. Among the shade levels, 25 per cent shade recorded higher dry matter production in most of the months and the effect was significant at 5, 7 and 8 MAP. This is probably due to the marginally higher leaf production and canopy spread coupled with



Effect of shade



Effect of spacing

Fig. 5.3.1. Effect of shade and spacing on growth of *Curculigo orchioides*

significantly higher chlorophyll content. The result corroborates the findings of Nizam and Jayachandran (1997) in ginger, Ravindran and Kulandaivelu (1998) in cardamom and Subramonium (2000) in *Centella asiatica*.

The adaptability of *C. orchioides* to shade is particularly evident from the significantly lower plant density and suckers m^{-2} at 6 MAP. Plant density and suckers per m^{-2} were significantly higher under shade compared to open condition showing a progressive increase with increase in shade (Table 4.3.18).

Though the plant density was uniform at 3 MAP, it was significantly lower under open condition at 6 MAP. Similarly, the total number of suckers m^{-2} at 6 MAP was significantly lower under open condition whereas it was 60 per cent or more under varying shade levels and that were on par. Weed infestation was significantly higher under open condition and there was a progressive reduction with increase in shade (Table 4.3.18). The heavy weed infestation under open condition and its progressive reduction with increase in shade is due to the positive influence of sunlight on weed growth (Thanuja, 2001).

The various growth parameters of *C. orchioides* such as plant height, number of leaves, canopy spread and sucker production were not significantly influenced by spacing in most of the months. More over, marginally higher values of the above parameters were observed at a closer spacing than at a wider spacing. This showed that 10 x 10 cm spacing is sufficient for the optimum growth of *C. orchioides*. The spacing did not influence the chlorophyll content in the leaves as it was more of a function of light and there was no mutual shading of the plants at closer spacing which again showed that 10 x 10 cm spacing was adequate for the growth of the plant.

The total dry matter was either the highest or on par with the highest value at 10 x 10 cm spacing. This is due to the marginally higher growth parameters. Higher plant density together with proper growth of the plant resulted in highest dry matter production at 10 x 10 cm spacing. Similar results were also reported by Joy *et al*. (1999) in *Alpinia calcarata* and *Kaepferia rotunda* at closer spacing. The number of plants m^{-2} and total number of suckers m^{-2} were the highest under 10 x 10 cm spacing and significantly decreased with increase in spacing. This again showed the adequacy of 10 x 10 cm spacing for the crop. Weed biomass was not influenced by spacing but a lesser value was observed at 10 x 10 cm spacing at 4 and 6 MAP (Table 4.3.18). The lack of influence of spacing on weed infestation is probably due to the uniform availability of sunlight at all the spacings owing to the short and compact structure of the plant.

The interaction effect showed that though the plant height at 8 MAP was the highest at 20 x 10 cm spacing and 25 per cent shade, it was on par with all the shade levels, except under open condition at 10 x 10 cm spacing. The number of leaves at 8 MAP and canopy spread at 5 MAP under 25 per cent shade and 10 x 10 cm spacing were on par with the highest values recorded by any treatment combination.

The superiority of 25 per cent shade and 10 x 10 cm spacing in dry matter production is also clearly evident from the significant interactions at 4, 7 and 8 MAP (Table 4.3.17). The dry matter production was the highest or on par with the highest value at 25 per cent shade and 10 x 10 cm spacing especially during the later phase of the crop. Similarly the plant density and sucker production at 6 MAP under 10 x 10 cm spacing and 25 per cent shade were on par with the highest value recorded by any treatment combination.

5.3.2 Yield Parameters

Biological yield was significantly higher under shade compared to open condition (Table 4.3.20). Among the shade levels, 25 per cent shade recorded the highest biological yield (76.05 per cent higher than under open condition). Lesser weed infestation, more plant density together with better vegetative growth under shade resulted in higher biological yield. Whereas heavy weed infestation, lesser plant population and lesser vegetative growth under open condition resulted in significantly lesser biological yield

Fresh rhizome yield was significantly higher under shade compared to open condition (Table 4.3.20). Among the shade levels, 25 per cent shade recorded the highest rhizome yield (71.65 per cent higher than under open condition). The higher biological yield and better partitioning of photosynthates might have resulted in significantly higher fresh rhizome yield under shade compared to open condition.

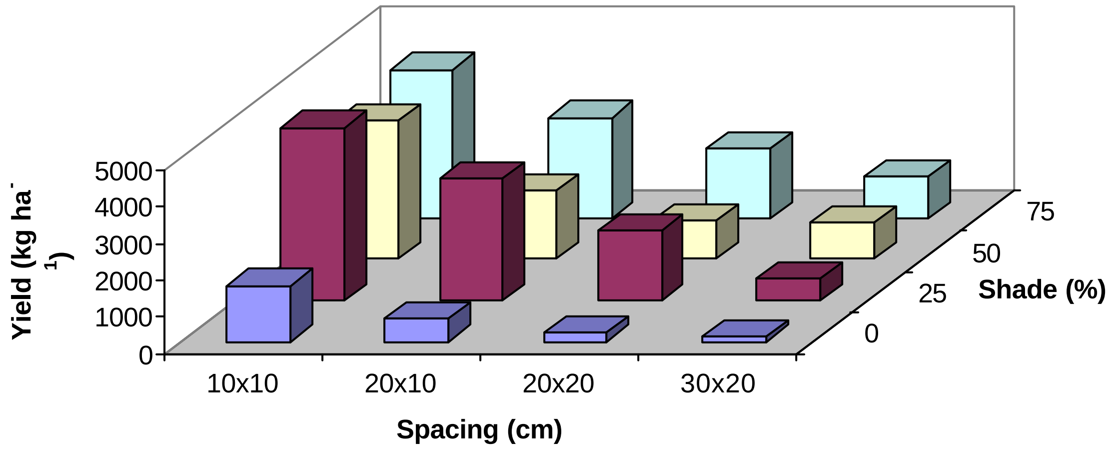
The interaction effect recorded the highest fresh rhizome yield (2736.74 kg ha^{-1}) at 25 per cent shade and 10 x 10 cm spacing, which was superior to all other treatment combinations (Fig. 5.3.2). This might be due to higher growth characteristics such as plant height, number of leaves, canopy spread and also higher chlorophyll content and harvest index.

Dry rhizome yield was significantly higher under shade compared to open condition. Among the shade levels, 25 per cent recorded the highest value which was 79.92 per cent higher than under open condition (Table 4.3.20).

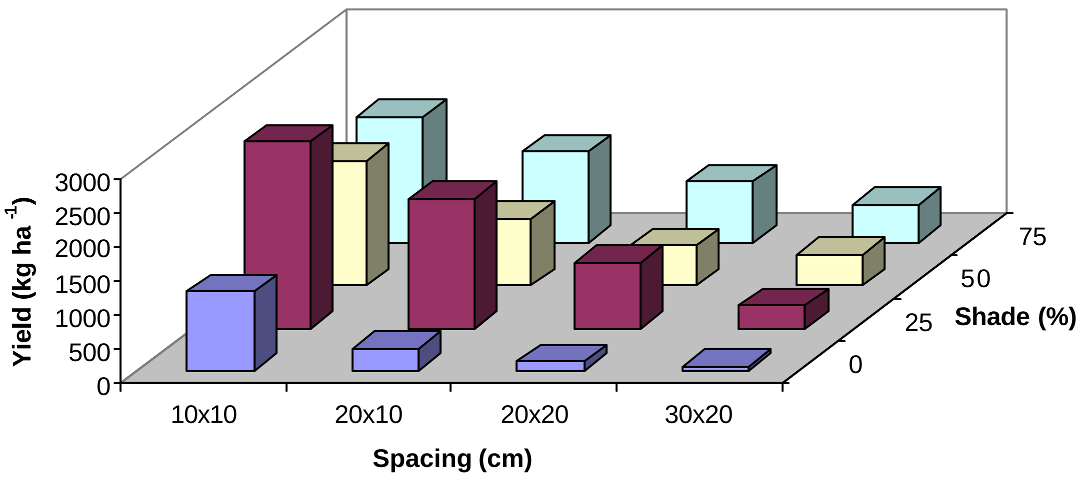
The biological, fresh rhizome and dry rhizome yields were higher under shade compared to open condition. Among shade levels, 25 per cent shade recorded the highest. The increase in yield under shade is attributable to the increase in growth parameters, such as plant height, number of leaves per plant and canopy spread and better partitioning of the photosynthates. This clearly indicates that *C. orchioides* is a shade loving plant and its growth and yield are much better under partially shaded conditions and 25 per cent shade seems to be the optimum level. Thanuja (2001) reported that Zingiberaceous medicinal crops like ginger, turmeric and mango ginger showed better growth and yield under partially shaded situation (25-50%).

The harvest index decreased with increasing level of shade and it was 56.57 per cent at 25 per cent shade as against 66.96 per cent under open condition. Under open condition, because of the intense light and high temperature, the shoot portion completely dried up at the time of harvest, which resulted in lower biological yield and thereby higher harvest index value. With increasing level of shade the shoot drying was delayed, which resulted in higher biological yield and lower harvest index values.

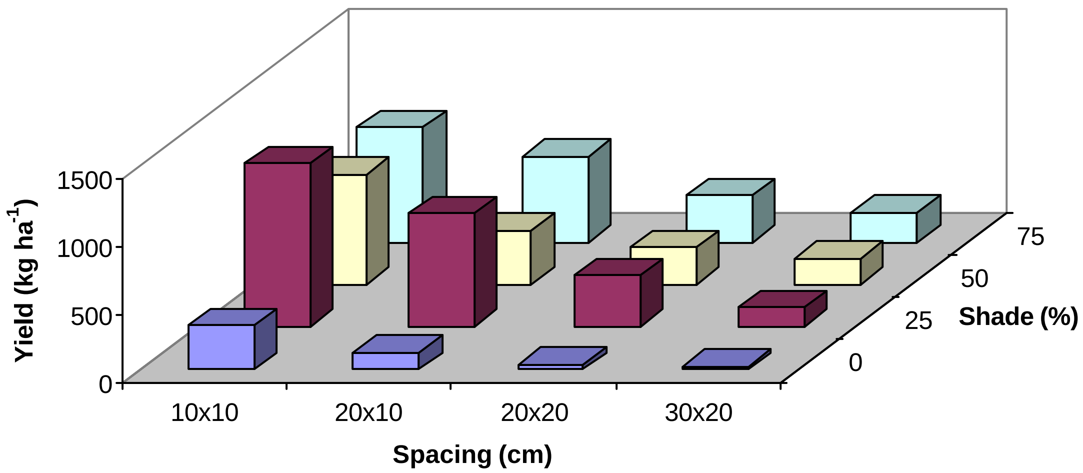
The biological, fresh rhizome and dry rhizome yields were the highest at 10 x 10 cm spacing and they decreased significantly with increase in spacing. The highest yield at 10 x 10 cm spacing is attributed primarily to the higher plant density and secondarily to the higher growth parameters such as plant height, number of leaves, canopy spread and number of suckers per plant and the better partitioning of the photosynthates. Similarly, Shina (1998) reported a high root yield of *Hemidesmus indicus* when it was planted at a closer spacing (10 x10 cm).



Biological yield



Fresh rhizome yield



Dry rhizome yield

Fig. 5.3.2. Interaction effect of shade and spacing on yield of *Curculigo orchioides*

Kurien *et al*. (2000) noted a significantly higher yield of rhizomes in *Costus speciosus* at the closest spacing. Yaseen *et al.* (2000) observed that different varieties of menthol mint produced higher herb at closer spacing. Ram *et al*. (2001) suggested that for achieving high root yield, *Asparagus racemosus* and *A. adscendens* should be grown at a closer spacing.

The harvest index decreased with increase in spacing and it ranged from the lowest 49.52 per cent at 30 x 20 cm to the highest 53.98 per cent at 10 x 10 cm spacing. This is due to higher plant density and better vegetative growth which resulted in higher biological yield. These results indicate that *C. orchioides* requires a narrow spacing of 10 x 10 cm for realizing maximum yield. Highest dry matter production and highest plant density resulted in significantly highest biological and fresh rhizome yields at 10 x 10 cm spacing which in turn resulted in highest harvest index.

5.3.3 Quality Parameters

The content of sucrose, starch and curculigoside in rhizome at harvest were highest at 25 per cent shade, glucose at 50 per cent shade and crude fibre, crude protein, crude fat and ash contents were highest under open condition (Table 4.3.22, Fig. 5.3.3). This indicated that the quality of the crude drug was much influenced by light intensity. The contents of crude protein, crude fibre, crude fat and ash were higher under open condition while the carbohydrate concentration was the highest under partially shaded condition. This also suggests that the crude protein, crude fat and crude fibre are synthesized from the basic primary metabolite of carbohydrate and the conversion is progressively hampered with increasing level of shade in *C. orchioides.* Quality improvements under shade have also been reported by Ancy and Jayachandran (1998) in ginger and Menon and Potty (1998, 1999) in *njavara* rice. Subramonium (2000) reported that 50 per cent shading of *Centella asiatica* resulted in higher yields of asiaticoside. In *Valeriana wallichii* maximum valepotriates content was noted under nylon net shade (Singh *et al.,* 2000c).

Most of the quality parameters were more at closer spacing compared to wider spacing (Fig. 5.3.3). This is probably due to the relatively lesser weed competition, more absorption of nutrients, proper growth and development of

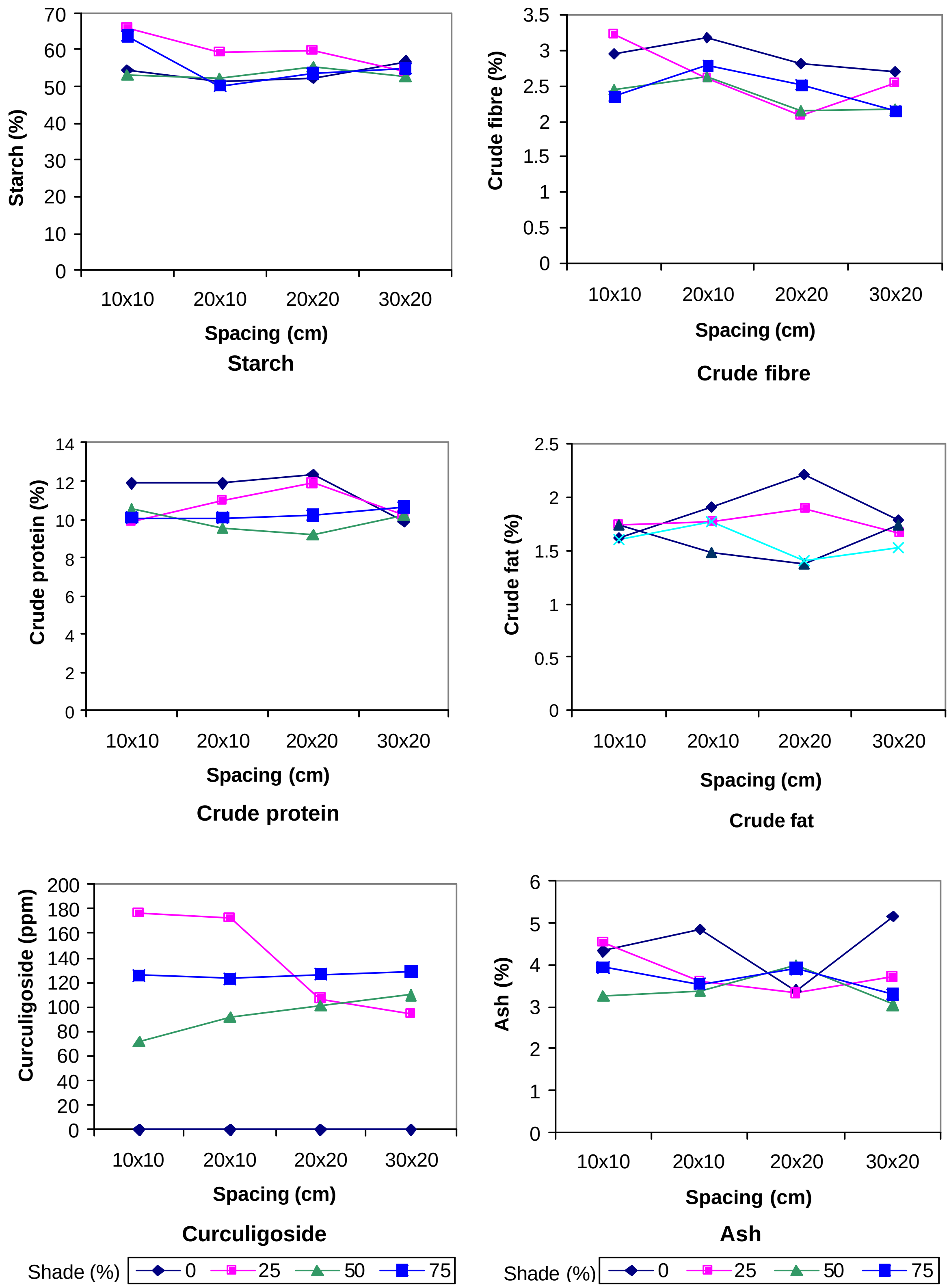


Fig. 5.3.3. Interaction effect of shade and spacing on quality of *Curculigo orchioides* dry rhizome at harvest

plants and efficient utilization of absorbed nutrients for quality development. Among spacings, closer spacings recorded higher curculigoside content than wider spacings and the highest content was at 20 x 10 cm followed by 10 x 10 cm spacing. The starch and ash contents were highest at 10 x 10 cm spacing while glucose, sucrose, crude fibre, and crude fat contents were highest at 20 x 10 cm spacing indicating that a closer spacing is beneficial for better quality in *C. orchioides* and the spacing 10 x 10 cm is most optimum for maximum yield of quality crude drug production in the crop. Gill and Randhawa (1999) reported that row spacing did not affect the oil content in *Ocimum basilicum*. The cineole, linalool, methyl chavicol and eugenol content in herb did not change in herb oil under various spacing. Kurian *et al.* (2000) reported that in *Costus speciosus* yield of diosgenin was significantly higher at the closest spacing (50 x 50 cm). Shina (1998) reported that high density planting of *Hemidesmus indicus* at 10 x 10 cm spacing resulted in high oil yield.

The starch and crude fibre contents in the rhizome at harvest were the highest under 10 x 10 cm spacing and 25 per cent shade (Table 4.3.23).. The crude fibre content at 25 per cent shade decreased with increase in spacing till 20 x 20 cm and then showed a slight increase whereas at all other shade levels including the open situation crude fibre content slightly increased at 20 x 10 cm and then decreased with increase in spacing.

5.3.4 Nutrient Content

Since the crop exhibited maximum vegetative growth and rhizome yield at 6 MAP the nutrient content in rhizome at that stage alone is discussed hereunder.

At 6 MAP in rhizome, the content of N, P and Mn was negatively correlated with yield in relation to shade (Appendix 5). With respect to spacing, N, Ca, Mg and Cu contents were positively correlated whereas K and Mn were negatively correlated with yield (Appendix 6).

Content of major nutrients such as N and P was higher under open and decreased with increase in shade probably due to higher absorption and utilization under open situation. There was not much variation in K content due to shade which might be due to the higher status of K in the soil and low requirement by the crop. Content of N and P was higher at closer spacing which might be due to lesser weed competition thereby higher absorption and utilization.

Content of secondary nutrients like Ca and Mg increased with increase in shade probably due to their accumulation under shaded condition while S was higher under open condition. Closer spacing recorded the highest content of secondary nutrients due to a possible synergistic effect caused by relative shading.

Among the micronutrients, only Fe content varied significantly. Fe content was reduced to half under shaded condition but it was comparatively higher at closer spacing.

Yield was highest under 25 per cent shade where Mg and S were higher and N, P and Mn were lower. At closer spacing yield was highest probably due to higher content of N, Ca, Mg and Cu and lower content of K and Mn (Appendix 5 and 6).

5.3.5 Nutrient Ratios

Shade levels showed considerable influence on the nutrient ratios in the rhizome (Table 4.3.34-35). Among the shade levels, 25 per cent shade recorded a comparatively higher ratio of (Ca+Mg)/K, Mn/K, Zn/K and Cu/K and all these ratios showed a positive correlation with rhizome yield whereas Fe/K recorded the lowest ratio which was negatively correlated with the yield of the crop.

Among spacings, 10 x 10 cm recorded a higher ratio of (Ca+Mg)/K, Fe/K and Cu/K which was positively correlated with rhizome yield and lower Mn/K and Zn/K which was negatively correlated with the yield.

5.3.6 Nutrient Uptake

The uptake of all nutrients increased with increase in shade and was the highest at 75 per cent shade (Table 4.3.36). The uptake at all levels of shade was much higher than that under open condition. This might be due to the higher growth and dry matter production under shaded condition rather than a higher content of the nutrients. Ancy and Jayachandran (1998) reported that nutrient uptake was more under shaded situation and was highest at 25 per cent shade in ginger.

Among the spacings, 10 x 10 cm recorded the highest uptake of all nutrients. It is due to more plant density with optimum growth, which leads to more dry matter production and uptake of nutrients.

5.3.7 Soil Characteristics

The soil pH and status of available major and secondary nutrients were significantly influenced by shade while that of micronutrients remained unaffected (Table 4.3.37). Soil pH increased with increase in shade. This might be due to the higher microbial activity under partially shaded situation as reported by Sadanandan and Hamza (1997) in ginger. 25 per cent shade recorded the lowest soil pH. However, it was the highest under open condition. The available N and P were highest at 25 per cent shade. Available K, Mg and S were less at 25 per cent shade compared to 50 per cent and 75 per cent shades. Available Ca content was highest at 25 per cent shade.

In general, shade and spacing significantly influenced the available major and secondary nutrients and not the available micronutrients in the soil.

The soil available N, K, Mg and S increased with increase in spacing, available Ca decreased while the content of other available nutrients and pH remained unaffected due to spacing. The build up in the available nutrients in the soil with increase in spacing might be due to the lesser uptake at the wider spacing. The soil pH, available P and micronutrients were not influenced by spacing. At closer spacing (10 x 10 cm) the comparatively lower nutrient content in soil after the harvest of the crop is due to more crop removal.

5.3.8 General Discussion

C. orchioides exhibited active vegetative growth till 6 MAP and senesced afterwards under field condition. The senescence was earlier under open and delayed by about a month with increase in shade up to 75 per cent.

The dry matter production and yields in *C. orchioides* were the highest at 25 per cent shade and 10 x 10 cm spacing due to higher growth characteristics such as plant height, number of leaves, canopy spread and also a higher chlorophyll a and a+b contents and a higher harvest index. The plant being a poor competitor, the higher plant density at 10 x 10 cm spacing coupled with low weed infestation and better partitioning of the photosynthates to the rhizome contributed to the higher yield.

Though the crude protein, crude fibre, crude fat and ash contents were the highest under open condition, the carbohydrate and curculigoside contents were the highest under partially shaded condition. The quality of the crude drug in terms of the primary metabolites and nutrient contents were higher at closer spacing especially 10 x 10 cm. The uptake of the nutrients were higher under shaded condition and closer spacing due to the higher plant densities, dry matter production. The partial shade also decreased the soil pH and increased the contents of available N, P, K, Ca and S in the soil.

The results of the experiment establish that *C. orchioides* is a shade loving plant and its growth, yield and quality are optimum under 25 per cent shade and 10 x 10 cm spacing.

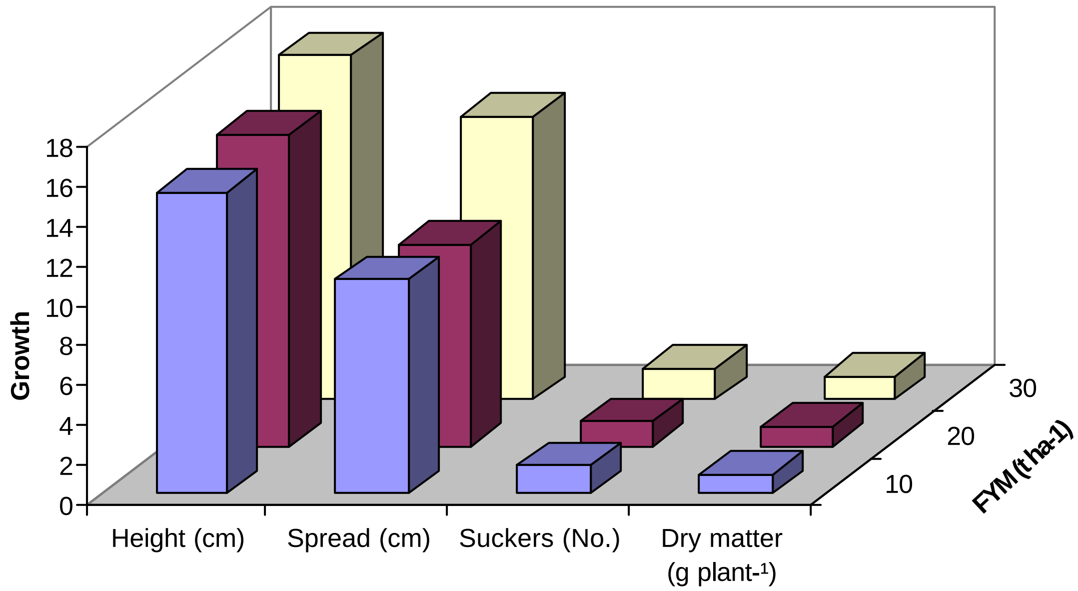
5.4 EXPERIMENT 4. MANURIAL REQUIREMENTS OF *CURCULIGO ORCHIOIDES*

This experiment was conducted to study the effect of FYM and its substitution with fertiliser in different proportions on the growth, yield and quality of *C. orchioides* and to assess their quantity requirements for maximizing the yield with optimum quality. Their main and interaction effects on growth, yield and quality parameters and on soil characteristics were studied in this experiment and are discussed hereunder.

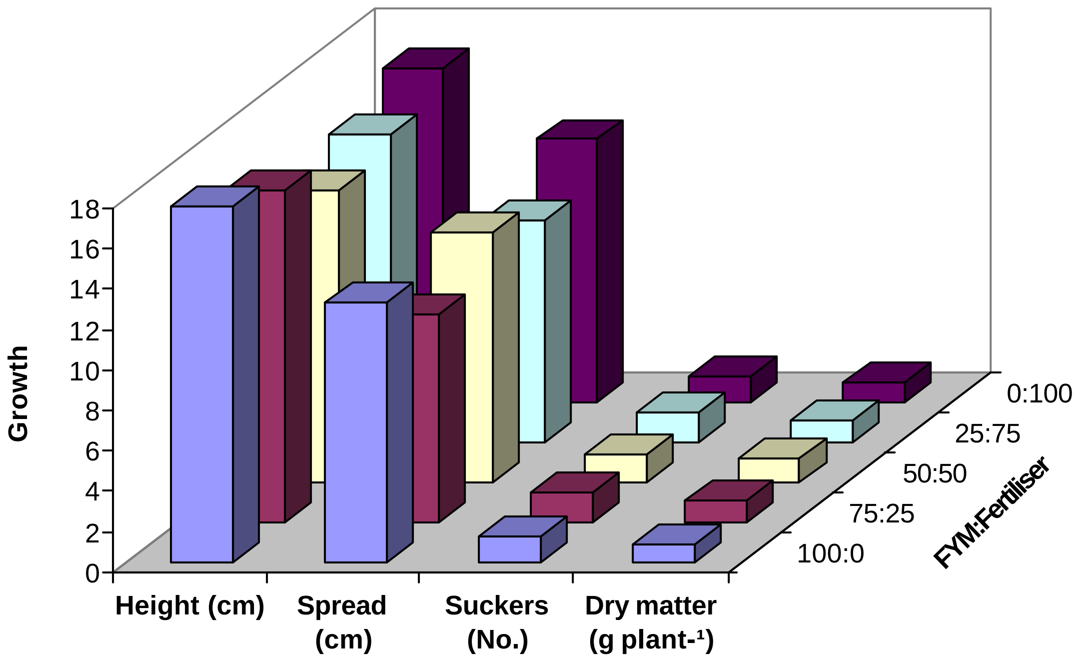
5.4.1 Growth Parameters

All growth parameters and dry matter production were increased up to 6 MAP and then decreased (Table 4.4.1-10). The decrease was due to the onset of dry season. The slight reduction in growth parameters after 3 months was due to the short dry spell between the two monsoons which is evident from Figure 1b. In general, increasing levels of FYM increased the growth parameters and the dry matter production. Application of 30 t FYM had greater impact on these attributes (Fig. 5.4.1).

The plant height increased with increase in the level of FYM in most of the months and it was significant at 4, 6 and 7 MAP. Canopy spread increased with



Effect of FYM levels



Effect of substitution of FYM with fertiliser

Fig. 5.4.1. Effect of FYM and substitution of FYM with fertiliser on growth of *Curculigo orchioides*

increase in FYM level and it was the highest at 30 t ha^{-1} FYM at 1, 3 and 6 MAP. More over, the increase was significant at 7 MAP. The number of suckers per plant was the highest at 30 t FYM at 4 and 5 MAP while it was significantly the highest at 8 MAP. The number of leaves per sucker was also marginally higher at 30 t ha^{-1} in most of the months. The growth promoting effect of FYM as a source of plant nutrients and humus, which improves the soil physical condition by increasing its capacity to absorb and store water, enhancement of aeration and by favouring microbial activity is well established (BCD, 1999; Sharma, 2001).

The dry matter production was the highest at 30 t FYM in most of the months and it was significant at 6 and 7 MAP. It is due to increased growth parameters such as plant height, canopy spread, number of suckers per plant and number of leaves per sucker. Increased growth and dry matter production due to the application of FYM have also been reported by Gill *et al.* (1999) in turmeric and by Riba (2000) in ginseng.

FYM application progressively increased the weed biomass and it was significant at 4 and 6 MAP (Table 4.4.11). It is probably due to the presence of more weed seeds in FYM and the more favourable condition formed by FYM for weed growth as reported by King (1974) and Sharma (2001).

The plant height, number of leaves, canopy spread and number of suckers per plant were not significantly influenced by varying proportions of FYM and fertiliser. The dry matter production was also not influenced by varying proportions of FYM and fertiliser in most of the months. However, supply of nutrients either through FYM or fertiliser or both in different proportions resulted in a marginally higher growth parameters and dry matter production in most of the months. Control recorded a marginally lower dry matter production compared to rest of the treatments. This indicates that for better growth and dry matter production in *C. orchioides*, supply of nutrients either through FYM or fertiliser or a combination of both is beneficial.

Weed competition was much higher in plots supplied with FYM and fertiliser and it was minimum in plots supplied with fertiliser alone which can be attributed to the contamination of FYM with substantial quantity of weed seeds as reported by King (1974) and the ready availability of nutrients through inorganic fertilizers (Tisdale *et al*., 1995).

The plant height at 8 MAP was the highest at 20 t FYM at 50:50 proportion followed by 30 t FYM at 25:75 proportion. Though the main effect of FYM and its substitution with fertiliser in different proportions on number of leaves per sucker was not significant at any month, control *vs* rest and interaction of FYM and its substitution with fertiliser in different proportions were statistically significant at 3 and 5 MAP, respectively indicating the overall beneficial effect of the treatments over the control in leaf production. The interaction effect of FYM and its substitution with fertiliser in different proportions at 5 MAP showed the highest number of leaves (5.60) per sucker at 30 t FYM and 75:25 proportion indicating the superiority of this combination. Canopy spread at 1 MAP was the highest at 30 t FYM and 100:0 proportion. Canopy spread at 8 MAP was highest at 30 t FYM and 25:75 proportion. This indicates the beneficial effect of integrated application of FYM and fertiliser on the growth of *C. orchioides*.

The significant interaction of levels of FYM and its substitution with fertiliser in different proportions on dry matter production also indicated that dry matter production was much higher when they were applied in combination.

Above results showed that more balanced growth and development of *C. orchioides* was brought about by the integrated application of FYM and fertilizer and their ideal proportion varies with the growth component over the period of growth. Integrated application of both FYM and inorganic fertilizer helped for the increased growth and more balanced development of the plant as reported by Menon and Potty (1998) in medicinal *njavara* rice, Joy *et al*. (1999) in alpinia and Kurian *et al*. (2000) in kacholam.

5.4.2 Yield Parameters

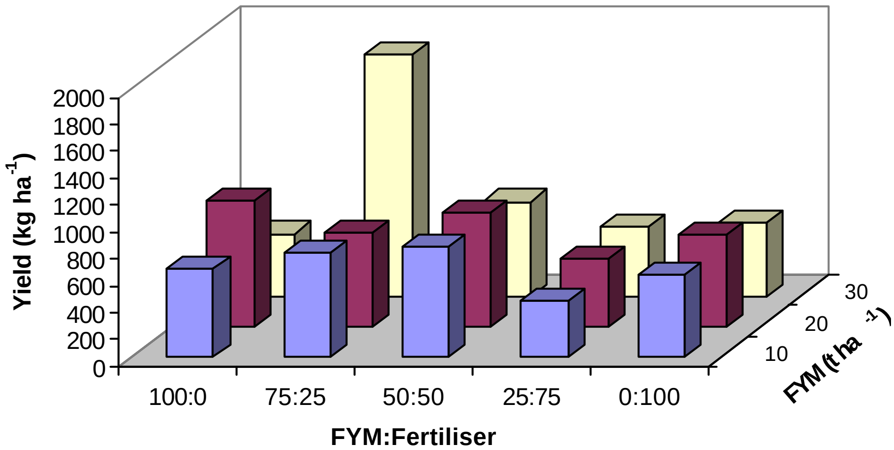
Increasing level of FYM progressively increased the biological yield whereas the fresh rhizome and dry rhizome yields were highest at 20 t FYM (Table 4.4.12). The higher biological yield with increasing levels of FYM was attributable to the higher growth of plants and dry matter production. The higher fresh rhizome and dry rhizome yields especially at 20 t FYM was probably due to a higher harvest index, that is, a greater partitioning of the dry matter into the rhizome which is the economic part. Kurian *et al*. (2000) reported an enhancement in growth and yield of *Piper longum* due to the application of FYM at 20 t ha^{-1}. Joy *et al*. (1999) reported that application of FYM at 20 t ha^{-1} produced significantly higher rhizome yields in alpinia.

The biological, fresh rhizome and dry rhizome yields were the highest at 75:25 proportion of FYM and fertiliser, followed by 50:50 and 100:0 proportions indicating that though a combination of both FYM and fertiliser was better for realizing maximum yield, the contribution of FYM was more pronounced. The harvest index was the highest of 71.50 per cent at 50:50 proportion followed by 25:75 proportion. It was 67.32 per cent at 75:25 proportion due to a relatively higher reduction in biological yield compared to fresh rhizome yield.

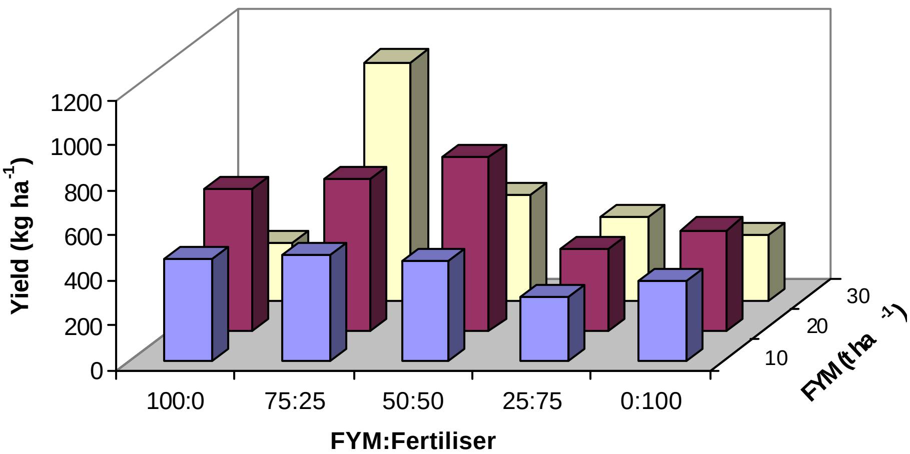
The interaction effect showed that biological, fresh rhizome and dry rhizome yields were the highest at 30 t FYM and 75:25 proportion (Fig. 5.4.2) indicating that *C. orchioides* responded well to organic manuring but it should be supplemented with inorganic fertilisers for better nutrition of the plant. Medicinal plants, in general responded more to organic manuring as reported by Joy *et al*. (1999) and Kurian *et al*. (2000). This also supported the views of Thomas *et al*. (1997, 1998). Since FYM application promotes weed infestation, adequate weed control measures need to be taken for checking weed growth. This is particularly important as *C. orchioides* is a poor competitor and weeds could smother the crop if they are not timely controlled.

With respect to FYM, N, P, K, Fe and Mn were found to be positively correlated whereas Ca, Mg and Zn were negatively correlated with the rhizome yield of the crop. In relation to substitution of FYM with fertilizer N, P, S, Fe and Cu were positively correlated while K and Mn were negatively correlated with the rhizome yield of the crop

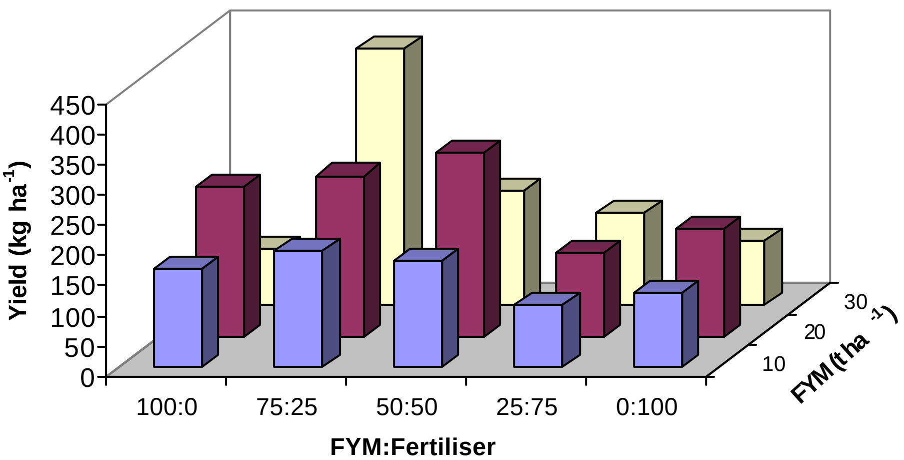
The ratio of (Ca+Mg)/K and Zn/K were positively correlated with the yield in relation to FYM levels. With respect to proportion of FYM and fertilizer none of the nutrient ratios was significantly correlated with the yield. Relatively higher ratios of (Ca+Mg)/K and Zn/K at 30 t ha^{-1} in 75:25 proportion might have contributed to the significantly highest yield in this treatment.



Biological yield



Fresh rhizome yield



Dry rhizome yield

Fig. 5.4.2. Interaction effect of FYM and substitution of FYM with fertiliser on yield of *Curculigo orchioides*

5.4.3 Quality Parameters

FYM application improved the content of glucose, starch, crude protein and curculigoside in the rhizome especially at 30 t ha^{-1} whereas the content of sucrose, crude fibre and ash were reduced (Table 4.4.14 and Fig. 5.4.3). The fat content was unaffected. Quality improvements due to the application of FYM have also been reported in terms of the alkaloid content in thippali (Sheela, 1996), oleoresin in ginger (Sadanandan and Hamza, 1997), caumarin in *Mikenia glomerata* (Pereira *et al*., 1998) and essential oil and oleoresin in *Curcuma zedoaria* (Joy *et al*., 1999).

With respect to the substitution of FYM with fertiliser in different proportions, sucrose, starch and fat contents were more in the rhizome when FYM and fertiliser were applied in combination while glucose and crude fibre were higher when they were applied alone and the crude protein content was the highest when fertiliser alone was applied. Curculigoside content was unaffected. Most of the quality parameters increased when nutrients were supplied through either FYM or fertiliser alone or in combination compared to no application.

The interaction effect showed that application of 30 t FYM in 75:25 proportion resulted in lower contents of glucose and sucrose but highest content of starch (Table 4.4.15). This might be due to the conversion of simple sugars to starch. The above treatment also recorded a higher content of protein and the highest content of curculigoside. This indicated that application of 30 t FYM in 75:25 proportion favourably influenced both the yield as well as the quality of *C. orchioides*.

These results establish the role of FYM in improving the quality of the produce in *C. orchioides*. In other words, both from the point of view of quantity and quality, FYM application is inevitable for the crop and an integrated application of FYM and fertiliser is more preferable for quality crude drug production in *C. orchioides*. This corroborates the findings of Ayisha (1997) in thippali, Joy *et al*. (1999) in Zingiberaceous medicinal plants and Riba (2000) in ginseng.

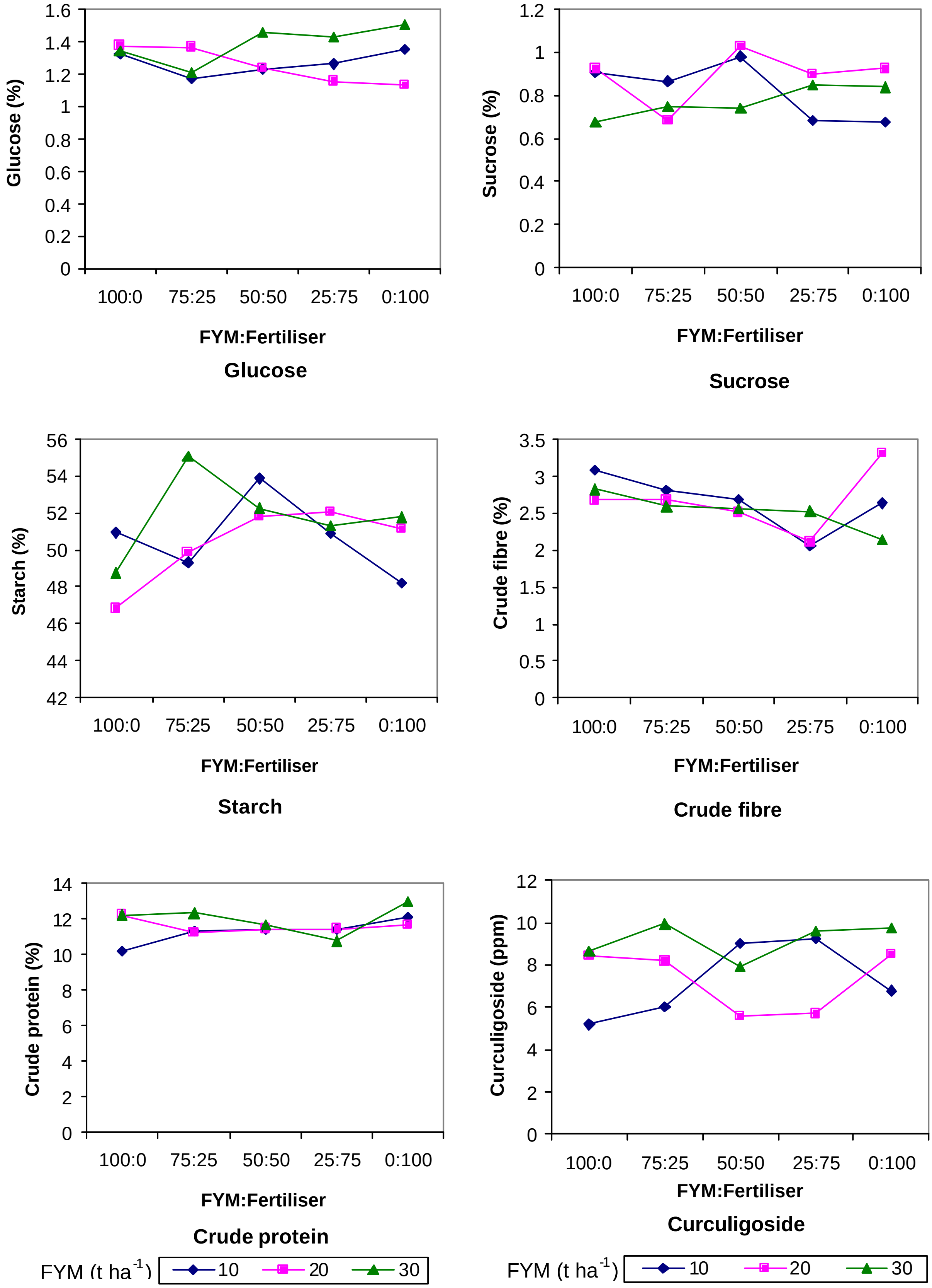


Fig. 5.4.3. Interaction effect of FYM and substitution of FYM with fertiliser on quality of *Curculigo orchioides* dry rhizome at harvest

5.4.4 Nutrient Content

Since the crop exhibited maximum vegetative growth and rhizome yield at 6 MAP the nutrient content in rhizome at that stage alone is discussed hereunder. Among the nutrients, in relation to FYM levels N, P and Fe and in relation to proportion of FYM and fertilizer, N, P and Cu were found to be positively correlated with the rhizome yield of the crop (Appendix 7 and 8).

Contents of major nutrients N and P in rhizome were higher in plots supplied with FYM or fertiliser alone or in combination compared to no application whereas that of K was not influenced by treatments over control (Table 4.4.16). Application of fertilizer alone at the highest level resulted in a higher N content in rhizome. This is probably due to the ready availability of the nutrient from the fertilizer source and its more uptake by the plant. In the case of P, substitution of FYM at 20 t ha^{-1} with fertilizer up to 50 per cent resulted in a higher P content in rhizome. More over, a significant reduction in P content was noticed at higher level of substitution with fertiliser and the least was noticed when fertilizer alone was supplied. This can be attributed to the more availability of P from the organic source which resulted in more uptake by the plant (Tisdale *et al.*, 1995). K content in rhizome was highest at the lowest level of application and it was not influenced by varying proportions of FYM and fertilizer. This is due to the high level of native available K in the soil, which is evident from the initial soil analysis (Table 3.1).

Among the secondary nutrients only Mg content in rhizome was significantly influenced by application of either FYM or fertilizer alone or in combination compared to no application (Table 4.4.18). Calcium and magnesium contents in rhizome were negatively correlated with rhizome yield in relation to FYM levels and the negative influence was considerable reduced by the substitution with fertilizer (Appendix 7 and 8). This again indicated the beneficial effect of combined application of FYM and fertiliser in *C. orchioides.*

Among the micronutrients, Mn, Zn and Cu contents in rhizome were significantly reduced by application of either FYM or fertilizer alone or in combination compared to no application whereas that of Fe content was not influenced by the same (Table 4.4.20). More over, Fe, Zn and Cu contents in rhizome were not influenced either by varying the level of application or by varying the proportion of FYM and fertilizer. However, Mn content was found to be significantly the highest when fertilizer alone was applied and at the lower levels of application. Mn content showed a negative trend in correlation to fresh rhizome yield which might be the reason for the lower yield.

The limiting factors of crop growth and yield of *njavara* were reported to be excess absorption and content of elements like Fe, Mn, Zn and Cu in plants and not the limited supply of growth promoting elements like N (Menon and Potty, 1998; 1999; Thomas, 2001; Potti, 2003).

5.4.5 Nutrient Ratios

Application of nutrients either through FYM or fertilizer alone or in combination resulted in a higher (Ca+Mg)/K ratio and a lower Fe/K and Cu/K ratios whereas a higher Zn/K ratio was observed in absolute control. Mn/K ratio was not influenced by treatment over control (Table 4.4.25).

The ratio of (Ca+Mg)/K and Zn/K were positively correlated with the yield in relation to FYM levels while Mn/K showed a negative trend (Appendix 7). This indicated that a higher content of Ca+Mg and Zn and lower contents of Mn contributed to higher rhizome yield with increasing levels of application. Higher ratios of (Ca+Mg)/K and Zn/K might have contributed to a higher rhizome yield at 20 t FYM ha^{-1}.

Comparatively higher (Ca+Mg)/K, lower Mn/K and Cu/K ratios in rhizome recorded in plots supplied with FYM and fertilizer in 75:25 proportion might be the probable reason for the higher rhizome yield in the treatment (Appendix 8). Relatively higher (Ca+Mg)/K and lower Mn/K ratios might have resulted in significantly highest yields at 30 tha^{-1} in 75:25 proportion.

5.4.6 Nutrient Uptake

Application of FYM or fertilizer alone or their combination resulted in a significantly higher uptake of N, P, K, Ca, Mg and Fe compared to control whereas that of S, Mn, Zn and Cu was not influenced by the treatments (Table 4.4.27).

Among the nutrients, only the uptake of K and Mg was significantly influenced by levels of FYM. Application of 20 t FYM ha^{-1} recorded the lowest K and Mg uptake, which might have contributed to the higher yield of rhizome due to the negative correlation of the nutrients to fresh rhizome yield.

Uptake of nutrients, except that of Mg and S was not significantly influenced by varying proportions of FYM and fertilizer. Among the various proportions, 75:25 recorded significantly lowest Mg uptake and a comparatively lower S uptake. This might be the reason for the higher rhizome yield of the crop at this proportion since these nutrients showed a negative correlation to fresh rhizome yield.

Uptake of Mg was the highest when FYM alone was applied. S uptake increased with increase in the proportion of fertiliser except at 0:100 proportion and it was the highest at 25:75 proportion. Ayisha (1997) reported that uptake of N, P and K, yield and quality of *Piper longum* were the highest with 20 t FYM ha^{-1}. Chalapathi *et al.* (1999) reported that the uptake of N, P and K increased with increase in levels of fertilizers in *Stevia rebaudiana*.

5.4.7 Soil Characteristics

With increase in the level of FYM, the available P and Ca contents in soil increased, the pH and available N decreased, available S increased up to 20 t FYM ha^{-1} while the content of other available nutrients remained unaffected (Table 4.4.28).

A reduction in soil pH was noticed after the experiment compared to the initial level. Application of FYM or fertilizer alone or their combination resulted in a significant reduction in soil pH compared to absolute control. This can be attributed to the influence of FYM or fertilizer or their combination applied as per treatments. Among the different levels of FYM, 10 t ha^{-1} recorded the highest soil pH which was on par with 20 t ha^{-1} and was superior to 30 t ha^{-1}. The progressive reduction in soil pH with increasing levels of FYM might be due to the relatively higher acidic condition created by the higher levels of FYM, in spite of the soil buffering capacity. Among the various proportion of FYM and fertilizer, 25:75 recorded the highest soil pH, which was on par with 75:25 proportion. The least soil pH was noted in plots supplied with fertilizer alone which was on par with application of FYM alone. This indicated that application of a combination of FYM and fertilizer is better than application of either FYM or fertilizer alone.

Contents of most of the available nutrients in the soil showed higher values compared to their initial status. Among them, only exchangeable Fe showed a lower value. Exchangeable Mg and Mn showed no change compared to absolute control whereas available P and available K showed an improvement in the status over control. The reduction in available N content is due to crop removal.

The results showed that application of FYM at higher proportion builds up the available N, P, Ca and Mg content in the soil but depletes the available K and S. The build up might be due to the slow and continuous release through the decomposition of organic matter and the depletion due to crop removal, fixation or other factors (Tisdale *et al*., 1995).

5.4.8 General Discussion

Increasing levels of FYM increased the growth parameters, dry matter production and yield. Application of 30 t FYM ha^{-1} had greater impact on these attributes. The dry matter production was much higher when they were applied in combination. Weed competition was much higher with increasing proportion of FYM and it was minimum when fertiliser alone was applied. The fresh rhizome as well as the dry rhizome yields were the highest at 30 t FYM ha^{-1} and 75:25 proportion of FYM and fertiliser. With regard to the quality of rhizome, 30 t FYM ha^{-1} increased the glucose, starch, protein and curculigoside contents in the rhizome. Sucrose, starch and fat contents were more in the rhizome when FYM and fertiliser were applied in combination. Available Mg content of soil was higher when FYM and fertiliser were applied in combination.

The results of the experiment indicated that 30 t FYM is the optimum dose and substitution of FYM to the tune of 25 per cent with inorganic fertilizers is ideal for realizing highest rhizome yield of good quality in *C. orchioides*.

5.5 EXPERIMENT 5. EFFECT OF MULCH AND SOURCES OF NUTRIENTS ON YIELD AND QUALITY OF *CURCULIGO ORCHIOIDES*

This experiment was conducted to study the effect of mulch and nutrient sources on the growth, yield and quality of *C. orchioides*, evaluate the usefulness of mulching and to identify the best source of nutrients for maximizing quality crude drug production in *C. orchioides*. The main effects of mulch and nutrient sources as well as their interaction effects on growth, yield, quality, nutrient content, nutrient ratios and nutrient uptake and on the soil characteristics were studied and are discussed hereunder.

5.5.1 Growth Parameters

Mulching increased the various growth parameters such as plant height, number of leaves, canopy spread and sucker production though the effect was not significant in most of the months (Table 4.5.1-4.5.4). The cumulative effect of mulching on growth parameters resulted in higher dry matter production compared to no mulching though the increase was marginal in most of the months (Table 4.5.5-9). Beneficial effects of mulching on growth and dry matter production have also been reported by Das (1999) in ginger, Gill *et al.* (1999) in turmeric, Shukla *et al.* (2000) in *Emblica officinalis* and by Joy *et al*. (2001a, b) in *Alpinia calcarata, Curcuma zedoaria* and *Kaempferia rotunda*.

Nutrient sources did not influence the various growth parameters significantly in most of the months which was reflected in total dry matter production also. Wherever the effect was significant, control recorded a significantly lower value compared to the treatment which recorded the highest value. Nutrient source as poultry manure recorded either the highest value or on par with the highest value. Similarly, FYM + phosphobacter and FYM+ VAM were also on par with the highest value. More over, poultry manure recorded a numerically higher value followed by FYM + phosphobacter and FYM+VAM in most of the months. The significant positive influence of poultry manure is attributed to the higher content of nutrients especially Ca and P which is evident from its composition given in Table 3.2.

Plants m^{-2} was not influenced either by mulching or by various nutrient sources (Table 4.5.10). More over, the interaction was not significant. Number of suckers m^{-2} was significantly more in mulched plots compared to no mulching. This can be attributed to the favourable conditions provided by mulch and the increased nutrient availability through its subsequent decomposition as reported by Mathew (2002). It was significantly influenced by nutrient source. Poultry manure recorded the highest number of suckers which might be due to the higher content and more availability of nutrients. Control recorded the least.

Weed biomass was significantly influenced by mulching (Table 4.5.10). The data clearly showed that mulching suppressed weed growth only during the early stages of growth, *ie*, up to 2 months, whereas it was significantly higher in mulched plots compared to no mulch after two months. This can be attributed to the decomposition of the mulch material by two months time and consequent addition of organic matter to the soil. That is, in two months time the spent-grass mulch ceased to function as mulch and transformed into a nutrient source. After two months, weed biomass was significantly influenced by nutrient source also. Control recorded the lowest weed growth followed by the nutrient source as inorganic fertilizers. Among the organic sources, vermicompost recorded the least weed growth. Highest weed growth was observed in poultry manure applied plots up to 2 MAP whereas it was highest in FYM + azotobacter after 2 months. This can be attributed to the contamination of weed seeds in the applied manure coupled with the favourable soil conditions provided by these manures and the biofertiliser for the germination and growth of weeds as highlighted by Rao (1992).

Interaction effect was significant at 2 MAP (Table 4.5.11). Poultry manure application resulted in heavy weed infestation in the early stages and it could be suppressed to a great extent through mulching. Effect of mulching on suppression of weed growth is reported by many workers (Das, 1999; Gill *et al,* 1999; Shukla *et al.,* 2000; Joy *et al*., 2001a,b)

5.5.2 Yield Parameters

Biological and fresh rhizome yields were not influenced by mulching (Table 4.5.12). Even though the various growth parameters and the total dry matter production were slightly enhanced by mulching compared to no mulching, it was not reflected in the biological and fresh rhizome yields. This can be attributed to the fact that mulching was not effective in suppressing weed growth after two months and the later weed infestation nullified the beneficial effect of mulching on the yield of the crop. Though the harvest index was slightly higher (39.04%) in the mulch treatment as against 37.89 per cent in the no mulch treatment, there was no significant increase in the yields in mulch treatment. At Bellary, mulching with different materials (paddy husk, Encap Esso mulch, grass mulch and *johar* stubble) did not give encouraging results in increasing the yields of cotton and *johar* crops (BCD, 1999). However, Das (1999) observed positive response of mulching on germination percentage, tiller number and rhizome yield of ginger. Gill *et al.* (1999) reported that application of wheat straw mulch (6 t ha^{-1}) improved growth and yield of turmeric significantly.

Both biological and fresh rhizome yields were significantly influenced by nutrient sources. Poultry manure application resulted in significantly highest biological and fresh rhizome yields followed by FYM + phosphobacter. Control recorded the lowest yield. The positive influence of poultry manure followed by FYM + phosphobacter on growth, plant density and suckers m^{-2} might have resulted in significantly higher biological and fresh rhizome yields even though the weed infestation was significantly higher in poultry manure applied plots up to two months. After 2 MAP, weed infestation in poultry manure applied plots was found to be on par with all other nutrient sources except FYM + azotobacter which recorded the highest. This might have nullified the significant adverse effect of weed infestation in poultry manure applied plots. Control recorded significantly lowest weed biomass. The harvest index was the highest of 39.53 per cent in FYM + phosphobacter, 38.94 per cent in poultry manure and the least of 36.52 per cent in fertiliser applied plots. The higher yields in poultry manure and FYM + phosphobacter were attributed to the higher availability of nutrients especially P and Ca which resulted in improved growth parameters such as plant height and canopy spread and higher dry matter production coupled with a higher harvest index. These results further establish the superiority of poultry manure and FYM + phosphobacter as ideal nutrient sources for maximizing yields in *C. orchioides*. The beneficial effects of poultry manure (Bahl and Aulakh, 2003) and phosphobacterium (Shina, 1998; Murthy *et al.* 1998) have been reported. Kurian *et al.* (2000) reported that in kacholam, treatment combination involving application of FYM 20 t ha^{-1} + azospirillum 2.5 kg ha^{-1} + 25 kg N and 50 kg each of K_2O and P_2O_5 and neem cake 1.5 t ha^{-1} + P solubilizer was beneficial in obtaining a consistently higher yield

The interaction effect showed that biological, fresh rhizome and dry rhizome yields were the highest in poultry manure followed by FYM + phosphobacter without mulch (Table 4.5.13 and Fig.5.5.1). Compared to control, all the nutrient sources recorded higher fresh rhizome yield and uptake of most of the nutrients. In general, though mulching was not contributing to the yield, it substantially increased the yield with fertiliser application as well as in the control. This indicated that mulching is beneficial with fertiliser application as well as in poor and marginal lands where no manuring is followed. However, it is of little benefit in situations where organic manuring is practised. Joy *et al*. (1999, 2001a,b) reported that mulching had the maximum pronounced effect on the yield of *Kaempferia rotunda* followed by the application of compost, FYM and vermicompost while in *Alpinia calcarata*, application of biofertilisers, green manuring and mulching were beneficial for improving the yields.

5.5.3 Quality Parameters

Most of the quality parameters were decreased by mulching compared to no mulching (Table 4.5.14 and Fig. 5.5.2). Curculigoside content was more than two times higher in no mulch treatment compared to mulch treatment. This can be attributed to heavy weed infestation in mulched plots after two months and their competition for nutrients which led to a lesser absorption and utilization of most of the nutrients for quality development by the crop as reported by Singh and Singh (2000) and Singh *et al*. (2000a)

Among the various nutrient sources, vermicompost recorded the highest curculigoside content, followed by FYM + azotobacter, whereas poultry manure applied plots recorded a lesser curculigoside content. Control recorded comparatively higher values for most of the quality components. This indicated that a higher fresh rhizome yield can lead to a lesser curculigoside production and vice-versa. This can be attributed to the quality development at the expense of the fresh rhizome yield. Considering the yield of rhizome and curculigoside, poultry manure was found to be the best treatment for quality crude drug production. The positive effects of poultry manure on growth, yield and quality have also been reported by Bahl and Aulakh (2003).

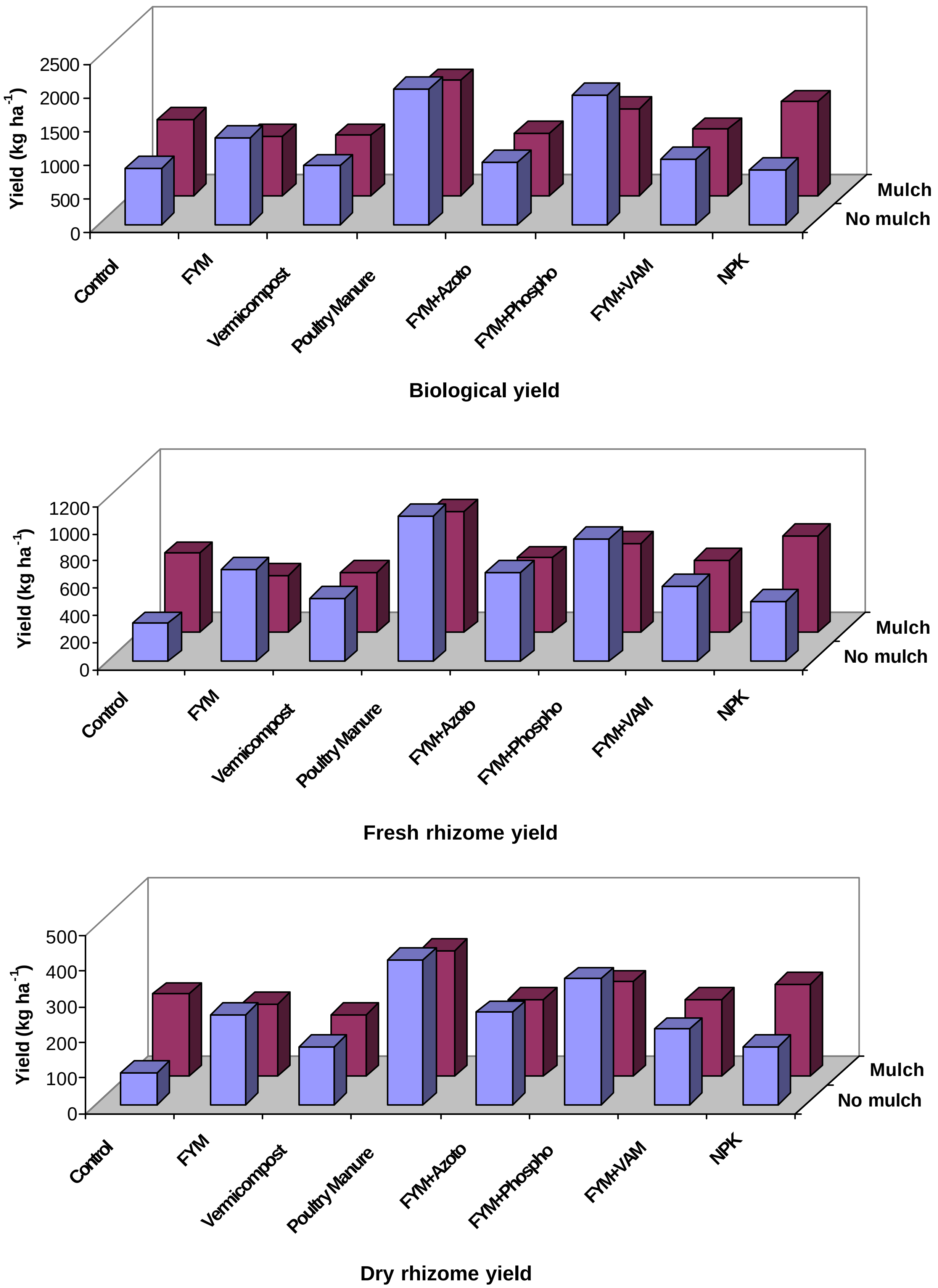


Fig. 5.5.1 Interaction effect of mulch and nutrient sources on yield of *Curculigo orchioides*

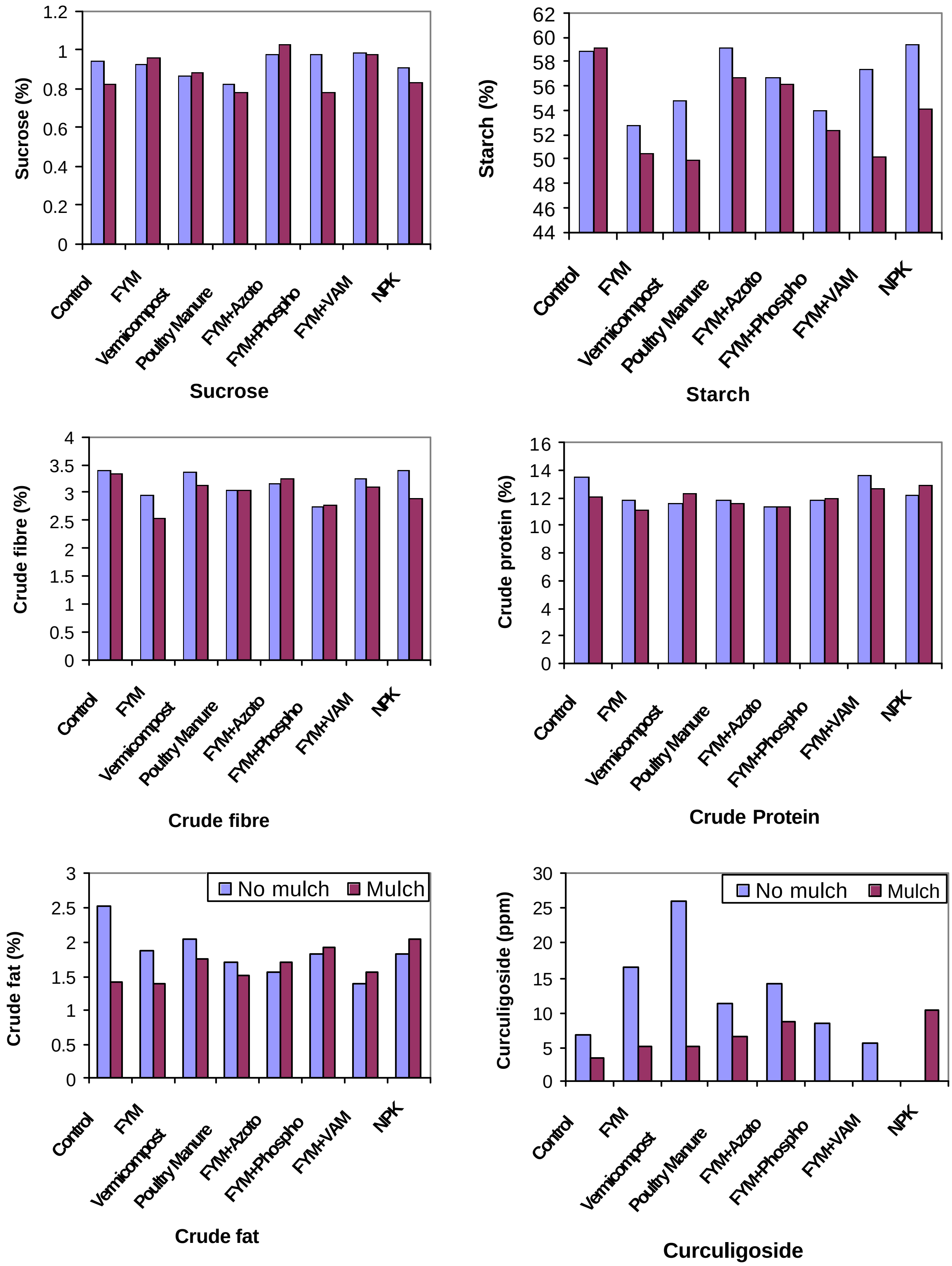


Fig. 5.5.2. Interaction effect of mulch and nutrient sources on quality of *Curculigo orchioides* dry rhizome at harvest

5.5.4 Nutrient Contents

Since the crop exhibited maximum vegetative growth and rhizome yield at 6 MAP the nutrient content in rhizome at that stage alone is discussed hereunder. Among the nutrients, in relation to nutrient sources, the content of P and Fe were found to be positively correlated while N and Mn were negatively correlated with the rhizome yield (Appendix 9).

The content of N, Ca, Mg, S and Mn was higher in no mulch treatment probably due to lesser weed infestation after 2 months in the treatment leading to lesser competition and consequently higher absorption by the crop. The content of P and K was higher in mulch treatment which might be the contribution from the mulch.

The content of N, P, Mg, S and Mn significantly varied in the rhizome due to nutrient sources. Application of poultry manure resulted in the highest yield which recorded higher P content (positively correlated with yield) but lower contents of N, S and Mn (negatively correlated with yield).

Control recorded the highest content of micronutrients (Table 4.5.19). Poultry manure application resulted in the highest content of P, comparatively higher contents of K, Ca and Mg and lower contents of micronutrients and S. This can be attributed to the higher content of major and secondary nutrients in the poultry manure applied and their influence on increasing the availability of these nutrients, especially P in acidic soils by chelating with Fe and Al thereby transforming mineral P towards plant available forms as reported by Bahl and Aulakh (2003). The negative influences of micronutrients like Fe and Mn have been highlighted by Musthafa (1995), Bridgit (1999) and Mathew (2002).

5.5.5 Nutrient Ratios

The ratio of Fe/K was positively correlated with fresh rhizome yield whereas Mn/K showed a negative correlation in relation to nutrient sources (Appendix 9).

Among the various nutrient sources, poultry manure application recorded the lowest ratio of Mn/K and a relatively lower ratio of Zn/K. The negative correlation of these nutrient ratios to fresh rhizome yield might have contributed to the higher yield of the crop in these treatments. The relatively higher ratio of Ca+Mg)/K, Fe/K and Cu/K might be a reason for the higher yield in FYM or FYM + phosphobacter. Control recorded the lowest ratios of (Ca+Mg)/K and Fe/K and hence resulted in the lowest fresh rhizome yield. More over, all the nutrient sources recorded higher values of (Ca+Mg)/K ratio which might be a reason for the higher yield of the crop in all the nutrient applied plots compared to the control. The significance of this ratio has been projected by Menon (1996).

5.5.6 Nutrient Uptake

Uptake of all the major nutrients were higher in mulch treatment compared to no mulch treatment and the effect was significant for K (Table 4.5.26). Among the secondary nutrients, mulching resulted in a higher S uptake but the effect was reverse in the case of Mg and Ca though the effect was not significant in the case of Ca. The uptake of micronutrients was not influenced by mulch. The higher uptake of nutrients in mulch treatment resulted in higher dry matter production due to better growth of plants.

Among the nutrient sources poultry manure applied plots recorded a higher uptake of most of the nutrients which is probably due to the higher nutrient contribution from the manure and resulted in higher dry matter production at the maximum vegetative growth stage of the crop. The uptake of most of the nutrients was least in the control plot which resulted in the lowest dry matter production.

Ayisha (1997) reported that in thippali, uptake of N, P and K, yield and quality were highest at 30:30:60 kg NPK ha^{-1} and with increase in age, N content decreased, P increased and K remained unchanged in the spikes. Kothari *et al.* (1999) observed that the VAM fungus *Glomus intraradices* (mycorrhiza) substantially increased root and shoot ratio, specific and total root length, nutrient (P, Zn and Cu) concentrations in root and shoot of *Mentha citrata*, total nutrient uptake and nutrient acquisition per unit length. Kalavathi *et al.* (2000) found that combined inoculation of VAM fungus and phosphobacteria markedly increased the growth of neem seedling and the increase in the growth had been attributed to the increase in nutrient uptake by the neem seedlings and the synergistic effect. Jat and Sharma (2000) reported that combined inoculation of *Rhizobium* plus phosphate solubilising bacteria significantly enhanced N and P contents in seed and straw and their total uptake.

5.5.7 Soil Characteristics

All the treatments, except FYM + azotobacter and FYM + phosphobacter resulted in a reduction in soil pH after the experiment (Table 4.5.27). A significantly lower soil pH was noticed in no mulch treatment compared to mulch treatment. The probable reason for this is the significantly lower Ca content in the soil after the experiment in no mulch treatment.

Among the nutrient sources, FYM + azotobater recorded significantly highest soil pH followed by FYM + phosphobacter. This can be attributed to the higher Ca content in the soil. Inorganic fertiliser applied plots recorded the lowest soil pH followed by the control, application of poultry manure and application of FYM + VAM. The probable reason for the lower soil pH in these treatments, except in poultry manure applied plots, is the lower Ca content in the soil.

The mulch treatment increased the soil available K, Ca and S contents in the soil; decreased the available Mg content while the contents of available N, P and micronutrients were unaffected (Table 4.5.27). The increase in the nutrient status might be due to the decomposition of the mulch and consequent release of the nutrients.

Among the nutrient sources, poultry manure application resulted in a comparatively higher content of most of the nutrients, especially Ca and P after the experiment. This can be attributed to the higher content of most of the nutrients in the poultry manure applied and its influence on increasing the availability of these nutrients as reported by Bahl and Aulakh (2003). FYM + azotobacter recorded a comparatively higher N, P, K and Ca contents in the soil due to lesser removal of these nutrients by the crop.

Gupta *et al.* (2001) noted that application of VAM and plant growth promoting rhizobacteria *Pseudomonas fluorescens* as alone or in combination enhanced the growth and biomass yield of a number of medicinal and aromatic plants. The capabilities of these microorganisms to solubilise the bound forms of P in the soil and render them available to plants contributed to their growth and productivity. These soil inhabiting ecofriendly microorganisms also produce growth promoting substances, antibiotic compounds *etc* which contribute to the improvement of seed germination and plant growth by inhibiting the activity of soil borne plant pathogens.

5.5.8 General Discussion

The results showed that mulch treatment marginally increased the growth parameters, such as plant height, canopy spread and sucker production and thereby the total dry matter production. More over, it showed more weed control efficiency up to two months. Since the weed control was only up to two months and there was more weed growth in mulched plots after two months, both the yield and quality of *C. orchioides* were better in no mulch treatment. Poultry manure application recorded the highest rhizome and curculigoside yields which indicated its superiority over other nutrient sources for getting a higher yield with better quality. The growth, dry matter production and yield were the highest in poultry manure applied plots followed by FYM + phosphobacter. Higher uptake of N, P, K, Ca, S, Fe and Mn was noted in poultry manure due to the higher nutrient contribution from the manure and the higher dry matter production. Its application resulted in comparatively higher contents of P, K, Ca and Mg and lower contents of micronutrients and S in the rhizome due to sufficient content of major and secondary nutrients and lower contents of micronutrients in the manure. It also improved the P and Ca status of the soil.

The experiment revealed that poultry manure is the best nutrient source for higher yield of quality crude drug in *C. orchioides* followed by FYM + phosphobacter and mulching is not good for the crop.

5.6 EXPERIMENT 6. QUALITY VARIATIONS IN *CURCULIGO ORCHIOIDES*

This study was taken up to investigate the biotype variations due to ecology and domestication and to assess the extent of variability present in the market samples in the state as well as in the other states of south India. Various quality parameters, including the primary and secondary metabolites, of *Curculigo orchioides* rhizome collected from various habitats and markets were studied and are discussed below.

5.6.1 Biotype Variation

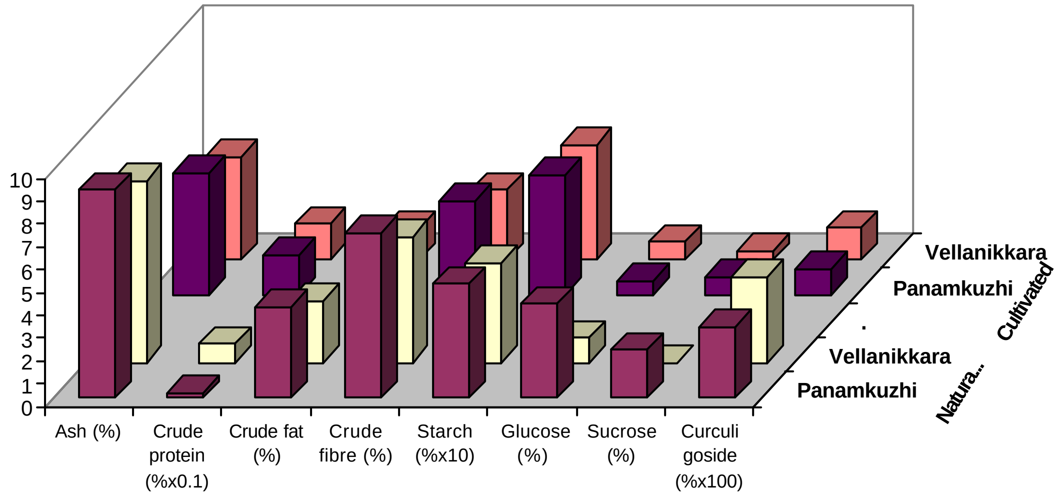
In general, natural habitat types recorded a higher content of curculigoside, most of the primary metabolites and ash (Fig 5.6.1). This indicated that *Curculigo orchioides* growing in natural habitat condition had a better quality compared to those under cultivation as reported by Menon (1996); Menon and Potty (1998; 1999) in *njavara* rice, Joy *et al.* (1998b,c) in cinnamon, Joy *et al.* (1999) in *Alpinia calcarata,* Kurian *et al.* (2000) in *O. sanctum,* adhatoda, plumbago, asparagus, kacholam, holostemma and gymnema germplasm accessions, Sreevalli *et al.* (2000) in periwinkle and Krishnamoorthy and Madalageri (2002) in ajowan.

Between the biotypes, Panamkuzhi type recorded higher values of most of the primary metabolites but a lower value of curculigoside. The lower value of primary metabolites in Vellanikkara biotype might be due to its utilization for the production of curculigoside.

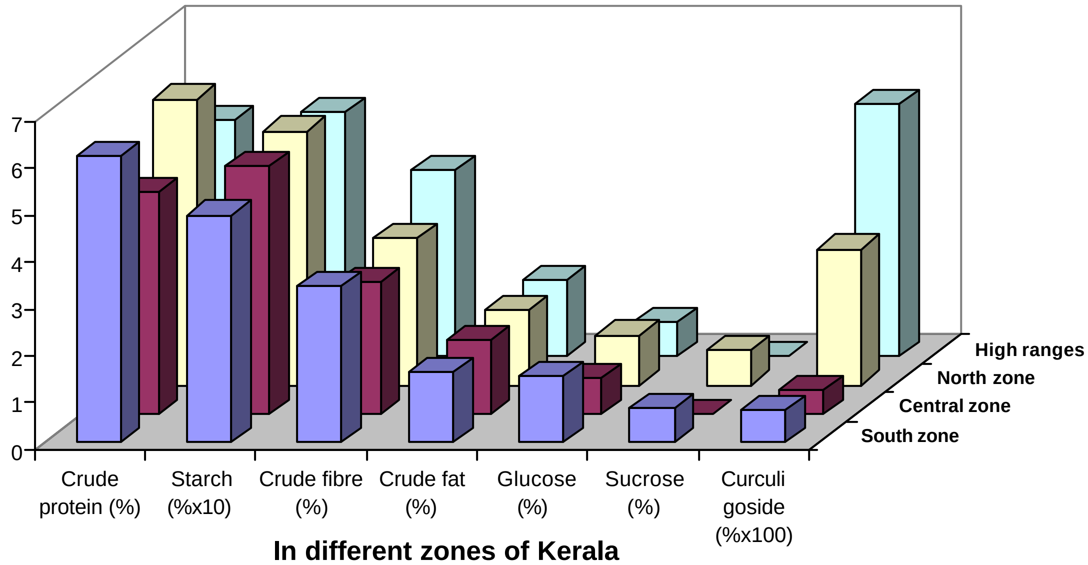
5.6.2 Market Samples

Among the market samples collected from various zones of Kerala, those from High Ranges recorded higher curculigoside content with a comparatively higher values of crude fat, crude fibre and ash (Fig. 5.6.1). The lesser content of the remaining primary metabolites might be due to its utilization for the production of curculigoside. The data showed that there is a wide variation in the quality of crude drug available in the various zones of the state.

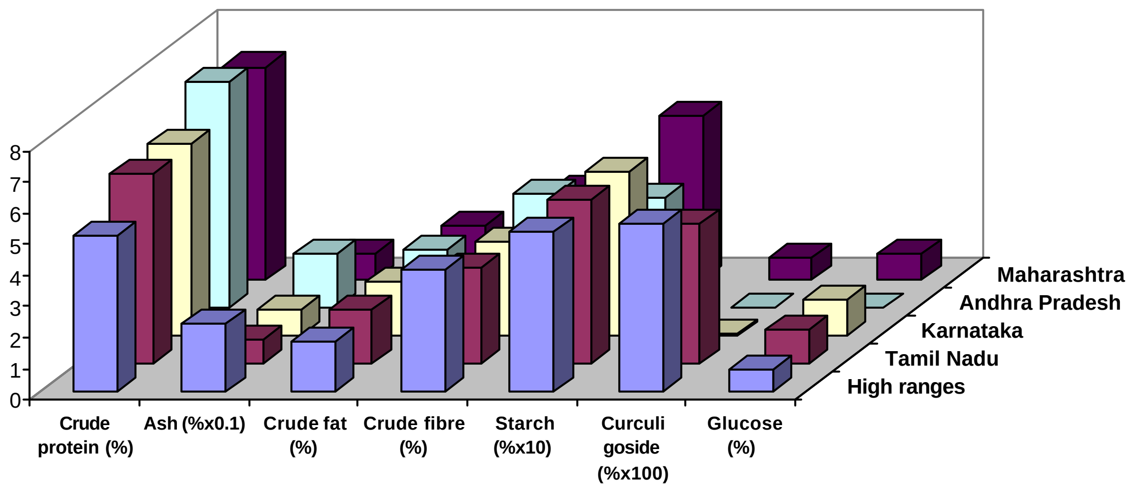
Among the various states, the samples collected from Tamil Nadu recorded higher curculigoside content next to that collected from High Ranges of Kerala. Samples from Andhra Pradesh did not contain detectable quantities of curculigoside but higher quantities of crude protein, crude fat, crude fibre and ash which again showed the inverse relationship between the primary and secondary metabolites. Samples from Karnataka and Maharashtra also recorded very low values of curculigoside. This indicates that there is a wide variation in the quality of crude drug available in the various states of south India as highlighted by Joy *et al.* (1999) in *Alpinia calcarata* and *Curcuma zedoaria*, Reynolds (1998) in *Panax quinquifolium* and Liu *et al.* (2001) in many herbal drugs. Samples from Tamil Nadu ranked second in quality with respect to curculigoside content next to the samples from the High Ranges of Kerala.



In natural habitat and cultivation



In different zones of Kerala



In south Indian states

Fig. 5.6.1. Quality variations in *Curculigo orchioides*

6. SUMMARY

6. SUMMARY

The research project entitled 'agrotechnological practices for quality crude drug production in *nilappana* (*C. orchioides* Gaertn.)' comprising six experiments were conducted for two years during 2000-'02 at the Aromatic and Medicinal Plants Research Station, Odakkali, Kerala and the salient research findings are furnished below.

1. *C. orchioides* was characterized by an active growth phase till 7 MAP, followed by reproductive phase under irrigated pot culture. The highest growth and yield of the crop was achieved in a period of 7 months when it could be harvested for the highest yield of quality rhizome.

2. The rhizome development in *C. orchioides* is upward which has got special agronomic significance in that it requires deep planting and regular earthing up for higher yields.

3. The highest rhizome length in the plant was attained in 8 MAP and there was not much variation in rhizome length afterwards. However, the rhizome thickness progressively increased marginally throughout the entire growth period. In spite of this increase in rhizome thickness, there was no increase in rhizome yield after 7 months.

4. The leaf production and consequently the leaf area were drastically reduced after 7 months which substantially reduced the photosynthetic efficiency of the plant after 7 months.

5. The primary metabolites like sucrose, crude fibre and crude fat decreased initially probably due to their utilisation by the plant for its establishment in the field. However, they increased substantially during later stages of the crop growth with the onset of active physiological activity in the plant.

6. The crude protein content in the rhizome progressively increased throughout the growth period.

7. Panamkuzhi biotype had good vegetative growth but poor fruit set enabling a better diversion of reserve food for the production of rhizome, which is the

economic part and this resulted in a higher harvest index and rhizome yield for the biotype.

8. Vellanikkara biotype though had good vegetative growth, its characteristic reproductive phase resulted in greater diversion of reserve food for fruit production leading to lesser harvest index and rhizome yield.

9. An HPLC system comprising of C18 column with 0.01 *M* phosphate buffer (pH 6.0) and peaks monitored spectrtophotometrically at 205 nm could be used for the estimation of curculigoside content of *C. orchioides*.

10. *C. orchioides* cannot withstand weed competition and rodent attacks. Hence, adequate control measures are essential for successful cultivation of the crop.

11. The dry matter production and yields in *C. orchioides* were the highest at 25 per cent shade and 10 x 10 cm spacing due to higher growth characteristics such as plant height, number of leaves, canopy spread and also a higher chlorophyll a and a+b contents and a higher harvest index. The plant being a poor competitor with weeds, the higher plant density at 10 x 10 cm spacing coupled with low weed infestation, contributed to the higher yields.

12. *C. orchioides* is a crop adapted to partially shaded condition and hence suitable for cultivation as intercrop in coconut and rubber plantations.

13. The quality of the crude drug in terms of crude protein, crude fibre, crude fat and ash contents was the highest under open condition while the starch and curculigoside contents were highest under 25 per cent shade.

14. The quality of crude drug in terms of primary metabolites was higher at closer spacing, especially 10 x 10 cm.

15. The uptake of nutrients was higher under shaded condition and closer spacing due to higher plant densities and dry matter production.

16. The partial shade (25%) decreased the soil pH and increased the contents of available N, P, K, Ca and S in the soil.

17. Increasing levels of FYM increased the growth parameters and dry matter production. The weed infestation increased with increasing level of FYM.

18. Increasing level of FYM progressively increased the biological yield. The fresh rhizome as well as the dry rhizome yields were highest at 30 t FYM ha^{-1} when 25 per cent of which was substituted with inorganic fertiliser.
19. Application of 30 t FYM increased the glucose, starch, protein and curculigoside contents in the rhizome.
20. The growth parameters and dry matter production were not influenced by substitution of FYM with fertilizer.
21. Weed infestation was higher with increasing proportion of FYM and it was minimum when fertiliser alone was applied.
22. Sucrose, starch and fat contents were more in the rhizome when FYM and fertiliser were applied in combination while glucose and crude fibre were higher when they were applied alone and the crude protein content was the highest when fertiliser alone was applied.
23. Uptake of most of the nutrients was not significantly influenced either by levels of FYM or its substitution with inorganic fertilizer in varying proportions. However, application of FYM or fertilizer alone or in combination resulted in a higher uptake of nutrients compared to control.
24. With increasing level of FYM the soil pH and available N decreased whereas available P and Ca increased.
25. The soil pH and available N, P and Ca contents in the soil after the harvest of the crop were the least while K and S were the highest when fertiliser alone was applied. Available Mg content in soil was higher when FYM and fertiliser were applied in combination.
26. Mulching increased the growth parameters such as plant height, canopy spread and sucker production thereby the dry matter production. Weed intensity was effectively decreased up to two months by mulching.
27. Mulching could not bring about any influence on the biological, fresh rhizome and dry rhizome yields.
28. Mulching showed an adverse effect on the quality of rhizome.

29. The growth, dry matter production and yield were the highest in poultry manure followed by FYM + phosphobacter.

30. Higher uptake of N, P, K, Ca, S, Fe and Mn was noted in poultry manure application. Poultry manure also improved the P and Ca status of the soil.

31. Panamkuzhi biotype was superior to Vellanikkara biotype in most of the quality parameters both in the natural habitat and under cultivation. Vellanikkara biotype had slightly higher curculigoside content.

32. Among the market samples collected from the state of Kerala, High Range samples were superior in most of the quality parameters, which may be more suitable for high quality drug formulations.

The study has convincingly established the following.

- *C. orchioides* is characterized by an active growth phase till 7 MAP, under irrigated pot culture and 6 MAP under rainfed field condition.
- The highest growth and yield of the crop is achieved in a period of 6-7 months when it could be harvested for the highest yield of quality rhizome.
- Panamkuzhi biotype is superior to Vellanikkara biotype in growth and yield and it is more suitable for cultivation and quality drug formulations.
- *C. orchioides* is a shade loving plant and its growth; yield and quality are optimum under 25 per cent shade and 10 x 10 cm spacing.
- About 30 t FYM ha^{-1} is the optimum dose and substitution of FYM to the tune of 25 per cent with inorganic fertilizers is ideal for realizing highest rhizome yield of good quality.
- Poultry manure is the best nutrient source for quality crude drug production of the crop and mulching is not inevitable for the same.
- With these management practices, over 2.5 t ha^{-1} of fresh (1.0 t dry) good quality rhizome can be obtained in warm humid tropical Oxisols.
- Among the market samples collected from the state of Kerala, High Range samples were superior in most of the quality parameters, which may be more suitable for high quality drug formulations.

- There exist large variability in the market samples and there is need for proper standardisation of the crude drug for ensuring quality in the drug formulations.

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7. REFERENCES

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*Original not seen

8. APPENDICES

8. APPENDICES

Appendix 1. Monthly mean weather data for the period from May 2000 to April 2001

Month	Maximum Temperature (°C)	Minimum Temperature (°C)	Relative Humidity (%)	Rainy days	Rainfall (mm)	Wind speed (km hr^{-1})	Total evaporation (mm)
2000							
May	33.8	22.1	85.5	7	92.9	4.0	129.3
June	30.3	21.8	98.0	27	661.7	2.1	52.6
July	31.5	22.1	96.1	17	379.1	1.4	78.4
August	30.2	21.7	97.8	24	557.1	3.1	83.2
September	31.5	21.8	94.3	15	116.8	3.5	102.5
October	31.5	20.8	95.5	14	215.7	2.0	107.3
November	32.7	20.5	93.1	8	166.1	1.6	87.4
December	33.2	19.3	92.0	1	27.2	1.6	107.4
2001							
January	34.0	20.1	88.4	1	4.4	1.9	116.4
February	34.9	19.8	92.0	2	2.8	2.5	118.7
March	35.1	22.5	91.9	0	0	2.7	158.3
April	34.1	22.2	95.3	19	336.8	2.1	127.1

Appendix 2. Monthly mean weather data for the period from May 2001 to April 2002

Month	Maximum Temperature (°C)	Minimum Temperature (°C)	Relative Humidity (%)	Rainy days	Rainfall (mm)	Wind speed (km hr^{-1})	Total evaporation (mm)
2001							
May	33.8	21.2	93.6	10	193.8	2.9	105.9
June	30.2	20.9	96.5	28	907.7	2.8	72.8
July	30.3	20.6	96.1	23	633.7	3.4	73.0
August	29.8	19.8	92.6	23	433.8	3.3	88.3
September	32.1	20.5	96.5	13	70.6	3.2	117.4
October	31.5	22.2	96.9	23	231.0	2.2	113.8
November	32.3	22.3	94.9	14	277.7	2.4	95.7
December	34.0	22.6	87.1	2	19.2	1.6	107.8
2002							
January	34.5	20.2	87.4	1	1.2	1.4	113.0
February	35.4	20.4	84.5	2	3.6	3.1	136.2
March	36.6	21.7	87.4	6	54.0	1.5	169.8
April	35.1	22.3	92.3	16	219.2	3.7	127.1

Appendix 5. Coefficients of correlation of nutrient contents and ratios in rhizome and uptake at 6 MAP and rhizome yield of Curculigo orchioides as influenced by shade

	N	P	K	Ca	Mg	S	Fe	Mn	Zn	Cu	(Ca+M	Fe/K	Mn/K	Zn/K	Cu/K	Nupta	Pupta	Kupta	Caupt	Mgupt	Supta	Feupt	Mnupt	Znupt	Cuupt	Rhizo
N	1.00																									
P	0.71	1.00																		[r 3 (0.05) = 0.878, r 3 (0.01) = 0.959]						
K	0.37	0.07	1.00																							
Ca	-0.06	0.29	0.62	1.00																						
Mg	-0.68	-0.83	0.36	0.27	1.00																					
S	-0.41	0.03	0.43	0.94	0.48	1.00																				
Fe	0.40	-0.35	0.55	-0.30	0.27	-0.43	1.00																			
Mn	0.89	0.40	0.70	0.06	-0.27	-0.26	0.71	1.00																		
Zn	-0.28	0.38	0.12	0.85	0.05	0.88	-0.76	-0.36	1.00																	
Cu	-0.47	-0.09	-0.99	-0.53	-0.29	-0.31	-0.63	-0.78	-0.01	1.00																
(Ca+Mg)/K	-0.69	-0.29	0.25	0.76	0.69	0.94	-0.42	-0.50	0.76	-0.13	1.00															
Fe/K	0.24	-0.49	0.10	-0.70	0.15	-0.73	0.88	0.43	-0.97	-0.19	-0.61	1.00														
Mn/K	0.04	0.25	-0.91	-0.68	-0.69	-0.64	-0.43	-0.36	-0.23	0.86	-0.57	-0.01	1.00													
Zn/K	-0.35	0.41	-0.34	0.52	-0.19	0.60	-0.97	-0.61	0.89	0.43	0.55	-0.97	0.22	1.00												
Cu/K	-0.30	0.29	-0.87	-0.21	-0.49	-0.08	-0.87	-0.70	0.34	0.90	-0.02	-0.55	0.82	0.73	1.00											
N uptake	-0.96	-0.62	-0.14	0.34	0.76	0.65	-0.42	-0.80	0.48	0.25	0.87	-0.39	-0.27	0.44	0.17	1.00										
P uptake	-0.94	-0.45	-0.28	0.35	0.58	0.65	-0.62	-0.88	0.59	0.40	0.85	-0.55	-0.11	0.62	0.38	0.97	1.00									
K uptake	-0.95	-0.68	-0.09	0.31	0.82	0.62	-0.32	-0.75	0.41	0.20	0.85	-0.30	-0.33	0.35	0.08	0.99	0.94	1.00								
Ca uptake	-0.86	-0.49	0.07	0.56	0.76	0.81	-0.41	-0.66	0.62	0.05	0.96	-0.50	-0.45	0.49	0.06	0.97	0.94	0.96	1.00							
Mg uptake	-0.87	-0.78	0.12	0.32	0.94	0.60	-0.07	-0.57	0.28	-0.02	0.83	-0.12	-0.52	0.12	-0.18	0.93	0.83	0.96	0.92	1.00						
S uptake	-0.67	-0.30	0.31	0.77	0.71	0.94	-0.36	-0.45	0.74	-0.19	1.00	-0.58	-0.62	0.50	-0.09	0.85	0.82	0.85	0.96	0.83	1.00					
Fe uptake	-0.86	-0.74	0.16	0.39	0.93	0.65	-0.09	-0.55	0.33	-0.06	0.86	-0.17	-0.55	0.16	-0.18	0.94	0.83	0.96	0.94	1.00	0.87	1.00				
Mn uptake	-0.97	-0.72	-0.13	0.26	0.82	0.57	-0.30	-0.77	0.36	0.23	0.82	-0.25	-0.30	0.31	0.09	0.99	0.94	1.00	0.94	0.96	0.81	0.96	1.00			
Zn uptake	-0.86	-0.37	-0.08	0.55	0.62	0.81	-0.58	-0.76	0.71	0.20	0.94	-0.63	-0.29	0.64	0.25	0.96	0.97	0.93	0.98	0.84	0.92	0.86	0.91	1.00		
Cu uptake	-0.98	-0.66	-0.20	0.26	0.76	0.58	-0.39	-0.82	0.41	0.30	0.82	-0.33	-0.22	0.40	0.19	1.00	0.97	0.99	0.94	0.93	0.81	0.93	0.99	0.93	1.00	
Rhizome yield	-0.87	-0.29	-0.62	0.11	0.26	0.41	-0.80	-0.98	0.52	0.72	0.60	-0.58	0.29	0.73	0.71	0.82	0.92	0.76	0.72	0.57	0.55	0.56	0.77	0.83	0.83	1.00

Appendix 6. Coefficients of correlation of nutrient contents and ratios in rhizome and uptake at 6 MAP and rhizome yield of Curculigo orchioides as influenced by spacing

	N	P	K	Ca	Mg	S	Fe	Mn	Zn	Cu	(Ca+M	Fe/K	Mn/K	Zn/K	Cu/K	Nupta	Pupta	Kupta	Caupt	Mgupt	Supta	Feupt	Mnupt	Znupt	Cuupt	Rhizo
N	1.00																									
P	0.09	1.00																		[r 3 (0.05) = 0.878, r 3 (0.01) = 0.959]						
K	-0.02	0.96	1.00																							
Ca	0.88	-0.33	-0.48	1.00																						
Mg	0.88	-0.19	-0.39	0.98	1.00																					
S	0.01	0.76	0.90	-0.47	-0.46	1.00																				
Fe	0.56	-0.75	-0.75	0.78	0.64	-0.50	1.00																			
Mn	-0.74	-0.12	0.14	-0.80	-0.90	0.39	-0.26	1.00																		
Zn	-0.24	0.80	0.94	-0.68	-0.64	0.96	-0.72	0.47	1.00																	
Cu	0.92	0.41	0.24	0.73	0.80	0.11	0.21	-0.85	-0.06	1.00																
(Ca+Mg)/K	0.80	-0.44	-0.59	0.99	0.96	-0.58	0.81	-0.78	-0.77	0.64	1.00															
Fe/K	0.51	-0.79	-0.79	0.76	0.63	-0.54	1.00	-0.24	-0.75	0.16	0.80	1.00														
Mn/K	-0.34	-0.61	-0.37	-0.25	-0.43	0.02	0.41	0.77	-0.03	-0.68	-0.20	0.42	1.00													
Zn/K	-0.51	0.35	0.59	-0.81	-0.86	0.79	-0.48	0.87	0.84	-0.51	-0.85	-0.49	0.50	1.00												
Cu/K	0.98	0.26	0.12	0.81	0.85	0.09	0.39	-0.79	-0.13	0.98	0.72	0.35	-0.50	-0.50	1.00											
N uptake	0.90	0.08	-0.13	0.90	0.96	-0.28	0.43	-0.96	-0.44	0.92	0.86	0.40	-0.63	-0.80	0.92	1.00										
P uptake	0.90	0.08	-0.14	0.90	0.96	-0.27	0.44	-0.96	-0.44	0.92	0.86	0.41	-0.62	-0.79	0.92	1.00	1.00									
K uptake	0.89	0.12	-0.10	0.88	0.95	-0.25	0.39	-0.96	-0.41	0.93	0.84	0.36	-0.66	-0.79	0.92	1.00	1.00	1.00								
Ca uptake	0.90	0.07	-0.15	0.90	0.97	-0.29	0.44	-0.96	-0.45	0.92	0.86	0.41	-0.62	-0.80	0.92	1.00	1.00	1.00	1.00							
Mg uptake	0.89	0.03	-0.18	0.92	0.97	-0.32	0.46	-0.96	-0.48	0.90	0.88	0.44	-0.61	-0.82	0.91	1.00	1.00	1.00	1.00	1.00						
S uptake	0.92	0.16	-0.04	0.87	0.94	-0.18	0.39	-0.94	-0.35	0.96	0.82	0.36	-0.64	-0.73	0.95	0.99	1.00	1.00	0.99	0.99	1.00					
Fe uptake	0.92	0.03	-0.17	0.93	0.97	-0.28	0.49	-0.94	-0.46	0.91	0.89	0.47	-0.56	-0.79	0.93	1.00	1.00	0.99	1.00	1.00	0.99	1.00				
Mn uptake	0.92	0.07	-0.14	0.91	0.97	-0.26	0.46	-0.95	-0.44	0.93	0.87	0.43	-0.60	-0.78	0.93	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00			
Zn uptake	0.92	0.13	-0.08	0.89	0.95	-0.21	0.41	-0.95	-0.38	0.95	0.84	0.38	-0.63	-0.75	0.94	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00		
Cu uptake	0.87	0.16	-0.07	0.85	0.93	-0.25	0.34	-0.98	-0.39	0.93	0.81	0.31	-0.70	-0.79	0.91	0.99	0.99	1.00	0.99	0.99	0.99	0.98	0.99	0.99	1.00	
Rhizome yield	0.95	-0.04	-0.22	0.96	0.98	-0.27	0.59	-0.89	-0.48	0.89	0.91	0.56	-0.46	-0.76	0.93	0.98	0.98	0.97	0.98	0.98	0.97	0.99	0.99	0.98	0.95	1.00

Appendix 7. Coefficients of correlation of nutrient contents and ratios in rhizome and uptake at 6 MAP and rhizome yield of Curculigo orchioides as influenced by FYM

	N	P	K	Ca	Mg	S	Fe	Mn	Zn	Cu	(Ca+M	Fe/K	Mn/K	Zn/K	Cu/K	N upta	P upta	K upta	Ca up	Mg up	S upta	Fe up	Mn up	Zn up
N	1.00																							
P	-0.36	1.00																		[r 1 (0.05) = 0.997, r 1 (0.01) = 1.0				
K	-0.86	-0.17	1.00																					
Ca	-0.92	0.70	0.59	1.00																				
Mg	0.79	-0.85	-0.37	-0.97	1.00																			
S	0.83	-0.83	-0.42	-0.98	1.00	1.00																		
Fe	-0.77	0.87	0.34	0.96	-1.00	-1.00	1.00																	
Mn	-0.82	0.83	0.41	0.98	-1.00	-1.00	1.00	1.00																
Zn	0.41	0.70	-0.82	-0.02	-0.22	-0.17	0.26	0.18	1.00															
Cu	0.87	-0.78	-0.49	-0.99	0.99	1.00	-0.99	-1.00	-0.09	1.00														
(Ca+Mg)/K	0.72	0.38	-0.98	-0.39	0.15	0.21	-0.12	-0.20	0.93	0.29	1.00													
Fe/K	-0.40	1.00	-0.13	0.73	-0.88	-0.85	0.89	0.85	0.67	-0.80	0.34	1.00												
Mn/K	-0.69	0.92	0.22	0.92	-0.99	-0.98	0.99	0.98	0.37	-0.96	0.00	0.94	1.00											
Zn/K	0.47	0.65	-0.86	-0.08	-0.17	-0.11	0.20	0.12	1.00	-0.03	0.95	0.62	0.32	1.00										
Cu/K	0.78	-0.87	-0.35	-0.96	1.00	1.00	-1.00	-1.00	-0.25	0.99	0.13	-0.89	-0.99	-0.19	1.00									
N uptake	-0.04	-0.91	0.55	-0.35	0.57	0.53	-0.60	-0.53	-0.93	0.46	-0.72	-0.90	-0.69	-0.90	0.59	1.00								
P uptake	-0.89	-0.11	1.00	0.63	-0.42	-0.47	0.39	0.46	-0.79	-0.54	-0.96	-0.07	0.28	-0.82	-0.40	0.50	1.00							
K uptake	-0.43	-0.68	0.83	0.04	0.21	0.16	-0.24	-0.16	-1.00	0.07	-0.93	-0.65	-0.36	-1.00	0.23	0.92	0.80	1.00						
Ca uptake	-0.74	-0.35	0.98	0.42	-0.19	-0.24	0.15	0.23	-0.92	-0.32	-1.00	-0.31	0.03	-0.94	-0.16	0.70	0.97	0.92	1.00					
Mg uptake	-0.40	-0.71	0.82	0.01	0.24	0.19	-0.27	-0.19	-1.00	0.10	-0.92	-0.68	-0.38	-1.00	0.26	0.93	0.78	1.00	0.91	1.00				
S uptake	-0.86	-0.17	1.00	0.58	-0.37	-0.41	0.33	0.41	-0.83	-0.49	-0.98	-0.13	0.22	-0.86	-0.34	0.56	1.00	0.84	0.98	0.82	1.00			
Fe uptake	-0.87	-0.15	1.00	0.60	-0.39	-0.43	0.36	0.43	-0.81	-0.51	-0.97	-0.11	0.24	-0.85	-0.36	0.54	1.00	0.82	0.98	0.81	1.00	1.00		
Mn uptake	-1.00	0.30	0.89	0.89	-0.75	-0.79	0.73	0.79	-0.47	-0.84	-0.76	0.34	0.64	-0.52	-0.74	0.11	0.91	0.49	0.79	0.46	0.89	0.90	1.00	
Zn uptake	-1.00	0.33	0.88	0.90	-0.77	-0.80	0.75	0.80	-0.45	-0.85	-0.75	0.37	0.66	-0.50	-0.76	0.08	0.90	0.46	0.77	0.44	0.87	0.89	1.00	1.00
Cu uptake	-0.81	-0.26	1.00	0.51	-0.28	-0.33	0.25	0.33	-0.87	-0.41	-0.99	-0.22	0.13	-0.90	-0.26	0.63	0.99	0.88	1.00	0.87	1.00	0.99	0.84	0.83
Rhizome yield	0.82	0.24	-1.00	-0.52	0.30	0.35	-0.27	-0.34	0.86	0.42	0.99	0.20	-0.15	0.89	0.27	-0.61	-0.99	-0.87	-0.99	-0.86	-1.00	-1.00	-0.85	-0.84

Appendix 8. Coefficients of correlation of nutrient contents and ratios in rhizome and uptake at 6 MAP and rhizome yield of Curculigo orchioides as influenced by proportion of FYM and fertiliser

	N	P	K	Ca	Mg	S	Fe	Mn	Zn	Cu	(Ca+M	Fe/K	Mn/K	Zn/K	Cu/K	N upta	P upta	K upta	Ca up	Mg up	S upta	Fe up	Mn up	Zn up
N	1.00																							
P	-0.84	1.00																		[r 4 (0.05) = 0.811, r 4 (0.01) = 0.9				
K	0.32	-0.04	1.00																					
Ca	-0.84	0.77	-0.67	1.00																				
Mg	0.80	-0.36	0.37	-0.53	1.00																			
S	0.34	-0.41	-0.38	-0.05	0.16	1.00																		
Fe	-0.56	0.66	-0.67	0.91	-0.13	0.11	1.00																	
Mn	0.45	-0.50	0.27	-0.51	0.12	0.73	-0.49	1.00																
Zn	0.03	-0.02	-0.48	0.31	0.06	0.91	0.47	0.52	1.00															
Cu	0.44	-0.15	0.99	-0.74	0.47	-0.29	-0.70	0.34	-0.43	1.00														
(Ca+Mg)/K	-0.43	0.44	-0.83	0.85	-0.12	0.23	0.96	-0.46	0.52	-0.84	1.00													
Fe/K	-0.52	0.52	-0.82	0.90	-0.21	0.20	0.97	-0.47	0.50	-0.84	0.99	1.00												
Mn/K	0.32	-0.48	-0.04	-0.30	-0.04	0.86	-0.30	0.95	0.68	0.03	-0.22	-0.22	1.00											
Zn/K	0.08	-0.17	-0.61	0.28	0.01	0.94	0.42	0.50	0.97	-0.55	0.53	0.51	0.70	1.00										
Cu/K	0.26	0.05	0.99	-0.58	0.36	-0.33	-0.58	0.30	-0.39	0.98	-0.77	-0.75	0.00	-0.54	1.00									
N uptake	0.82	-0.79	0.65	-1.00	0.46	0.04	-0.93	0.53	-0.32	0.72	-0.87	-0.91	0.32	-0.29	0.56	1.00								
P uptake	-0.74	0.92	0.27	0.51	-0.30	-0.68	0.35	-0.53	-0.36	0.15	0.11	0.19	-0.60	-0.51	0.34	-0.53	1.00							
K uptake	0.69	-0.57	0.82	-0.94	0.44	0.05	-0.90	0.64	-0.24	0.87	-0.92	-0.94	0.39	-0.28	0.78	0.94	-0.31	1.00						
Ca uptake	-0.67	0.27	-0.36	0.47	-0.90	0.24	0.13	0.27	0.32	-0.43	0.12	0.20	0.44	0.35	-0.31	-0.41	0.13	-0.31	1.00					
Mg uptake	0.26	0.28	0.51	-0.15	0.76	-0.37	0.13	-0.33	-0.24	0.52	-0.02	-0.05	-0.53	-0.39	0.53	0.08	0.38	0.17	-0.82	1.00				
S uptake	0.25	-0.49	-0.57	0.02	-0.08	0.94	0.09	0.62	0.81	-0.50	0.27	0.24	0.82	0.91	-0.55	0.00	-0.76	-0.08	0.39	-0.63	1.00			
Fe uptake	-0.71	0.69	-0.20	0.67	-0.50	0.28	0.53	0.19	0.57	-0.27	0.38	0.46	0.30	0.44	-0.07	-0.66	0.47	-0.40	0.72	-0.23	0.20	1.00		
Mn uptake	0.56	-0.67	0.42	-0.74	0.12	0.52	-0.76	0.94	0.21	0.49	-0.71	-0.72	0.84	0.23	0.41	0.76	-0.57	0.81	0.16	-0.34	0.46	-0.08	1.00	
Zn uptake	0.13	-0.14	-0.24	0.08	0.06	0.94	0.18	0.76	0.95	-0.18	0.21	0.21	0.86	0.90	-0.15	-0.08	-0.40	0.05	0.38	-0.30	0.81	0.56	0.50	1.00
Cu uptake	0.31	-0.15	0.95	-0.72	0.24	-0.53	-0.79	0.15	-0.69	0.93	-0.91	-0.90	-0.14	-0.77	0.90	0.71	0.22	0.81	-0.33	0.37	-0.63	-0.38	0.39	-0.45
Rhizome yielc	-0.89	0.57	-0.27	0.60	-0.90	-0.54	0.23	-0.50	-0.37	-0.39	0.17	0.25	-0.39	-0.34	-0.26	-0.55	0.59	-0.54	0.64	-0.44	-0.32	0.37	-0.46	-0.42

Appendix 9. Coefficients of correlation of nutrient contents and ratios in rhizome and uptake at 6 MAP and rhizome yield of Curculigo orchioides as influenced by nutrient sources

Source	N	P	K	Ca	Mg	S	Fe	Mn	Zn	Cu	(Ca+M	Fe/K	Mn/K	Zn/K	Cu/K	N upta	P upta	K upta	Ca up	Mg up	S upta	Fe up	Mn up	Zn up	Cu up	Rhizo
N	1.00																									
P	-0.23	1.00																			[r 6 (0.05)=0.707, r 6 (0.01)=0.834]					
K	-0.47	-0.72	1.00																							
Ca	-0.22	-0.61	0.85	1.00																						
Mg	0.23	0.53	-0.63	-0.64	1.00																					
S	-0.11	-0.71	0.72	0.60	-0.44	1.00																				
Fe	-0.72	0.67	-0.12	-0.21	0.13	-0.46	1.00																			
Mn	0.10	-0.91	0.72	0.61	-0.65	0.77	-0.49	1.00																		
Zn	0.10	-0.60	0.39	0.31	-0.75	0.08	-0.29	0.52	1.00																	
Cu	-0.33	-0.36	0.43	0.08	-0.27	0.45	0.11	0.37	0.29	1.00																
(Ca+Mg)/K	0.42	0.62	-0.82	-0.69	0.95	-0.57	0.07	-0.72	-0.69	-0.44	1.00															
Fe/K	-0.38	0.88	-0.56	-0.57	0.38	-0.71	0.89	-0.72	-0.39	-0.08	0.42	1.00														
Mn/K	0.70	-0.44	-0.17	-0.13	-0.20	0.27	-0.57	0.56	0.27	0.02	-0.07	-0.37	1.00													
Zn/K	0.25	0.11	-0.36	-0.37	-0.06	-0.45	0.15	-0.18	0.45	0.40	0.06	0.32	0.17	1.00												
Cu/K	-0.28	-0.24	0.28	-0.02	-0.32	0.46	0.11	0.33	0.23	0.95	-0.42	-0.01	0.16	0.43	1.00											
N uptake	-0.08	0.57	-0.50	-0.55	0.36	-0.08	0.12	-0.59	-0.46	0.16	0.40	0.32	-0.19	0.14	0.33	1.00										
P uptake	-0.29	0.92	-0.64	-0.63	0.45	-0.48	0.56	-0.85	-0.58	-0.13	0.51	0.74	-0.42	0.11	0.03	0.83	1.00									
K uptake	-0.63	0.54	-0.05	-0.18	0.28	0.09	0.52	-0.49	-0.61	0.30	0.17	0.43	-0.60	-0.17	0.36	0.76	0.75	1.00								
Ca uptake	-0.46	0.40	-0.02	-0.07	0.05	0.20	0.24	-0.39	-0.39	0.30	0.02	0.19	-0.47	-0.08	0.41	0.84	0.69	0.90	1.00							
Mg uptake	0.10	0.66	-0.68	-0.73	0.93	-0.39	0.18	-0.76	-0.78	-0.16	0.89	0.45	-0.26	-0.02	-0.13	0.68	0.71	0.54	0.38	1.00						
S uptake	-0.30	-0.13	0.30	0.13	-0.11	0.72	-0.15	0.17	-0.26	0.52	-0.23	-0.28	-0.05	-0.28	0.61	0.61	0.23	0.68	0.79	0.15	1.00					
Fe uptake	-0.66	0.78	-0.28	-0.41	0.23	-0.30	0.79	-0.66	-0.45	0.21	0.19	0.78	-0.58	0.12	0.31	0.68	0.88	0.87	0.73	0.48	0.33	1.00				
Mn uptake	-0.22	0.36	-0.20	-0.35	0.41	0.27	0.19	-0.29	-0.66	0.41	0.32	0.24	-0.13	-0.07	0.52	0.82	0.62	0.84	0.78	0.64	0.78	0.63	1.00			
Zn uptake	-0.12	-0.04	-0.02	-0.24	-0.29	0.00	0.06	-0.03	0.48	0.73	-0.28	0.08	0.01	0.73	0.78	0.46	0.21	0.24	0.42	-0.05	0.34	0.34	0.27	1.00		
Cu uptake	-0.40	-0.17	0.31	-0.01	-0.24	0.47	0.17	0.23	0.12	0.95	-0.38	0.01	-0.02	0.33	0.98	0.42	0.13	0.53	0.55	-0.03	0.71	0.42	0.62	0.76	1.00	
Rhizome yield	-0.71	0.66	-0.10	-0.22	0.22	-0.20	0.60	-0.67	-0.43	0.07	0.14	0.52	-0.80	-0.15	0.10	0.66	0.80	0.88	0.81	0.47	0.41	0.89	0.54	0.22	0.27	1.00

Appendix 10. Periodic light intensity under different shade levels (lux)

MAP	1	2	3	4	5	6	7	8	9
Shade (%)									
0	46147	54071	25141	86540	49045	38354	66613	61045	76569
25	20673	45722	15675	46450	24955	18535	32627	30241	37843
50	11187	27351	8927	23209	13315	9321	15866	13172	17991
75	6087	19252	7019	18533	10626	8427	12457	10067	14915

AGROTECHNOLOGICAL PRACTICES FOR QUALITY CRUDE DRUG PRODUCTION IN NILAPPANA (*Curculigo orchioides* Gaertn.)

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9. ABSTRACT

Nilappana, golden eye grass or black musali (*Curculigo orchioides* Gaertn.) of the family Amaryllidaceae is a key member of the *dasapushpa* and a highly useful plant in the indigenous system of medicine. It is a small, geophilous herb, the rhizome of which is used as a rejuvenating and aphrodisiac drug. This important medicinal plant on the verge of extinction has to be conserved and domesticated for which agrotechnology is to be developed to ensure adequate availability of quality crude drug and fetch maximum returns for the farmer. More over, large variations are observed in the quality of the crude drug available in the market. Hence, a project entitled 'agrotechnological practices for quality crude drug production in *nilappana* (*Curculigo orchioides* Gaertn.)' comprising of six experiments was undertaken during 2000-'02 at AMPRS, Odakkali to study the growth and development pattern, characterize the primary and secondary metabolites, assess the quantity and quality variations as influenced by cultural practices and to develop a satisfactory management practice for maximizing the yield with good quality.

The study on developmental physiology of *C. orchioides,* with two biotypes observed for 12 months, revealed that it was characterized by an active growth phase of 7 months, after which it could be harvested for quality rhizomes. The rhizome development is upward which has got special agronomic significance in that it requires deep planting and regular earthing up for higher yields. The quality parameters like sucrose, crude fat and curculigoside contents of rhizome decreased initially probably due to their utilisation by the plant for its establishment in the field. However, they increased substantially during later stages of the crop growth with the onset of active physiological activity in the plant. The two biotypes significantly differed in growth, yield and quality parameters. Panamkuzhi biotype is a better choice for cultivation. A lot of crop improvement efforts need to be taken up in this crop to make it more remunerative as it is a slow growing, less competitive and poor yielding. More over, it cannot withstand weed competition and rodent attacks. Hence, adequate control measures are essential for successful cultivation of the crop.

The study on characterisatrion of glycosides proved that an HPLC system comprising of C18 column with 0.01 *M* phosphate buffer (pH 6.0) and peaks monitored spectrtophotometrically at 205 nm could be used for the estimation of curculigoside content of *Curculigo orchioides*.

The split plot experiment with four shade levels (0, 25, 50 and 75 per cent) as main plots and four spacings (10x10, 20x10, 20x20 and 30x20 cm) as subplots showed that the dry matter production and yields in *Curculigo orchioides* were the highest at 25 per cent shade and 10 x 10 cm spacing due to higher growth characteristics such as plant height, number of leaves, canopy spread and also a higher chlorophyll a and a+b contents and a higher harvest index. The plant being a poor competitor, the higher plant density at 10 x 10 cm spacing coupled with low weed infestation, contributed to the higher yields. The content of primary metabolites and curculigoside in rhizome was higher at closer spacing. The uptake of nutrients was higher under shaded condition and closer spacing due to the higher plant densities and dry matter production. The partial shade also increased the soil pH and the content of available N, K, Ca and S in the soil. It is suitable for cultivation as intercrop in coconut and rubber plantations.

The field experiment in RBD with three levels of FYM (10, 20 and 30 t ha^{-1}), five proportions of FYM and fertiliser (0:100, 25:75, 50:50, 75:25 and 100:0) and a control of no FYM and fertilizer showed that increasing levels of FYM increased the growth parameters, dry matter production and yield. Application of 30 t FYM ha^{-1} had greater impact on these attributes. The fresh rhizome as well as the dry rhizome yields were the highest at 30 t FYM in 75:25 proportion of FYM and fertiliser. Application of 30 t FYM increased the glucose, starch, curculigoside and protein contents in the rhizome. Weed competition was much higher with increasing proportion of FYM and it was minimum when fertiliser alone was applied. Uptake of Mg was the highest when FYM alone was applied while S uptake increased with increasing proportion of fertiliser. Available Mg content in soil was higher when FYM and fertiliser were applied in combination.

The field experiment in RBD with eight nutrient sources (control, FYM 10 t ha^{-1}, vermicompost 1.3 t ha^{-1}, poultry manure 2.7 t ha^{-1}, FYM 10 t ha^{-1} +

Azotobacter 10 kg ha^{-1}, FYM 10 t ha^{-1} + *Phosphobacter* 10 kg ha^{-1}, FYM 10 t ha^{-1} + VAM 10 kg ha^{-1} and fertiliser N, P_2O_5, K_2O @ 40:30:20 kg ha^{-1}) with and without mulch (spent lemongrass 10 t ha^{-1}) showed that considering both the yield and quality of *Curculigo orchioides* no mulch treatment is better than mulch treatment. Poultry manure application recorded the highest rhizome and curculigoside yields which indicated its superiority over other nutrient sources for getting a higher yield with better quality. The growth, dry matter production and yield were the highest in poultry manure treartment followed by FYM + phosphobacter. Poultry manure applied plots recorded a higher uptake of most of the nutrients due to the higher nutrient contribution from the manure and the higher dry matter production. It also improved the P and Ca status of the soil.

The study on the quality variations in *C. orchioides* (with two biotypes under natural habitat and cultivation and market samples from south, central, north and High Range zones of Kerala and the south Indian states of Kerala, Karnataka, Tamil Nadu, Andhra Pradesh and Maharashtra) showed that there was variation in quality with biotypes and those in natural habitat was superior in quality compared to those under cultivation. Among the market samples collected from the various zones of Kerala, those from High Ranges were superior in most of the quality parameters, which indicated its superiority for high quality drug formulations. Among the southern states, Tamil Nadu samples ranked next to High Range samples in this respect. There exists large variability in the market samples and there is a felt-need for proper standardisation of the crude drug for ensuring quality in the drug formulations.

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