STUDIES ON YIELD AND QUALITY OF BYADGI CHILLI (*Capsicum annuum* L.) IN RELATION TO SOIL PROPERTIES IN TRANSITIONAL ZONE AND PART OF DRY ZONE OF NORTH KARNATAKA

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By
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CERTIFICATE

This is to certify that the thesis entitled **"STUDIES ON YIELD AND QUALITY OF BYADGI CHILLI (*Capsicum annuum* L.) IN RELATION TO SOIL PROPERTIES IN TRANSITIONAL ZONE AND PART OF DRY ZONE OF NORTH KARNATAKA"** *submitted by* **Mr. B.I. BIDARI** *for the degree of* **DOCTOR OF PHILOSOPHY** *in* **SOIL SCIENCE,** *to the University of Agricultural Sciences, Dharwad, is a record of research work done by him during the period of his study in this university under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.*

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(B.I. BIDARI)

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

INTRODUCTION

I. INTRODUCTION

Among spices and condiments, chillies (*Capsicum annuum* L.) form by far the most important and widely used crop. Chilli is native of South America and was introduced into India by Portuguese in the seventeenth century. Chilli is generally adapted to tropical situation and major chilli growing countries are India, China, Indonesia, Korea, Pakistan, Turkey and Sri Lanka. The important states where chillies are grown on large scale are, Andhra Pradesh, Karnataka, Maharashtra and Tamil Nadu, together accounting for about seventy five per cent of the area and production of the country. In India, chilli is being grown on an area of 918 thousand hectares with a production of 789 thousand tonnes of dry chillies. The status report on Agriculture indicates that, Andhra Pradesh stands first in area (181.6 thousand hectares) and production (327.8 thousand tonnes) of dry chilli, while Karnataka stands second in area (158.2 thousand hectares) and production (87.7 thousand tonnes).

India is not only the major producer and consumer of chillies, but also major exporter of chillies. During 1995-96, export of chillies has reached an all time high of 55,200 metric tonnes valued at Rs. 190.84 crores. Chillies stand next only to pepper in the total spice export from India and provide 25.7 per cent of the total value of export earnings from spices during 1995-96 (Anon., 1996).

In Karnataka, the crop is being extensively grown in Dharwad, Haveri, Gadag, Belgaum, Shimoga, Bellary and Chitradurga Districts. Dharwad, Haveri and Gadag districts together stand first in Area (115 thousand hectares) and production (55,737 metric tonnes) closely followed by Belgaum and Shimoga districts.

Titillating pungency and fascinating natural colour of chillies form an indispensable adjunct in every home all over the world. It is liked for its pungency, spicy taste, besides the appealing colour it adds to the food. Pungency in chilli is due to an alkaloid viz., capsaicin a substituted benzylamine derivative present to an extent of 0.1 to one per cent in different varieties. Capsaicin has significant physiological action, which is used in many pharmaceutical preparations like balms, lineaments and ointments for cold, sore throat and chest congestion. It is also reported to have carminative, tonic and stimulative properties. Capsaicin is mostly concentrated in the placenta of fruits, which connects seeds to pericarp.

Dry chillies occur in different shades of red colour ranging from orange to blood red. The principal colouring matter is the carotenoid pigment capsanthin, constituting about 35 per cent of the total pigment. The red colour extracted from chilli fruits is being extensively used in the cosmetics, perfumes, paints, dyes and for colouring food stuffs. Colour plays a very important role in assessing the quality of chillies and further determines the market price and demand.

Chilli belongs to the family solanaceae and two main species are *Capsicum annuum* and *Capsicum frutescens*. Chillies are classified as pungent and non-pungent varieties. Most of the Indian chillies belong to the *Capsicum annuum* species and this constitutes the major commercial variety used in food flavourings. Based on the fruit shape and size, Byadgi chillies are classified into 3 types as (I) Byadgi kaddi with 15 to 20 cm fruit length, 0.5 to 1 cm breadth with wrinkles on dried fruits and are highly pungent (ii) Byadgi dabbi with 5 to 10 cm fruit length and 2 to 2.5 cm breadth with less pungency and (iii) Dyavnur fruits, which have intermediate characters of Byadgi kaddi and dabbi. Though the yield and quality of fruits (particularly capsaicin and oleoresin contents) is controlled by the genetic make up of the plants, yet the soil properties, climatic factors and cultural practices alter the yield and quality attributes of these cultivars to some extent.

In the transitional belt of Dharwad and Haveri districts, temperature around 25°C and high relative humidity (90%) that prevail during the months of June-July synchronising with planting of chili seedlings, result in quick establishment, vigorous vegetative growth and high flower production. Further, high temperature (35°C) during September-October and it's gradual reduction in November-December months, coupled with frost free period result in higher yields of ripe dry chillies. It is observed that, the optimum temperature range for raising best quality chilli crop is 10 to 35°C and this temperature range prevails in this transitional zone during the entire growth period..

Chilli is a tropical and subtropical plant grown in all the three seasons *kharif, rabi* and summer. It comes up well from sea level to as high as 1600 metres. In the transitional tract of Dharwad and Haveri districts, capsicums are usually grown as rainfed crop in areas with rainfall ranging from 600 to 1250 mm and highly sensitive to excess rainfall and ill drained conditions. It can withstand drought better than water logging. Chilli crop can be grown on a variety of soils, provided they are well drained and well aerated.

In the transitional belt of Dharwad and Haveri districts, and dry tract of Gadag district chilli crop is extensively grown for red dry fruits in deep black soils (Vertisols) and medium black soils (vertic intergrades), and yield/quality of chillies differ widely from area to area. Major soils of this tract are deep black, medium black, mixed red and black and red soils. With such an ecological combination of soils and the chilli crop, it is essential to know what makes chilli to grow and produce different quality fruits and varying yields. Is it the soil factor or climatic factor ? Climate, being mostly the same within the limited area, it is likely that soil factor may play an important role for its yield and quality differences.

The data on properties of chilli growing soils, nutrient composition of different quality chilli fruits, capsaicin, colour value and oleoresin content of varying quality fruits are lacking. Therefore, it was felt necessary to study the relationship between soil properties and yield and quality of chilli (Byadgi variety) crop grown extensively in the transitional belt of Dharwad and Haveri districts and also dry tract of Gadag district. The present investigation was therefore undertaken with the following objectives :

1. To study the morphological and physico-chemical properties of chilli growing soils.
2. To study the nutrient status of soils and the uptake of nutrients by chilli crop in these soils.
3. To correlate chilli yields and quality attributes with soil properties.
4. To study the partitioning of nutrients within fruit components (pericarp and seed) and to identify the probable nutrients that influence the quality attributes, particularly capsaicin and colour value of fruits.
5. To correlate the uptake of nutrients and nutrient composition of fruits with yield and quality of Byadgi chillies and to compare Byadgi cultivars with Guntur (G-3) and Sankeshwari varieties for quality attributes which are also extensively grown in the district.

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

In determining the productivity and quality of any crop, it's phenotypic characters, genotypic make-up, climate and the soil environment in which it is grown are known to play important role. Since chilli crop is being grown on a variety of soils, the soil properties are known to influence the yield and quality of this crop.

Climate being mostly the same in an agroecological region, the different soil types occurring in that region, produce chilli yields of varying quantity and quality, depending upon the native and applied nutrients and also management practices. The soil properties and nutrient status have a great role in influencing the yield and quality of a particular crop in an agroecological region. This serves as a data base for the purpose of knowing the best suited soils for growing a particular crop of best quality and high yield. Further, this will give feed back for crop improvement by conducting field experiments in different locations by imposing treatments. Therefore, it is important from the growers point of view, to assess the performance of Byadgi chilli variety, grown in different soils in farmers fields under their cultivation practices for it's variation in yield and quality.

Since literature on this type of subject is very meagre, information pertaining to the yield and quality of closely related crops viz., tomato and other spices, their performance in different soil types is reviewed here under the following headings :

2.1 Chilli growing soils

2.2 Soil properties influencing the yield and quality of chilli, tomato and other spices.

2.3 Response to the applied soil nutrients and cultivation practices.

2.4 Rooting habit of chilli plants in different soil types.

2.5 Quality attributes of chilli fruits, their biosynthesis and determination.

2.1 Chilli growing soils

A knowledge regarding the type and distribution of soils is essential for the proper appraisal of their productivity and assessment of input requirements and inturn relative response to them. In the transitional zone of Dharwad and Haveri districts, due to assured rainfall, chilli is being mostly grown on medium and deep black soils during kharif and rainfed cotton/onion or garlic were also grown as mixed crops. These soils vary in their genesis, morphological and physico-chemical properties. In few areas, chilli is also grown on red and reddish brown soils under rainfed conditions, which occur in association with black soils.

2.1.1 Morphological characteristics

Singh (1956) studied the colour of few black and red soils of West Bengal and stated that, colour of soils is greatly influenced by organic matter content and free iron oxides. Roy and Barde (1962) reported that these soils have sub angular blocky to blocky structure. A review of soil survey reports on the black soils of Tungabhadra project area revealed that, the various soil series consisted of granular structure in Ap horizon which grades to sub-angular blocky to angular blocky with slicken sides on their faces in some cases (Godse *et al.*, 1970; Yaalon and Kalmar, 1978 and Murthy *et al.*, 1982). Dudal (1965) observed that these black soils generally lack distinct or prominent horizons. They had characteristics of darkened surface layer or A-1 horizon, which grades progressively into 'C' horizon and may be quite thick. As regards the horizon sequences, the author stated the dominant sequence as 'A_1', AC and 'C' horizons. Krishnamoorthy and Govindarajan (1977) reported that black soil pedons are more deep than red soil pedons and depth of any pedon is influenced by intensity of weathering.

Sehgal and Sohanlal (1988) studied a profile from Hugalur series in Dharwad district and stated that, these soils are moderately deep having subangular blocky structure to coarse angular blocky structure. They are highly calcareous, sticky and plastic. This soil can be put under chilli/cotton cultivation under assured rainfall. Similarly, a benchmark series viz., Hungund was also described by Murthy *et al.* (1982), which occurs extensively in the transitional tract of Dharwad and Haveri districts. Hungund and it's associated series viz., Hugalur and Devihosur have prominent slickensides and medium in clay content.

Practically, all good agricultural soils with proper treatment produce fair or good crops of most vegetables. Splittstoesser (1978) reported that, for vegetable growing, good texture and structure are of great importance. He further stated that silty loam soils are the best soils for growing most of the vegetable crops especially when high yields are desired. Further, moisture retentive soils are best, if vegetables have to be raised under unirrigated conditions.

Raychaudhuri *et al.* (1965) reported that Dharwad district has three types of soils viz., (i) red (ii) black and (iii) brown. The red soil is comparatively shallow and gravelly and needs irrigation for long duration crops like cotton, chilli etc. The medium black soils, which are predominant have 45 per cent clay, 12.4 per cent sand and are rich in lime (4.5 to 6.2%). These black soils are moderately deep to very deep and are suited for growing jowar, groundnut, soybean, cotton and chilli under rainfed conditions. They further studied the properties of these soils and reported their suitability for crop production. Hosmani (1993) reported that saline and sodic conditions hinder crop growth and also fruit development. Soils derived from chlorite schist with a sandy clay loam texture are more favourable for crop growth and yield. He further generalised the properties of these black soils occurring in transitional zone of Dharwad district where chilli is being grown extensively on these soils.

Black soils occupy large areas in the states of Maharashtra, Karnataka, Gujarat, Madhya Pradesh, Andhra Pradesh and Tamil Nadu (Raychaudhuri *et al.*, 1963). Most black soils are derived from basalt, though some have formed from limestone, shales and schists. Usually black soils occurring on the uplands are shallow and less than a metre depth, whereas in the valleys and plains, they are very deep.

Bhattacharjee *et al.* (1977), in a study on the profile development of deep black soils reported that there is appreciable vertical mixing within the profiles due to changes in moisture content. This process leads to non-differentiation of horizons and results in A-C profiles.

Krishnamurthy (1993) reported that majority of red soils in Ranebennur taluka belong to the order Alfisols. The bulk density of these red soil pedons was more in surface and decreased in 'B' horizon due to high clay content. Excessive gravelliness, surface crust formation and susceptibility to erosion due to high slopes are some of the problems encountered in these soils. These red soils are shallow to moderately deep.

Rudramurthy (1994) studied few black soil pedons in Dharwad district and stated that horizon differentiation in black soils is mainly based on prominence, abundance and intersection of slickensides. The predominant structure in these soils was subangular blocky in surface horizons and angular blocky in subsurface horizons due to slickensides formation.

2.2 Soil properties and yield/quality of chilli, tomato and other spices

2.2.1 Soil physical properties versus growth characters, yield and quality

Flocker and Menary (1960) studied the influence of bulk density on physiology of two tomato varieties and stated that high soil bulk density restricts the root density of tomato plants and it reduces the soil air spaces, root distribution and absorption of nutrients by plants. Maximum root density was observed in the top inch of soil, in soils having bulk density of 1.7 g/c.c, but they are distributed to 4 to 6 inch layer in soils having bulk density of 1.4 g/c.c. Similarly, Menary and Kruger (1966) stated that, high soil bulk density results in stunting of plants, purpling of stems and reduced surface area of leaves due to changes in root anatomy and reduced root development. Hosmani (1993) reported that, chilli roots function best in soils having deep crumb structures rich in organic matter.

Ivanov (1970) studied the effect of soil bulk density on the growth and reproductive characteristics of tomatoes. Tomato plants grew best at a soil bulk density of 1.1 to 1.2 g/c.c. He gave the critical soil density value as 1.3 g/c.c for most of the crop plants above which some physiological functions were depressed. Further, he stated that, high soil bulk density disturbs the energy balance in soil plant atmosphere system and an air porosity below 8 to 10 per cent of soil volume reduces the plant vigour and ultimately the yield and quality. Based on this he concluded that, plants grown on red soils have stunted growth and reduced yields compared to plants grown on black or medium black soils.

Bunt (1961) studied the effect of soil compaction and soil structure on the growth of tomato plants. In red soils having poor structure, slight degree of compaction adversely affects plant growth due to mechanical impedance caused to the root growth because of increased bulk density of soil. This indirectly affects the yield of fruits.

The absorption of nutrients by plants is governed by soil moisture tension, air space and soil density. Flocker and Nielsen (1962) reported that, plants absorb moisture and nutrients over a wide range of density and air-space conditions, but under a limited soil moisture tension. There is a significant negative correlation between the nutrient absorbed per plant and increasing soil moisture tension. Similarly Ghildyal and Satyanarayana (1965) reported the importance of clay content and bulk density in influencing the nutrient absorbed by plant. Ali *et al.* (1966) stated that, moisture holding capacity of soils is closely related to texture and have a profound effect on plant growth.

Soil structure and nutrient mobility play important role in the uptake of nutrients. Wiersum (1962), conducted a pot culture experiment with different sized gravels on tomato plants. According to him, texture of the substrate had no effect on nitrogen uptake, but phosphorus uptake increased with decreasing particle size. This shows that, in fine textured soils due to high specific surface and low mobility of phosphorus, it is adsorbed and retained for longer period and subsequently absorbed by plant. But nitrogen is quickly lost through leaching in coarse textured soils due to it's high mobility and larger air spaces in soil.

Texture of the soil influences the absorption and accumulation of cations by plants. Hipp (1969) reported that, tomato plants grown on clay soils contained higher concentrations of magnesium, manganese, zinc and calcium in foliage than those plants grown on sandy loams. This shows that, clay soils because of greater surface area and higher moisture retention are in a position to adsorb and supply nutrients for longer period than sandy loam soils.

Availability of soil water to plants is greatly influenced by the clay content and aggregate size. Shaykewich and Warkentin (1970) measured the growth rate of tomato plants grown under controlled environment in three different textured soils. Increased leaf area as a fraction of existing leaf area was taken as index for increased growth rate. According to them, at a given soil suction, growth rate of a particular plant was high in soils containing high clay content than in medium textured soils. Differences in hydraulic conductivity, water retention properties and aggregate size are accounted for most of the differences in growth rate soil suction relationships. This indicates the importance of soil texture in influencing the growth and yield of crops grown in different textural conditions. Bhargava *et al.* (1973) and Boul (1965) stated that, in black soil pedons due to frequent cracking and swelling, there is vertical mixing of clay which resulted in enhanced clay content in lower layers. This influenced the growth and yield of crops by virtue of better retention of moisture and nutrients in sub surface horizons.

2.2.2. Soil chemical properties influencing the yield.

Geraldson (1966) reported the effect of salt accumulation in profile on tomato production. He stated that, salt accumulation due to poor leaching leads to spodic horizon causing salinity. Salinity of profiles causes physiological and pathological problems associated with calcium deficiency and these processes drastically reduced tomato production.

The importance of soil reaction in affecting plant growth was elucidated by Thorup (1967). Tomato plants fail to grow in soils containing high levels of Na_2CO_3 than soils containing NaCl. At soil pH levels above 9.0, there was root damage in the form of blackened root tips, curled lateral roots and general discolouration of the root system. If pH is allowed to drop below 8.00, then new adventitious roots develop around crown root area and plant growth revived. This shows that, neutral soil pH is highly favourable for growth of tomato plants and at high pH values, CO_3 ions prevented the growth of new roots. Satyanarayana and Biswas (1970) highlighted the importance of soil reaction in influencing the plant growth. Similarly Manjunathaiah (1981) elucidated the reasons for low pH in red soils and their impact on plant growth. Alase (1977) stated that, black soil pedons have higher CEC values than red soil pedons and it is governed by clay content. Nutrient absorbed by plant is closely related to CEC, provided moisture and other factors are favourable for root growth.

Navrot and Ravikovitch (1969) reported the importance of calcareous nature of soils in influencing the absorption of zinc by tomato plants. Zinc absorption was inversely related to the size of $CaCO_3$ nodules originating from homogenous carbonaceous parent rock. Pathak and Patel (1980) studied the calcareous nature of black soils and stated that, calcium carbonate content increased with depth and has influenced the absorption of nutrients. Similarly Talbot *et al.* (1971), Kaushik and Shukla (1977) and Deshpande (1985) studied the distribution of soluble cations in black soil pedons and their influence on the uptake of nutrients. Subbaiah and Manickam (1992) studied the distribution of exchangeable Na^+ and K^+ in black soils of Andhra Pradesh where chillies are extensively cultivated. They stated that, exchangeable sodium content increased with depth, while no definite trend in the distribution of exchangeable potassium was observed. Further, exchangeable sodium has antagonistic effect on the growth and yield of chillies by inhibiting root growth.

Similarly Nandi and Dasog (1992) studied the origin and distribution of lime nodules in few black soils of Upper Krishna Project where chillies are cultivated under irrigation. They stated that, exchangeable Ca^{2+} + Mg^{2+} are dominant over Na^+ + K^+ and black soils have higher CEC than red soils because of dominance of smectite type of clay mineral. CEC, Ca^{2+} + Mg^{2+} have profound effect in influencing the growth and yield of crops. Similarly Alur (1994) studied the genesis of few red soils of North Karnataka and stated that, red soils usually are deficient in calcium and magnesium.

Sahu *et al.* (1990) studied the organic matter status of few red soils of Orissa, where chillies/tomato and other vegetables are grown. According to them, organic matter content decreased with depth in all pedons and has a direct impact in influencing the nutrient absorbed by plants.

2.2.3 Soil available nutrients influencing the yield

Jenny and Raychaudhury (1960) studied the effect of climate and cultivation on nitrogen and organic matter reserves in few Indian soils. They stated that, nitrogen content is closely to related to clay content and black soils have high absorption capacities for organic molecules. Further higher exchangeable Ca^{2+} of these pedons helps to preserve humic substances by forming calcium humate and organo mineral compounds which are less available to microbial attack. All these contribute to higher N status of black soils, which contribute for higher uptake and increased yields of crops. Similarly Ramamoorthy and Velayutham (1976) studied the forms, distribution and availability of nitrogen, phosphorus and potassium for few benchmark soil series of India. They stated that, coarse textured soils have lower status of nutrients than fine textured soils and there is rapid loss of applied nutrients in coarse textured soils. Hence, plant growth is limited in coarse textured soils compared to fine textured soils.

The importance of soil phosphorus in influencing the yield is being elucidated by Raut (1962) and Pearson *et al.* (1940). Vertisols usually have low phosphorus availability owing to calcareous nature and plants grown on black soils often show deficiency symptoms. This is attributed to formation of insoluble phosphorus compounds on account of excess calcium carbonate (Raut, 1962). Pearson *et al.* (1940) studied the vertical distribution of phosphorus and its availability to plants in soils of Texas (USA). They stated that, available phosphorus decreased with depth to a minimum in lower horizon and then increased markedly.

Potassium requirement of any crop is usually met through native soil K. But, indeterminate and long duration crops need constant supply of K to meet their requirement, Rajukkannu *et al.* (1970) studied potassium status and its distribution in red and alluvial soils of Tamil Nadu. They stated that, available K content decreased with depth in all soil pedons, because of coarse textured nature and extensive leaching. Similarly, Chahal *et al.* (1976) reported potassium status and distribution for few soils of Haryana.

Among secondary nutrients, sulphur appears to play significant role in enhancing the yield and quality of few crops. Tabatabai (1986) and Fox (1982) reported that, sulphur uptake by plants is closely related to the amount of solution sulphur and adsorbed sulphur and black soils have high solution sulfur to meet the needs of plant. Balasubramaniam and Kothandaraman (1985) reported that, sulphate sulphur content invariably increased with depth in major black soil series of Coimbatore district. This is attributed to high solubility of sulphates sulphur leading to leaching and gypsiferous nature of lower horizons. Similar studies were also conduced by Kanwar (1963) for groundnut growing soils of Punjab, Dolui and Saha (1983) for lateritic soils of West Bengal and Hogg (1966) for grass land soils of New Zealand.

The role of available micronutrients in influencing the yield of any crop is governed by their concentration, form and other soil factors including the concentration of other major and microelements that may have antagonistic or synergistic effect.

The distribution, solubility and availability of copper in soils was studied by many research workers. Rai *et al.* (1972) stated that, deep black soils usually have lower copper than red soils. This is attributed to high calcium carbonate content of black soils. Similarly Tekale and Ghonsikar (1977) reported the distribution of copper in few soils of

Parbhani district in Maharashtra. Lindsay (1979) studied the solubility of copper in soils and stated that acidic reaction of soils enhances the solubility of copper compounds leading to increased availability. Similar to copper, zinc availability and distribution was also studied by few workers. Appavu and Sreeramulu (1981) reported the availability indices and distribution of zinc in some soils of Tamil Nadu. According to them, soils have wide range of zinc availability (0.16 to 5.14 ppm) and black soil pedons had no consistent distribution. Hence, the availability of zinc to crop growth is difficult to predict.

The DTPA extractable iron status for few Indian soils was studied by many authors. Malewar and Randhawa (1977) studied the status and distribution of DTPA-Fe for few black calcareous soils of Marathwada region, where chilli is extensively cultivated. They stated that, wide range existed between iron status of pedons and no definite trend in the distribution was observed. Sakal *et al.* (1985) suggested critical limit for Fe (6.95 ppm) and stated that, most of the calcareous black soils are deficient in iron.

Similar to iron, DTPA extractable manganese status and distribution was studied by Biswas (1951) and Arora and Sekhon (1981) for few soil series of Punjab. They stated that, high pH values coupled with semi arid conditions decrease the availability by converting Mn^{++} to Mn^{+++}.

2.3 Response to the applied soil nutrients and cultivation practices

2.3.1 Major and Secondary nutrients

Relwani (1962) conducted field experiments on fertilization of chilli crop (var. Patna) over a period of three years at IARI substation Karnal. Three levels each of nitrogen and phosphorus at 0, 40 and 80 lb. per acre from the sources of ammonium sulfate and super phosphate were compared singly and in combination. He worked out the response curves for nitrogen and phosphate levels and response curve was found to be quadratic for nitrogen levels indicating diminishing rate of increase with higher doses of nitrogen, whereas for phosphorus levels, it was linear indicating a more or less uniform increase with every additional unit of P-fertilizer. Interaction between N and P was not found to be significant in any of the years. Further, lower doses of P application does not bring significant increase in yield, possibly due to fixation of greater proportion of available phosphate from small doses on coming in contact with soil. With higher dose, a substantial amount of phosphate may still be available for utilization by the crop after fixation in a restricted area below the plant. Barooah and Zaman Ahmed (1964) stated that, nitrogen at various levels brought about a very large increase in plant growth by significantly increasing the height of the plant, number of branches, number of leaves and yield of tomato fruits. This is attributed to entry of nitrogen into chlorophyll, alkaloids, proteins and protoplasm of the plant. Phosphorus fed plants grew much faster during the early period of plant's life, may be due to early stimulation of the growth of the root system through efficient translocation to the roots certain growth stimulating substances formed on account of protoplasmic activity of the tops. Potash had little effect on tomato yield probably due to the existence of negative correlation between the absorption of phosphorus and potassium N and P interaction was significant indicating phosphorus fed plants are able to absorb more nitrogen than other nutrients. Similar type of study was carried out by Thomas and Heilman (1967) on sweet pepper. They underlined the importance of balanced application of N and P fertilizers along with maintenance of optimum soil moisture regime. As the soil moisture tension increased, the soil strength increased and the rate at which roots grew through the soil decreased. The soil moisture regime, N and P supply affected the distribution of dry matter between the various plant parts. Mehrotra *et al.* (1968) also studied the deficiency symptoms of NPK in chillies and their impact on growth and yield. Similarly Chaudhuri and De (1969) studied the effect of N application on vitamin C content of red ripe tomato fruits. Vitamin-C content decreased as N supply to plant increased possibly because of greater shading effect of the more vigorous shoot growth. Phosphorus did not affect vitamin-C content. Sambasiva Rao and Ankaiah (1968) reported that, in sandy soils of Andhra Pradesh, chillies cultivated for vegetable purpose produced low yields. They attributed low yields in sandy soils to intense leaching and non availability of adequate nutrients during flowering and fruiting. Similar studies were also reported by Mohamed Kunju and George (1969) for chillies cultivated in red loam soils of Kerala.

Tukalova and Para (1970) reported the effects of monoculture and crop rotation on nutrient status of soil and tomato fruit composition. According to them, monoculture of tomato in a field for few years leads to exhaustion of NPK from soil and the fruit quality and yields are lowered. But rotation of tomato with lucerne improves not only yield and quality of tomato, but the soil nutrient status was maintained adequately enough for future crop production. So nutrient exhaustive crops like chilli, cotton, tomato etc. should not be grown on the same land continuously owing to reduced yields and quality.

Satisfactory balance between the applied nutrients decides the maturity, fruit size, yield and quality of vegetables. Imbalance between these nutrients either in the soil or in the plant hampers the physiological processes. In this context, Gnanakumari and Satyanarayana (1971) reported the effect of different rates of NPK on flowering, yield and composition of Brinjal. Too high doses of N, P and K affect the yield, vitamin-A and vitamin-C content in fruits. Similarly, Uzo (1971) highlighted the importance of balance between N, P and K nutrients on the yield of tomato grown in sandy-loam soil.

In a field experiment conducted by Nathulal and Pundrik (1971) to study the effect of N, P and K on growth and yield of chilli (var. Patna), it was found that, increase in dose of nitrogen results in increased yield due to increase in carbohydrate synthesis and it's translocation to developing fruits, enhancing the size and weight of fruits. The effect of nitrogen is more pronounced, when the applied nitrogen is in optimum ratio with soil P, because phosphorus promotes the uptake of nitrogen. Similar observations were reported by Dass and Mishra (1972), Selvaraj *et al.* (1973), Iruthayaraj and Kulandaivelu (1973), Rahimkhan and Suryanarayana (1977).

The price of chillies/tomato in the market is based on the lusture, colour and glossiness of fruits. Now-a-days the pigment of these fruits has acquired great importance owing to it's unique properties. Some efforts have been made in both chilli and tomato to improve and maintain the red colour of fruits by altering the nutrient supply to plants. In one such study, Trudel and Ozbun (1971) studied the influence of potassium levels on carotenoid content of tomato fruits. Results of their experiment revealed that, most of the carotenoids and lycopene particularly responsible for the red colour in tomato increased with increasing K supply. Similarly Lachover (1972) reported the effect of potassium on the yield and quality of tomato (var. Roma). He stated that, potassium application had no effect on vitamin-C and citric acid content of fruits, but K enhances reducing sugar content.

The uptake pattern of N, P and K by chilli crop was studied in detail by Rajendraprasad and Subramaniam (1978). They found that, uptake of potassium by the crop was highest followed by that of N and P at all stages of growth. In a detailed study with chilli variety Agronomka, Spaldon and Ivanic (1968) observed, NPK uptake during the early stages to be low, followed by a steep increase during the peak vegetative growth to flowering period with a slight decline by final harvest time.

Capsaicin content is mainly responsible for pungency in chillies. The influence of different levels of N, P and K on the capsaicin content of MDU-1 chilli was studied by Subbiah *et al.* (1980). Addition of N alone lowered the capsaicin content, but it is improved when P and K are added with N. This highlights the importance of balanced application of NPK for producing better quality fruits. Subbiah *et al.* (1982) worked out the optimum dosage of nutrients needed and to ascertain the possible reasons for increased uptake of nutrients when organics and inorganic fertilizers are combined together leading to enhanced yields of chilli (var. MDU-1). There was increased uptake of N, P, K, Ca and Mg in FYM applied plots due to solubilisation effect of minerals by decomposing FYM as well as the chelating effect on metals where by metal ion availability gets increased. Further, the decomposing FYM improves soil physical properties within the vicinity of root zone, thereby roots activity gets increased leading to increase in uptake of nutrients and yields. They further highlighted the importance of split application of nitrogen to chilli crop, because of it's prolonged flowering and fruiting which should synchronise with the nutrient application. They also worked out the relationship between yields of dry chillies with nutrient ratios and found that, significant positive relationship exists between N:P and N:(K+Mg+Ca) with yield and negative relationship with nutrient ratios of Ca:K and Ca:K+Mg. Similarly Dod *et al.* (1983) highlighted the importance of split application of N and K on the yield and quality of chillies (G-3). They stated that, the time of nutrient application should synchronise with requirement, and for chillies two to three split applications particularly for nitrogen are very essential.

Rama Rao *et al.* (1988) reported that, the response of chilli to nitrogen depends on the pattern of rainfall distribution under rainfed conditions. Foliar spraying of N is admissible only when soil moisture is not adequate for the uptake of topdressed nitrogen.

Genetic potential of any crop can be exploited in commercial production by supplementing with nutrients. Nitrogen plays a vital role in enhancing the yield of chillies along with P and K, by increasing the size and weight of fruits due to it's role in the synthesis of photoassimilates. Since leaf is the main component involved in photosynthesis, the concentration of nitrogen in leaf at different stages of plant growth may be used as an index for assessing the nitrogen requirement of crop and it's possible influence on yield. Based on this approach, Narasappa *et al.* (1985) carried out an experiment on chilli (var. Sindhur), to study the effect of graded doses of nitrogen on leaf N concentration and yield. Results of their experiment revealed that, leaf N concentration increases from initial flowering to fruit growth stage and further decreases at fruit ripening stage irrespective of the levels of nitrogen applied to soil. High concentration of leaf N (3.9%)at fruit growth stage indicates the peak N uptake for growth of developing fruits, while a reduction at the ripening stage (2.4%) is attributed to rapid translocation of nutrients to developing seeds. They further correlated the leaf N concentration at initial flowering (3.1%), fruit growth and fruit ripening stage to yields, which showed positive correlation. So high levels of leaf N should be maintained at fruit growth stage for better yields and maturity.

Nitrogen and potassium have different roles to play in influencing the yield and quality of chilli. Parminder Singh *et al.* (1986) reported that, nitrogen played a major role in the enhancement of vegetative growth and fruit size, while potassium influences the quality of fruits. Similar observations were reported by Roychoudhury *et al.* (1990). Nair and Peter (1990) studied the effect of organics and inorganic fertilizers and their combination on the yield and storage life of hot chilli. They stated that, application of inorganic fertilizers alone enhanced the yield, but fruits get deteriorated early during storage. However, application of fertilizers in combination with FYM not only enhanced the yields, but storage life of chillies was improved.

Uptake of nutrients by plants for growth and yield mainly depends upon the soil moisture. Maintenance of optimum soil moisture level for higher uptake of nutrients and increased yields is the basic criteria in irrigated agriculture. Shibhila Mary and Balakrishnan (1990), studied the effect of irrigation, nitrogen and potassium on the fruit characters and quality of chilli (var. K2). Optimum soil moisture level leads to better uptake and translocation of absorbed nutrients. Moisture is very essential for the elongation and multiplication of cells, while increased N levels influence the fruit length, girth and seed content in fruits. Apart from influencing the yield, optimum soil moisture and optimum K levels increased cell metabolism and enzymatic activities, thus enhancing the ascorbic acid and capsaicin synthesis in fruits. Similarly, Omran *et al.* (1995) underlined the importance of maintaining optimum soil moisture within root zone for growth and absorption of nutrients by pepper plants.

The importance of sulphur as the fourth major element is being recognized and most of the research works on sulphur are centered around oilseeds and legumes. In this context, Niranjana and Suseela Devi (1990) studied the response of chillies (var. Pusa Jwala) to sulphur in different ratios to P in a pot culture using oxisol of sandy loam texture having acidic pH. They concluded that, chilli crop responds to phosphorus and sulphur application in laterite soils, both in terms of yield and quality.

For efficient utilisation of applied nutrients by the crop, the dose and time of fertilizer application should synchronise with crop requirement. In chilli, where flowering and fruiting last for longer period, plants need continuous supply of nutrients. Based on this approach, Subhani *et al.* (1990) reported the effect of graded levels and time of application of N and K on fruiting and yield of irrigated chilli (G-4). They tried four levels of N and K_2O (0-0, 60-40, 120-80 and 180-120 kg/ha), each applied at 4 split doses. Results of their experiment revealed that, levels and split application of N and K had profound effect on yield and fruit quality attributes. Similarly, Rajput and Singh (1991) studied the effect of NPK application on the yield of Turnip. Gupta *et al.* (1990) studied the response of turmeric to phosphorus levels and stated that, phosphorus fed plants enhanced the size of rhizomes and improved the curcumin content.

Turmeric is another spice cum aromatic crop being valued for it's curcumin content in rhizomes. Vijayakumar *et al.* (1992) studied the properties of turmeric growing soils in Cuddapah and Guntur regions of Andhra Pradesh and correlated these properties with curcumin content. They lamented the importance of organic carbon, available N and available Mn contents in significantly influencing the yield and quality of rhizomes. Negative correlation exists between clay content and rhizome yield, probably rhizome prefers well drained soil conditions and cannot sustain restricted drainage. They further studied the variability in turmeric germplasm interms of nutrient composition and curcumin content of rhizomes. It was found that, nitrogen concentration of rhizome had significant positive correlation while K concentration had negative correlation with curcumin content. This suggests that, at higher levels of soil available K, plants absorb excess K which might hinder curcumin accumulation in rhizomes. Hence, it can be inferred that, more amount of organic fertilizers such as FYM, rural compost, green manures etc., N fertilizers like urea, ammonium sulphate can be applied to increase the curcumin content in rhizomes. Similar type of study was carried out by Singh *et al.* (1992) and they contradicted the observations made by Vijayakumar *et al.* (1992), particularly the role of K in enhancing curcumin content of rhizomes along with N.

The rate of absorption of nutrients by plant depends upon the availability of nutrient in soil, it's concentration, form and finally the requirement of plant. Cheng *et al.* (1993) studied the characteristics of nutrient absorption by tomato. The uptake of nutrients decreased in the order K>NO_3-N>Ca>P>Mg and after fruit set, K uptake was considerable in tomato. Similarly, Olsen *et al.* (1993) studied the pattern of uptake of nutrients by Bell pepper as related to applied nitrogen. He ranked the uptake of nutrients as K>N>Ca>Mg>S>P. Accordingly, fruits accumulated greatest proportions of total K, followed by N. This highlights the importance of potassium after fruit set. Similarly, Sharma *et al.* (1996) highlighted the importance of calcium in vegetables. They stated that, calcium uptake is more related to root growth than shoot growth. This is attributed to absence of casparian strip on root tips which are the sites for calcium absorption.

Asiegbu and Oikeh (1995) stated that, NPK fertilizers appeared to be more efficient than organic manures in supplying NPK to meet the immediate needs of plant in the short run, but organic manures had an advantage in the supply of other macro and micronutrients not contained in fertilizers.

Castillo *et al.* (1996) studied the influence of plant population on growth, yield and quality of garlic (*Allium sativum* L.). They stated that, high plant population reduced the nutrient and moisture uptake. Theses have a profound bearing on yield and quality of garlic. They attributed low yield of garlic to lack of competition free environment in high plant population that resulted in restricted root growth and subsequent reduction in the uptake of moisture and nutrients.

Wankhade *et al.* (1997) studied the periodic concentration and uptake of nutrients by different crops grown under recommended cultivation practices and NPK fertility levels. According to them, the behaviour of uptake of nutrients differed from plant species to species and mainly governed by the duration of crops. In crops like jowar, groundnut and soybean, uptake was slow upto 45 days and rapid to very rapid during 45 to 60 days. But in long duration crops like cotton, chilli and tur, peak period of uptake was during 60 to 75 days.

Chilli needs heavy manuring for putting up good plant growth and high yields. Vegetables respond to addition of nutrients through FYM and chemical fertilizers. Chemical fertilizers applied alone may not bring increased uptake and yields, possibly because of quick losses through leaching, volatilisation and soil conditions not favourable for quick absorption by roots. Further, these fertilizers may affect the soil properties and also quality of crop by virtue of their reaction and high concentration. Hence, the combined application of FYM and fertilizers on chilli yield, uptake and quality was studied by Chavan *et al.* (1997), on a typic Haplustert at Parbhani. There was significant increase in yield and ascorbic acid content of chilli fruits, when N was applied through FYM and urea compared to fertilizers applied alone. The reason being, when FYM is added to the soil, complex nitrogenous compounds slowly break down and make steady N supply throughout growth period of crop leading to increased N uptake. Further, the various organic acids liberated during decomposition of FYM bring about solubilisation of native phosphates leading to increased availability and uptake besides improving the soil physical properties for better root penetration and increased uptake. Jat *et al.* (1998) studied the effect of phosphorus, sulphur and growth regulators on growth and yield of fenugreek. They stated that, sulphur uptake was highest at peak vegetative growth owing to its role in energy transformation and carbohydrate metabolism. Both sulphur and phosphorus uptake follow the same trend.

2.3.2 Micronutrients

Pillai (1967) studied the effect of certain micronutrient combinations on growth and yield of chillies under field conditions. They tried $CuSO_4$, $MnSO_4$ and $ZnSO_4$ in different doses through foliar and soil application on yield of chillies. Soil application is preferable to foliar spray in increasing the yield of chillies. Combination of all the three has raised the yield over control to an extent of at least five per cent. In a similar study, Khomchak *et al.* (1972) studied the effect of minor elements viz., boron and manganese on tomato yield and quality. It was found that, zinc increased fruit sugar, acidity and vitamin-C content, whereas boron increased ash and acidity.

The effect of micronutrients on the growth, yield and quality of mustard was studied by Mehrotra *et al.* (1977). Statistically significant increase in seed yields were obtained by fertilising mustard crop with micronutrients along with NPK. In general, foliar feeding of micronutrients appeared promising than soil dressing by about 14 per cent. Further, there was 3 to 14 per cent acceleration in oil content of mustard seeds by supplying micronutrients along with NPK. Thomas and Mathers (1979) reported that organic manures and soil available iron influenced the yield of sorghum significantly in iron deficient soil. They attributed this to formation of stable complexes by decomposition of manure with native iron and making it more stable and available crop growth. Similarly Parsa and Wallace (1979) reported that in iron deficient soils, organic solid wastes can be used as sources of iron for sorghum cultivation.

Sharma *et al.* (1980) studied the effect of micronutrients on herb, oil and menthol yield of Japanese Mint (*Mentha arvensis* L.). Application of micronutrient combinations increased the herb and oil yield of mint over control. Similarly Subrahmanyam *et al.* (1991) studied antagonistic effects of Zn-P interactions on the uptake of zinc by Japanese Mint. He stated that, low zinc uptake by the crop was due to high P availability.

Plants require wide range of nutrients for growth and development so as to express their maximum genetic potential. The results of the influence of zinc, copper, iron and manganese on flowering, fruits set and yield of tomato were reviewed by Mallick and Muthukrishnan (1980). Soil application of zinc and copper significantly increased the total and marketable yield of fruits. This is due to zinc induces pollen growth while copper leads to earlier truss formation and better retention of flowers, which eventually lead to increased fruit set and yields. Besides, there was improvement in fruit grades producing extra large and large sized fruits. The effect of iron was inhibitory compared to copper and zinc in both soil and foliar application, probably due to its immobilisation either by roots or by the leaves or by the plant tissues. Application of manganese increased the number of flowers and increased total as well as marketable yields, because Mn could be related to the accumulation of carbohydrates due to increased photosynthetic activity.

Prasad *et al.* (1984) reported that, poultry manure serves as source of zinc and iron and also as complexing agent in enhancing the yield in calcareous soils. Elabdeen and Metwally (1982) studied the effect of foliar spraying of micronutrients on quality of tomato and pepper. They stated that micronutrients enhance juice content in tomato and carbohydrate content in pepper.

Hegde and Dwivedi (1992) stated that, uptake of micronutrients is greatly influenced by the presence of macronutrients and organic matter. They stated that, in rice-wheat cropping system, higher amounts of organic matter enhance microbial activity in presence of added N and weak organic acids are released. These acids form stable complexes and reduce adsorption/fixation/precipitation reactions and make micronutrients more available. Similarly Krishnan and Christopher (1997) reported that, in black soils due to higher level of N and in presence of organic matter, there was enhanced activity of microorganisms which release organic acids. These acids solubilizer native micronutrient cations and form chelates, which are readily available to plant.

2.4 Rooting habit

Growth is a function of interrelated genetic and environmental factors. A well developed root system is essential for optimal plant growth and uptake of water. Early root growth assists in determining the potential for subsequent plant growth and for withstanding environmental stresses. Patterns of root growth and development are determined by both genetic and environmental factors (Weaver, 1926; Troughton and Whittington 1969; Zobel, 1986, Barley, 1970 and Russell, 1977). In long duration crops like cotton, chilli and tur, root system plays a vital role in the absorption of nutrients and makes the plant to survive for longer period during adverse climatic conditions. Although literature pertaining to study of root system in chilli is limited, studies undertaken by different authors to examine the root system of tomato and bell peppers are briefly reviewed here.

Widders and Lorenz (1979) studied root development in tomato as related to K nutrition in both determinant and semideterminant cultivars. According to them, the primary root parameter is root length, which determines the capacity of root system to absorb mineral nutrients. Plants having determinant type of growth habit have smaller root system than plants having indeterminant growth habit and they studied the partitioning of photosynthates between plant organs in both type of plants. Usually determinant plants have strong sinks and consequently monopolise photosynthates/absorbed nutrients at the expense of roots. In indeterminant type of plants, partitioning of assimilates and nutrients between fruits and developing roots is 50 per cent, resulting in continued root growth during fruiting. Mckea (1981) studied the physiology of rooting pattern in transplanting of vegetables. He stated that, transplanting of vegetables resulted in greater modification of tap root and subsequent development of lateral and basal roots. All these contribute to greater root weight and enhanced uptake of nutrients. But in drill sown crops there was slightly less modification of tap root and roots were more fibrous resulting in less root weight.

Sequence of root development in bell pepper (var. California wonder and Yolo wonder) seedlings was studied by Stoffella *et al.* (1988). They characterised three types of roots,(i) tap root of embryonic origin (ii) lateral roots originating from the pericycle in existing root system (iii) adventitious roots originating from non root tissue. Lateral and adventitious roots play role in the absorption of nutrients and moisture, whereas tap root anchors the plants. Similar study was carried out by Leskovar *et al.* (1989), on chilli root growth and its relation to shoot growth in response to applied nitrogen. They stated that, tap roots accounted for only seven per cent of total root mass, while basal and lateral roots accounted for 40 and 53 per cent of total root mass, respectively. Increased level of N application increases both leaf and root sink. Jackson and Bloom (1990) studied root distribution of field grown tomatoes in relation to nitrogen availability. The deep and extensive root system of tomato maintains prolific growth and explores an increasingly large soil volume thus saturating it's demand with soil derived-N.

Usha Rani (1996) studied root characters of different chilli genotypes and correlated these characters with fruit yield. She highlighted the importance of root weight

(RW) and root volume (RV) in influencing plant growth and fruit yield. In chilli, transplanted crop develops a distinct root system caused by the early modification of the tap root and subsequent development of lateral and basal roots. She found out a positive correlation ($r = 0.919^{**}$) between root weight and root volume.

2.5 Quality attributes of chilli fruits, their biosynthesis, determination etc

Chilli (*Capsicum annuum* L.) is a unique crop among all the spices, being the only source of capsaicin - an alkaloid which is a digestive stimulant, an important ingredient of daily diet and a cure for many rheumatic troubles (Anon., 1964). In addition to capsaicin, chilli is said to be a rich source of vitamin-C. In food and beverage industries, chilli has acquired great importance in the form of oleoresin which permits better distribution of colour and flavour in food as compared to chilli powder (Anon., 1968). Now-a-days, chillies have acquired great importance owing to their attractive red colour. Chillies with bright red colour command higher prices than those which are dull red or orange or yellow in colour and deep red fruits tend to retain their colour in storage longer than those which are of lighter shade (Hosmani, 1993).

India is the largest exporter of chillies and Indian chillies have major share in deciding the price in international market and they bring considerable amount of revenue to the country. The price of spices in the international market is based on the limits of quality parameters as prescribed by American Spice Trade Association (ASTA) and Essential Oil Association of America (EOA), (Natarajan *et al.*, 1968). Of late Indian chillies are not getting good price in the international market owing to their low quality and adulteration. So cultivation practices should be aimed at producing high yields of good quality. Research work carried out with special reference to the study of quality parameters of chillies are reviewed here under the following sub heads.

2.5.1 Physico-chemical properties and nutrient composition of fruits

Pankar and Magar (1978a) studied the physico-chemical characteristics along with nutrient composition of ten important commercial chilli varieties extensively cultivated in India. Accordingly, the average length and breadth of chilli fruits ranged from 2 cm to 17 cm and 0.5 to 2.0 cm,respectively. The length/breadth (L/B ratio) ranged from 1.10 to 30.00. They also studied the contribution of pericarp, seed and pedicel to total fruit weight for the selected varieties. Accordingly, pericarp seed and pedicel per cent ranged from 43.44 to 62.30. Among the chemical properties, crude fibre percentage was highest, which ranged from 31.00 to 35.00 and carbohydrates ranged from 18.95 to 23.38 per cent. They also gave ranges for protein (13.46 to 15.00), total ether extracts (14.80 to 18.02) and total ash content (5.32 to 6.33). Further, they studied the proximate mineral composition of fruits and their partitioning within fruit components (pericarp and seed). They stated that, fruits invariably contain highest potassium followed by phosphorous, silica, magnesium, calcium and sodium. The partitioning of these nutrients within fruit components revealed that, irrespective of cultivar, K and Ca get partitioned more in pericarp than in seed, whereas other nutrients get partitioned more in seed than in pericarp. They attributed this differential partitioning of nutrients to genetic nature of crop and their specific role in influencing the quality and chemical constitutents of fruits. Similar studies were conducted by Desai and Patil (1984) for few chilli varieties cultivated in Maharashtra.

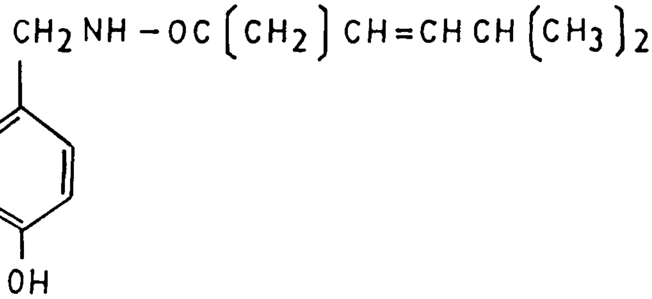
Farrell (1990) elucidated the nutrient composition of chillies and stated that, K concentration was highest, followed by that of nitrogen, phosphorus, calcium, magnesium, iron, manganese, zinc and copper. He further reported that, varietal differences, fertilizers, soil and climatic conditions alter the composition of fruits.

The partitioning of nutrients within fruit components was also studied by Marcelle (1995), who stated that in apple fruit, calcium gets partitioned more in the skin of fruit than in pulp. This might be due to its specific role in protecting the quality of fruit by photo degradation.

2.5.2 Pungency in chillies

Capsaicin

The pungent principle of capsicum is capsaicin ($C_{18}H_{27}NO_3$), an alkaloid. It is a condensation product of 3-hydroxy-4-methoxy benzylamine and decylenic acid. Nelson (1920) elucidated the structure of capsaicin and is furnished below.



The structural investigation of capsaicin has shown that, the acid amide bond in the side chain considerably enhances the pungency (Ananthakrishna and Govindarajan, 1975). On heating capsaicin, a high irritating vapour is produced and retains pungency in a dilution of one to million parts of water. In commercial samples, the concentration of capsaicin is about 0.1 per cent. Pure capsaicin is a crystalline colourless solid and if inhaled without dilution, severe irritation persists in the human body for many days. Capsaicin stimulates the flow of saliva when it comes in contact with sensory organs of mouth. It also increases the amylase activity and digestion of carbohydrates and stimulates gastric secretion. Capsaicin enhances the volume of blood pumped in each heart beat by 15 per cent. Ananthasamy *et al.* (1960) studied capsaicin content in few Indian varieties and stated that, varieties vary widely in their capsaicin content.

Kamalam and Rajamani (1965), studied capsaicin content in different varieties and it's correlation with colour of fruits, seeds and plant height. Fruit colour and seeds do not appear to furnish any clue on capsaicin but shorter varieties have high capsaicin content than taller varieties.

Bennett and Kirby (1968) and Hoffman *et al.* (1983) suggested that, the pungent principle is a mixture of at least five closely related vanillyl amides, named as capsainoids. Kosuge and Furuta (1970) gave the approximate contribution of these capsaicinoids to pungency. Accordingly 50 per cent of pungency in chillies was due to capsaicin alone, followed by dihydrocapsaicin (36.0%), nordihydrocapsaicin (7.4%), homodihydrocapsaicin (2.0%) and homocapsaicin (2.0%). There are two more analogues of capsaicin viz., monoyl vanillylamide (1.0%) and decoyl vanillylamide (1.5%) which also contribute to pungency, but are negligible.

Sooch *et al.* (1977) evaluated some chilli genotypes for their capsaicin content. Capsaicin content ranged from 0.23 mg to 0.49 mg. per 100 mg. of dry fruit. They also found that, capsaicin content was higher in small fruits with thin pericarp compared to fruits which are having thick pericarp.

Sankarikutty *et al.* (1978) standardised the procedure for determination of pungency from whole chillies. Results of their experiment revealed that, acetone and ethanol extracted 95 per cent of capsaicin present in whole chillies and optimum time for extraction was three hours. Acetone was choosen as the most appropriate solvent, because of it's low boiling point and capsaicin content in the whole chillies ranged from 0.12 to 0.42 per cent.

Pankar and Magar (1978b) evaluated ten commercially important varieties of chilli for their capsaicin content using multi-band thin layer chromatography and modifieds Gibb's reagent (2, 6-dichloro-p-benzoquinone-4-chorimne). Further, whole chillies were separated into pericarp and seeds and the distribution of capsaicin in these fruit components was studied. Results indicated that, capsaicin content in whole chillies ranged from 0.053 to 0.912 per cent, 0.092 to 1.53 per cent in pericarp and 0.012 to 0.098 per cent in seeds. It was noticed that, 90 to 95 per cent of pungency is located in pericarp alone and the capsaicin determined in seeds might be due to the small portion of inside placenta which might have contaminated the seeds (Tandon *et al.*, 1964). Guntur-3 variety from Andhra Pradesh has the highest content of capsaicin (0.33%) closely followed by Bor from Tamil Nadu (0.31%). Byadgi variety of Karnataka has lowest capsaicin (0.053%).

Capsaicin content in fruits is expressed in terms of Scoville Heat Units (SHU) (Scoville, 1912). They were calculated as per the relationship established by Suzuki *et al.* (1957) as one per cent of pure capsaicin has a scoville heat value of 15,000,000 units. Pankar and Magar (1978b) calculated the scoville heat values for these varieties and found that most of the varieties fulfill the Indian Standard Institute Specification (Anon., 1963).

Capsaicin content and it's correlation with different plant characters were studied by Balasubramanian *et al.* (1982) for as many as 53 genotypes. Capsaicin content of the cultivars ranged from 0.09 to 0.59 per cent. Among the different plant characters studied, size of the leaves was found to have a significant positive correlation with capsaicin content of the fruits. This was further supported by the observations made by Bennett and Kirby (1968), Lette and Louden (1968) and Suzuki *et al.* (1981) that, capsaicin gets synthesised from photosynthates like phenylalanine, valine and leucine produced in the leaf. Number of fruits and weight of fruits also have positive correlation with capsaicin. They further studied the relationship between the shape and colour of fruit with capsaicin content. It was found that, globular varieties had slightly lower capsaicin (0.23%) than cylindrical variety (0.29%) which again is lower than the thin and pointed varieties (0.37%). In general, bright red coloured fruits with thin pericarp and pointed shape have higher capsaicin content than thick pericarped and blunt shaped fruits.

Capsaicin production in sweet bell peppers was studied by Rowland *et al.* (1983) using scanning electron microscopy technique. They identified specialised gland cells on the cross walls of pungent peppers and are modified epidermal cells. These glands secrete capsaicin of organoleptic pungency. Capsaicin gets synthesied in these specialised group of cells.

Maurya *et al.* (1984) studied the capsaicin content of few varieties of Indian chillies at green and red stages. They found that, capsaicin content increased from green to red stage and similar study was carried out by Teotia and Raina (1987) and Rajput *et al.* (1991) for varieties cultivated in Haryana and Maharashtra states, respectively.

2.5.3 Pigment in chillies

Chillies occur in different shades of colour ranging from yellow to blood red. Colour of chilli is due to the presence of carotenoid pigments. Pigment content of chilli is 0.2 to 0.5 per cent. The principal colouring matter is carotenoid pigment capsanthin constituting about 35 per cent of the total pigment. Others present are ß-carotene, capsorubin, zeaxanthin, crytoxanthin and violaxanthin. Nearly 37 pigments have been isolated from capsicum (Sumathykutty and Mathew, 1984).

Carotenes are isoprenoid polyenes formed by the joining of eight C_5 isoprene units (Gross, 1991). These isoprene units are linked in a regular head to tail manner except in the centre of molecule, where the order is inverted tail to tail so that, the molecule is symmetrical. Carotenes are divided into two groups (i) carotenes that are hydrocarbons ($C_{40}H_{56}$) and (ii) their oxygenated derivatives (xanthophylls).

Carotenoids are lipids, soluble in organic solvents such as acetone, alcohol, ether and chloroform. Carotenes can be crystallised into various forms, coloured from orange-red to dark violet, carotenoids can absorb light in the ultraviolet (UV) and visible region of the spectrum. The structural feature responsible for light absorption is chromophore, a system of conjugated double bonds in carotenoids. Because of these conjugated double bonds in the molecule, carotenoids are easily destroyed by oxidative degradation. Chemical oxidation, autoxidation and photooxidation of carotenoids lead to bleaching of colour. Chilli fruits stored for long time in controlled atmosphere loose colour mainly because of autoxidation where oxygen of air at root temperature combines with some substances and attacks free radical chain. This process is stimulated by temperature, light, humidity and some metals.

Chilli fruits dried in sunshine in the open yards are subjected to bleaching or decoloration because of photo oxidation. Carotenoid biosynthesis in higher plants involves six stages (i) formation of mevalonic acid (ii) formation of geranyl geranyl pyrophosphate (iii) formation of phytoene (iv) desaturation of phytoene (v) cyclization and (vi) formation of xanthophylls.

Carotenes serve as accessory pigments in photosynthesis and absorb light at different wave lengths and transfer the absorbed light to chlorophylls. They act as protective agents of photosynthetic apparatus against potential damage from UV rays. In human nutrition, carotenoids act as precursors of vitamin-A.

In carotenogenic fruits that synthesize large amounts of carotenoids during ripening, such as tomato and chillies, chloroplasts change into chromoplasts.

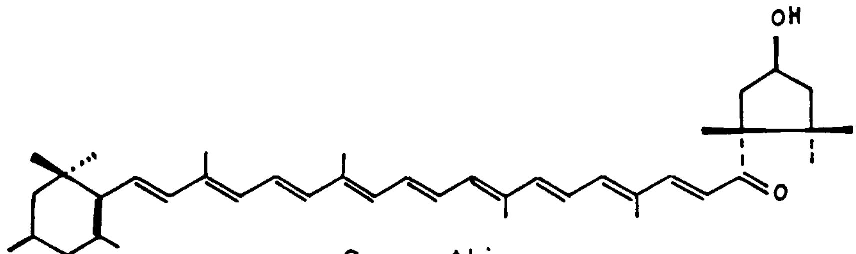
The important carotenoids found in chillies are (i) capsanthin (ii) capsorubin (iii) cryptocapsin (iv) capsanthin 5,6-epoxide (v) capsanthin 3,6-epoxide and (vi) Tetrol.

Among these, capsanthin is the most abundant one closely followed by capsorubin and cryptocapsin. Structural formula of these are furnished in Fig. 1.

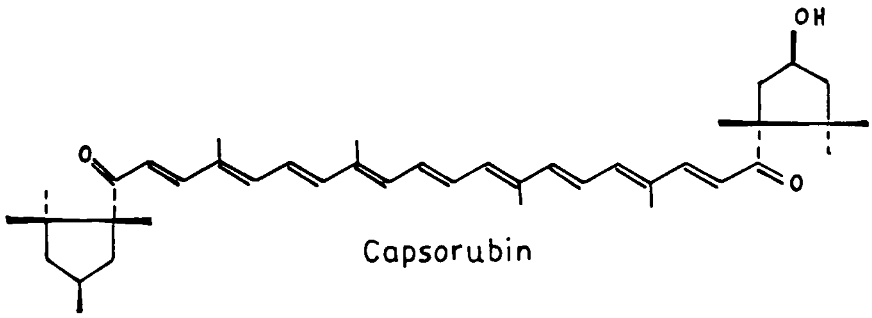
Owing to the importance of these carotenoids, several workers have studied the nature and chemistry of carotenoids occurring in chillies and being reviewed here.

Natarajan *et al.* (1968) stated that, pigments found in chillies are mostly in ester forms and only a small percentage of these carotenoids are in non-esterified forms. Further, they extracted these pigments with different organic solvents and found that ether and acetone extracted nearly 65 to 70 per cent of colouring matter whereas alcohol extracted only 20 per cent.

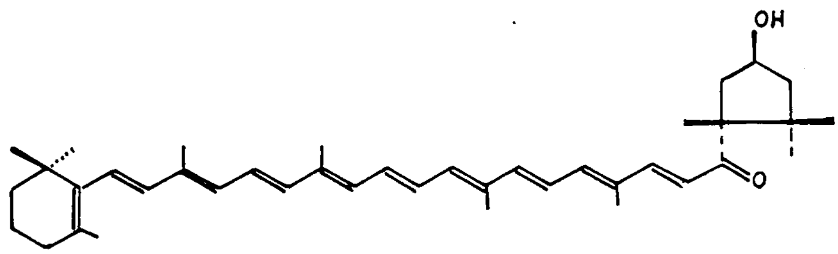
Kanner *et al.* (1977) reported that, moisture level and ripening stage of fruit considerably affected the deterioration rate of colour in stored chilli powder. Initial colour intensity was highest in powder produced from dry chilli fruits left to dry on the plant itself (270 ASTA Units). Whereas, in succulent red fruits having 80 to 85 per cent moisture, the colour intensity was only 160 ASTA units and in half dry fruits, it was 265 ASTA units. They clarified that, certain amount of moisture (about 14%) in powder is necessary for the stability of colour and this is related to the differences in the composition and contents of the lipids in fruits harvested at different stages of maturity. When the fruit is allowed to dry in the plant itself, there is increase in the lipid level in the fruit viz., linoleic acid, which is a stable unsaturated fatty acid at certain degree of moisture. Similarly Rahman *et al.* (1978) reported that, in all the chilli cultivars they studied, total pigment contents increased by several fold as the fruit advanced from immature to fully ripened stage. Similarly, the quantitative distribution of chlorophylls



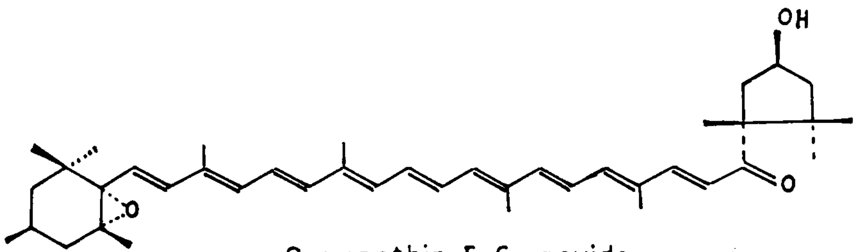
Capsanthin



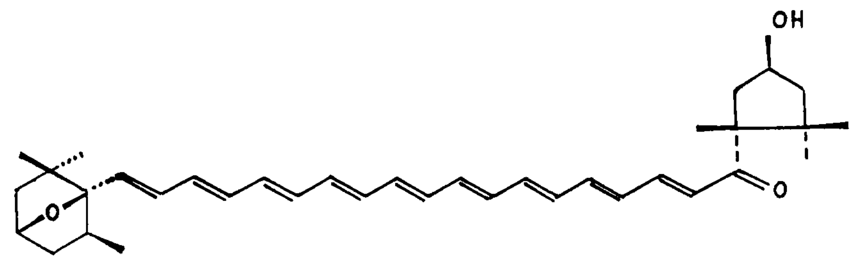
Capsorubin



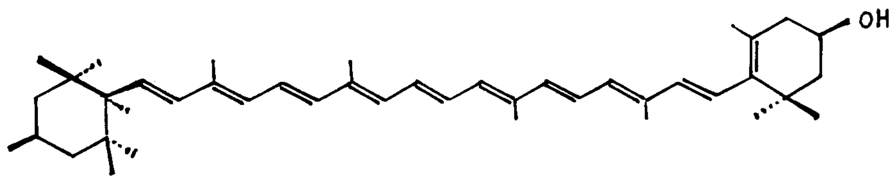
Cryptocapsin



Capsanthin 5,6-epoxide



Capsanthin 3,6-epoxide



Shamoutixanthin

Fig. 1 : Structural formulae for pigments of chilli fruits.

and carotenoids at four stages of maturation and ripening was also established using chromatographic, spectroscopic and chemical methods. (Rahman and Buckle, 1980). It was found that, at the immature stage of green fruits, chlorophylls a and b are major pigments, at the half ripened stage, chlorophylls a and b decreased significantly. At the mature green stage, lutein appears in high concentration followed by decreasing concentration of ß-carotene, violaxanthin, neoxanthin and zeaxanthin. At the fully ripened stage, lutein disappears and appearance of antheraxanthin and crytoxanthin occurs and significant increase in the levels of zeaxanthin and violaxnthin lead to red pigments viz., capsanthin and capsorubin.

Pankar and Magar (1978b) evaluated ten commercial chilli varieties for their total colouring matter and found that, in whole chillies it ranges from 117.7 to 537.7 mg. per 100 g and 269.8 and 924.4 mg. per100 g in pericarp alone. Byadgi variety of Karnataka has highest colouring matter and can be employed for extracting coloured oleoresin. Narayanan *et al.* (1980) also studied colour value of different chilli samples obtained from market. Similarly Teotia and Raina (1987) also evaluated capsicums grown in Haryana for their extractable colour and it ranges from 0.22 to 0.56 per cent for whole chillies. Cazi (1961) stated that, application of potash makes chilli fruits to give attractive red colour, glossiness and lustre.

Martinez-Sanchez *et al.* (1990) established the relationship between micronutrients composition in several portions of chilli plants to red colour of fruits. It was found that, only iron concentration in stem and leaves is significantly correlated with fruit red colour. It was concluded that iron has an important role in carotenoid synthesis in red pepper crops. Manganese and zinc have no relation with red colour of fruits.

Sweet pepper fruits are often affected with colour spots on the surface of the fruit. The spots may occupy a large area of the fruit surface and yellowish or white in colour, thereby reducing the value of the fruits. Aloni *et al.* (1994) stated that, colour spot incidence increases with increasing nitrogen application and it is more pronounced in densely planted peppers due to shading effect. The probable reason for this disorder in shaded and high nitrogen supplied plants is due to imbalance between the nitrogen and carbon assimilates accumulated in fruits. They further analysed the colour spot affected pericarp for nutrient content and found that, calcium concentration was higher in this portion than the unaffected tissue. Increasing N supply to plant leads to synthesis of high levels of oxalic acid in fruit tissues. High calcium concentration in fruits chelates with oxalic acid and forms calcium oxalate which affects normal cellular function resulting in cell rupture. Usually shading of plants reduces N accumulation in fruits because of lower synthesis of sugars and their transportation to fruits. This leads to imbalance between nitrogen and carbon assimilates in fruits, leading to golden coloured spots on pericarp.

Spices Board has given the specifications for grading chillies based on pungency and total extractable colour. Accordingly chillies are classified as first grade, if their colour units are greater than 200 ASTA units and capsaicin per cent between 1.00 to 1.50, second grade, if colour units are between 100 to 200 ASTA units and capsaicin between 0.25 to 0.75 per cent and third grade if ASTA units are below 100 with capsaicin per cent between 0.11 to 0.25. But for paprikas, these values of colour units are still higher.

2.5.4 Ascorbic acid

Chillies are rich source of ascorbic acid. Ripe chillies are known to have higher vitamin-C content than tomatoes. Chillies tend to accumulate higher ascorbic acid when fruits turn towards maturity. Ascorbic acid content in chilli fruits ranges from 100 to 320 mg per 100 gm. of fruits.

Sooch *et al.* (1977) reported ascorbic acid content in few genotypes and it ranges from 21.69 to 117.31 mg. per 100 g of fresh fruit. With the advance of fruit maturation and ripening, ascorbic acid concentration increases and was highest in the fully ripened stage (Rahman *et al.*, 1978 ; Shukla and Pandey, 1967). Similarly, Saimbhi *et al.* (1972), Bajaj *et al.* (1977) and Awasthi and Singh (1979) reported higher ascorbic acid in turning red stage than present in Green fruit. Chillies usually contain 5 to 10 times more ascorbic acid than fresh tomatoes which usually contain 12 to 19 mg. per 100 gm of fruit (Rahman, 1970). Pankar and Magar (1978b) also studied ascorbic acid content in matured red chillies and it varied from 37.9 mg. per cent of 86.5 mg. per cent in different varieties. Maurya *et al.* (1984) while studying vitamin-C content in different chilli varieties at different stages of maturity inferred that, it decreases slightly when fruits passed from green to red stage, contrary to the observations made by earlier workers.

2.5.5 Oleoresin

It is the extract or essential volatile oil derived from spice. It is viscous semi solid gel like substance free from bacteria, spores and molds. It contains all the important quality characters present in chillies. In nut shell, oleoresin is the sum and substance of chillies. Freshly prepared oleoresin has deep blood red colour and has it's own flavour. Oleoresin permits uniform distribution of colour and flavour to the food. The yield of oleoresin from different chilli varieties ranges from 8 to 17.5 per cent and it can be stored for long time without any change in its composition unlike whole chillies. Oleoresin contains essential oils and non volatile resins, which are very important for its flavour. Govindarajan and Ananthakrishna (1970) made observations on the separation of oleoresin from capsicums including capsaicin. They highlighted the importance of utilising different organic solvents for oleoresin extraction and concluded that, ethylene dichloride in the best solvent to get high oleoresin recovery from fruits.

Narayanan *et al.* (1980) reported that, three types of oleoresins can be prepared from chillies. They are (i) oleoresin red pepper, which has medium pungency and high colour and most of the Indian chilli varieties yield this type of oleoresin. (ii) Oleoresin capsicum, which has high pungency and low colour having pharmaceutical application. (iii) Oleoresin paprika, which has low pungency and very high colour. This one is highly preferred in food industry, because slight pungency in oleoresin alters the taste of food material and high colour component gives attractive and uniform distribution of colour to the food material.

They further stated that, since pericarp contains 90 per cent of pungency and 99 per cent of colour, only pericarp portion can be used for extraction of pungency oleoresin insted of whole chillies. Colour fraction from this pericarp oleoresin can be separated by column chromatography using solvents like petroleum ether, hexane, ethylene dichloride. The capsaicin content of pericarp oleoresin varies from 4.5 to 5.5 per cent, whereas in chilli oleoresin it ranges from only 2.5 to 3.0 per cent.

Similarly Tandon *et al.* (1964) stated, that it is better to separate seeds from fruits before oleoresin extraction, because chilli seeds are rich in fatty oil (25.7%), which is unsaturated and affects the quality of oleoresin. He also advocated the use of pericarp alone for oleoresin extraction because of its high concentration of colour and pungency.

It is found that 100 kg of dry chillies can be converted to 5 kg of oleoresin. Byadgi chilli extensively cultivated in Dharwad district yields good quantity and quality oleoresin having high colour and low pungency. Because of this, it has export value and extensively used in food industry for colouring food stuffs.

MATERIAL AND METHODS

III. MATERIAL AND METHODS

The materials used and methods followed during the course of investigation are described in this chapter.

3.1 Criteria for the location of study sites

Chilli is being grown extensively as rainfed crop in different taluks of Dharwad. Haveri and Gadag districts. The main centre for grading and marketing this dry chilli is located at Byadgi town in Haveri district. Detailed survey was conducted by interviewing number of farmers from each taluk for knowing the yield levels and quality of chilli obtained from their fields. Further, detail discussions were also held with few chilli traders in Byadgi market to know which quality parameters of chilli fruits are used for grading and fixing the price of the produce. Accordingly, colour of the fruits, their lusture, glossiness and and resistance to breakage are found to be the main criteria for fixing the grade and price of chilli produce. Chilli fruits are classified mainly into three grades based on visual observations as furnished below.

Fruit grade	Visual observation
I grade	Blood red colour, bright, shining, wrinkled. This fetches highest price
II grade	Light red colour, less wrinkled, soft, etc. (medium price)
III grade	Orange, golden yellow, white patches on fruits, dull, no shining etc. These fetch lowest price.

Information was collected from the Department of Agriculture to know the extent of area under chilli cultivation in each taluk for the last ten years. Based on the extent of area in a particular taluk, quality and yield of fruits obtained by different farmers, traversing of these districts was carried out to know the different soil types associated with chilli cultivation.

Based on the information obtained from the farmers with regard to yield and different grades of fruits produced from their fields and also the extent of area under chilli cultivation in that taluka for the past ten years, profile sites were selected representing major soil type of that taluk. Byadgi chilli is being grown every year during kharif season in such soils.

3.1.1 Profile locations

Soil profiles were selected from the farmers fields of Dharwad district where Byadgi chillies (Byadgi kaddi, Dyavnur and Byadgi dabbi cultivars) were grown under rainfed conditions during 1996-97 and 1997-98. The details of profile locations along with name of the farmer, soil type and chilli cultivars grown are given in Table 1.

Table 1 indicates that, the fifteen profiles selected for the study represent eleven taluks of study area, where chilli is being grown extensively during kharif season. These eleven taluks include major soil types like medium black, black, deep black, mixed red and black and red soils. Out of the 11 taluks selected for the study, only two taluks viz., Navalgund and Gadag are under zone-3 and the remaining nine taluks are under zone-8 of Dharwad and Haveri district.

The detailed description of the soil pedons are given in Appendix-1 and locations are shown in Fig. 2. Geographically the study area lies between the longitudes 75°5'E and 75°20'E and latitudes 14°N to 15°N.

Table 1: Location of study sites with name of the farmer, soil type and chilli cultivar grown

Location/ ProfileNo	Name of the farmer	Village	Taluka (Dist.)	Survey No.	Soil type	Chilli cultivar
I	Shivanna Dyapai	GUDGERI	Kundagol (Dharwad)	1/12	Deep Black	Byadgi kaddi, Dyavnur and Byadgi dabbi
II	Gangappa Battur	DEVANUR	Kundagol (Dharwad)	-	Deep black	Byadgi kaddi, Dyavnur and Byadgi dabbi
III	Nagaraj Chinnappanavar	GUNJIGATTI	Shiggaon (Haveri)	18/4	Medium black	Byadgi kaddi and Dyavnur
IV	Shembanna Hubballi	DEVAGIRI	Haveri (Haveri)	-	Medium black	Byadgi kaddi
V	Y.B. Yadagodi	SOMANAHALLI	Hirekerur (Haveri)	23/3	Medium black	Byadgi kaddi
VI	Main research Station	MRS DHARWAD	Dharwad (Dharwad)	D-96	Medium black	Byadgi kaddi and Dyavnur
VII	R. C. Patil	SAVANUR	Savanur (Haveri)	106/1	Mixed red and black	Byadgi kaddi
VIII	Laxman Hullatti	KALAGOND	Hirekerur (Haveri)	53	Red	Byadgi kaddi
IX	P.H. Tevari	THIMMENHALLI	Byadgi (Haveri)	22/3	Red	Byadgi kaddi
X	Puttappa B. Neglur	ASUNDI	Ranebennur (Haveri)	248	Red	Byadgi kaddi
XI	H.T. Kademani	ANNIGERI	Navalgund (Dharwad)	-	Medium black	Dyavnur
XII	N.R. Hiregoudar	YALIWAL	Kundagol (Dharwad)	224/3	Medium black	Byadgi dabbi
XIII	G.T. Inamadar	MALLIGAWAD	Hubli (Dharwad)	-	Medium black	Byadgi dabbi
XIV	B.S.Patil	SAIDAPUR	Navalgund (Dharwad)	-	Medium black	Byadgi dabbi
XV	T.K. Gadareddy	KURTKOTI	Gadag (Gadag)	-	Medium black	Byadgi dabbi

LOCATIONS.

1. GUDGERI.
2. DEVANUR
3. GANJIGATTI.
4. DEVAGIRI.
5. SOMANHALLI.
6. DHARWAD.
7. SAVANUR.
8. KALAGOND.
9. THIMMENHALLI.
10. ASUNDI.
11. ANNIGERI.
12. YALIWAL.
13. MALLIGAWAD.
14. SAIDAPUR.
15. KURTKOTI.

I GRADE LOCATIONS 1 & 2

II GRADE LOCATIONS 3,4,5,6,11,12,13,14, & 15

III GRADE LOCATIONS 7,8,9, & 10

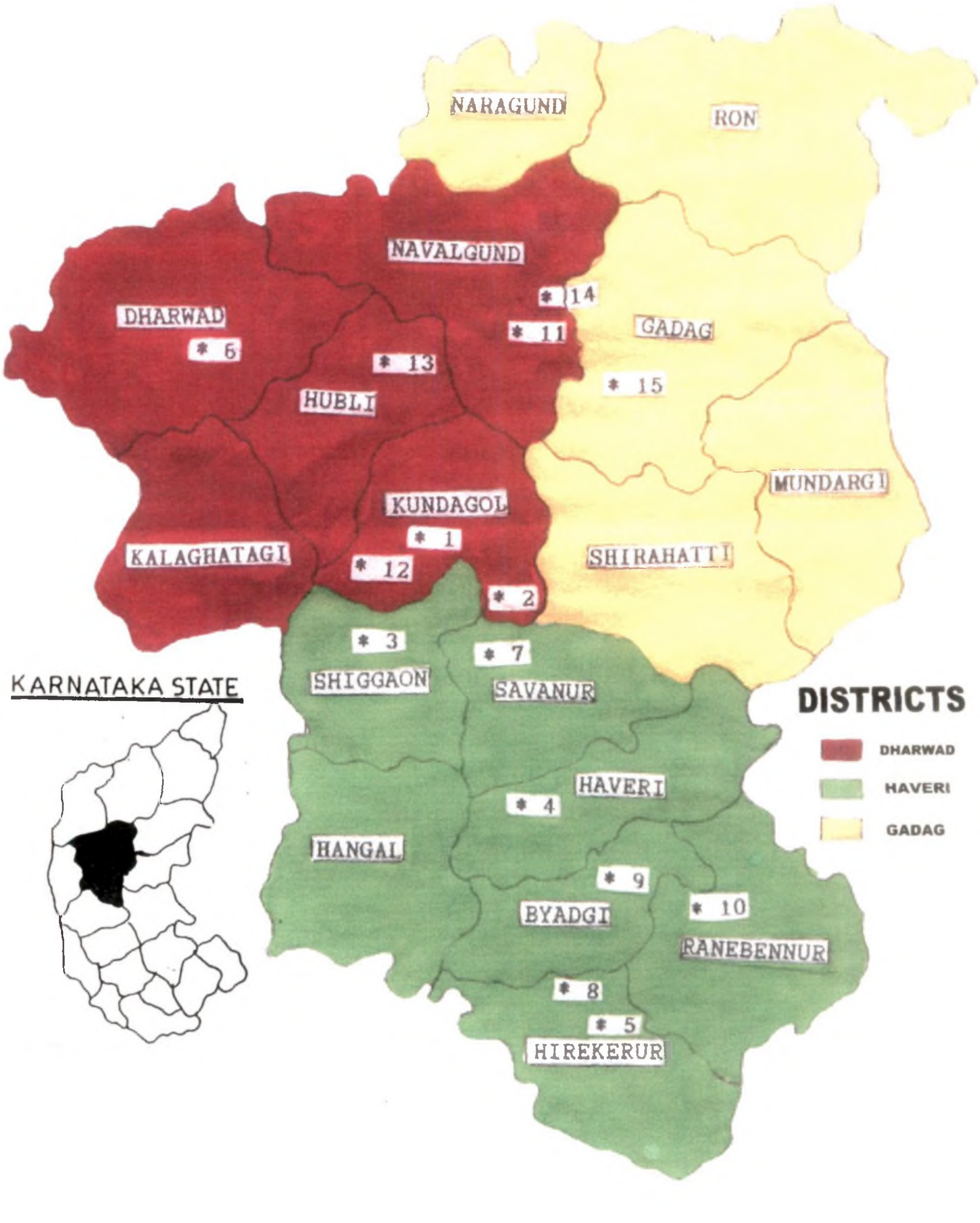


Fig. 2 MAP OF DHARWAD, HAVERI AND GADAG DISTRICTS SHOWING LOCATIONS OF SOIL PROFILES AND STUDY SITES

3.1.2 Climate

The nine taluks of zone-8 in Dharwad and Haveri districts have maximum temperature ranging from 35°C to 39°C, which occurs during April and minimum temperature ranges from 12°C to 15°C which occurs during December. The total rainfall of the region ranges from 619 to 1303 mm with an average of 750 to 800 mm. Most of the rainfall (about 84%) is received through south west monsoon from June to October and July is the peak rainfall month.

The climate of remaining two taluks viz., Navalgund and Gadag is slightly different with maximum temperature ranging from 37°C to 41°C which occurs during April/May and minimum temperature ranges from 15°C to 24°C which occurs during December-January. The total rainfall in these two taluks ranges from 435 mm to 785 mm with an average of 600 mm.

Monthly rainfall recorded in different taluks of Dharwad, Haveri and Gadag districts along with number of rainy days during the two years of experimentation (1996 and 1997) are presented in Table 2. Based on the rainfall pattern, it can be concluded that, the average rainfall of the study area ranges from 400 mm to 1050 mm with rainy days ranging from 35 to 67. Further sixty per cent of the total rainfall received during July to October.

3.2 Soil sample collection

The soils used in this study were collected from 15 profiles spread over eleven taluks in Dharwad, Haveri and Gadag districts belonging to zone-8 and zone-3 of the agroclimatic zones of Karnataka state. Soil samples were collected depthwise (0-15, 15-

Table 2: Monthly rainfall data recorded at taluka headquarters (HQ) representative of study locations during 1996 and 1997.

TALUKA	MONTHS												Total rainfall (mm)	No.of Rainy days
	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC		
KUNDAGOL	-	-	-	25.2	74.6	102.2	69.3	69.3	135.9	140.5	55.3	2.6	674.9	46
	-	**-**	**24.1**	**47.9**	**42.9**	**201.4**	**81.8**	**91.4**	**8.5**	**224.1**	**20.9**	**17.0**	**760.0**	**51**
SHIGGAON	-	-	-	24.3	56.1	90.0	119.9	72.0	81.9	153.8	6.2	12.0	616.2	54
	10.4	**-**	**14.4**	**23.3**	**38.4**	**07.0**	**145.6**	**183.6**	**13.7**	**221.4**	**64.2**	**31.4**	**953.4**	**67**
HAVERI	-	-	-	47.2	51.8	135.7	117.9	108.2	125.7	159.8	5.0	29.6	780.9	59
	0.2	**-**	**38.4**	**12.6**	**58.2**	**154.2**	**138.8**	**170.2**	**21.8**	**147.6**	**98.6**	**31.2**	**871.8**	**60**
SAVANUR	-	-	-	16.0	62.2	107.2	136.4	75.3	218.8	115.7	17.5	8.0	747.1	55
	10.4	**-**	**14.4**	**23.3**	**38.4**	**207.0**	**145.6**	**183.6**	**13.7**	**221.4**	**64.2**	**31.4**	**953.4**	**60**
HIREKERUR	-	-	-	26.0	7.6	126.0	123.2	215.8	230.2	127.6	19.8	21.4	897.6	57
	-	**-**	**46.2**	**5.8**	**25.8**	**21.8**	**203.0**	**273.0**	**12.6**	**95.4**	**117.6**	**44.6**	**1045.8**	**68**
BYADGI	-	-	-	30.4	19.0	114.5	159.2	85.8	112.0	85.8	-	8.8	615.5	47
	2.2	**-**	**10.0**	**43.0**	**80.8**	**141.4**	**142.4**	**191.1**	**1.7**	**130.2**	**75.4**	**19.0**	**837.2**	**65**
RANEBENNUR	-	-	-	8.2	16.2	68.5	60.0	36.2	52.1	41.3	-	-	282.5	35
	2.2	**-**	**5.6**	**20.6**	**18.6**	**63.5**	**49.2**	**86.8**	**12.6**	**147.8**	**49.4**	**6.0**	**462.3**	**55**
DHARWAD	-	-	5.0	13.2	65.6	130.1	95.3	70.9	134.5	166.4	-	2.0	683.0	60
	-	**-**	**52.9**	**93.0**	**34.0**	**104.0**	**100.0**	**202.3**	**6.5**	**99.2**	**36.4**	**20.8**	**749.1**	**59**
HUBLI	-	-	-	4.0	46.9	139.0	76.5	60.2	87.7	79.5	0.5	3.5	497.8	48
	-	**-**	**31.5**	**55.6**	**14.4**	**170.8**	**99.1**	**122.9**	**12.8**	**71.2**	**31.0**	**27.0**	**483.3**	**58**
NAVALGUND	-	-	-	22.9	58.5	175.1	88.0	99.1	606.3	129.3	8.8	7.3	1195.3	49
	-	**-**	**32.8**	**11.6**	**11.5**	**76.5**	**55.5**	**63.2**	**30.7**	**129.0**	**52.2**	**11.6**	**474.6**	**49**
GADAG	-	-	7.0	29.2	114.7	177.5	107.3	76.0	189.2	172.4	-	7.0	880.3	49
	-	**-**	**39.1**	**19.3**	**44.4**	**66.9**	**22.8**	**40.0**	**109.8**	**65.0**	**113.6**	**13.0**	**533.9**	**45**

Note : Figures in bold letters indicate rainfall for the year 1997.

30, 30-60, 60-110 and >110 cm) from these profiles after recording the morphological features.

3.2.1 Preparation of the soil sample

The soil samples were dried under shade and ground with wooden pestle and mortar and passed through two mm sieve. The sieved samples were preserved in polythene bags for analysis. For the estimation of organic carbon, the soil was again ground in an agate mortar and passed through 0.5 mm sieve.

Physical and chemical estimates were done by adopting following procedure.

3.3 Physical properties

3.3.1 Particle size distribution

Particle size distribution was determined by hydrometer method as described by Piper (1966).

3.3.2 Bulk density

Bulk density of the soil samples was determined using a clod by mercury displacement method (Black, 1965).

3.3.3 Particle density

The particle density of the soil samples was determined by picnometer method (Black, 1965).

3.3.4 Per cent pore space

Per cent pore space in the samples was computed based on the values of bulk density and particle density using the formula

$$\left[1 - \frac{\text{Bulk density}}{\text{Particle density}}\right] \times 100$$

3.3.5 Water holding capacity

The maximum water holding capacity of soil samples was determined using Keen-Raczkowski box (Piper, 1966).

3.3.6 Moisture retention capacity at 33 kPa and at 1500 kPa

Moisture retention capacity of soils at 33 kPa and 1500 kPa was determined by using pressure plate apparatus (Richards, 1954).

3.4 Physico-chemical properties

3.4.1 Soil reaction (pH)

It was determined in 1:2 soil water suspension as described by Jackson (1967) using systronic pH meter.

3.4.2 Electrical conductivity

Electrical conductivity of the soil was determined in the supernatant solution of 1:2 soil to water suspension as described by Jackson (1967) using conductivity metre (systronic 304 model).

3.4.3 Organic carbon

Organic carbon was determined by Walkley and Black's wet oxidation method as described by Jackson (1967).

3.4.4 Cation exchange capacity (CEC)

The cation exchange capacity of the soil was determined by leaching the soil with neutral normal sodium acetate solution and the excess salts were removed by 60 per cent ethanol. The adsorbed sodium was replaced by neutral normal NH_4OAC and the concentration of sodium in the leachate was measured by flame photometer and CEC was calculated as described by Black (1965).

3.4.5 $CaCO_3$ equivalent

The alkaline earth carbonate (free $CaCO_3$) content of the soil was estimated by acid neutralisation as per the procedure outlined by Piper (1966).

3.4.6 Exchangeable cations

The exchangeable cations were determined in neutral normal NH_4OAC leachate as described by Black (1965).

a. Exchangeable sodium and potassium were determined using flame photometer (systronics).

b. In non-calcareous soils, calcium and magnesium were determined by versenate titration, where as in calcareous soils, exchangeable calcium + magnesium were computed by working out the difference between CEC and sum of exchangeable sodium and potassium.

3.4.7 Soluble cations and anions

Forty grams of soil was shaken with 80 ml. of distilled water for half an hour in a mechanical shaker and the extract collected was used to determine the soluble cations and anions as described in USDA, Hand book-60.

3.5 Nutrient status of soils

Since, chilli roots are concentrated in the first 60 cm depth, nutrient status was determined only for the first three depths of profiles viz., 0-15, 15-30 and 30-60 cm.

3.5.1 Available nitrogen

It was determined by alkaline permanganate method of Subbaiah and Asija (1956).

3.5.2 Available phosphorus

a. For neutral to alkaline soils : It was determined by Olsen's method as described by Jackson (1967) using spectrophotometer (Spectronic-20D) at 660 nm wave length.

b. For Acid soil : Bray's No.1 extractant (0.09 N NH_4F-0.025 N HCl) was used for extracting available phosphorus as described by Jackson (1967).

3.5.3 Available potassium

It was determined by extracting soil with neutral normal ammonium acetate as described by Black (1965) using flame photometer (Systronics).

3.5.4 Sulphate sulphur

It was determined by extracting five grams of soil with 50 ml. of 0.15 per cent $CaCl_2$ shaken for 30 minutes and filtered. Sulphate sulphur was determined as outlined by Black (1965) using spectrophotometer at 420 nm.

3.5.5 Available zinc, copper, iron and manganese

Available zinc, copper, iron and manganese were determined by following Lindsay and Norvell (1978) procedure using DTPA extractant. The concentration of Zn, Cu, Fe and Mn in the filterate was read in Atomic Absorption Spectrophotometer (AAS Hitachi Model).

3.6 Observations and plant sample collection from cultivators fields

Byadgi chilli cultivars (Byadgi kaddi, Dyavnur and Byadgi dabbi) were planted in the cultivators fields for two years (1996-97 and 1997-98). Chilli is an indeterminate plant, in which flowering and fruiting continues for 3 to 4 months after transplanting, the biometric observations like plant height, number of branches and dry matter yield were recorded at four stages viz., 45th, 75th, 105th and 140th day after transplanting (DAT). In drill sown locations, the observations were recorded on those days which coincide with the day after normal transplanting date of other locations. The details of locations, area planted, date of transplanting, dates of sampling, fertilizers applied etc. are furnished in Table 3, 3(a) and 3(b).

A total of twenty plants were selected randomly in each location and were tagged after 30 days of transplanting. Observations were made on these plants at different stages and five plants were uprooted at each observation for computing the dry matter yield and pattern of uptake of nutrients at different growth stages.

3.6.1 Growth/yield attributes

3.6.1.1 Plant height

The height of five plants (cm) at different growth stages was measured from the base of the plants to growing tip of the plants. The average of five plants was taken as plant height.

3.6.1.2 Number of branches per plant

Number of branches produced were recorded from the five plants tagged in each field and average was taken as the number of branches per plant.

Table 3 : Cultivation practices followed by farmers for Byadgi kaddi cultivar

Locations	Year	Date of transplanting (DAT)	Area planted (ha)	Soil type	Spacing (feet)	Plant population per hectare	Fertilizers applied	Fertilizers in terms of NPK/ha	Dates of plant sampling	Peak picking date	Yield qtls./ha
								N P K			
GUDGERI (I) (Kundagol)	96-97	31.7.96	1.00	Deep black	2.5 x 2.5	34,850	1 Tr. Load FYM 100 kg DAP – Based 50 kg Urea-Top dressed + 25 kg MOP	18 : 4 : 6 23 : 0 : 12 top dress	14.9.96 15.10.96 15.11.96 22.12.96	13.12.96	10.50
	97-98	3.8.97	1.00		2.5 x 2.5	34.850	1 Tr. Load FYM 75 kg DAP-Basal 100 kg MOP-Top dressed	16 : 23 - - 60 top dress	18.9.97 18.10.97 18.11.97 25.12.97	20.12.97	12.50
DEVANUR (II) (Kundagol)	96-97	23.7.96	0.50	Deep black	3 x 2.5	29.040	3 Cart load FYM 90 kg DAP 20 kg Urea-Top dressed +50 kg MOP	16 : 37 - 9 : - 30 top dress	7.9.96 7.10.96 7.11.96 15.12.96	9.12.96	12.00
	97-98	1.8.97	0.50		3 x 2.5	29,040	3 cart load FYM 90 kg DAP 20 kg Urea-Top dressed+ 50 kg MOP	16 : 21 - 9 : - 30 top dress-	15.9.97 15.10.97 15.11.97 22.12.97	18.12.97	13.20
GANJIGATTI (III) (Shiggaon)	96-97	21.7.96	0.40	Medium black	2 x 2	54,450	16:20:0:15-25 kg No FYM	9 12.5 : 0 : 9 kg S N P	7.9.96 8.10.96 8.11.96 15.12.96	1.12.96	5.00
	97-98	2.8.97	1.60		2 x 2	54,450	100 kg DAP, No FYM	11 : 30 : -	17.9.97 17.10.97 17.11.97 22.12.97	7.12.97	7.50
DEVAGIRI (IV) (Haveri)	96-97	28.7.96	2.40	Medium black	3 x 3	24,200	200 kg DAP No FYM	15 : 38 : 0	12.9.96 12.10.96 12.11.96 18.12.96	15.12.96	8.25
	97-98	11.7.97	4.80		3 x 3	24.200	600 kg DAP 100 kg MOP No. FYM	22.5 : 57.5 : 60	27.8.97 28.9.97 28.10.97 28.11.97	30.11.97	10.01
SOMANHALLI (V) (Hirekerur)	96-97	21.6.96	0.70	Medium black	2 x 2.5	43,560	16:20:0-50 kg D 50 kg – Urea top dressed 1 cart load FYM	11 : 14 : 0 33 kg N top dress	6.8.96 6.9.96 6.10.96 12.11.96	28.10.96	4.50
	97-98	22.7.97	1.60		2 x 2.5	43.560	16:20:0-100 kg 2 cart load FYM	10 : 12.5 : 0	7.9.97 7.10.97 7.11.97 13.12.97	5.1.98	6.00

Locations	Year	Date of transplanting (DAT)	Area planted (ha)	Soil type	Spacing (feet)	Plant population per hectare	Fertilizers applied	Fertilizers in terms of NPK/ha	Dates of plant sampling	Peak picking date	Yield qtls./ha
DHARWAD (VI)	96-97	3.8.96	1.60	Medium black	3 x 2	36,300	17:17:17-200 kg 10 kg-urea top dress No-FYM	21 : 21 : 21 22 29 kg N top dress	17.9.96 17.10.96 17.11.96 23.12.96	20.12.96	5.00
	97-98	7.7.97	1.60		3 x 2	36,300	20:20:0 – 200 kg 100 kg Urea-Top dressed No FYM	25 : 25 : 0 29 kg N top dress	22.8.97 22.9.97 22.10.97 28.11.97	22.11.97	6.75
SAVANUR(VII) (Savanur)	96-97	28.7.96	0.80	Mixed red and black	2.4 x 2	47,350	7 cart loads FYM 50 kg DAP	11.25 : 29 : 0	12.9.96 12.10.96 12.11.96 18.12.96	22.11.96	2.75
	97-98	31.7.97	1.20		24 x 2	47,350	8 Cart loads FYM 50 kg DAP 50 kg 20:20:0	16 : 28 : 0	15.9.97 15.10.97 15.11.97 21.12.97	30.11.97	4.00
KALAGOND (VIII) (Hirekerur)	96-97	13.7.96	0.40	Red soil	2 x 2	54,450	1 cart load FYM 50 kg DAP	22.5 : 57.5 : 0	28.8.96 28.9.96 28.10.96 28.11.96	23.11.96	2.30
	97-98	5.7.97	0.80		2 x 2	54,450	1 cart load 50 kg DAP 50 kg MOP	11 : 29 : 38	21.8.97 21.9.97 21.10.97 26.11.97	20.11.97	2.50
THIMMENHALLI (IX) (Byadgi)	96-97	28.7.96	0.40	Red soil	2 x 2.5	43,560	2 cart load FYM 16:20:0 – to kg	20 : 25 : 0	11.9.96 11.10.96 11.11.96 17.12.96	28.11.96	2.75
	97-98	17.7.97	0.40		2 x 2.5	43,560	50 kg DAP 25 kg urea top dressed No FYM	22.5 : 57.5 : 0 22.6 29 : - : - top dress	31.8.97 30.9.97 31.10.97 6.12.97	19.11.97	3.50
ASUNDI (X) (Ranebennur)	96-97	30.7.96	0.40	Red soil	2 x 2	54,450	1 cart load FYM 25 kg DAP	11 : 29 : 0	15.9.96 15.10.96 15.11.96 21.12.96	30.11.96	2.25
	97-98	18.7.97	0.40		2 x 2	54,450	1 Cart load FYM 25 kg DAP	11 : 29 : 0	2.9.97 2.10.97 2.11.97 8.12.97	16.11.97	2.00

Table 3(a) : Cultivation practices followed for Dyavnur cultivar chilli in different locations

Locations	Year	Date of transplanting (DAT)	Area planted (ha)	Soil type	Spacing (feet)	Plant population per hectare	Fertilizers applied	Fertilizers in terms of NPK/ha (N P K)	Dates of plant sampling	Peak picking date	Yield Qtls /ha
GUDGERI (I) (Kundagol)	96-97	31.7.96	1.00	Deep black	2.5 x 2.5	34,850	250 kg DAP 100 kg Urea 2 tractor FYM	45 115 - 45 - - top dressed	14.9.96 15.10.96 15.11.96 22.12.96	13.12.96	7.70
	97-98	3.8.97	1.00		2.5 x 2.5	34,850	2 tractor FYM 75 kg DAP 100 kg MOP-top dressed	13.5 34 - - - 60 top dress	18.9.97 18.10.97 18.11.97 25.12.97	20.12.97	9.75
DEVANUR (II) (Kundagol)	96-97	23.7.96	3.20	Deep black	3 x 2.5	29,040	3 tractor load Bonemeal + FYM 200 kg DAP+100 kg MOP	11 29 - - - 60 top dress	7.9.97 7.10.96 7.11.96 15.12.96	9.12.96	8.13
	97-98	1.8.97	3.20		3 x 2.5	29,040	8 Tractor load FYM 200 kg DAP 100 kg urea +100 kg MOP	11 29 - 14 - 60 top dress	15.9.97 15.10.97 15.11.97 22.12.97	18.12.97	10.00
GANJIGATTI (III) (Shiggaon)	96-97	21.7.96	1.60	Medium black	2 x 2	54,450	100 kg 16:20:0	10 12.5 -	7.9.96 8.10.96 8.11.96 15.112.96	1.12.96	4.20
	97-98	2.8.97	1.60		2 x 2	54,450	100 kg DAP 50 kg MOP	10 12.5 -	17.9.97 17.10.97 17.11.97 22.12.97	7.12.97	4.50
DHARWAD (VI)	96-97	2.8.96	1.60	Medium black	3 x 2	36,300	200 kg 15:15:15	11 29 19	16.9.96 16.10.96 16.11.96 22.12.96	20.12.96	4.25
	97-98	8.7.97	1.60		3 x 2	36,300	1300 kg DAP 500 kg urea – top dressed	19 19 19	23.8.97 23.9.97 23.10.97 29.11.97	23.11.97	5.50
ANNIGERI (XI) (Navalgund)	96-97	10.8.96	16.00	Medium black	2 x 3"	2,17,800$^{\alpha}$	1300 kg DAP 500 kg urea – top dressed	15 37 - 14 - - top dress	25.10.96 25.11.96 25.12.96 30.1.97	22.1.97	5.50
	97-98	28.7.97	4.80		2 x 3"	2,17,800$^{\alpha}$	400 kg 23:23:0 200 kg Urea	19 19 - 19 - - top dress	13.10.97 13.11.97 13.12.97 19.1.98	19.12.97	6.25

α - Drill sown crop.

Table 3(b) : Cultivation practices followed for Byadgi dabbi cultivar chilli in different locations.

Locations	Year	Date of transplanting (DAT)	Area planted (ha)	Soil type	Spacing (feet)	Plant population per hectare	Fertilizers applied	Fertilizers in terms of NPK/ha	Dates of plant sampling	Peak picking date	Yield Qt.s//ha
								N P K			
GUDGERI (I) (Kundagol)	96-97	31 7 96	0 80	Deep black	2 5 x 2 5	34,850	2 Tr load FYM 100 kg DAP 50 kg Urea+50 kg MOP	22 57 - 29 - -30 top dressed	14.9.96 15.10.96 15.11.96 22.12.96	28.12.96	8.50
	97-98	3 8 97	0 80		2 5 x 2 5	34,850	2 Tractor load FYM 100 kg DAP 50 kg urea+50 kg MOP	22 57 - 29 - - 30 top dressed	18.9.97 18.10.97 18.11.97 25.12.97	30.12.97	9.75
DEVANUR (II) (Kundagol)	96-97	27 7 96	2 40	Deep black	3 x 2 5	29,040	10 Tractor FYM 100 kg 20 20 0 200 kg Super phosphate 100 kg urea+100 kg MOP	8.5 8.5 - Basal - 13.0 - top dressed 19 - 60 top dressed	11.9.96 11.10.96 11.11.96 17.12.96	24.12.96	10.00
	97-98	1 8 97	2 40		3 x 2 5	29,040	10 tractor load FYM 150 kg 20 20 0 300 kg Super phosphate 300 kg urea+100 kg MOP	12.5 12.5 - - 20 - top dressed 57.5 - 60 top dressed	15.9.97 15.10.97 15.11.97 22.12.97	12.1.98	12.50
YALIWAL (XII) Kundagol	96-97	30 7 96	3 20	Medium black	2 3 x 2 3	40,110	400 kg 20 20 0 15	25 25 - 15 S	14.9.96 14.10.96 14.11.96 20.12.96	26.12.96	5.50
	97-98	17 8 97	3 20		2 3 x 2 3	40,110	200 kg DAP - Basal 100 kg DAP 100 kg urea top dressed	11 29 - 20 14 - top dressed	2.10.97 2.11.97 2.12.97 8.1.98	28.12.97	6.00
MALLIGAWAD (XIII) Hubli	96-97	10 7 96	2 80	Medium black	2.5 x 4"	1,32,000[α]	20 tractor load FYM 1050 kgs 20 20 0 350 kgs DAP	75 75 - 22.5 57 - top dressed	25.9.96 25.10.96 25.11.96 30.12.96	18.12.96	6.50
	97-98	21 7 97	3 20		2 5 x 4"	1,32,000[α]	20 Tractor load FYM 1200 kg 20 20 0 complex 400 kg DAP	75 75 - 22.5 57 - top dressed	6.10.97 6.11.97 6.12.97 12.1.98	30.12.97	7.25
SAIDAPUR (XIV) Navalgund	96-97	10 7 96	0 40	Medium black	3 x 3"	1,45,200[α]	50 kg DAP	22.5 57	25.9.96 25.10.96 25.11.96 30.12.96	30.12.96	4.60
	97-98	8 8 97	1 20		3 x 3"	1,45,200[α]	200 kg DAP	30 76	23.10.97 23.11.97 23.12.97 29.1.98	28.1.98	5.00
KURTKOTI (XV) Gadag	96-97	18 6 96	4 80	Medium black	2 x 3"	2,17,800[α]	50 kg DAP 75 kg Neem cake 75 kg 20 20 0	4 8 -	2.9.96 2.10.96 2.11.96 8.12.96	15.12.96	3.75
	97-98	30 6 97	4 80		2 x 3"	2,17,800[α]	100 kg DAP 2 tr load FYM 150 kg 20 20 0	10 15 -	15.9.97 15.10.97 15.11.97 20.12.97	27.12.97	4.70

α - Drill sown crop.

3.6.1.3 Total dry matter production

Out of twenty tagged plants, five plants were uprooted each time at four different stages and separated into shoots and roots. The shoot portion was air dried first and later dried in hot air oven to constant weight at 65-70°C and their dry weight was recorded. From this information, total dry matter produced per plant at each stage was worked out and expressed in grams per plant.

3.6.1.4 Root weight

At 75th day after transplanting, roots of five uprooted plants were washed in water and oven dried. Their oven dry weight was recorded and expressed in grams per plant.

3.6.1.5 Number of fruits per plant

Since chilli is an indeterminate plant, where flowering and fruiting continues for 3 to 4 months and fruits mature continuously and some fruits drop down due to physiological disorders, this observation was recorded at only 140th day after transplanting from tagged plants. Number of fruits were counted and average number of fruits per plant was worked out.

3.6.1.6 Weight of 100 chilli fruits

Red ripe fruits harvested at the peak of the harvest season, from cultivators field were air dried in sunshine for fifteen days till fruits attain brittleness. At this stage, 100 fruits were selected randomly and their weight was recorded.

3.6.1.7 Fruit weight per plant

The red ripe fruits harvested from the five tagged plants at 140th day after transplanting were sun dried thoroughly till they attain brittleness and weighed together. The fruit weight per plant was worked out and expressed in grams per plant.

3.6.1.8 Yield per hectare of dry chillies

Yield as obtained by farmers is recorded and expressed in quintals per hectare.

3.7 Chemical analysis of whole plant samples and fruits

3.7.1(a) Preparation of plant sample

The five plants sampled for estimating the dry matter production at different growth stages were ground in a willey mill to considerable fineness before storing them in polythene bags for further analysis.

3.7.1(b) Preparation of red fruit samples

Representative composite samples of red ripe fruits were collected at the peak of the harvest season from different locations. They were sundried till they attain brittless. About 20 to 25 whole red fruits were separated from pedicel and powdered in stainless steel mixer and stored in plastic container.

Further 10 red fruits were partitioned into pericarp and seeds. These separated components were powdered separately and used for nutrient analysis.

3.7.2 Digestion of plant and fruit samples

Powdered whole plant, whole fruits, pericarp and seeds were separately treated with concentrated HNO_3 for twelve hours for pre-digestion. Then the predigested samples were treated with diacid (HNO_3:$HClO_4$) mixture (10:4 ratio) and digested on sand bath at low temperature till colourless white precipitate is obtained. The residue is dissolved in 6N HCl, filtered, then the content was made to known volume by using double distilled water. This was used for further nutrient analysis.

The following analysis were carried out from the diacid digested samples of whole plant, whole fruits, pericarp and seeds.

3.7.2.1 Phosphorus

Phosphorus in samples was determined by Vanado molybdophosphoric yellow colour method (Jackson, 1967) by using spectrophotometer at 420 nm wave length.

3.7.2.2 Potassium

Potassium in the aliquot was estimated with the help of flame photometer after appropriate dilution (Jackson, 1967).

3.7.2.3 Sulphur

Sulphur content was determined turbidometrically using spectronic-20D at 420 nm (Blanchar *et al.*, 1965).

3.7.2.4 Calcium and Magnesium

Calcium and Magnesium in the aliquot were determined by using standard Versenate method, after precipitating the heavy metals with zirconium oxychloride as suggested by Derderian (1961).

3.7.2.5 Copper, Zinc, Iron and Manganese

Cu, Zn, Fe and Mn were estimated in the aliquot of plant extract using Atomic Absorption Spectrophotometer (Perkin-Elmer model).

3.7.2.6 Nitrogen estimation in plant/fruit samples

For the estimation of nitrogen in plant/fruit samples, 500 milligrams of powdered, samples were digested with concentrated sulphuric acid in presence of digestion mixture

($CuSO_4$ + K_2SO_4 + Selenium powder) till it turned colourless. The digested sample was further diluted with distilled water to a known volume.

Nitrogen was estimated in a Microkjeldahl unit as described by Black (1965).

3.8 Nutrient uptake studies

The nutrient uptake by chilli at 45, 75, 105 and 140 days after transplanting was worked out using the equation.

$$\text{Nutrient uptake} = \frac{\text{Nutrient content (\%)}}{100} \times \text{dry matter yield}$$

The results are expressed in mg/plant.

3.9 Physical properties of chilli fruits

3.9.1 Length/Breadth ratio of fruits (L/B ratio)

Ten sundried red fruits were collected randomly from the composite samples harvested at the peak of the harvest season. Length was measured excluding pedicel and breadth was measured at the base of the fruit. Average of length/breadth for ten fruits was computed (Pankar and Magar, 1978a).

3.9.2 Per cent seeds, pericarp and pedicel

Ten oven dried fruits which were weighed to a constant weight were partitioned carefully into pericarp, seeds and pedicel. These individual components were weighed separately and converted to 100 gm. fruit weight.

3.9.3 Nature of pericarp

Ten sun-dried fruits selected for L/B ratio were visually observed for pericarp nature like colour, wrinkles and brightness.

3.10 Chemical properties

3.10.1 Moisture per cent of fresh fruits

At peak picking stage, freshly harvested red-ripe fruits (10 Nos) of different locations were transferred to wet muslin cloth bag. After recording initial weight, they were air-dried in shade for 2 to 3 days and then transferred to hot air oven for oven drying at 50°C for 12 hours or more till constant weight is obtained. The loss in weight recorded between fresh fruits and oven dried fruits was taken as moisture content of freshly harvested fruits and expressed in percentage.

3.10.2 Moisture per cent of sun dried fruits

Composite fruit samples collected from different locations were destalked and dried thoroughly in sunshine for about 15 days till they became brittle. They were weighed and transferred to hot air oven for oven drying at 50°C for 12 hours or more to get constant weight. The loss in weight due to evaporation was accepted as the moisture content of sundried fruits and expressed in percentage.

3.10.3 Total ash per cent

About two grams of powdered chilli fruit sample is weighed in a previously weighed crucible. The material is charred slowly on a low flame. After charring, it was ashed in muffle furnace at 550°C. The crucible was taken out and cooled, kept in a desiccator and weighed. The crucible is returned to the muffle furnace for heating at

550°C for half an hour, cooling and weighing as before till the difference between two successive weighings is less than one milligram (Mahindru, 1987). Total ash per cent was calculated by the formula,

Total ash % = 100 (W_2 - W)/W_1-W

W_2 = Weight in gm. of total ash and crucible

W = Weight in gm. of empty crucible

W_1 = Weight in gm. of sample for test and crucible.

3.10.4 Crude protein per cent

Per cent crude protein in chilli fruits was computed by multiplying nitrogen content of whole fruit samples with a factor 6.25 (Pankar and Magar, 1978a).

3.10.5 Non-volatile ether extract (NVEE)

It was determined by extracting ground chilli powder with diethyl ether in a soxhlet extractor for 18 hours. The ether is removed by distillation and the flask is dried on a boiling water bath and then in air oven at 110°C till the loss in weight between successive weighings is less than two milligram (Mahindru, 1987).

3.10.6 Volatile oil

The volatile oil present in chilli fruits was determined by distilling well pulverised chilli powder (50 gm) in distilled water. Since the volatile oil is lighter, it floats on the top of the flask and separated by separating funnel. Volume of oil is measured and expressed as ml. per 100 gm of sample (Mahindru, 1987).

3.11 Quality attributes

Representative composite samples of red ripe fruits collected at the peak of the harvest season from different fields were sundried for 15 to 20 days till they become brittle and destalked fruits were used for the analysis of capsaicin, colour value and oleoresin. Oven drying of fruits at 60 to 70°C leads to loss of volatile oil, aroma and colour, hence only sun dried fruits were used.

3.11.1 Ascorbic acid

Freshly harvested green and turning red fruits collected from different locations were washed in distilled water and stored in refrigerator for 2 to 3 days. Ascorbic acid was determined volumetrically by reducing 2,6-dichlorophenol indophenol dye to a colourless leuco-base (Sadasivam and Manickam, 1992).

3.11.2 Capsaicin

Capsaicin content in the whole chilli fruits was analysed by high pressure liquid chromatography method (HPLC) in quality evaluation laboratory at Spices Board Cochin. HPLC method quantitates other capsaicinoids viz., dihydrocapsaicin and nordihydrocapsaicin responsible for pungency. The detail methodology followed for capsaicin estimation in chilli fruits is as follows.

3.11.2(a) Sample preparation

Ground or crushed whole chilli fruits (25 grams) were extracted with 200 ml of 95 per cent ethanol by heating in a round bottom flask at 65-75°C for 5 hours and refluxing. The suspended material was allowed to settle and a sample of the supernatant was filtered through a 0.45 μm syringe filter to a Teflon-lined screw cap vial. This filterate contains capsaicin and other capsaicinoids.

3.11.2(b) Standard pure capsaicin solution

One gm. of 99 per cent pure capsaicin is dissolved in 95 per cent ethanol and volume is made upto 500 ml. with ethanol. This solution contains 2 mg/ml of capsaicin.

3.11.2(c) HPLC system and detection of capsaicin

Capsaicin has fluorescent properties. Both spectrophotometric absorption and fluorescent technique can be used in quantification of pungency but fluorescent method is 100 times more sensitive than spectrophotometer absorption method.

Using a loop injection valve, inject 20 microlitres of standard capsaicin solution (2 mg/ml) into the HPLC system and average peak area of the standard was obtained at 325 nm fluorescence.

Using a sample loop injection valve, inject in duplicate 20 microlitres of sample solution extracted from whole chillies into the HPLC column. After injecting the standard, purge the column with 100% acetonitrile for 30 minutes at the rate of 1.5 ml/minute. Capsaicin present in sample solution is detected at 325 nm for fluorescence.

The relative retention time of pure standard capsaicin is 1.00 and sample peak will be obtained and peak area was determined by integration. The peak area of sample capsaicin is compared with the peak area of standard capsaicin solution (2 mg/ml) and the concentration of capsaicin in fruit samples was determined (Mark Parrish, 1996).

3.11.3 Colour value

Extractable colour value in chilli fruits was determined by measuring the absorbance of acetone extract of ground chilli fruits at 460 nm in spectrophotometer. 70 to 100 mg. of chilli powder is extracted with 100 ml of pure acetone for 16 hours at room temperature in dark area. Pure acetone is taken as blank. There is a standard reference glass material, whose absorbance is known as 0.4 to 0.6 at 465 nm, which is taken as standard for comparing the absorbance values of samples. Determine the absorbance of standard red glass filter at 465 nm, which is needed for instrument correction factor (I_f). Colour value of chilli fruits was calculated by the formula as suggested by Woodbury (1977).

$$I_f = \frac{\text{Declared absorbance of glass reference std.}}{\text{Absorbance obtained at 465 nm on glass reference std.}}$$

$$\text{Extractable colour value in } \textbf{ASTA} \text{ units} = \frac{\text{Absorbance at 460 nm x 16.4 X } I_f}{\text{Sample weight (gm)}}$$

16.4 is a conversion factor to express the colour value in American Spice Trade Association (ASTA) units.

3.11.4 Oleoresin content

It was determined by extracting the destalked chilli fruits with ethylene dichloride by cold percolation giving over night contact time. Later by distillation procedure, the excess of organic solvent not consumed by spice is separated. The semi solid gel like substance containing volatile and non-volatile constituents of chilli fruits having original flavour and fragrance was weighed and per cent oleresin was calculated (Mahindru, 1987).

3.12 Statistical analysis and interpretation

The data obtained was subjected to statistical analysis by adopting suitable designs and test of significance as given by Sundararaj *et al.* (1972). The following statistical analysis was carried out for the data obtained pertaining to plant analysis and biometric observations.

3.12.1(a). Uptake of nutrients by chilli crop at different growth stages in different locations was analysed by adopting two factorial completely randomised design. For this, locations were treated as first factor and growth stages (45th, 75th, 105th and 140th) of plant were treated as second factor. Two years (1996-97 and 1997-98) were considered as two replications. The number of levels of first factor for kaddi, dyavnur and dabbi plant cultivars were 10, 5 and 6 respectively, where as the second factor was at 4 levels for all the three cultivars.

(b). Same design was adopted for interpretation of data pertaining to plant height, number of branches and dry matter yield.

(c). Based on the colour value of chilli fruits they were classified as first grade, second grade and third grade fruits. Accordingly locations were also classified as locations producing first grade, second and third grade fruits. In order to test the means of these groups for their significance, contrasts were formed by grouping the observations separately into two or three groups from locations producing first, second and third grade fruits. In Byadgi kaddi cv. three contrasts were formed from three groups of locations, where as in Dyavnur and Byadgi dabbi cultivars, only 2 contrasts were formed because of two grades of fruits. F-test was carried out to test for the significance between two contrasts.

(d). For the statistical analysis of observations recorded at harvest in Byadgi kaddi cultivar (10 locations), completely randomised block design was adopted with 10 locations as treatments and two years as replications. Same design was followed for interpretation of data pertaining to physical, chemical and quality characters of chilli fruits. After testing for the over all significance between locations, contrasts were formed to test for the significance between 1st, 2nd and 3rd grade fruits by grouping the observations of concerned locations.

(e). Student **'t'** test was carried out to test for the significance between means of two groups and for observations recorded at harvest, since the number of locations are only 5 and 6 for Dyavnur and Byadgi dabbi cultivars respectively.

3.12.2 Correlation studies

Correlation studies were made between the chilli yield and quality attributes with soil properties, fertility status and nutrient uptake by plants. Simple correlation analysis was also done to understand some of the interrelationships between nutrient composition of whole red fruits and red pericarp with quality attributes viz., capsaicin, colour units and oleoresin contents. Correlation coefficients(r) were worked out and tests of significance were applied as per the procedure given by Snedecor and Cochran (1956).

EXPERIMENTAL RESULTS

IV. EXPERIMENTAL RESULTS

The results on the various morphological, physical, chemical and fertility status of fifteen soil pedons are described in this chapter. Chilli crop (Byadgi kaddi, Dyavnur and Byadgi dabbi cultivars) was grown in these fifteen locations for two seasons and plant observations like growth parameters, yield and yield components, nutrient uptake, nutrient concentration in chilli fruits, quality attributes studied along with correlation studies are described in this chapter under the following headings.

4.1 Morphological features of the soils

4.2 Physical properties of the soils

4.3 Chemical properties

4.4 Fertility status of soils

4.5 Growth attributes, yield and yield components of chilli

4.6 Nutrient uptake studies

4.7 Physical characteristics of chilli fruits of study area.

4.8 Chemical characteristics of chilli fruits

4.9 Proximate nutrient composition and concentration in whole chilli fruits and fruit components

4.10 Quality attributes of chilli fruits of study area

4.11 Correlation studies.

4.1 Morphological features of the soil pedons

The detailed morphological description of the pedons are presented in Appendix-I.

Among black soil pedons, Gudgeri and Devanur (Pedons I and II) pedons of Kundagol taluka producing high yields and first grade fruits were the deepest compared to pedons of Shiggaon, Haveri, Hirekerur, Dharwad, Navalgund, Hubli and Gadag (Pedons, III, IV, V, VI, XI, XII, XIII, XIV and XV) talukas which produce medium yields and second grade fruits. The mixed red and black and red soil pedons (pedons VII, VIII, IX and X) located in Savanur, Hirekerur, Byadgi and Ranebennur talukas, were shallow in depth and produce third grade fruits coupled with low yields.

In black soil pedons, colour varied from dark grey to very dark greyish brown and black, while in red soil pedons, it varied from yellowish red to dark red. Structure in black soils varied from granular to sub angular blocky and angular blocky with moderate to very strong. In red pedons, it was weak to moderate, coarse to very coarse and granular to subangular blocky. Among the black soil pedons, pedons I and II which produce first grade fruits and high yields have prominent intersecting slicken sides appearing right from 60 cm onwards and extend upto 180 cm depth, but in other black soil pedons which produce medium yields and second grade fruits, less number of slicken sides were observed and extend upto only 120 cm depth. Lime concretions and slickensides were absent in red pedons which produce third grade fruits and low yields.

4.2 Physical properties

The data on physical properties are presented in Table 4.

4.2.1 Particle size distribution

Soil texture is one of the important characteristic as it is not modified by the management practices and secondarily, it influences the physico-chemical properties of the soil, water movement and nutrient supply.

Table 4 . Physical properties of soil pedons

Depth (cm)	Particle size distribution (% oven dry basis)			Textural class	Bulk density	Particle density	% pore space	Moisture content (cm)		Available soil moisture (cm)
	Sand	Silt	Clay		($Mg.m^{-3}$)	($Mg.m^{-3}$)		33 kPa	1500 kPa	
1	2	3	4	5	6	7	8	9	10	11
PEDON-I (GUDGERI, Tq. Kundagol)										
0-15	10.76	27.05	62.19	Clay	1.32	2.51	47.41	7.90	3.75	4.15
15-30	16.27	22.34	61.39	Clay	1.35	2.52	46.43	8.36	4.01	4.35
30-60	15.21	21.30	63.49	Clay	1.36	2.50	45.60	17.76	9.50	8.26
60-110	-	-	-		1.37	-	-	30.04	15.63	14.41
>110	-	-	-		1.37	-	-	-	-	-
										31.17
PEDON-II (DEVANUR, Tq. Kundagol)										
0-15	12.39	24.16	63.45	Clay	1.30	2.50	48.00	7.86	3.62	4.24
15-30	12.86	20.87	66.27	Clay	1.34	2.51	46.61	8.41	3.83	4.58
30-60	15.21	16.10	68.69	Clay	1.40	2.53	44.66	18.31	9.16	9.15
60-110	-	-	-		1.37	-	-	29.92	14.14	15.78
>110	-	-	-		1.37	-	-	-	-	-
										33.75
PEDON-III (GANJIGATTI, Tq. Shiggaon)										
0-15	18.24	31.06	50.70	Clay	1.45	2.62	44.65	7.11	3.91	3.20
15-30	27.49	25.61	46.90	Clay loam	1.49	2.61	42.91	7.61	4.03	3.58
30-60	21.30	28.85	49.85	Clay	1.42	2.66	46.62	14.45	7.84	6.61
60-110	-	-	-		1.41	-	-	22.58	12.51	10.07
>110	-	-	-		1.47	-	-	-	-	-
										23.46

Figure in bold number in column 11 indicate total available soil moisture (cm) in 110 cm soil profile.

Contd...

Depth (cm)	Particle size distribution (% oven dry basis)			Textural class	Bulk density	Particle density	% pore space	Moisture content (cm)		Available soil moisture (cm)
	Sand	Silt	Clay		(Mg.m^{-3})	(Mg.m^{-3})		33 kPa	1500 kPa	
1	2	3	4	5	6	7	8	9	10	11
PEDON-IV (DEVAGIRI, Tq. Haveri)										
0-15	11.64	28.33	60.03	Clay	1.34	2.66	49.62	6.95	3.76	3.19
15-30	1920	21.20	59.60	Clay	1.39	2.59	46.33	7.48	4.07	3.41
30-60	13.25	29.16	57.59	Clay	1.40	2.62	46.56	15.48	7.41	8.07
60-110	-	-	-		1.40	-	-	23.16	11.82	11.34
>110	-	-	-		1.45	-	-	-	-	-
										26.01
PEDON-V (SOMANHALLI, Tq. Hirekerur)										
0-15	12.28	34.34	53.38	Clay	1.42	2.61	45.59	7.67	4.04	3.63
15-30	18.25	26.29	54.46	Clay	1.47	2.62	43.89	8.27	4.25	4.02
30-60	20.91	23.82	55.87	Clay	1.51	2.63	42.58	17.07	8.98	8.09
60-110	-	-	-		1.51	-	-	26.50	13.25	13.25
>110	-	-	-		1.52	-	-	-	-	-
										28.99
PEDON-VI (MRS DHARWAD, Tq. Dharwad)										
0-15	15.00	25.76	59.24	Clay	1.38	2.56	46.09	7.33	3.76	3.57
15-30	14.08	23.54	62.38	Clay	1.40	2.55	45.10	7.57	4.01	3.56
30-60	14.76	20.70	64.00	Clay	1.39	2.60	46.54	15.17	8.04	7.13
60-110	-	-	-		1.40	-	-	24.92	12.14	12.78
>110	-	-	-		1.42	-	-	-	-	-
										27.04

Figure in bold number in column 11 indicate total available soil moisture (cm) in 110 cm soil profile.

Contd...

Depth (cm)	Particle size distribution (% oven dry basis)			Textural class	Bulk density	Particle density	% pore space	Moisture content (cm)		Available soil moisture
	Sand	Silt	Clay		($Mg.m^{-3}$)	($Mg.m^{-3}$)		33 kPa	1500 kPa	(cm)
1	2	3	4	5	6	7	8	9	10	11
PEDON-VII (SAVANUR) Mixed red & black soil pedon										
0-15	23.30	32.58	43.62	Clay loam	1.50	2.61	42.53	6.47	3.76	2.71
15-30	25.66	29.17	45.17	Clay	1.56	2.62	40.45	6.77	3.90	2.87
30-60	25.79	32.85	40.85	Clay loam	1.55	2.66	41.72	11.69	6.43	5.26
60-110	-	-	-	-	1.55	-	-	20.69	11.06	9.63
>110	-	-	-	-	-	-	-	-	-	-
										20.47
PEDON-VIII (KALAGOND, Tq. Hirekerur) Red soil pedon										
0-15	45.10	18.40	36.50	Sandy clay	1.52	2.64	42.42	3.89	1.79	2.10
15-30	36.98	21.67	41.35	Clay loam	1.49	2.66	43.98	4.06	1.89	2.17
>30	37.23	19.39	43.38	Clay loam	1.50	2.60	42.30	-	-	-
										4.27
PEDON-IX (THIMMENHALLI, Tq. Byadgi) Red soil pedon										
0-15	46.10	32.65	21.25	Loam	1.55	2.63	41.06	2.84	0.78	2.06
15-30	48.26	28.27	23.47	Loam	1.56	2.60	40.00	2.88	0.96	1.92
30-60	32.32	24.75	42.93	Clay loam	1.52	2.59	41.31	8.80	3.99	4.81
60-90	-	-	-	-	1.46	-	-	9.47	4.26	5.21
>90	-	-	-	-	1.46	-	-	-	-	-
										14.00
PEDON-X (ASUNDI, Tq. Ranebennur) Red soil pedon										
0-15	43.27	20.93	35.30	Clay loam	1.57	2.62	40.07	3.66	1.51	2.15
15-30	44.53	18.47	36.50	Clay loam	1.50	2.61	42.53	3.49	1.40	2.09
>30	52.80	13.40	33.60	Sandy clay loam	1.59	2.63	39.54	-	-	-
										4.24

Figure in bold number in column 11 indicate total available soil moisture (cm) in soil profiles

Contd...

Depth (cm)	Particle size distribution (% oven dry basis)			Textural class	Bulk density	Particle density	% pore space	Moisture content (cm)		Available soil moisture (cm)
	Sand	Silt	Clay		($Mg.m^{-3}$)	($Mg.m^{-3}$)		33 kPa	1500 kPa	
1	2	3	4	5	6	7	8	9	10	11
PEDON-XI (ANNIGERI, Tq. Navalgund)										
0-15	11.87	27.35	60.56	Clay	1.34	2.62	48.85	7.19	3.80	3.39
15-30	12.65	23.25	63.10	Clay	1.33	2.65	49.81	7.28	3.88	3.40
30-60	8.97	25.17	64.15	Clay	1.37	2.60	47.30	15.23	8.25	6.98
60-110	-	-	-		1.36	-	-	23.62	11.72	11.90
>110	-	-	-		1.39	-	-	-	-	-
										25.67
PEDON-XII (YALIWAL, Tq. Kundagol)										
0-15	21.21	20.44	57.85	Clay	1.37	2.58	46.89	7.64	3.70	3.94
15-30	24.26	17.64	58.10	Clay	1.41	2.65	46.79	7.89	3.92	3.97
30-60	18.36	22.34	59.30	Clay	1.42	2.59	45.17	16.68	8.55	8.13
60-110	-	-	-		1.41	-	-	28.02	15.39	12.63
>110	-	-	-		1.44	-	-	-	-	-
										28.67
PEDON-XIII (MALLIGAWAD, Tq. Hubli)										
0-15	14.71	22.44	62.85	Clay	1.38	2.55	45.88	6.71	3.13	3.58
15-30	15.57	20.87	63.16	Clay	1.41	2.57	45.14	7.01	3.44	3.57
30-60	11.95	21.38	66.17	Clay	1.41	2.59	45.56	14.72	6.97	7.75
60-110	-	-	-		1.40	-	-	23.87	12.16	11.71
>110	-	-	-		1.42	-	-	-	-	-
										26.61

Figure in bold number in column 11 indicate total available soil moisture (cm) in 110 cm soil profile.

Contd...

Depth (cm)	Particle size distribution (% oven dry basis)			Textural class	Bulk density	Particle density	% pore space	Moisture content (cm)		Available soil moisture
	Sand	Silt	Clay		($Mg.m^{-3}$)	($Mg.m^{-3}$)		33 kPa	1500 kPa	(cm)
1	2	3	4	5	6	7	8	9	10	11
PEDON-XIV (SAIDAPUR, Tq. Navalgund)										
0-15	13.56	24.64	61.30	Clay	1.39	2.54	45.27	7.82	3.95	3.87
15-30	15.80	21.03	62.67	Clay	1.39	2.55	45.49	7.17	3.59	3.58
30-60	11.95	24.40	63.15	Clay	1.38	2.60	46.92	13.92	6.64	7.28
60-110	-	-	-	-	1.34	-	-	24.14	12.66	11.48
>110	-	-	-	-	1.39	-	-	-	-	-
										26.21
PEDON-XV (KURTKOTI, Tq. Gadag)										
0-15	25.27	19.87	54.36	Clay	1.33	2.58	48.45	6.09	3.24	2.85
15-30	17.99	22.64	59.17	Clay	1.42	2.55	44.31	6.85	3.98	2.87
30-60	20.46	20.89	58.65	Clay	1.37	2.54	46.06	14.70	7.16	7.54
60-110	-	-	-	-	1.40	-	-	23.77	11.54	12.23
>110	-	-	-		1.43	-	-	-	-	-
										25.49

Figure in bold number in column 11 indicate total available soil moisture (cm) in 110 cm soil profile.

4.2.1(a) Pedons I and II producing high yields and first grade fruits

The results of mechanical analysis revealed that in pedons I and II, clay content ranged from 61.39 to 63.49 and 63.45 to 68.69 per cent, respectively. These two pedons have higher clay content than other black soil pedons producing second grade fruits with medium yields. Silt content ranged from 21.30 to 27.05 and 16.10 to 24.16 per cent in pedons I and II, respectively and decreased with depth in both pedons. Coarse and fine sand fractions put together ranged from 10.76 to 16.27 and 12.39 to 15.21 per cent in pedons I and II, respectively.

4.2.1(b) Pedons III, IV, V, VI, XI, XII, XIII, XIV and XV producing medium yields and second grade fruits

Perusal of data presented in Table 4 revealed that, in the surface depth of these pedons, clay content ranged from 50.70 per cent to 62.85 per cent in pedons III and XIII, respectively. Lowest clay content (46.90%) was observed in the 15-30 cm depth of pedon III, whereas highest was 63.16 per cent found in pedon XIII. In the 30-60 cm depth, clay content ranged from 49.85 to 66.17 per cent as observed in pedons III and XIII, respectively. Generally clay content increased with depth in all the pedons except in pedons III, IV and XV where no definite trend was observed.

Silt content in the 0 to 15 cm depth of these pedons ranged from 19.87 to 34.34 per cent found in pedons XV and V, respectively. Similarly in the 15 to 30 and 30 to 60 cm, depths, it ranged from 21.03 (pedon XIV) to 26.29 (pedon IV) per cent, respectively. No definite trend was observed in the distribution of silt with depth.

Pedons vary widely in their sand contents. Maximum sand content (27.49%) was observed in the 15-30 cm depth of pedon III,while lowest (8.97%) was found in the 30-

60 cm depth of pedon XI, whereas highest value (25.27%) was noticed in pedon XV. No definite trend was observed in the distribution of sand with depth in these pedons. Pedon-XI has lowest sand fraction in all the depths compared to other pedons.

4.2.1(c)Pedons VII, VIII, IX and X producing low yields and third grade fruits

In pedon VII, which is a mixed red and black soil pedon, the clay and silt fractions ranged from 40.85 to 45.17 and 29.17 to 32.85 per cent, respectively. Similarly sand fraction ranged from 23.30 to 25.79 per cent. No definite trend was observed in the distribution of clay and silt fractions with depth, but sand content increased with depth.

In the surface depth of red soil pedons (VIII, IX and X), clay content ranged from 21.25 per cent (pedon IX) to 36.50 per cent (pedon VIII). In the 15 to 30 and 30 to 60 cm depths, it ranged from 23.47 to 41.35 and 33.60 to 43.38 per cent, respectively. This indicates higher clay content in the lower depth of these pedons. Silt fraction ranged from 13.40 per cent pedon X) to 32.65 per cent (pedon IX) and it decreased with depth in pedon IX and X, while in pedon VIII no definite trend was observed.

Sand fraction ranged from 36.98 to 45.10 per cent in pedon VIII, while in pedons IX and X, it varied from 32.32 to 52.80 per cent. Pedons IX and X have higher sand content than pedon VIII and its content increased with depth in pedon X, while no definite trend was observed in pedons VIII and IX. Among these red soil pedons, pedon IX located on the foot hills is deep (>90 cm) and has very high sand content in the surface layer.

In general, these pedons (VII, VIII, IX and X) have lower clay and very high sand contents in their pedons compared to black soil pedons.

4.2.2 Bulk density

In pedons I and II, the bulk density ranged from 1.32 to 1.37 and 1.30 to 1.40 Mg m^{-3}, respectively and it increased with depth in both pedons. In other black soil pedons (III, IV, V, VI, XI, XII, XIII, XIV and XV) which produce second grade fruits, highest bulk density (1.52 Mg m^{-3}) was observed in the lowest depth (>110 cm) of pedon-V, while lowest value (1.28 Mg m^{-3}) was noticed in the 30 to 60 cm depth of pedon-XIV. Among these pedons, pedon V has higher bulk density values ranging from 1.42 to 1.52 Mg m^{-3} compared to other pedons, where the values ranged from 1.33 to 1.43 Mg m^{-3}.

The mixed red and black soil pedon (VII) has bulk density values ranging from 1.50 to 1.56 Mg m^{-3} which is more than black soil pedons. The red soil pedons (VIII, IX and X) which produce low yields and third grade fruits, have bulk density values ranged from 1.46 to 1.59 Mg m^{-3}. Pedons VIII and X have narrow variation compared to pedon IX (1.46 to 1.56 Mg m^{-3}).

4.2.3 Per cent pore space

In pedons I and II, per cent pore space ranged from 45.60 to 47.41 and 44.66 to 48.00 per cent, respectively and decreased with depth in both pedons. In pedons that produced second grade fruits (pedons III, IV, V, VI, XI, XII, XIII, XIV and XV) highest pore space (50.76%) was noticed in the 30-60 cm depth of pedon XIV while lowest (42.48%) was found in the same depth of pedon V. Generally not much variation was observed in the pore space contents of pedons producing first and second grade fruits. In red soil pedons (VIII, IX and X), lowest pore space (39.54%) was found in >30 cm depth of pedon X, while highest value (43.98%) was observed in the 15-30 cm depth of pedon VIII. Mixed red and black soil pedon (VII) has narrow variation (40.45 to 42.53%) in pore space content with depth. Red soil pedons have lower pore space content than black soil pedons.

4.2.4 Moisture retention capacity

The results obtained on moisture retention capacity of surface and subsurface soils at 33 kPa and 1500 kPa of different pedons are summarized here.

4.2.4(a) Pedons I and II

In these pedons, the moisture retained at 33 kPa was higher than that of pedons producing second grade fruits and medium yields. At 33 kPa, moisture content ranged from 7.90 to 30.04 and 7.86 to 29.92 cm in pedons I and II, respectively. At 1500 kPa, highest moisture content (9.50 cm) was noticed in the 30 to 60 cm depth of pedon I and lowest value of 3.62 cm was noticed in the 0-15 cm depth of pedon II. In both pedons moisture content at both pressures increased with depth.

4.2.4(b) Pedons (III, IV, V, VI, XI, XII, XIII, XIV and XV) producing second grade fruits and medium yields

In general, the moisture content in all these pedons at 33 kPa was slightly lower than that of pedons I and II producing first grade fruits. In the surface depth, highest moisture content (7.82 cm) was observed in pedon XIV while lowest (6.09 cm) was noticed in pedon IX. Pedons V and XII have higher moisture contents (7.67 to 26.50 and 7.64 to 28.02 cm) in all the depths at 33 kPa compared to other pedons. Pedons XI and XIII have moisture contents ranging from 7.19 to 23.62 and 6.71 to 23.87 cm, respectively.

At 1500 kPa, in surface depth, highest moisture content (4.04 cm) was found in pedon V closely followed by pedon XIV (3.95 cm). Lowest value (3.13 cm) was observed in the same depth of pedon XIII. Generally, the range in moisture content with depth at 1500 kPa in all these pedons was in the order of 3 to 5 per cent. In all the pedons, moisture content increased with depths.

4.2.4(c) Pedons (VII, VIII, IX and X) producing third grade fruits and low yields

In mixed red and black soil pedon (VII), the moisture content at 33 kPa and 1500 kPa ranged from 6.47 to 20.69 and 3.76 to 11.06 cm, respectively which were lower than found in black soil pedons. The red soil pedons (VIII, IX and X) retained very less moisture at both 33 and 1500 kPa in all the depths. In the surface depth of these pedons at 33 kPa, moisture content ranged from 2.84 cm (pedon IX) to 3.89 cm (pedon VIII), while at 1500 kPa, it ranged from 0.78 to 1.79 cm in the same pedons. Pedon IX being slightly deep (>90 cm) has wide range in moisture content at both 33 and 1500 kPa (2.84 to 9.47 and 0.78 to 4.26 cm).

4.2.5 Total available soil water

The available soil water was calculated by obtaining the difference in the moisture retention capacity of soil at 33 and 1500 kPa. The total available soil water was highest (33.75 cm) in pedon II closely followed by pedon I (31.17 cm) both of which produce high yields and first grade fruits. Other black soil pedons which produce second grade fruits and medium yields have recorded slightly lower total available soil water ranging from 23.46 to 28.99 cm. Pedons VII, VIII, IX and X have shown lowest values of total available soil water, which ranged from 4.24 cm to 20.47 cm.

4.3 Chemical properties of soils

The data on chemical properties of soils are presented in Table 5.

4.3.1 Soil reaction (pH)

The data on soil pH revealed a wide range from acidic to neutral and alkaline reaction. Generally, black soil pedons producing first and second grade fruits have the soil pH ranging from 6.90 to 8.70 and most of the soils were neutral in reaction. The red soil pedons (VIII, IX and X) have pH values ranging from 5.8 to 8.0. The pH value has no definite trend in distribution with depth.

4.3.2 Electrical conductivity (EC)

Black soil pedons have higher electrical conductivity values than red soil pedons. In black soils, EC values ranged from 0.21 to to 1.00 dSm^{-1}, but in red soil pedons, it ranged from 0.10 to 0.40 dSm^{-1}. Generally black soil pedons showed wide range than red soil pedons.

4.3.3 Cation exchange capacity (CEC)

Data presented in Table 5 indicated that, pedons-I and II, which produce high yields with first grade fruits have CEC values ranged from 40.21 to 58.69 and 51.08 to 54.35 cmol(p+)kg^{-1}, respectively. Other black soil pedons which produce medium yields and second grade fruits have wide variation in CEC values (34.78 to 55.43 cmol(p+)kg^{-1}). In mixed red and black soil pedon (VII), CEC value ranged from 28.26 to 31.52 cmol(p+)kg^{-1}). Red soil pedons (VIII, IX and X) which produce low yields and third grade fruits have recorded very low values ranged from 8.69 to 24.45 cmol(p+)kg^{-1}). In general, pedons producing first grade fruits with high yields have higher CEC values than

Table 5 : Chemical properties of soil pedons

Depth (cm)	pH_w (1:2 soil water ratio)	EC (dSm^{-1})	CEC [cmol (p+)kg^{-1}]	Exchangeable cations [cmol (p+) kg^{-1}]			Organic carbon gkg^{-1}	Free $CaCO_3$ gkg^{-1}	Soluble cations (cmol. L^{-1})				Soluble Anions (cmol L^{-1})			
				Na^+	K^+	Ca+Mg			Na^+	K^+	Ca^{++}	Mg^{++}	$CO_3^{=}$	HCO_3^-	Cl^-	SO_4
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
PEDON-I (GUDGERI, Tq: Kundagol)																
0-15	7.40	0.21	52.17	1.82	0.73	49.62	6.30	60.00	2.04	0.05	1.80	0.40	-	2.50	1.40	0.65
15-30	7.10	0.23	57.61	3.74	0.54	53.33	6.30	50.00	2.25	0.08	1.90	0.55		2.70	1.60	0.80
30-60	7.20	0.54	58.69	2.35	0.71	55.63	5.10	70.00	2.33	0.14	2.10	1.15	-	2.45	1.70	1.10
60-110	7.30	0.83	57.61	3.21	0.62	53.78	5.10	90.00	-	-	-	-	-	-	-	-
>110	8.20	0.95	40.21	3.34	0.52	36.35	4.20	130.00	-	-	-	-	-	-	-	-
PEDON-II (DEVANUR, Tq: Kundagol)																
0-15	7.20	0.40	54.35	0.61	0.86	52.88	6.90	40.00	2.17	0.11	1.65	0.50	-	2.00	1.10	0.83
15-30	7.60	0.44	51.08	1.56	0.56	48.96	6.90	70.00	2.19	0.06	1.88	0.65	-	2.20	1.80	1.10
30-60	7.80	0.49	54.34	1.74	0.48	52.12	5.40	30.00	2.83	0.07	1.98	0.79	-	2.20	1.70	1.35
60-110	7.80	0.43	52.17	2.35	0.48	49.34	4.80	60.00	-	-	-	-	-	-	-	-
>110	8.20	0.49	52.17	2.61	0.39	49.17	4.80	80.00	-	-	-	-	-	-	-	-
PEDON-III (GANJIGATTI, Tq: Shiggaon)																
0-15	7.50	0.63	45.65	1.74	0.32	43.59	3.90	90.00	2.08	0.04	1.40	0.80	-	3.20	1.35	0.40
15-30	7.50	0.64	43.48	3.91	0.54	39.03	3.20	80.00	2.43	0.06	1.65	0.66	-	3.40	1.88	0.55
30-60	7.10	0.69	45.65	3.91	0.46	41.28	3.30	130.00	2.56	0.05	1.80	0.90	-	3.10	1.40	0.74
60-110	7.40	0.69	47.82	4.13	0.60	43.09	3.30	90.00	-	-	-	-	-	-	-	-
>110	8.00	0.61	48.91	4.82	0.52	43.57	2.70	130.00	-	-	-	-	-	-	-	-

Contd...

Depth (cm)	pH_w (1:2 soil water ratio)	EC (dSm^{-1}) (1:2 soil water ratio)	CEC [cmol (p+)kg^{-1}]	Exchangeable cations [cmol (p+) kg^{-1}] Na+	K+	Ca+Mg	Organic carbon gkg^{-1}	Free $CaCO_3$ gkg^{-1}	Soluble cations (cmol. L^{-1}) Na^+	K^+	Ca^{++}	Mg^{++}	Soluble Anions (cmol L^{-1}) $Co_3^=$	HCO_3^-	Cl^-	SO_4
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
PEDON-IV (DEVAGIRI, Tq : Haveri)																
0-15	7.50	0.47	48.91	1.99	0.39	46.53	5.80	40.00	2.86	0.08	1.40	0.50	-	2.65	1.76	1.73
15-30	8.60	0.39	49.04	3.91	0.50	44.63	3.90	50.00	2.90	0.04	1.60	0.72	-	3.10	1.88	1.88
30-60	8.30	0.40	46.74	3.65	0.37	42.72	3.80	120.00	2.95	0.05	1.85	0.80	-	2.47	1.93	1.92
60-110	8.40	0.32	44.56	3.68	0.50	40.38	3.60	200.00	-	-	-	-	-	-	-	-
>110	8.40	0.34	41.30	3.14	0.44	37.72	3.00	220.00	-	-	-	-	-	-	-	-
PEDON-V (SOMANHALLI, Tq: Hirekerur)																
0-15	8.10	0.38	39.13	0.78	0.46	37.89	5.10	50.00	2.86	0.03	1.39	0.65	-	1.75	1.65	0.96
15-30	8.10	0.33	40.21	1.22	0.70	38.29	5.00	40.00	3.00	0.06	1.42	0.60	-	2.10	1.75	1.00
30-60	8.40	0.42	34.78	2.08	0.48	32.22	4.20	60.00	3.25	0.05	1.39	0.60	-	2.00	1.70	1.25
60-110	8.50	0.51	34.78	3.74	0.44	30.60	3.90	60.00	-	-	-	-	-	-	-	-
>110	8.50	0.50	36.95	2.35	0.39	34.21	ND	ND	-	-	-	-	-	-	-	-
PEDON-VI (MRS, DHARWAD, Tq: Dharwad)																
0-15	7.00	0.23	48.91	0.52	0.58	47.81	5.50	10.00	2.80	0.06	0.95	0.20	-	3.00	1.90	0.50
15-30	6.90	0.28	49.99	0.52	0.57	48.90	5.10	50.00	2.88	0.08	1.10	0.70	-	3.00	1.85	0.65
30-60	7.30	0.31	48.91	0.52	0.36	48.03	4.80	30.00	3.00	0.10	1.20	0.80	-	2.75	1.80	0.90
60-110	7.40	0.38	48.91	0.61	0.35	47.95	4.80	30.00	-	-	-	-	-	-	-	-
>110	8.00	0.61	51.08	0.78	0.40	49.90	3.90	60.00	-	-	-	-	-	-	-	-

Contd...

Depth (cm)	pH_w (1:2 soil water ratio)	EC (dSm^{-1})	CEC [cmol (p+)kg^{-1}]	Exchangeable cations [cmol (p+) kg^{-1}]			Organic carbon gkg^{-1}	Free $CaCO_3$ gkg^{-1}	Soluble cations (cmol. L^{-1})				Soluble Anions (cmol L^{-1})			
				Na^+	K^+	Ca+Mg			Na^+	K^+	Ca^{++}	Mg^{++}	CO_3^-	HCO_3	Cl	SO_4
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
PEDON-XI (ANNIGERI, Tq : Navalgund)																
0-15	7.10	0.82	55.43	1.56	0.70	53.17	5.70	70.00	2.14	0.03	0.85	0.36	-	3.52	1.89	0.65
15-30	7.00	0.87	53.26	2.95	0.52	49.79	5.60	70.00	2.32	0.04	1.10	0.61	-	3.40	1.92	0.70
30-60	7.60	0.58	57.60	4.26	0.49	52.85	4.80	70.00	2.54	0.03	1.29	0.60	-	3.65	1.88	0.73
60-110	7.70	0.61	53.26	4.34	0.56	48.36	4.60	70.00	-	-	-	-	-	-	-	-
>110	8.50	0.93	57.61	4.52	0.50	52.59	3.90	100.00	-	-	-	-	-	-	-	-
PEDON-XII (YALIWAL, Tq: Kundagol)																
0-15	7.50	0.21	43.48	1.83	0.48	41.17	5.10	10.00	2.21	0.04	1.20	0.69	-	3.35	1.40	0.55
15-30	7.30	0.26	46.74	3.13	0.41	43.20	4.50	20.00	2.28	0.06	1.60	0.70	-	4.10	1.50	0.67
30-60	7.40	0.28	43.48	3.95	0.39	39.14	4.00	30.00	2.32	0.02	1.85	0.80	-	2.90	1.68	0.92
60-110	7.50	0.82	44.56	4.60	0.43	39.53	3.20	50.00	-	-	-	-	-	-	-	-
>110	7.40	1.00	41.30	4.74	0.40	36.16	3.00	80.00	-	-	-	-	-	-	-	-
PEDON-XIII (MALLIGAWAD, Tq: Hubli)																
0-15	7.90	0.47	52.13	1.45	0.53	50.15	5.80	80.00	2.40	0.08	1.35	0.50	-	4.16	2.40	1.40
15-30	8.10	0.52	54.32	1.89	0.49	51.94	5.40	60.00	2.65	0.10	1.60	0.65	-	5.00	2.60	1.55
30-60	8.00	0.54	50.67	2.37	0.52	47.78	4.50	90.00	2.80	0.12	1.70	0.70	-	3.40	2.90	1.70
60-110	8.30	0.66	ND	3.14	0.40	ND	4.30	100.00	-	-	-	-	-	-	-	-
>110	8.30	0.68	ND	3.40	0.39	ND	4.30	130.00	-	-	-	-	-	-	-	-

ND-Not determined.

Contd...

Depth (cm)	pH_w (1:2 soil water ratio)	EC (dSm^{-1})	CEC [cmol $(p+)kg^{-1}$]	Exchangeable cations [cmol (p+) kg^{-1}]			Organic carbon gkg^{-1}	Free $CaCO_3$ gkg^{-1}	Soluble cations (cmol. L^{-1})				Soluble Anions (cmol L^{-1})			
				Na^+	K^+	Ca+Mg			Na^+	K^+	Ca^{++}	Mg^{++}	$Co_3^=$	HCO_3^-	Cl^-	SO_4
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
PEDON-XIV (SAIDAPUR, Tq: Navalgund)																
0-15	8.10	0.38	54.34	0.78	0.50	53.06	5.70	60.00	2.15	0.05	0.64	0.49	-	2.83	1.40	0.88
15-30	8.00	0.62	55.43	1.65	0.50	53.28	5.40	70.00	2.30	0.08	1.25	0.70	-	3.00	1.70	1.25
30-60	8.60	0.89	52.17	2.78	0.51	48.88	5.00	70.00	2.40	0.03	1.30	0.90	-	2.90	1.90	1.70
60-110	8.30	0.48	53.26	2.78	0.44	50.04	4.80	50.00	-	-	-	-	-	-	-	-
>110	8.50	0.44	52.17	3.91	0.45	47.81	4.40	60.00	-	-	-	-	-	-	-	-
PEDON-XV (KURTKOTI, Tq: Gadag)																
0-15	8.50	0.23	42.39	1.13	0.47	40.79	5.20	70.00	2.17	0.06	0.60	0.39	-	2.86	2.15	1.12
15-30	7.90	0.34	49.99	2.52	0.44	47.03	5.00	80.00	2.32	0.04	1.10	0.45	-	3.11	2.30	1.27
30-60	8.10	0.38	48.91	3.91	0.47	44.53	5.00	80.00	2.64	0.02	1.25	0.50	-	2.90	2.60	2.20
60-110	8.00	0.41	52.17	5.56	0.30	46.31	3.30	90.00	-	-	-	-	-	-	-	-
>110	8.70	0.48	52.17	5.82	0.35	46.00	2.10	150.00	-	-	-	-	-	-	-	-

other pedons producing second grade fruits with medium yields. There is no definite trend in the distribution of CEC values with depth within black soil pedons, but in red soil pedons, it increased with depth in pedons VIII and IX but decreased in pedon X.

4.3.4 Exchangeable cations

4.3.4(a) Exchangeable Ca + Mg

Deep black soil pedons (pedons I and II) have exchangeable Ca^{++} + Mg^{++} contents which ranged from 35.35 to 55.63 and 49.17 to 52.88 cmol(p+)kg^{-1}), respectively. In other medium black soil pedons, the exchangeable Ca + Mg contents ranged from 30.60 (60-110 cm depth of pedon V) to 53.28 (15-30 cm depth of pedon XIV) cmol(p+)kg^{-1} which is slightly less than pedons I and II. In pedon VII, (mixed red and black soil pedon), the exchangeable Ca + Mg contents ranged from 25.78 cmol(p+)kg^{-1} to 30.55 cmol(p+)kg^{-1} slightly more than red soil pedons (VIII, IX and X). Among the red soil pedons, pedon IX has higher exchangeable Ca + Mg values which ranged from 7.29 to 21.71 cmol(p+)kg^{-1} and lowest values were recorded in pedon VIII (9.36 to 13.60 cmol(p+)kg^{-1}). Deep black soil pedons which produce high yields and first grade fruits have higher exchangeable Ca + Mg contents than pedons producing second grade fruits. Red soil pedons have very low exchangeable Ca + Mg contents.

4.3.4(b) Exchangeable sodium

It is seen from table that, exchangeable sodium content was high in all the black soil pedons compared to red soil pedons. In pedons I and II, exchangeable Na^{+} content ranged from 1.82 to 3.34 and 0.61 to 2.61 cmol(p+)kg^{-1}, respectively. It increased with depth in pedon II, while no definite trend was observed in pedon I. In other black soil pedons (III, IV, V, VI, XI, XII, XIII, XIV and XV) which produce second grade fruits, lowest value (0.52 cmol(p+)kg^{-1}) was found in the surface depth of pedon VI, while highest value (5.82 cmol(p+)kg^{-1}) was recorded in the lower most depth of pedon XV. In all the pedons, it increased with depth except in pedon IV where no definite increase or decrease with depth was observed. Pedon VI recorded very low values (0.52 to 0.78 cmol(p+)kg^{-1}) in all the depths. Pedons VII, VIII, IX and X, which produce low yields and third grade fruits have exchangeable Na+ content ranging from 0.13 cmol(p+)kg^{-1} found in >30 cm depth of pedon VIII to 2.08 cmol(p+)kg^{-1} found in 60 to 110 cm depth of pedon VII. Red soil pedons (VIII, IX and X) have lower contents than mixed red and black soil pedon (pedon VII).

4.3.4(c) Exchangeable potassium

It is seen from table that, exchangeable potassium was highest (0.86 cmol(p+)kg^{-1}) in the surface depth of pedon II, closely followed by the same depth of pedon I (0.73 cmol(p+)kg^{-1}). It decreased with depth in pedon II, while no definite pattern was observed in pedon I. Lowest value (0.39 cmol(p+)kg^{-1}) was noticed in >110 cms depth of pedon II. In other medium black soil pedons, that produce medium yields and second grade fruits, it's content ranged from 0.32 (0-15 cm depth of pedon-III) to 0.70 cmol(p+)kg^{-1} (0-15 cm depth of pedon XIII). The red soil pedons (VIII, IX and X) have exchangeable K^+ contents which ranged from 0.20 cmol(p+)kg^{-1} found in the surface depth of pedon VIII to 0.29 cmol(p+)kg^{-1} found in the 30-60 cm depth of pedon IX. Generally, black soil pedons contain more exchangeable potassium than red soil pedons (pedon VIII, IX and X).

4.3.5 Organic carbon

The results presented in Table 5 clearly revealed that, pedons I and II have higher organic carbon contents than other black soil pedons. In pedons I and II, it ranged from

4.20 to 6.30 g kg^{-1} and 4.80 to 6.90 g kg^{-1}, respectively and decreased with depth in both pedons. In other black soil pedons (III, IV, V, VI, XI, XII, XIII, IXV and XV) which produce second grade fruits, highest value (5.80 g kg^{-1}) was found in the surface depth of pedon XIII and lowest value (2.10 g kg^{-1}) was noticed in the >110 cm depth of pedon XV. In all the pedons, it decreased or remained same with depth. In the surface depth of these pedons, it ranged from 3.90 to 5.80 g kg^{-1} and was higher than found in subsurface depths. In mixed red and black soil pedon (VII), organic carbon content ranged from 1.70 to 3.00 g kg^{-1} found in the lowest and the surface depths,respectively. In red soil pedons which produce low yields with third grade fruits, organic carbon content ranged from 2.00 to 2.80 g kg^{-1} in the surface depth. Lowest value (1.00 g. kg^{-1}) was recorded in >90 cm depth of pedon IX and in all these pedons, it decreased with depth. Red soil pedons have lower values than black soil pedons.

4.3.6 Water soluble cations

A cursory look at the contents of Table 5 revealed that, among water soluble cations, sodium and calcium dominate over potassium and magnesium in all the pedons. Pedon I has lowest sodium content (2.04 to 2.33 cmol(p+)L^{-1}) than all other black soil pedons which produce second grade fruits. Highest value (3.25 cmol(p+)L^{-1}) was found in the 30-60 cm depth of pedon VI and lowest (2.04 cmol(p+)L^{-1}) was noticed in the surface depth of pedon I. Red soil pedons (VIII, IX and X) have lower water soluble sodium than other black soil pedons. It ranged from 1.10 to 1.20 and 1.02 to 1.20 cmol(p+)L^{-1} in pedons VIII and IX, respectively. Pedon X has lowest contents (0.16 to 0.24 cmol(p+)L^{-1}) and there is no definite trend in it's distribution with depth in all these red soil pedons unlike black soil pedons. Mixed red and black soil pedon (VII) has a range of 1.15 to 1.60 cmol(p+)L^{-1} and increased with depth.

Black soil pedons recorded higher water soluble potassium than red soil pedons (VIII, IX and X) including pedon VII (mixed red and black soil pedon). Highest value (0.14 cmol(p+)L^{-1}) was found in the 30 to 60 cm depth of pedon I, closely followed by the same depth of pedon XIII, followed by the surface depth of pedon I (0.11 cmol(p+)L^{-1}).

Water soluble calcium content was high in pedons I and II which produce first grade fruits and high yields. It ranged from 1.80 to 2.10 and 1.65 to 1.98 cmol(p+)L^{-1} in pedons I and II, respectively and increased with depth in both pedons. In other black soil pedons, that produce second grade fruits, highest value (1.85 cmol(p+)L^{-1}) was found in 30-60 cm depth of pedons IV and VI while lowest was 0.60 cmol(p+)L^{-1} recorded in the surface depth of pedon XV. Red soil pedons (VIII, IX and X) have water soluble calcium ranged from 0.40 (0-15 cm depth of pedon VIII) to 1.00 cmol(p+)L^{-1} found in the 30 to 60 cm depth of pedon IX and it was lower than observed in black soil pedons. Wide variation exist between black and red soil pedons with regard to water soluble calcium and magnesium contents.

4.3.7 Water soluble anions

Perusal of data presented in Table 5 indicated that, carbonates are negligible in all the pedons and the concentration of bicarbonates, chlorides and sulphates follow the order HCO_3>Cl>SO_4.

In general, all the black soil pedons have higher contents of all anions than red soil pedons and there was a narrow range in variation of all these anions with depth. Sulphate content increased with depth, while no definite trend was seen in the distribution of bicarbonates and chlorides.

4.4 Fertility status of soils

To evaluate the fertility status of chilli growing soils, the available nutrient status of major, secondary and micronutrients was determined. The data on fertility status of soils are presented in Table 6.

4.4.1 Available nitrogen

The black soil pedons (I and II) which produce first grade fruits with high yields have higher available nitrogen content in their soil bodies compared to other black soil pedons which produce second grade fruits with medium yields. Red soil pedons producing low yields and third grade fruits, have very low nitrogen content in their soil bodies. Highest available nitrogen content (366.40 kg ha^{-1}) was found in the surface depth of pedon II, closely followed by the surface depth of pedon I (312.40 kg ha^{-1}). In both pedons it decreased with depth.

Among black soil pedons, that produce second grade fruits and medium yields (pedons III, IV, V, VI, XI, XII, XIII, XIV and XV) highest nitrogen content (295.80 kg ha^{-1}) was found in the surface depth of pedon XIII closely followed by pedons IV, XI and XIV which recorded 259.10, 238.30 and 238.30 kg ha^{-1}, respectively. Lowest value (109.60 kg ha^{-1}) was found in the 30-60 cm depth of pedons III. In all these pedons, available nitrogen decreased with depth.

Among pedons that produce third grade fruits and low yields (pedons VII, VIII, IX and X), pedon VII has higher nitrogen content than other red soil pedons which ranged from 89.30 to 180.80 kg ha^{-1}. Among red soil pedons (VIII, IX and X), the surface depth of pedon IX has highest nitrogen content (164.10 kg ha^{-1}) closely followed by the same depth of pedon VIII (115.00 kg ha^{-1}) followed by the 15-30 cm depth of pedon IX

Table 6 . Fertility status of soil pedons

Depth (cm)	Major nutrients			Available sulphur (ppm)	Available micronutrients			
	Available nitrogen (kg/ha)	Available phosphorus P_2O_5 (kg/ha)	Available potassium K_2O (kg/ha)		Cu	Zn	Fe	Mn
					← ppm →			
1	2	3	4	5	6	7	8	9
PEDON-I (GUDGERI, Tq. Kundagol)								
0-15	312.40	36.60	847.90	28.70	1.50	1.00	3.68	28.90
15-30	219.80	26.60	666.50	31.50	1.38	0.44	4.22	21.90
30-60	205.60	14.60	506.10	35.10	1.62	0.64	4.68	29.20
60-110	-	-	-	-	1.66	0.60	2.92	14.00
>110	-	-	-	-	1.88	0.68	3.14	19.30
PEDON-II (DEVANUR, Tq. Kundagol)								
0-15	366.40	51.30	872.40	32.50	1.70	0.50	3.24	38.60
15-30	309.00	40.30	591.60	39.60	1.52	0.56	3.52	32.90
30-60	283.60	21.90	525.10	48.40	1.82	0.62	4.70	24.10
60-110	-	-	-	-	1.78	0.50	4.44	21.40
>110	-	-	-	-	1.86	0.58	4.00	19.80
PEDON-III (GANJIGATTI, Tq. Shiggaon)								
0-15	190.10	16.50	457.60	15.50	1.42	0.46	4.06	25.60
15-30	164.90	14.10	432.80	17.20	1.48	0.40	4.12	25.90
30-60	109.60	14.60	432.50	20.60	1.80	0.46	3.82	30.90
60-110	-	-	-	-	2.06	0.52	3.58	30.20
>110	-	-	-	-	1.96	0.92	2.98	33.30

Contd...

Depth (cm)	Major nutrients			Available sulphur (ppm)	Available micronutrients			
	Available nitrogen (kg/ha)	Available phosphorus P_2O_5 (kg/ha)	Available potassium K_2O (kg/ha)		Cu	Zn	Fe	Mn
					← ppm →			
1	2	3	4	5	6	7	8	9
PEDON-IV (DEVAGIRI, Tq. Haveri)								
0-15	259.10	25.40	470.60	16.10	1.36	0.36	4.44	39.70
15-30	158.90	18.20	456.50	19.00	1.52	0.64	3.82	37.20
30-60	155.60	11.10	348.30	26.80	1.74	0.98	3.28	31.70
60-110	-	-	-	-	1.65	0.88	3.14	30.60
>110	-	-	-	-	1.50	0.82	3.32	24.90
PEDON-V (SOMANHALLI, , Tq. Hirekerur)								
0-15	209.40	18.50	504.20	14.50	1.10	0.54	2.08	24.50
15-30	154.40	17.10	492.20	15.20	1.04	0.54	1.94	25.40
30-60	119.80	15.20	450.20	24.50	1.22	0.96	2.02	26.40
60-110	-	-	-	-	1.44	0.42	1.80	24.60
>110	-	-	-	-	1.08	0.34	1.62	23.80
PEDON-VI (MRS DHARWAD, Tq. Dharwad)								
0-15	215.50	21.10	613.60	15.00	1.54	0.48	6.52	23.40
15-30	186.00	19.50	536.60	17.10	1.08	0.34	4.32	13.50
30-60	164.90	14.80	337.90	21.50	1.80	0.24	2.06	15.70
60-110	-	-	-	-	1.60	0.26	2.12	13.10
>110	-	-	-	-	1.50	0.30	2.20	12.90

Contd...

Depth (cm)	Major nutrients			Available sulphur (ppm)	Available micronutrients			
	Available nitrogen (kg/ha)	Available phosphorus P_2O_5 (kg/ha)	Available potassium K_2O (kg/ha)		Cu	Zn	Fe	Mn
					← ppm →			
1	2	3	4	5	6	7	8	9
PEDON-VII (SAVANUR) Mixed red & black soil								
0-15	180.80	12.10	413.40	9.00	1.88	0.46	3.86	26.40
15-30	150.00	6.60	398.60	10.10	2.34	0.56	5.24	31.90
30-60	89.30	4.70	261.60	9.00	2.10	0.42	3.60	25.20
60-110	-	-	-	-	1.86	0.44	2.82	28.30
PEDON-VIII (KALAGOND, , Tq. Hirekerur) Red soil pedon								
0-15	115.00	14.20	375.30	3.50	2.10	0.44	13.34	45.70
15-30	74.30	12.20	265.40	4.50	2.08	0.32	8.82	30.60
>30	49.50	8.30	218.60	6.00	1.58	0.20	3.76	17.70
PEDON-IX (THIMMENHALLI, Tq: Byadgi) Red soil pedon								
0-15	164.10	22.90	340.60	6.25	1.56	0.56	4.90	17.30
15-30	112.40	21.10	316.10	7.50	1.74	0.30	4.58	21.60
30-60	98.30	17.50	246.80	9.00	2.26	0.36	4.36	10.70
60-90	-	-	-	-	2.26	0.30	4.86	9.74
>90	-	-	-	-	2.32	0.36	5.30	9.94
PEDON-X (ASUNDI, Tq. Ranebennur) Red soil pedon								
0-15	97.90	18.90	342.60	4.20	1.88	0.66	2.48	8.30
15-30	77.50	12.10	319.40	3.70	1.78	0.84	2.18	6.00
>30	50.00	13.10	315.70	4.80	1.68	0.58	1.38	7.50

Contd...

Depth (cm)	Major nutrients			Available sulphur (ppm)	Available micronutrients			
	Available nitrogen (kg/ha)	Available phosphorus P_2O_5 (kg/ha)	Available potassium K_2O (kg/ha)		Cu	Zn	Fe	Mn
					← ppm →			
1	2	3	4	5	6	7	8	9
PEDON-XI (ANNIGERI, Tq. Navalgund)								
0-15	238.30	30.40	796.60	23.20	1.10	0.38	3.00	20.60
15-30	189.40	25.60	666.80	30.50	1.16	0.54	2.94	16.90
30-60	164.40	17.40	540.40	35.90	1.20	0.54	2.48	15.20
60-110	-	-	-	-	1.44	1.00	3.36	18.60
>110	-	-	-	-	1.58	0.50	3.42	16.80
PEDON-XII (YALIWAL, Tq: Kundagol)								
0-15	184.80	18.40	450.20	22.50	1.42	0.66	3.70	39.40
15-30	164.00	11.80	380.70	27.20	1.34	0.52	4.28	35.70
30-60	118.30	10.10	364.00	28.00	1.58	0.82	3.80	24.20
60-110	-	-	-	-	1.68	0.98	3.16	22.00
>110	-	-	-	-	1.46	1.28	2.24	18.50
PEDON-XIII (MALLIGAWAD, Tq: Hubli)								
0-15	295.80	32.00	677.80	26.70	1.65	0.65	3.50	25.60
15-30	243.70	28.60	439.80	29.30	1.70	0.70	3.70	28.50
30-60	216.40	22.60	575.30	35.90	1.60	0.60	4.70	19.60
60-110	-	-	-	-	1.55	0.55	4.30	17.30
>110	-	-	-	-	1.50	0.49	4.00	13.50

Contd...

Depth (cm)	Major nutrients			Available sulphur (ppm)	Available micronutrients			
	Available nitrogen (kg/ha)	Available phosphorus P_2O_5 (kg/ha)	Available potassium K_2O (kg/ha)		Cu	Zn	Fe	Mn
					← ppm →			
1	2	3	4	5	6	7	8	9
PEDON-XIV (SAIDAPUR, Tq. Navalgund)								
0-15	238.30	23.90	785.20	28.50	1.56	0.82	3.48	22.10
15-30	209.60	23.50	510.40	34.10	1.66	0.52	4.34	23.00
30-60	183.70	22.10	436.50	35.85	1.28	0.54	2.04	24.20
60-110	-	-	-	-	1.28	0.32	2.42	25.10
>110	-	-	-	-	1.60	1.02	1.84	25.60
PEDON-XV (KURTKOTI, Tq: Gadag)								
0-15	209.90	23.80	612.60	22.00	1.60	0.50	2.96	22.80
15-30	188.40	17.50	632.10	26.20	1.96	1.54	3.64	28.70
30-60	165.30	17.80	526.20	34.20	1.62	0.44	3.70	19.70
60-110	-	-	-	-	2.48	0.44	3.36	33.50
>110	-	-	-	-	1.98	2.14	1.82	22.80

(112.40 kg ha^{-1}). Pedon X has lower nitrogen content than other two red soil pedons ranging from 50.00 to 97.90 kg ha^{-1}. Lowest nitrogen content (49.50 kg ha^{-1}) was observed in the 30-60 cm depth of pedon VIII. Nitrogen content decreased with depth in these red soil pedons also.

4.4.2 Available phosphorus

Phosphorus content in pedon I and II ranged from 14.60 to 36.60 and 21.90 to 51.30 kg ha^{-1}, respectively and decreased with depth in both pedons. In other black soil pedons that produce second grade fruits (pedons III, IV, V, VI, XI, XII, XIII, XIV and XV) highest value (32.00 kg ha^{-1}) was found in the surface depth of pedon XIII, while lowest value (16.50 kg ha^{-1}) was found in the surface depth of pedon III. Available phosphorus decreased with depth in all these pedons. Pedon XIII has higher phosphorus status closely followed by pedon XI. Among pedons that produced third grade fruits and low yields, pedon VII has lower phosphorus content than other red soil pedons (VIII, IX and X). In the 0-15 cm depth, highest value of 22.90 kg ha^{-1} was found in pedon IX closely followed by pedon X (18.90 kg ha^{-1}), followed by pedon VIII (14.20 kg ha^{-1}). Among these red soil pedons, pedon IX has higher available phosphorus content than pedons VIII and X.

4.4.3 Available potassium

Black soil pedons have higher available potassium content than red soil pedons. In the surface depth of pedons I and II, maximum potassium content (872.40 kg ha^{-1}) was noticed in pedon II, closely followed by pedon I (847.90 kg ha^{-1}) and decreased with depth. In other black soil pedons (III, IV, V, VI, XI, XII, XIII, IXV and XV), highest available potassium (796.60 kg ha^{-1}) was recorded in the surface depth of pedon XIII, closely followed by the same depth of pedon XIV (785.20 kg ha^{-1}) followed by pedon

XII (677.80 kg ha^{-1}). Lowest value (337.96) was found in the 30-60 cm depth of pedon VI. Pedons III and IV have lower potassium status in their soil bodies compared to other soil pedons.

In pedon VII, available potassium content ranged from 261.60 to 413.40 kg ha^{-1} and decreased with depth.

Among red soil pedons (VIII, IX and X) which produce low yields and third grade fruits, the surface depth of pedon-VIII recorded highest available potassium (375.30 kg ha^{-1}) closely followed by the same depth of pedon X (342.60 kg ha^{-1}) and followed by pedon IX (340.60 kg ha^{-1}). Lowest value (218.60 kg ha^{-1}) was found in the >30 cm depth of pedon VIII. It decreased with depth in all these pedons.

4.4.4 Available sulphur

The data on available sulphur is presented in Table 6. Pedon II has highest available sulphur content in all the depths compared to other pedons. Pedons I and II have sulphur content ranging from 28.70 to 35.10 and 32.50 to 48.40 ppm respectively and increased with depth in both pedons. In other black soil pedons (III, IV, V, VI, XI, XII, XIII, XIV and XV), sulphur content in the surface ranged from 14.50 ppm (pedon V) to 28.50 ppm (pedon XIV). Highest sulphur content (35.90 ppm) was noticed in 30-60 cm depth of pedons XI and XIII, while pedons III has lowest (20.60 ppm) sulphur in the same depth. In 15 to 30 cms. depth of these pedons, sulphur content ranged from 15.20 ppm (pedon V) to 34.10 ppm (pedon XIV). In general, pedon XIV has higher available sulphur content, closely followed by pedons XIII, XI, XII and XV. Pedons III, IV, V and VI have lower sulphur content in all the depths compared to other pedons. In all the pedons it increased with depth.

The mixed red and black soil (pedon VII), has sulphur content ranged from 9.00 to 10.10 ppm. In other red soil pedons (VIII, IX and X) that produced third grade fruits, with low yields, in the surface layer, it ranged from 3.50 ppm (pedon VIII) to 6.25 (pedon IX). Highest sulphur content (9.00 ppm) was noticed in 30-60 cm depth of pedon IX. Red soil pedons have lower sulphur content in all the depths compared to black soil pedons and have narrow variation with depth.

4.4.5 Available micronutrients

The data pertaining to status of available micronutrients viz., copper, zinc, iron and manganese in soil bodies is presented in Table 6. In all the soil bodies studied, the concentration of micronutrients follow the order Mn>Fe>Cu>Zn. In general, not much variation was noticed in the concentration of copper, zinc and iron in soil profiles which produce different quality fruits, but manganese concentration differs widely in its concentration. Hence, results pertaining to available micronutrients are summarised by grouping all the profiles together.

4.4.5(a) Available copper

In the 0-15 cms. depth, available copper was maximum (2.54 ppm) in pedon VI closely followed by pedon VIII (2.10 ppm). Lowest copper content in this depth was noticed in pedons V and XI (1.10 ppm). In the 15 to 30 cm depth, highest value (2.34 ppm) was in pedon VII closely followed by pedons VIII and VI (2.08 ppm), while lowest value of 1.04 ppm was observed in pedon V. In the 30 to 60 cm depth, it's value ranged from 1.20 ppm to 2.26 ppm found in pedons XI and IX respectively. In the lower depths of 60 to 110 cm and >110 cm it's value ranged form 1.28 (pedon XIV) to 2.48 ppm (pedon XV) and 1.08 ppm (pedon V) to 2.32 ppm (pedon IX), respectively. No definite trend in it's distribution with depth was observed.

4.4.5(b) Available zinc

Pedon-I recorded highest zinc content (1.00 ppm) in the surface closely followed by pedon XIV which recorded 0.82 ppm in the same depth. Lowest concentration of 0.36 ppm was noticed in pedon IV. In 15-30 cm depth, zinc content ranged from 0.30 ppm (pedon IX) to 1.54 ppm (pedon XV). Zinc concentration ranged from 0.20 to 0.98, 0.30 to 1.00 and 0.30 to 2.14 ppm in 30 to 60, 60 to 110 and >110 cm depths, respectively. No definite increase or decrease was noticed in all these pedons with depth.

4.4.5(c) Available iron

Perusal of data presented in Table 6 indicates that, red soil pedon (pedon VIII) which is acidic in nature has highest iron content (13.34 ppm) in the surface layer, closely followed by the 15 to 30 cm depth of same pedon (8.82 ppm). In the surface, lowest iron content (2.08 ppm) was observed in pedon V and 6.52 ppm of iron was recorded in pedon VI, next only to pedon VIII. In 15-30 cm depth, available iron ranged from 1.94 ppm (pedon V) to 8.82 ppm (pedon VIII), and in 30 to 60 cm depth, its range was 1.38 ppm found in pedon X to 4.70 ppm found in pedons II and XIII. Similarly in lower depths of 60 to 110 cm and >110 cm depths, lowest concentration of 1.80 ppm was found in pedon V, while highest value was 5.30 ppm found in pedon IX. No definite pattern of distribution with depth was observed in all the pedons.

4.4.5(d) Available manganese

Perusal of data presented in Table 6 indicates that, wide variation exists in the manganese content of pedons producing different quality fruits unlike copper, zinc and iron contents in profiles. Pedons I and II which produce first grade fruits and high yields have manganese content in the range of 14.00 to 29.20 and 19.80 to 38.60 ppm, respectively. In pedon II, it decreased with depth, while no definite trend was observed in pedon I. In other black soil pedons (III, IV, V, VI, XI, XII, XIII, XIV and XV) which produce second grade fruits with medium yields, pedon IV has highest Mn content with a range of 24.90 to 39.70 ppm and lowest was present in pedon VI with a range of 12.90 to 23.40 ppm. Most of the pedons show wide variation in the concentration of Mn and no definite pattern of distribution with depth was noticed in all these pedons.

In pedons (VII, VIII, IX and X) which produce low yields with third grade fruits, highest Mn content (45.70 ppm) was noticed in the surface of pedon VIII closely followed at 15-30 cm of same pedon (30.60 ppm). Among pedons IX and X, pedon X has lower manganese content which ranged from 6.00 ppm to 8.30 ppm compared to pedon IX (9.74 to 21.00 ppm). Pedon VII has Mn concentration in the range of 25.20 to 31.90 ppm.

4.5 Growth attributes of chilli cultivars

Growth attributes recorded at different growth stages in different locations are presented below.

4.5.1 Plant height

4.5.1(a) Byadgi kaddi cv.

Data pertaining to plant height recorded at different growth stages (45, 75, 105 and 140 DAT) in different locations are tabulated in Table 7.

The three groups of locations producing different grade fruits differed significantly with respect to plant height as shown by F test by contrast. Highest plant

Table 7 : Plant height of chilli (Cv. Byadgi kaddi)at different growth stages at various locations

PLANT HEIGHT (cm)

Days after transplanting (DAT)	LOCATIONS										
	Gudgeri	Devanur	Ganjigatti	Devagiri	Somanhalli	Dharwad	Savanur	Kalagond	Thimmenhalli	Asundi	MEAN
	Ist grade (A)		IInd grade (B)				IIIrd grade (C)				
45	46.18	46.70	33.90	42.80	36.80	38.65	34.05	27.85	32.10	27.10	**36.61**
75	74.95	75.20	61.05	74.10	68.60	72.05	63.65	49.95	53.70	46.60	**63.99**
105	88.75	89.90	71.15	88.90	76.80	85.50	74.35	54.85	59.55	52.30	**74.21**
140	96.45	95.80	80.95	95.70	81.45	89.20	77.30	56.45	61.90	53.63	**78.88**
MEAN (Location)	**76.58**	**76.90**	**61.76**	**75.38**	**65.91**	**71.35**	**62.34**	**47.28**	**51.81**	**44.91**	
MEAN (for grade)	**76.74**		**68.60**				**51.59**				

For comparing means of	S.Em±	CD (0.05)	For comparing grade means by contrast F test	
Locations (L)	1.32	3.76	A Vs. B	*
DAT	0.83	2.38	A Vs. C	*
L X DAT	2.63	7.52	B Vs. C	*

* Significant at 5%

height (76.74 cm) was found in plants of first group locations while lowest (51.59 cm) was found in plants of third group locations and plants of second group locations were intermediate in plant height (68.60 cm).

Table 7 indicated that, plants of Devanur location recorded highest height (76.90 cm), whereas plants of Asundi location recorded lowest (44.91 cm) and significant difference existed between the two locations. Plants of Devanur and Gudgeri locations were on par with each other which produced first grade fruits.

Among second grade locations, plants of Devagiri location recorded significantly higher plant height (75.38 cm) than plants of other three locations. Similarly among third grade locations,plants of Savanur location recorded higher plant height (62.34 cm) compared to other three locations and significant difference existed between these locations. Among these three red soil locations, plants of Thimmenhalli location recorded significantly higher value (51.81 cm) than plants of Kalagond and Asundi locations.

All growth stages differed significantly with respect to plant height. It increased from 36.61 cm to 78.88 cm recorded at 45 and 140 DAT,respectively.

Interaction effects of locations and growth stages influenced the plant height significantly. At all growth stages, plants of Devanur location recorded highest height closely followed by plants of Gudgeri, Devagiri and Dharwad locations, while plants of Asundi location recorded lowest height. Among second grade locations, plants of Devagiri location recorded higher plant height at all the stages compared to other three locations. Similarly, all the interactions of Savanur location differed significantly from other three locations.

4.5.1(b) Dyavnur and Byadgi dabbi cvs. **Table 7(a)**

In both cultivars, significant difference existed between first and second grade locations with respect to plant height and plants of first grade locations recorded higher height (74.29 and 74.63 cm for Dyavnur and Byadgi dabbi cultivars, respectively) than second grade locations (F test by contrast).

It is observed that, plants of Devanur location recorded highest height (76.41 and 77.56 cm for Dyavnur and Byadgi dabbi cvs. respectively) closely followed by plants of Gudgeri location. Similarly lowest plant height was recorded in drill sown plants of Annigeri (60.44 cm) and Saidapur (54.85 cm) locations for Dyavnur and Byadgi dabbi cultivars, respectively.

Plant height differed significantly at all growth stages and in Dyavnur cv. it increased from 39.31 cm at 45 DAT to 88.50 cm at 140 DAT and in Byadgi dabbi cv. it increased from 36.82 cm to 85.19 cm recorded at 45 and 140 DAT, respectively.

In both cultivars, interaction effects were non significant in influencing the plant height, which suggests that, plants of different locations did not differ significantly with respect to plant height at a particular growth stage (either at 45 or 75 or 105 or at 140 DAT). However, plants of Devanur location recorded highest height at all stages followed by plants of Gudgeri location. Usually drill sown plants had lower height than transplanted locations in both cultivars.

4.5.2 Number of branches

4.5.2(a) Byadgi kaddi cv. **Table 8**

Plants of first grade locations produced highest number of branches (16.19) and differed significantly plants of second (10.32) and third grade (6.47) locations as shown

Table 7(a) : *Plant height of chilli (Cvs. Dyavnur and Byadgi dabbi) at different growth stages at various locations*

PLANT HEIGHT (cm)

Days after transplanting (DAT)	Cv. DYAVNUR					MEAN	Cv. BYADGI DABBI						MEAN
	LOCATIONS						LOCATIONS						
	Gudgeri	Devanur	Ganjigatti	Dharwad	Annigeri ¢		Gudgeri	Devanur	Yaliwal	Malligawad¢	Saidapur¢	Kurtkoti ¢	
	Ist GRADE (A)		IInd GRADE (B)				Ist GRADE (A)		IInd GRADE (B)				
45	41.80	45.05	37.45	41.30	30.95	**39.31**	42.15	45.75	38.35	35.05	28.75	30.85	**36.82**
75	69.55	75.30	67.40	69.48	56.80	**67.71**	67.60	75.40	65.45	62.35	50.60	52.05	**62.24**
105	85.00	91.30	80.45	83.55	74.05	**82.87**	85.70	91.00	79.00	81.00	67.20	67.85	**78.63**
140	92.30	94.00	86.70	89.75	79.95	**88.50**	91.30	98.10	89.95	84.85	72.85	74.10	**85.19**
MEAN (LOCATIONS)	**72.16**	**76.41**	**68.00**	**70.97**	**60.44**		**71.69**	**77.56**	**68.19**	**65.81**	**54.85**	**56.21**	
MEAN FOR GRADE	**74.29**		**66.47**				**74.63**		**61.27**				

For comparing means of	S.Em±	CD (0.05)	For comparing grade means by contrast	F test		For comparing means of	S.Em±	CD (0.05)	For comparing grade means by contrast	F test
Locations (L)	0.85	2.50	A Vs. B	*		Locations (L)	3.27	9.55	A Vs. B	*
DAT	0.75	2.23				DAT	2.67	7.80		
L X DAT	1.69	NS				L X DAT	6.55	NS		

*Significant at 5 per cent   NS – Non significant   ¢ - Drill sown locations.

Table 8 : Number of branches per plant (Cv. Byadgi kaddi) at different growth stages at various locations

NO. OF BRANCHES

Days after transplanting (DAT)	LOCATIONS										
	Gudgeri	Devanur	Ganjigatti	Devagiri	Somanhalli	Dharwad	Savanur	Kalagond	Thimmenhalli	Asundi	MEAN
	Ist grade (A)		IInd grade (B)				IIIrd grade (C)				
45	5.15	6.15	2.95	3.35	3.35	4.65	3.00	2.35	2.65	2.15	**3.58**
75	14.05	18.40	9.85	9.75	8.00	12.85	8.55	6.10	6.80	5.35	**9.97**
105	18.85	20.50	11.60	13.50	10.80	14.05	10.80	7.05	7.65	6.35	**12.12**
140	21.70	24.70	13.55	14.35	13.70	18.75	11.85	7.70	8.35	6.80	**14.15**
MEAN (Locations)	**14.94**	**17.44**	**9.49**	**10.24**	**8.96**	**12.58**	**8.55**	**5.80**	**6.36**	**5.16**	
MEAN (for grade)	**16.19**		**10.32**				**6.47**				

For comparing means of	S.Em±	CD (0.05)	For comparing grade means by contrast F test	
Locations (L)	0.47	1.34	A Vs. B	*
DAT	0.29	0.85	A Vs. C	*
L X DAT	0.94	2.69	B Vs. C	*

* Significant at 5%

by F test after contrasting. Further, plants of Devanur location produced highest number of branches (17.44) followed by plants of Gudgeri, Dharwad and Devagiri locations and significant difference existed between these locations. Lowest number of branches (5.16) were found in plants of Asundi red soil location and were on par with plants of Kalagond and Thimmenhalli locations.

Among second grade locations, plants of Dharwad location with 12.58 number of branches differed significantly from other three locations. Similarly among third grade locations plants of Savanur location with 8.55 number of branches differed significantly from other three locations which were on par with each other.

Growth stages differed significantly with respect to number of branches produced and increased from 3.58 (at 45 DAT) to 14.15 (at 140 DAT).

Interaction effects of locations and growth stages influenced the number of branches per plant significantly. This implies that, at a particular growth stage plants of various locations differed significantly with respect to number of branches. At all growth stages, plants of Devanur location recorded highest number of branches closely followed by plants of Gudgeri and Dharwad locations. Similarly, lowest number of branches at all stages were observed in plants of Asundi red soil location, which were on par with plants of Kalagond and Thimmenhalli locations but differed significantly from plants of other locations except at 45 DAT.

4.5.2(b) Dyavnur and Byadgi dabbi cvs. **Table 8(a)**

F test showed that in both cultivars, significant difference existed between first and second grade locations for the number of branches produced by plants. Plants of first grade locations recorded higher number of branches (14.67 and 15.16 for Dyavnur and

Table 8(a) : Number of branches per plant (Cv. Dyavnur and Byadgi dabbi) at different growth stages at various locations

NO. OF BRANCHES

Days after transplanting (DAT)	Cv. DYAVNUR					MEAN	Cv. BYADGI DABBI						MEAN
	LOCATIONS						LOCATIONS						
	Gudgeri	Devanur	Ganjigatti	Dharwad	Annigeri ⊄		Gudgeri	Devanur	Yaliwal	Malligawad⊄	Saidapur⊄	Kurtkoti ⊄	
	Ist GRADE (A)		IInd GRADE (B)				Ist GRADE (A)		IInd GRADE (B)				
45	4.70	5.20	3.35	3.75	3.50	**4.10**	3.75	5.50	3.50	3.35	2.25	2.60	**3.49**
75	15.45	16.90	9.75	11.25	8.05	**12.28**	14.40	17.20	12.85	8.85	6.60	5.30	**10.87**
105	17.10	18.60	12.55	12.25	10.65	**14.23**	18.35	18.85	14.70	10.35	8.20	7.55	**13.00**
140	18.75	20.60	14.35	13.70	13.15	**16.11**	20.95	22.30	16.65	12.25	10.50	9.45	**15.35**
MEAN (LOCATIONS)	**14.00**	**15.33**	**10.00**	**10.24**	**8.84**		**14.36**	**15.96**	**11.93**	**8.70**	**6.89**	**6.23**	
MEAN FOR GRADE	**14.67**		**9.69**				**15.16**		**8.44**				

For comparing means of	S.Em±	CD (0.05)	For comparing grade means by contrast	F test		For comparing means of	S.Em±	CD (0.05)	For comparing grade means by contrast	F test
Locations (L)	0.53	1.57	A Vs. B	*		Locations (L)	0.50	1.47	A Vs. B	*
DAT	0.48	1.41				DAT	0.41	1.20		
L X DAT	1.06	NS				L X DAT	1.00	2.93		

* Significant at 5 per cent NS – Non significant ⊄ - Drill sown locations.

Byadgi dabbi cvs. respectively) than plants of second grade locations (9.69 and 8.44 for Dyavnur and Byadgi dabbi cvs. respectively).

In both cultivars, plants of Devanur location recorded highest number of branches (15.33 and 15.92 for Dyavnur and Byadgi dabbi cultivars respectively) closely followed by plants of Gudgeri location. In Dyavnur cv. all the three locations that produced second grade fruits were on par with one another, but in Byadgi dabbi cv. among the four locations plants of Saidapur and Kurtkoti locations were on par with each other but differed significantly from Yaliwal and Malligawad locations. Generally drill sown plants recorded less number of branches than transplanted plants in both cultivars.

All the growth stages differed significantly with respect to number of branches produced and increased from 4.10 to 16.11 and 3.49 to 15.35 for Dyavnur and Byadgi dabbi cultivars,respectively.

Interaction effects were non significant in influencing the number of branches produced by plants in Dyavnur cultivar, but in Byadgi dabbi cv. interaction effects were significant.

4.5.3 Total dry matter yield

4.5.3(a) Byadgi kaddi cv. **Table 9**

Significant difference existed between first, second and third grade locations with respect to dry matter yield produced by plants (F test by contrast). Plants of first grade locations produced highest dry matter yield (74.53 g/plant), while those of third grade locations recorded lowest (24.88 g/plant) and plants of second grade locations were in between plants of first and third grade locations (59.16 g/plant).

Table 9 : Total dry matter yield of chilli (Cv. Byadgi kaddi) at different growth stages at various locations

TOTAL DRY MATTER YIELD (g/plant)

Days after transplanting (DAT)	LOCATIONS										
	Gudgeri	Devanur	Ganjigatti	Devagiri	Somanhalli	Dharwad	Savanur	Kalagond	Thimmenhalli	Asundi	MEAN
	Ist grade (A)		IInd grade (B)				IIIrd grade (C)				
45	6.53	6.61	5.85	6.92	4.63	3.90	3.48	2.48	2.60	2.33	**4.53**
75	48.25	47.87	42.79	45.63	30.19	31.56	24.68	11.25	21.76	15.59	**31.96**
105	110.08	108.82	96.33	102.67	68.25	73.61	54.79	22.38	31.90	25.15	**69.40**
140	133.26	134.78	112.78	131.84	89.73	101.10	67.63	32.33	47.58	32.33	**88.32**
MEAN (Locations)	**74.53**	**74.52**	**64.43**	**71.76**	**48.20**	**52.54**	**37.64**	**17.08**	**25.96**	**18.85**	
MEAN (for grade)	**74.53**		**59.16**				**24.88**				

For comparing means of	S.Em±	CD (0.05)	For comparing grade means by contrast F test	
Locations (L)	2.46	7.02	A Vs. B	*
DAT	1.55	4.44	A Vs. C	*
L X DAT	4.92	14.05	B Vs. C	*

* Significant at 5%

Plant samples of different locations differed significantly with respect to total dry matter yield produced by plants. Plants of Gudgeri and Devanur locations produced highest dry matter (75.53 and 74.52 g/plant, respectively) closely followed by plants of Devagiri location (71.76 g/plant) and all the three locations were on par with each other. Lowest dry matter yield (17.08 g/plant) was found in plants of Kalagond location and were on par with plants of Asundi location having 18.85 g per plant of dry matter yield. Among second grade locations, plants of Devagiri location with 71.76 g/plant of dry matter yield differed significantly from plants of other three locations, whereas plants of Somanhalli and Dharwad locations were on par with each other. Similarly among third group locations plants of Savanur location recorded highest value (37.64 g/plant) and differed significantly from plants of other three red soil locations.

All growth stages differed significantly with respect to dry matter yield and there was almost eight fold increase at 75 DAT (31.96 g/plant) from 45 DAT (4.53 g/plant) and two fold increase at 105 DAT (69.40 g/plant) from 75 DAT.

Interaction effects were significant in influencing the dry matter yield and at all the stages plants of Gudgeri and Devanur locations have produced almost same amount of dry matter and were on par with each other. Among second grade locations at 45 DAT, plants of all the four locations were on par with each other, but in subsequent growth stages (75, 105 or 140 DAT), plants of Devagiri location differed significantly from Somanhalli and Dharwad location plants. Plants of all the three red soil locations were on par with each other for dry matter yield at first three stages and plants of Thimmenahalli location recorded higher dry matter yield than plants of Kalagond and Asundi locations.

4.5.3(b) Dyavnur and Byadgi dabbi cvs. Table 9(a)

In both cultivars, plants of first grade locations recorded higher dry matter yield (65.00 and 64.52 g/plant for Dyavnur and Byadgi dabbi cultivars respectively) than second grade locations and significant difference existed between them as revealed by F test by contrast.

In both cultivars, plants of Devanur location recorded highest dry matter yield (72.86 and 68.77 g/plant for Dyavnur and Byadgi dabbi cvs. respectively) followed by plants of Gudgeri location and significant difference existed between them. Among locations that produced second grade fruits in Dyavnur cultivar, plants of Ganjigatti location recorded significantly higher dry matter yield (49.53 g/plant) than plants of Dharwad and Annigeri locations. Similarly in Byadgi dabbi cultivar, plants of Yaliwal location recorded highest dry matter yield (52.85 g plant) and differed significantly from other three locations. Lowest dry matter yield (27.75 g/plant) was found in drill sown plants of Kurtkoti location that differed significantly from Malligawad and Saidapur locations having 41.04 and 36.24 g per plant of dry matter yield respectively.

Growth stages of plants differed significantly with respect to dry matter yield in both cultivars. In Dyavnur cv. ,it increased from 5.06 g per plant at 45 DAT to 98.69 g per plant at 140 DAT and in Byadgi dabbi cv. it increased from 4.53 g per plant to 89.53 g per plant.

Interaction effects of locations and growth stages influenced the dry matter yield significantly in both cultivars. However at 45 DAT, plants of all locations were on par with one another. Plants of Devanur location recorded highest dry matter yield at all stages and differed significantly from plants of other locations with few exceptions of non significant difference between Gudgeri and Devanur locations at 75 and 105 DAT in

Table 9(a) : Total dry matter yield of chilli (Cvs. Dyavnur and Byadgi dabbi) at different growth stages at various locations

TOTAL DRY MATTER YIELD (g/plant)

Days after transplanting (DAT)	Cv. DYAVNUR					MEAN	Cv. BYADGI DABBI						MEAN
	LOCATIONS						LOCATIONS						
	Gudgeri	Devanur	Ganjigatti	Dharwad	Annigeri ⊄		Gudgeri	Devanur	Yaliwal	Malligawad⊄	Saidapur⊄	Kurtkoti ⊄	
	Ist GRADE (A)		IInd GRADE (B)				Ist GRADE (A)		IInd GRADE (B)				
45	5.78	5.92	5.13	4.61	3.87	**5.06**	5.23	6.53	5.10	3.38	3.98	2.96	**4.53**
75	31.61	44.76	29.56	24.45	21.56	**30.38**	38.41	43.24	31.68	22.92	22.30	18.54	**29.51**
105	78.03	101.79	65.76	54.30	47.87	**69.55**	83.78	100.15	71.28	58.67	52.86	39.56	**67.72**
140	113.14	138.99	97.68	74.13	69.54	**98.69**	113.63	125.18	103.36	79.21	65.83	49.96	**89.53**
MEAN (LOCATIONS)	**57.14**	**72.86**	**49.53**	**39.37**	**35.71**		**60.26**	**68.77**	**52.85**	**41.04**	**36.24**	**27.75**	
MEAN FOR GRADE	**65.00**		**41.54**				**64.52**		**39.47**				

For comparing means of	S.Em±	CD (0.05)	For comparing grade means by contrast	F test		For comparing means of	S.Em±	CD (0.05)	For comparing grade means by contrast	F test
Locations (L)	1.55	4.58	A Vs. B	*		Locations (L)	1.21	3.53	A Vs. B	*
DAT	1.39	4.10				DAT	0.98	2.88		
L X DAT	3.10	9.16				L X DAT	2.41	7.05		

*Significant at 5 per cent ⊄ - Drill sown locations.

Byadgi dabbi cv. Usually drill sown plants recorded lower dry matter yield at all stages than transplanted plants in both cultivars.

4.5.4 Root weight/plant at 75 DAT

4.5.4(a) Byadgi kaddi cv. Table 10

Root samples of first, second and third grade locations differed significantly with respect to root weight at 75 DAT (F test by contrast) and plants of first grade locations recorded highest root weight (10.23 g/plant), while those of third grade locations recorded lowest (2.60 g/plant) and plants of second grade locations were intermediate (7.50 g/plant) in root weight.

It is observed that, plants of Devanur location producing first grade fruits recorded highest root weight (10.75 g/plant) and were on par with plants of Gudgeri and Devagiri locations with 9.70 and 9.60 g per plant of root weight, respectively. Similarly plants of Asundi location that produced third grade fruits and lowest yield recorded lowest value (1.85 g/plant), and were on par with plants of other two red soil locations but differed significantly from other locations.

4.5.4(b) Dyavnur and Byadgi dabbi cvs. Table 10(a)

In both cultivars, significant difference existed between first and second grade locations (t-test) with respect to root weight and plants of first grade locations recorded higher root weight (10.60 and 12.80 g/plant for Dyavnur and Byadgi dabbi plants, respectively) than second grade locations (5.48 and 6.64 g/plant for Dyavnur and Byadgi dabbi plants, respectively).

Similar to Byadgi kaddi, in both cultivars plants of Devanur location recorded highest root weight (12.75 and 14.65 g/plant) for Dyavnur and Byadgi dabbi cvs. respectively) closely followed by plants of Gudgeri location (8.45 and 10.95 g/plant). Similarly, drill sown plants of Annigeri and Saidapur locations recorded lowest values (3.75 and 5.05 g/plant) of root weight for Dyavnur and Byadgi dabbi cultivars, respectively. It was found that, in both cultivars transplanted crop locations have higher root weight than drill sown locations.

4.5.5 Yield and yield components

Data on yield and yield components (cvs. Byadgi kaddi, Dyavnur and Byadgi dabbi) recorded at harvest are presented in Tables 10 and 10(a).

4.5.5(a) Byadgi kaddi cv.

Perusal of data presented in Table 10 reveal that, significant difference existed between first, second and third grade locations with respect to yield and yield components. Plants of first grade locations (Gudgeri and Devanur) recorded highest yield (12.05 q/ha) and yield components, while, those of third grade locations recorded lowest yield (2.76 q/ha) and yield components and plants of second grade locations were intermediate in yield (6.63 q ha^{-1}) and yield components.

Among first grade locations plants of Devanur location recorded highest yield (12.60 q/ha) and yield components and were on par with plants of Gudgeri location (11.50 q/ha). These two locations differed significantly from all other locations with respect to yield and yield components except for 100 fruit weight of Devagiri location. Among second grade locations, plants of Devagiri location recorded significantly highest yield (9.13 q/ha) and yield components whereas plants of remaining three locations

Table 10. Root weight per plant at 75 DAT and yield and yield components of chilli (cv. Byadgi kaddi) at harvest at different locations

Locations	Fruit grade	Root weight per plant (gm) [at 75 DAT]	No. of fruits per plant	Weight of 100 chilli fruits (gm)	Fruit weight per plant (gm)	Yield (qtls./ha.)
Gudgeri	Ist Grade	9.70	83.50	94.76	68.75	11.50
Devanur	(A)	10.75	84.00	95.23	69.38	12.60
		10.23	**83.75**	**94.99**	**69.07**	**12.05**
Ganjigatti		7.35	50.00	77.05	34.00	6.25
Devagiri		9.60	72.00	92.20	54.88	9.13
Somanhalli	IInd Grade	5.80	46.00	76.06	24.00	5.25
Dharwad	(B)	7.25	63.00	73.49	37.88	5.88
		7.50	**57.75**	**79.70**	**37.69**	**6.63**
Savanur		3.50	25.00	64.89	11.00	3.38
Kalagond		3.05	18.00	63.54	7.50	2.40
Thimmenhalli	IIIrd Grade	2.00	21.00	65.89	10.00	3.13
Asundi	(C)	1.85	16.50	59.88	5.13	2.13
		2.60	**20.13**	**63.55**	**8.41**	**2.76**
For comparing locations	S.Em±	0.47	2.18	1.72	1.49	0.42
	C.D. (0.05)	1.49	6.97	5.50	4.77	1.33
	F-test					
For comparing grade means by contrast	A Vs B	*	*	*	*	*
	A Vs C	*	*	*	*	*
	B Vs C	*	*	*	*	*

Note: Figures in bold indicate grade means compared with F test by contrast
* Significant at 5 per cent.

Table 10(a) . Root weight per plant at 75 DAT and yield/yield components of chilli (Cvs. Dyavnur and Byadgi dabbi) at harvest at different locations

Dyavnur Cv.

Locations	Fruit grade	Root weight per plant (gm) [at 75 DAT]	No. of fruits per plant	Weight of 100 chilli fruits (gm)	Fruit weight per plant (gm)	Yield (qtls./ha.)
Gudgeri	Ist Grade	8.45	40.50	109.69	34.88	8.73
Devanur	(A)	12.75	49.50	109.92	41.25	9.07
	Mean (A)	**10.60**	**45.00**	**109.81**	**38.06**	**8.90**
Ganjigatti		6.20	27.50	103.35	22.00	4.35
Dharwad	IInd Grade	6.50	30.50	108.17	26.00	4.88
Annigeri	(B)	3.75	20.50	102.40	16.75	5.88
	Mean (B)	**5.48**	**26.17**	**104.64**	**21.58**	**5.04**
Cal. 't' value		3.53	3.71	2.24	3.93	6.54
Table 't' (0.05) at 3df	3.18	*	*	NS	*	*

Byadgi dabbi Cv.

Locations	Fruit grade	Root weight per plant (gm) [at 75 DAT]	No. of fruits per plant	Weight of 100 chilli fruits (gm)	Fruit weight per plant (gm)	Yield (Qtls./ha.)
Gudgeri	Ist Grade	10.95	28.50	184.75	42.50	9.13
Devanur	(A)	14.65	36.00	194.43	60.13	11.25
	Mean (A)	**12.80**	**32.25**	**189.59**	**51.32**	**10.19**
Yaliwal		7.65	23.50	175.94	30.25	5.75
Malligawad	IInd Grade	6.65	20.50	166.32	27.00	6.88
Saidapur	(B)	5.05	15.50	166.07	21.50	4.80
Kurtkoti		7.20	13.00	152.04	13.63	4.23
	Mean (B)	**6.64**	**18.13**	**165.09**	**23.10**	**5.42**
Cal. 't' value		4.34	3.33	3.08	3.68	4.38
Table 't' (0.05) at 4df	2.78	*	*	*	*	*

NS – Nonsignificant , * Significant at 5 per cent.

(Gangigatti, Somanhalli and Dharwad) were on par with each other with regard to yield and 100 fruit weight with Somanhalli location recorded lowest yield (5.25 q/ha). Among third grade locations plants of Savanur location recorded highest yield (3.38 q/ha) and yield components whereas plants of Asundi location recorded lowest yield (2.13 q/ha) and yield components. All the three red soil locations (Kalagond, Thimmenhalli and Asundi) were on par with each other.

4.5.5(b) Dyavnur and Byadgi dabbi cvs. **Table 10(a)**

Fruit yield in the study area that grow Dyavnur and Byadgi dabbi cultivars ranged from 4.35 to 9.07 and 4.23 to 11.25 quintals per ha, respectively and plants of Devanur location recorded highest yield in both cultivars. Similarly, drill sown plants of Annigeri and Kurtkoti locations, recorded lowest yield and yield components for Dyavnur and Byadgi dabbi cultivars, respectively. Among drill sown locations in Byadgi dabbi cv. plants of Malligawad location recorded highest yield (6.88 q/ha) and yield components compared to plants of other two locations (Saidapur and Kurtkoti). Similarly, among transplanted locations, plants of Yaliwal location recorded lowest yield and yield components than other two locations. Generally, drill sown plants have lower yield components than transplanted plants, except for drill sown plants of Annigeri and Malligawad locations recording slightly higher yield than transplanted plants in Dyavnur and Byadgi dabbi cultivars, respectively.

T-test showed that, in both cultivars significant difference existed between first and second grade locations with respect to yield and yield components produced by plants except for 100 fruit weight in Dyavnur cultivar. It is observed that plants of first grade locations recorded higher yield and yield components than plants of second grade locations.

Comparison among the three cultivars (Byadgi kaddi, Dyavnur and Byadgi dabbi) for yield and yield components revealed that Byadgi kaddi cultivar recorded highest yield, fruit weight and number of fruits per plant, while plants of Dyavnur and Byadgi dabbi cultivars recorded lowest fruit weight and number of fruits per plant, respectively. But with regard to 100 fruit weight, plants of Byadgi dabbi cultivar have highest value while Byadgi kaddi plants have lowest.

4.6 Uptake studies

4.6.1 Nitrogen

Uptake of nitrogen by chilli cultivars at different growth stages at different locations are presented in Tables 11 and 11(a).

4.6.1(a) Byadgi kaddi cv. **Table 11**

Significant difference existed between plants of first, second and third grade locations with highest uptake of 1517.57 mg per plant recorded in plants of first grade locations and lowest uptake (403.01 mg/plant) in plants of third grade locations (F test by contrast).

Among first grade locations, plants of Devanur location recorded significantly higher uptake (1550.22 mg/plant) and were on par with those Gudgeri location (1484.91 mg/plant). Among second grade locations, plants of Devagiri, Somanhalli and Dharwad locations differed significantly from each other with respect to N uptake whereas plants of Ganjigatti and Dharwad locations were on par with each other. Similarly among third grade locations, plants of Savanur location recorded significantly higher uptake (464.65 mg/plant) than plants of other three locations (Kalagond, Thimmenahalli and Asundi).

Table 11: Nitrogen concentration and uptake (mg/plant) by chilli (Cv. Byadgi kaddi) at different growth stages at various locations

Days after transplanting (DAT)	LOCATIONS										
	Gudgeri	Devanur	Ganjigatti	Devagiri	Somanhalli	Dharwad	Savanur	Kalagond	Thimmenhalli	Asundi	MEAN
	Ist grade (A)		IInd grade (B)				IIIrd grade (C)				
45	174.28 (2.67)	224.88 (3.41)	125.84 (2.17)	165.45 (2.41)	100.97 (2.20)	111.93 (2.88)	77.08 (2.20)	69.95 (2.59)	63.97 (2.46)	51.92 (2.23)	**116.03**
75	1152.52 (2.39)	1175.79 (2.46)	814.77 (1.91)	969.11 (2.14)	593.28 (1.97)	719.24 (2.32)	518.69 (2.10)	244.02 (2.19)	464.45 (2.14)	240.06 (1.53)	**689.19**
105	2253.13 (2.05)	2293.95 (2.11)	1725.51 (1.78)	2013.01 (1.97)	1080.34 (1.58)	1429.50 (1.98)	922.58 (1.67)	367.14 (1.61)	474.59 (1.49)	350.39 (1.49)	**1291.01**
140	2359.72 (1.77)	2506.07 (1.86)	1814.48 (1.60)	2231.03 (1.70)	1223.97 (1.38)	1744.72 (1.74)	1068.26 (1.57)	483.04 (1.48)	641.23 (1.35)	416.78 (1.29)	**1448.95**
MEAN (Locations)	**1484.72**	**1550.22**	**1120.15**	**1344.65**	**749.64**	**1001.35**	**646.65**	**289.54**	**411.06**	**264.79**	
MEAN (for grade)	**1517.57**		**1053.95**				**403.01**				

For comparing means of (only uptake)	S.Em±	CD (0.05)	For comparing grade means by contrast	F test
Locations (L)	51.50	147.14	A Vs. B	*
DAT	32.57	93.06	A Vs. C	*
L X DAT	103.00	294.28	B Vs. C	*

Figures in the parentheses indicate concentration (%)
* Significant at 5%.

N uptake increased significantly at all growth stages and there was almost six fold increase in N uptake (689.19 mg/plant) at 75 DAT from 45 DAT and two fold increase at 105 DAT (1291.01 mg/plant) from 75 DAT and only marginal increase was noticed at 140 DAT.

Interaction effects were significant in influencing the N uptake, which implies that, at a particular growth stage, plants of different locations differed significantly with regard to N uptake. However, both the locations that produced first grade fruits were on par with each other with plants of Devanur location recorded higher uptake at all stages compared to Gudgeri location. Similarly at 45 DAT, plants of all locations were on par with each other and plants of Devanur location recorded highest uptake (224.08 mg/plant) followed by Gudgeri (174.28 mg/plant) and Devagiri (165.45 mg/plant) locations. Among second grade locations, plants of Devagiri location recorded highest uptake at all stages, whereas plants of Somanhalli location recorded lowest. Similarly, among third grade locations, plants of Asundi red soil location recorded lowest and were on par with plants of Kalagond and Thimmenhalli location.

4.6.1(b) Dyavnur and Byadgi dabbi cvs.

Perusal of data presented in Table 11(a) reveal that, in both cultivars, significant difference existed between plant samples of different locations with respect to N uptake. In both cultivars, plants of Devanur location recorded significantly highest uptake (1391.61 and 1493.97 mg/plant for Dyavnur and Byadgi dabbi cvs. respectively) followed by plants of Gudgeri location. Similarly lowest uptake was recorded in drill sown plants of Annigeri (758.35 mg/plant) and Kurtkoti (523.13 mg/plant) locations for Dyavnur and Byadgi dabbi cultivars, respectively. In Dyavnur cultivar, though drill sown plants of Annigeri location recorded lowest N uptake yet they were on par with transplanted plants

Table 11(a) : Nitrogen concentration and uptake (mg/plant) by chilli (Cvs. Dyavnur and Byadgi dabbi) at different growth stages at various locations

Days after transplanting (DAT)	Cv. DYAVNUR					MEAN	Cv. BYADGI DABBI						MEAN
	LOCATIONS						LOCATIONS						.
	Gudgeri	Devanur	Ganjigatti	Dharwad	Annigeri⊄		Gudgeri	Devanur	Yaliwal	Malligawad⊄	Saidapur⊄	Kurtkoti⊄	
	Ist GRADE (A)		IInd GRADE (B)				Ist GRADE (A)		IInd GRADE (B)				
45	136.61 (2.37)	171.31 (2.91)	123.78 (2.42)	133.33 (2.90)	99.39 (2.52)	**132.88**	156.28 (3.50)	226.83 (3.50)	118.46 (2.33)	81.42 (2.40)	102.76 (2.58)	75.72 (2.54)	**126.91**
75	653.29 (2.07)	1067.04 (2.40)	630.22 (2.14)	624.01 (2.56)	618.45 (2.88)	**718.64**	1145.32 (2.65)	1145.32 (2.65)	656.21 (2.07)	458.36 (2.00)	602.69 (2.70)	416.18 (2.23)	**704.24**
105	1434.69 (1.84)	1998.21 (1.96)	1223.35 (1.87)	1112.32 (2.05)	1090.82 (2.29)	**1371.88**	2194.05 (2.20)	2194.05 (2.20)	1357.47 (1.90)	1351.48 (2.31)	1083.31 (2.05)	775.63 (1.96)	**1444.47**
140	1624.14 (1.44)	2329.89 (1.68)	1349.67 (1.39)	1215.87 (1.64)	1224.76 (1.76)	**1548.86**	2409.68 (1.93)	2409.68 (1.93)	1657.27 (1.60)	1555.31 (1.97)	1126.33 (1.97)	825.01 (1.65)	**1417.31**
MEAN (LOCATIONS)	**962.18**	**1391.61**	**831.76**	**771.43**	**758.35**		**1493.97**	**1493.97**	**947.35**	**861.64**	**728.77**	**523.13**	
MEAN FOR GRADE	**1176.90**		**787.18**				**1389.25**		**765.22**				

For comparing means of (only uptake)	S.Em±	CD (0.05)	For comparing grade means by contrast	F test		For comparing means of (only uptake)	S.Em±	CD (0.05)	For comparing grade means by contrast	F test
Locations (L)	34.15	100.76	A Vs. B	*		Locations (L)	48.12	140.52	A Vs. B	*
DAT	30.55	90.12				DAT	39.29	114.74		
L X DAT	68.31	201.53				L X DAT	96.25	281.05		

Figures in the parentheses indicate conc. (%) * Significant at 5 per cent. ⊄ - Drill sown locations.

of Ganjigatti (831.76 mg/plant) and Dharwad (771.43 mg/plant) locations. But in Byadgi dabbi cultivar among second grade locations, transplanted plants of Yaliwal location with 347.35 mg per plant of N uptake were on par with drill sown plants of Malligawad location.

Results of F test after contrast reveal that, in both cultivars, plants of first grade locations recorded significantly higher N uptake (1176.90 and 1389.25 mg/plant for Dyavnur and Byadgi dabbi cultivars, respectively) than plants of second grade locations with 787.18 and 765.22 mg per plant of N uptake for Dyavnur and Byadgi dabbi cultivars, respectively.

Growth stages differed significantly with respect to N uptake in both cultivars. In Dyavnur cultivar N uptake increased from 132.88 mg per plant (45 DAT) 45 DAT to 1548.86 mg per plant at 140 DAT and in Byadgi dabbi cv., it increased from 126.91 (45 DAT) to 1671.31 mg per plant (140 DAT).

Interaction effects were significant in influencing the N uptake by plants in both cultivars. However at 45 DAT, plants of all locations were on par with each other and highest uptake was found in plants of Devanur location (171.31 and 226.83 mg/plant for Dyavnur and Byadgi dabbi cvs., respectively) followed by plants of Gudgeri location. Similarly at 75, 105 and 140 DAT, plants of Devanur location recorded highest uptake and differed significantly from plants of all other locations in case of Dyavnur cv. whereas in Byadgi dabbi cultivar, plants Devanur location were on par with those of Gudgeri location, but differed significantly from other four locations. Generally in both cultivars, drill sown plants have comparatively lower uptake than transplanted plants at all growth stages.

4.6.2 P uptake

4.6.2(a) Byadgi kaddi cv. **Table 12**

Highest P uptake (217.35 mg/plant) was noticed in plants of first grade locations, while lowest (38.89 mg/plant) was observed in plants of third grade locations and plants of second group locations were intermediate in P uptake (116.79 mg/plant). Significant difference existed between these three groups of locations producing first, second and third grade fruits (F test by contrast).

Similar to N uptake, highest P uptake (218.34 mg/plant) was noticed in plants of Devanur location which was on par with those of Gudgeri location (216.36 mg/plant), both produced first grade fruits and high yields. These two locations differed significantly from plants of all other locations. Among second grade locations, plants of Devagiri location recorded highest uptake (138.37 mg/plant) and differed significantly from plants of Dharwad location which recorded 85.99 mg per plant of P uptake. However, plants of Ganjigatti, Somanhalli and Dharwad locations were on par with each other.

Similarly among third grade locations that produced low yields plants of Savanur location with 90.04 mg per plant of P uptake differed significantly from plants of other three locations. It is found that, P uptake in all the red soil locations (Kalagond, Thimmenhalli and Asundi) was very low (17.89 to 31.50 mg/plant) and all were on par with each other.

All growth stages differed significantly with respect to P uptake and it increased from 13.74 mg per plant at 45 DAT to 181.61 mg per plant at 140 DAT.

Interaction effects of locations and growth stages influenced the P uptake by plants significantly. At all growth stages, plants of Gudgeri and Devanur locations were

Table 12 : Phosphorus concentration and uptake (mg/plant) by chilli (Cv. Byadgi kaddi) at different growth stages at various locations

Days after transplanting (DAT)	LOCATIONS										
	Gudgeri	Devanur	Ganjigatti	Devagiri	Somanhalli	Dharwad	Savanur	Kalagond	Thimmenhalli	Asundi	MEAN
	Ist grade (A)		IInd grade (B)				IIIrd grade (C)				
45	24.46 (0.38)	38.70 (0.28)	13.08 (0.22)	16.42 (0.24)	17.00 (0.38)	8.81 (0.23)	7.12 (0.20)	4.13 (0.17)	4.86 (0.19)	2.80 (0.12)	**13.74**
75	164.29 (0.34)	177.48 (0.37)	74.42 (0.18)	74.94 (0.17)	94.59 (0.32)	41.03 (0.13)	58.66 (0.23)	12.26 (0.12)	31.01 (0.14)	14.87 (0.10)	**74.35**
105	302.90 (0.28)	292.74 (0.27)	184.38 (0.20)	208.61 (0.21)	190.25 (0.28)	125.13 (0.17)	140.98 (0.26)	25.63 (0.12)	40.06 (0.13)	21.83 (0.09)	**153.25**
140	373.80 (0.28)	364.44 (0.27)	189.35 (0.17)	253.52 (0.20)	208.04 (0.23)	168.99 (0.17)	153.39 (0.23)	29.53 (0.10)	50.06 (0.11)	24.96 (0.08)	**181.61**
MEAN (Locations)	**216.36**	**218.34**	**115.31**	**138.37**	**127.47**	**85.99**	**90.04**	**17.89**	**31.50**	**16.11**	
MEAN (for grade)	**217.35**		**116.79**				**38.89**				

For comparing means of (only uptake)	S.Em±	CD (0.05)	For comparing grade means by contrast	F test
Locations (L)	8.97	25.64	A Vs. B	*
DAT	5.67	16.22	A Vs. C	*
L X DAT	17.96	51.31	B Vs. C	*

Figures in the parentheses indicate concentration (%)

* Significant at 5%.

on par with each other, but they differed significantly from other locations except at 45 DAT.

At 75 DAT, among second and third grade locations, plants of Somanhalli location recorded highest P uptake (94.59 mg/plant) and differed significantly from plants of Dharwad and other three red soil locations which have very low P uptake (12.26 to 31.01 mg/plant).

At all growth stages, plants of red soil locations were on par with each other with plants of Thimmenhalli location recording slightly higher uptake than plants of Kalagond and Asundi locations.

4.6.2(b) Dyavnur and Byadgi dabbi cvs. Table 12(a)

Significant difference existed between plants of first and second grade locations with respect to P uptake (F test by contrast) and for both cultivars, first grade locations recorded higher uptake (203.56 mg/plant and 209.14 mg/plant for Dyavnur and Byadgi dabbi cvs. respectively) than second group locations.

For both cultivars, highest uptake (260.81 mg/plant and 230.95 mg/plant for Dyavnur and Byadgi dabbi cvs. respectively) was observed in plants of Devanur location followed by plants of Gudgeri location which differed significantly from one another. In Dyavnur cultivar, all the three locations that produced second grade fruits were on par with each other and P uptake ranged from 89.27 to 111.44 mg per plant. But in Byadgi dabbi cultivar, among second grade locations plants of Yaliwal and Malligwad locations were on par with each other and plants of Kurtkoti location with lowest P uptake (71.65 mg/plant) differed significantly from other locations. Generally drill sown plants have lower uptake than transplanted plants in both cultivars.

Table 12(a) : Phosphorus concentration and uptake (mg/plant) by chilli (Cvs. Dyavnur and Byadgi dabbi) at different growth stages at various locations

Days after transplanting (DAT)	Cv. DYAVNUR LOCATIONS					MEAN	Cv. BYADGI DABBI LOCATIONS						MEAN
	Gudgeri	Devanur	Ganjigatti	Dharwad	Annigeri α		Gudgeri	Devanur	Yaliwal	Malligawad α	Saidapur α	Kurtkoti α	
	Ist GRADE (A)		IInd GRADE (B)				Ist GRADE (A)		IInd GRADE (B)				
45	31.12 (0.54)	34.01 (0.57)	19.72 (0.39)	18.47 (0.41)	11.60 (0.32)	**22.98**	25.64 (0.49)	37.40 (0.58)	20.34 (0.40)	17.96 (0.53)	12.65 (0.32)	12.35 (0.42)	**21.05**
75	97.77 (0.31)	175.71 (0.39)	80.18 (0.27)	72.43 (0.30)	61.27 (0.29)	**97.47**	149.85 (0.39)	162.04 (0.38)	107.81 (0.34)	84.95 (0.37)	55.43 (0.25)	62.12 (0.33)	**103.70**
105	202.35 (0.26)	368.01 (0.36)	85.91 (0.13)	162.07 (0.30)	118.07 (0.25)	**187.28**	267.22 (0.32)	355.21 (0.36)	185.78 (0.26)	175.94 (0.30)	129.37 (0.25)	97.24 (0.25)	**201.79**
140	253.99 (0.23)	465.50 (0.34)	171.27 (0.18)	192.78 (0.26)	166.57 (0.24)	**250.02**	306.57 (0.27)	369.16 (0.30)	217.37 (0.21)	201.82 (0.26)	151.27 (0.23)	114.90 (0.23)	**226.85**
MEAN (LOCATIONS)	**146.30**	**260.81**	**89.27**	**111.44**	**89.38**		**187.32**	**230.95**	**132.82**	**120.17**	**87.18**	**71.65**	
MEAN FOR GRADE	**203.56**		**96.70**				**209.14**		**102.96**				

For comparing means of (only uptake)	S.Em±	CD (0.05)	For comparing grade means by contrast	F test		For comparing means of (only uptake)	S.Em±	CD (0.05)	For comparing grade means by contrast	F test
Locations (L)	7.73	22.81	A Vs. B	*		Locations (L)	6.32	18.47	A Vs. B	*
DAT	6.91	20.40				DAT	5.16	15.08		
L X DAT	15.47	45.63				L X DAT	12.65	36.95		

Figures in the parentheses indicate conc. (%) * Significant at 5 per cent. α - Drill sown locations.

P uptake differed significantly at all growth stages and for Dyavnur and Byadgi dabbi cultivars, P uptake increased from 22.98 (at 45 DAT) to 250.02 (at 140 DAT) and 21.05 to 226.85 mg per plant,respectively.

Interaction effects were significant in influencing the P uptake by plants in both cultivars. However at 45 DAT all locations were on par with each other and highest uptake (34.01 and 37.40 mg/plant for Dyavnur and Byadgi dabbi cultivars respectively) was observed in plants of Devanur location followed by those of Gudgeri location. At all growth stages (75, 105 and 140 DAT), plants of Devanur location recorded highest P uptake and differed significantly from plants of other locations with an exception of nonsignificant difference between Gudgeri and Devanur locations at 75 DAT for P uptake.

4.6.3 K uptake

4.6.3(a) Byadgi kaddi cv. Table 13

Plants of Devanur location recorded highest uptake (3198.14 mg/plant) and were on par with those of Gudgeri location (3127.42 mg/plant), but these two locations differed significantly from plants of all other locations. Among second grade locations plants of Devagiri location recorded significantly highest value (2521.30 mg/plant) whereas plants of Dharwad location recorded lowest (1300.83 mg/plant) and plants of Ganjigatti and Somanhalli locations were on par with each other. Similarly among third grade locations, plants of Savanur location recorded significantly higher uptake (1343.09 mg/plant) than plants of Kalagond (471.41 mg/plant) and Asundi (564.94 mg/plant) locations which were on par with one another but differed significantly from Thimmenhalli location (938.15 mg/plant).

Table 13: Potassium concentration and uptake (mg/plant) by chilli (Cv. Byadgi kaddi) at different growth stages at various locations

Days after transplanting (DAT)	LOCATIONS										
	Gudgeri	Devanur	Ganjigatti	Devagiri	Somanhalli	Dharwad	Savanur	Kalagond	Thimmenhalli	Asundi	MEAN
	Ist grade (A)		IInd grade (B)				IIIrd grade (C)				
45	144.78 (2.22)	268.34 (4.05)	145.03 (2.63)	127.98 (1.89)	92.18 (2.08)	79.04 (2.00)	47.85 (1.35)	43.58 (1.70)	76.28 (2.93)	44.39 (1.90)	**106.94**
75	1786.45 (3.70)	1725.74 (3.60)	1216.73 (2.85)	958.23 (2.10)	1000.42 (3.35)	1046.77 (3.30)	903.35 (3.55)	112.45 (1.00)	597.57 (2.75)	234.88 (1.55)	**958.66**
105	5176.33 (4.70)	5143.42 (4.73)	3206.51 (3.34)	4009.60 (3.91)	3037.84 (4.45)	1766.64 (2.40)	2128.33 (3.86)	768.04 (3.55)	1358.96 (4.27)	925.50 (3.65)	**2752.12**
140	5402.12 (4.05)	5655.08 (3.70)	3377.33 (3..00)	4989.40 (3.80)	3451.63 (3.85)	2310.88 (2.30)	2288.85 (3.35)	961.58 (3.08)	1719.93 (3.63)	1054.97 (3.25)	**3121.17**
MEAN (Locations)	**3127.42**	**3198.14**	**1986.40**	**2521.30**	**1895.51**	**1300.83**	**1343.09**	**471.41**	**938.18**	**564.94**	
MEAN (for grade)	**3162.78**		**1926.01**				**829.41**				

For comparing means of (only uptake)	S.Em±	CD (0.05)	For comparing grade means by contrast	F test
Locations (L)	83.56	238.73	A Vs. B	*
DAT	52.84	150.98	A Vs. C	*
L X DAT	167.12	477.46	B Vs. C	*

Figures in the parentheses indicate concentration (%)
* Significant at 5%.

K uptake was highest (3162.78 mg/plant) in plants of first grade locations and differed significantly from plants of second grade locations (1926.01 mg/plant). Plants of third grade locations recorded significantly lowest uptake (829.41 mg/plant) compared to first and second grade locations (F test by contrast).

K uptake differed significantly at all growth stages and increased from 106.94 mg per plant (45 DAT) to 958.66, 2752.12 and 3121.17 mg per plant recorded at 75, 105 and 140 DAT respectively. There was almost nine fold increase in K uptake from 45 DAT to 75 DAT and three fold increase from 75 to 105 DAT.

Interaction effects of locations and growth stages influenced the K uptake significantly which implies that, at a particular growth stage, plants of different locations differed significantly with respect to K uptake. However at 45 DAT, plants of all locations were on par with each other, whereas at 75, 105 and 140 DAT, plants of only Gudgeri and Devanur locations were on par with each other but differed significantly from plants of all other locations. Plants of Kalagond red soil location recorded lowest uptake at all stages and were on par with those of Asundi location, but differed significantly from plants of Thimmenhalli location.

4.6.3(b) Dyavnur and Byadgi dabbi cvs. **Table 13(a)**

In both cultivars, plants of Devanur location which recorded highest uptake (3351.41 and 3749.47 mg/plant for Dyavnur and Byadgi dabbi cvs.,respectively differed significantly from plants of all other locations with an exception of non significant difference between plants of Devanur and Gudgeri locations in case of Byadgi dabbi cultivar. Lowest K uptake (1015.27 and 970.45 mg/plant for Dyavnur and Byadgi dabbi cultivars, respectively) was recorded in plants of Ganjigatti and Kurtkoti locations for Dyavnur and Byadgi dabbi cultivars, respectively. Among second grade locations in

Table 13(a) : Potassium concentration and uptake (mg/plant) by chilli (cvs. Dyavnur and Byadgi dabbi) at different growth stages at various locations

Days after transplanting (DAT)	Cv. DYAVNUR LOCATIONS					MEAN	Cv. BYADGI DABBI LOCATIONS						MEAN
	Gudgeri	Devanur	Ganjigatti	Dharwad	Annigeri⊄		Gudgeri	Devanur	Yaliwal	Malligawad⊄	Saidapur⊄	Kurtkoti⊄	
	Ist GRADE (A)		IInd GRADE (B)				Ist GRADE (A)		IInd GRADE (B)				
45	269.85 (4.68)	252.92 (4.25)	94.88 (1.85)	210.61 (4.60)	187.07 (4.85)	**203.06**	208.06 (3.98)	329.34 (5.05)	233.73 (4.60)	120.80 (3.55)	172.23 (4.35)	100.93 (3.45)	**194.18**
75	1389.27 (4.40)	1725.01 (3.85)	488.66 (1.65)	997.71 (4.10)	1008.71 (4.70)	**1121.87**	1536.40 (4.00)	1987.69 (4.60)	1341.90 (4.25)	687.60 (3.00)	860.19 (3.90)	530.95 (2.95)	**1157.45**
105	3263.91 (4.20)	4830.99 (4.70)	1400.27 (2.13)	1708.38 (3.15)	2280.00 (4.82)	**2696.71**	4151.18 (4.95)	6163.96 (6.15)	3874.64 (5.45)	2729.28 (4.65)	2839.95 (5.38)	1475.14 (3.85)	**3539.02**
140	4674.03 (4.15)	6596.83 (4.75)	2077.27 (2.13)	2076.06 (2.80)	2673.16 (3.85)	**3619.47**	4829.44 (4.25)	6516.92 (5.20)	4374.63 (4.25)	3642.42 (4.60)	3419.02 (5.20)	1774.77 (3.65)	**4092.87**
MEAN (LOCATIONS)	**2399.26**	**3351.44**	**1015.27**	**1248.19**	**1537.23**		**2681.27**	**3749.47**	**2456.22**	**1795.02**	**1822.85**	**970.45**	
MEAN FOR GRADE	**2875.35**		**1266.90**				**3215.37**		**1761.14**				

For comparing means of (only uptake)	S.Em±	CD (0.05)	For comparing grade means by contrast	F test		For comparing means of (only uptake)	S.Em±	CD (0.05)	For comparing grade means by contrast	F test
Locations (L)	133.33	393.33	A Vs. B	*		Locations (L)	98.24	286.85	A Vs. B	*
DAT	119.25	351.80				DAT	80.21	234.21		
L X DAT	266.66	786.66				L X DAT	196.47	573.69		

Figures in the parentheses indicate conc. (%) * Significant at 5 per cent. ⊄ - Drill sown locations.

Dyavnur cultivar, plants of Annigeri location with K uptake of 1537.23 mg per plant differed significantly from plants of Ganjigatti location (1015.27 mg/plant) but were on par with plants of Dharwad location (1248.19 mg/plant). In Byadgi dabbi cultivar, plants of Kurtkot location with lowest K uptake (970.45 mg/plant) differed significantly from all other locations.

In both cultivars, plants of first grade locations recorded higher K uptake (2875.35 and 3215.37 mg/plant for Dyavnur and Byadgi dabbi cvs. respectively) than plants of second grade locations and significant difference exixted between them (F test by contrast).

K uptake differed significantly at all growth stages and in Dyavnur cv. uptake increased from 203.06 mg per plant to 3619.47 mg per plant recorded at 45 and 140 DAT, respectively. Similarly in Byadgi dabbi cultivar, K uptake increased from 194.18 to 4092.87 mg per plant recorded at 45 and 140 DAT, respectively. Increase in K uptake at 75 DAT in both cultivars was almost six fold from 45 DAT and three fold at 105 DAT from 75 DAT, only marginal increase at 140 DAT was observed.

Interaction effects were significant in influencing the K uptake by plants in both cultivars. However at 45 DAT, plants of all locations were on par with each other and plants of Gudgeri and Devanur locations recorded highest uptake (269.85 and 329.34 mg/plant) for Dyavnur and Byadgi dabbi cultivars,respectively. In both cultivars at 75 DAT, plants Gudgeri and Devanur locations were on par with each other whereas at 105 and 140 DAT, they differed significantly from one another and also from other locations. Plants of Annigeri and Kurtkoti locations recorded lowest uptake at all stages for Dyavnur and Byadgi dabbi cultivars,respectively.

4.6.4 S uptake

4.6.4(a) Byadgi kaddi cv. Table 14

Significant difference existed between first, second and third grade locations for sulphur uptake by plants as shown by F test by contrast. Plants of first grade locations recorded highest uptake (350.87 mg/plant), while lowest uptake (115.93 mg/plant) was found in plants of third grade locations.

Further, plants of Devanur location recorded highest uptake (378.93 mg/plant) which differed significantly from plants of all other locations. Among second grade locations, plants of Devagiri, Somanhalli and Dharwad locations were on par with each other but they differed significantly from plants of Ganjigatti location having 188.06 mg per plant of S uptake. Similarly among third grade locations, plants of Savanur location with 141.43 mg per plant of S uptake differed significantly from plants of Asundi red soil location (94.29 mg/plant). However plants of all the three red soil locations were on par with each other with Thimmenhalli location recording highest uptake (127.70 mg/plant).

All growth stages differed significantly with respect to sulphur uptake and it increased from 13.18 mg per plant at 45 DAT to 398.48 mg per plant at 140 DAT. There was almost eight fold increase in S uptake at 75 DAT (109.19 mg/plant) and three fold increase at 105 DAT (347.25 mg/plant).

Interaction effects of locations and growth stages influenced the sulphur uptake significantly. However at 45 DAT, plants of all locations were on par with each other and at all growth stages plants of Devanur location recorded highest uptake. Generally plants of red soil locations (Kalagond, Thimmenhalli and Asundi) recorded lower S uptake at all

Table 14 : Sulphur concentration and uptake (mg/plant) by chilli (Cv. Byadgi kaddi) at different growth stages at various locations

Days after transplanting (DAT)	LOCATIONS										
	Gudgeri	Devanur	Ganjigatti	Devagiri	Somanhalli	Dharwad	Savanur	Kalagond	Thimmenhalli	Asundi	MEAN
	Ist grade (A)		IInd grade (B)				IIIrd grade (C)				
45	13.45 (0.21)	23.92 (0.37)	16.84 (0.29)	16.70 (0.25)	21.13 (0.46)	6.94 (0.18)	12.19 (0.34)	8.48 (0.35)	4.94 (0.20)	7.23 (0.31)	**13.18**
75	154.52 (0.32)	181.91 (0.38)	149.39 (0.35)	112.89 (0.25)	161.30 (0.54)	80.72 (0.27)	61.45 (0.23)	58.45 (0.53)	68.92 (0.32)	62.36 (0.40)	**109.19**
105	525.32 (0.48)	633.31 (0.58)	257.78 (0.27)	438.22 (0.43)	444.34 (0.65)	446.66 (0.62)	232.65 (0.42)	150.04 (0.68)	198.89 (0.63)	145.37 (0.58)	**347.25**
140	597.98 (0.45)	676.61 (0.50)	328.23 (0.29)	538.49 (0.41)	512.85 (0.58)	486.74 (0.49)	259.43 (0.38)	184.23 (0.58)	238.08 (0.51)	162.22 (0.50)	**398.48**
MEAN (Locations)	**322.81**	**378.93**	**188.06**	**276.57**	**284.90**	**255.27**	**141.43**	**100.30**	**127.70**	**94.29**	
MEAN (for grade)	**350.87**		**251.20**				**115.93**				

For comparing means of (only uptake)	S.Em±	CD (0.05)	For comparing grade means by contrast	F test
Locations (L)	16.24	46.39	A Vs. B	*
DAT	10.27	29.34	A Vs. C	*
L X DAT	32.46	92.74	B Vs. C	*

Figures in the parentheses indicate concentration (%)
* Significant at 5%.

stages compared to those of medium black soil locations (Ganjigatti, Devagiri, Somanhalli and Dharwad).

4.6.4(b) Dyavnur and Byadgi dabbi cvs. Table 14(a)

Plants of first grade locations recorded higher S uptake (399.77 and 432.22 mg plant-1 for Dyavnur and Byadgi dabbi cvs. respectively) than plants of second grade locations and significant difference existed between the first and second grade locations as indicated by F test after contrast.

It is observed that, plants of Devanur location recorded significantly highest uptake (446.00 mg/plant and 467.29 mg/plant for Dyavnur and Byadgi dabbi cvs. respectively) in both cultivars, whereas plants of Ganjigatti (149.68 mg/plant) and Kurtkoti (178.83 mg/plant) locations recorded lowest uptake for Dyavnur and Byadgi dabbi cultivars, respectively. Among second grade locations in Dyavnur cultivar, plants of Dharwad location with 199.60 mg per plant of S uptake were on par with drill sown plants of Annigeri location having 177.99 mg per plant of S uptake. Similar relationship exist between plants of Ganjigatti and Annigeri location. Similarly in Byadgi dabbi cultivar, among second grade locations, transplanted plants of Yaliwal location recorded significantly higher uptake (349.41 mg/plant) than drill sown plants of other three locations.

S uptake differed significantly at all growth stages and increased from 16.57 to 480.94 and 19.78 to 582.14 mg per plant for Dyavnur and Byadgi dabbi cultivars respectively. Increase in sulphur uptake was almost 8 to 9 times more at 75 DAT from 45 DAT, three fold at 105 DAT from 75 DAT and marginal increase at 140 DAT.

Table 14(a) : Sulphur concentration and uptake (mg/plant) by chilli (Cvs. Dyavnur and Byadgi dabbi) at different growth stages at various locations

Days after transplanting (DAT)	Cv. DYAVNUR LOCATIONS					MEAN	Cv. BYADGI DABBI LOCATIONS						MEAN
	Gudgeri	Devanur	Ganjigatti	Dharwad	Annigeriα		Gudgeri	Devanur	Yaliwal	Malligawadα	Saidapurα	Kurtkotiα	
	Ist GRADE (A)		IInd GRADE (B)				Ist GRADE (A)		IInd GRADE (B)				
45	20.44 (0.36)	24.94 (0.43)	10.25 (0.20)	14.64 (0.32)	12.60 (0.32)	**16.57**	21.73 (0.42)	30.74 (0.47)	23.88 (0.47)	18.53 (0.55)	13.08 (0.33)	10.74 (0.37)	**19.78**
75	134.42 (0.43)	256.48 (0.58)	71.07 (0.24)	120.04 (0.50)	109.17 (0.51)	**138.23**	195.94 (0.51)	248.51 (0.58)	206.36 (0.66)	176.49 (0.77)	117.75 (0.53)	84.99 (0.47)	**171.67**
105	607.00 (0.78)	710.97 (0.70)	227.61 (0.35)	319.13 (0.59)	263.87 (0.56)	**425.71**	644.21 (0.77)	765.01 (0.77)	560.86 (0.79)	539.54 (0.92)	425.17 (0.81)	292.99 (0.76)	**537.96**
140	652.30 (0.58)	791.62 (0.57)	289.81 (0.30)	344.61 (0.47)	326.34 (0.47)	**480.94**	726.90 (0.64)	824.93 (0.66)	606.53 (0.59)	573.99 (0.73)	453.89 (0.69)	306.62 (0.63)	**582.14**
MEAN (LOCATIONS)	**353.54**	**446.00**	**149.68**	**199.60**	**177.99**		**397.14**	**467.29**	**349.41**	**327.13**	**252.47**	**178.83**	
MEAN FOR GRADE	**399.77**		**175.76**				**432.22**		**275.71**				

For comparing means of (only uptake)	S.Em±	CD (0.05)	For comparing grade means by contrast	F test		For comparing means of (only uptake)	S.Em±	CD (0.05)	For comparing grade means by contrast	F test
Locations (L)	15.33	45.23	A Vs. B	*		Locations (L)	14.15	41.32	A Vs. B	*
DAT	13.71	40.46				DAT	11.55	33.75		
L X DAT	30.67	90.47				L X DAT	28.31	82.67		

Figures in the parentheses indicate conc. (%) * Significant at 5 per cent. α - Drill sown locations.

Interaction effects were significant in influencing the sulphur uptake by plants, however at 45 DAT plants of all locations were on par with each other with highest uptake (24.94 and 30.74 mg plant-1 for Dyavnur and Byadgi dabbi cultivars, respectively) recorded in plants of Devanur location. Lowest sulphur uptake at all growth stages was observed in plants of Ganjigatti and Kurtkoti locations for Dyavnur and Byadgi dabbi cultivars, respectively.

4.6.5 Ca and Mg uptake

4.6.5(a) Byadgi kaddi cv. **Tables 15 and 16**

Highest Ca (1402.75 mg/plant) and Mg (1181.00 mg/plant) uptake was noticed in plants of Devanur and Gudgeri locations respectively, both of which produced first grade fruits. These two locations were on par with one another for Ca uptake, whereas they differed significantly with regard to Mg uptake. Among second grade locations, plants of Devagiri location recorded highest uptake of both nutrients (1053.90 and 796.09 mg/plant of Ca and Mg respectively) and differed significantly from other three locations with respect to Mg uptake whereas, for Ca uptake, they were on par with Ganjigatti location (870.48 mg/plant of Ca uptake) and differed significantly from plants of Somanhalli and Dharwad locations. Plants of Ganjigatti and Somanhalli locations were on par with each other for Ca and Mg uptake. For both Ca and Mg uptake, plants of Kalagond red soil location recorded lowest uptake (106.72 mg/plant of Ca and 50.30 mg/plant of Mg) and were on par with plants of other two red soil locations.

Plants of first grade locations recorded highest uptake of both nutrients (1322.50 mg/plant of Ca and 1140.66 mg/plant of Mg) and differed significantly from plants of second and third grade locations. Similarly significant difference existed between second and third grade locations also with regard to the uptake of both nutrients and plants of

Table 15: Calcium concentration and uptake (mg/plant) by chilli (Cv. Byadgi kaddi) at different growth stages at various locations

Days after transplanting (DAT)	LOCATIONS										
	Gudgeri	Devanur	Ganjigatti	Devagiri	Somanhalli	Dharwad	Savanur	Kalagond	Thimmenhalli	Asundi	MEAN
	Ist grade (A)		IInd grade (B)				IIIrd grade (C)				
45	148.40 (2.28)	157.41 (2.40)	76.20 (1.35)	120.35 (1.75)	104.09 (2.30)	73.06 (1.90)	38.05 (1.05)	12.75 (0.50)	32.95 (1.25)	12.55 (0.54)	**77.58**
75	927.17 (1.93)	1027.39 (2.15)	558.13 (1.30)	658.08 (1.45)	485.96 (1.60)	644.34 (2.05)	163.88 (0.65)	87.19 (0.75)	361.04 (1.65)	61.13 (0.40)	**497.43**
105	1761.28 (1.60)	2067.58 (1.90)	1155.96 (1.20)	1591.39 (1.55)	955.50 (1.40)	1214.57 (1.65)	495.48 (0.85)	147.51 (0.65)	399.33 (1.25)	298.79 (1.20)	**1008.74**
140	2132.16 (1.60)	2358.65 (1.75)	1691.63 (1.50)	1845.76 (1.40)	1121.63 (1.25)	1112.10 (1.10)	535.80 (0.75)	179.45 (0.55)	453.00 (0.95)	320.47 (1.00)	**1175.07**
MEAN (Locations)	**1242.25**	**1402.75**	**870.48**	**1053.90**	**666.79**	**581.67**	**308.30**	**106.72**	**311.58**	**173.23**	
MEAN (for grade)	**1322.50**		**793.21**				**224.96**				

For comparing means of (only uptake)	S.Em±	CD (0.05)	For comparing grade means by contrast	F test
Locations (L)	73.12	208.91	A Vs. B	*
DAT	46.24	132.12	A Vs. C	*
L X DAT	146.24	417.82	B Vs. C	*

Figures in the parentheses indicate concentration (%)
* Significant at 5%.

Table 16 : Magnesium concentration and uptake (mg/plant) by chilli (Cv. Byadgi kaddi) at different growth stages at various locations

Days after transplanting (DAT)	LOCATIONS										
	Gudgeri	Devanur	Ganjigatti	Devagiri	Somanhalli	Dharwad	Savanur	Kalagond	Thimmenhalli	Asundi	MEAN
	Ist grade (A)		IInd grade (B)				IIIrd grade (C)				
45	88.09 (1.35)	87.38 (1.33)	55.63 (0.98)	72.19 (1.04)	57.79 (1.30)	45.63 (1.18)	18.63 (0.50)	6.75 (0.25)	11.85 (0.45)	6.93 (0.30)	**45.09**
75	573.64 (1.19)	516.76 (1.08)	320.00 (0.75)	425.07 (0.93)	316.56 (1.05)	323.45 (1.05)	74.03 (0.30)	40.32 (0.35)	76.83 (0.35)	31.18 (0.20)	**269.78**
105	1964.27 (1.79)	1851.14 (1.71)	782.37 (0.82)	1303.84 (1.27)	873.89 (1.28)	920.81 (1.27)	207.58 (0.38)	71.72 (0.33)	136.52 (0.43)	80.99 (0.33)	**819.31**
140	2098.00 (1.58)	1946.03 (1.45)	756.79 (0.68)	1383.27 (1.05)	939.33 (1.05)	1003.79 (1.00)	218.86 (0.32)	82.41 (0.26)	143.77 (0.30)	89.96 (0.28)	**866.22**
MEAN (Locations)	**1181.00**	**1100.32**	**478.70**	**769.09**	**546.89**	**573.42**	**129.77**	**50.30**	**92.24**	**52.26**	
MEAN (for grade)	**1140.66**		**598.78**				**81.14**				

For comparing means of (only uptake)	S.Em±	CD (0.05)	For comparing grade means by contrast	F test
Locations (L)	26.55	75.86	A Vs. B	*
DAT	16.79	47.98	A Vs. C	*
L X DAT	53.11	151.73	B Vs. C	*

Figures in the parentheses indicate concentration (%)
* Significant at 5%.

third grade locations recorded lowest uptake (224.96 and 81.14 mg/plant of Ca and Mg uptake, respectively).

All growth stages differed significantly with respect to the uptake of both nutrients and Ca and Mg uptake increased from 77.58 to 1175.07 mg per plant and 45.09 to 866.22 mg per plant recorded at 45 and 140 DAT, respectively.

Interaction effects were significant in influencing the uptake of both Ca and Mg by plants. However at 45 DAT, plants of all locations were on par with each other with regard to the uptake of both nutrients. At all growth stages, plants of Devanur and Gudgeri locations recorded highest Ca and Mg uptake, respectively both of which produced first grade fruits (Tables 15 and 16). All the four locations that produced third grade fruits were on par with one another with regard to Ca and Mg uptake at all the stages and plants of Kalagond location recorded lowest uptake of both Ca and Mg at all stages while highest uptake was found in plants of Savanur location.

4.6.5(b) Dyavnur and Byadgi dabbi cvs. Tables 15(a) and 16(a)

In both cultivars, plants of Devanur location recorded highest uptake (1075.53 and 1141.22 mg/plant of Ca and 895.07 and 1026.67 mg/plant of Mg uptake for Dyavnur and Byadgi dabbi cvs. respectively) followed by plants of Gudgeri location. Lowest uptake was found in drill sown plants of Annigeri and Kurtkoti locations for Dyavnur and Byadgi dabbi cultivars, respectively.

Similar to Byadgi kaddi cultivar, in these cultivars also plants of first grade locations differed significantly from second grade locations with respect to the uptake of both Ca and Mg and first grade locations recorded higher uptake than second grade locations.

Table 15(a) : Calcium concentration and uptake (mg/plant) by chilli (Cvs. Dyavnur and Byadgi dabbi) at different growth stages at various locations

Days after transplanting (DAT)	Cv. DYAVNUR LOCATIONS					MEAN	Cv. BYADGI DABBI LOCATIONS						MEAN
	Gudgeri	Devanur	Ganjigatti	Dharwad	Annigeri α		Gudgeri	Devanur	Yaliwal	Malligawad α	Saidapur α	Kurtkoti α	
	Ist GRADE (A)		IInd GRADE (B)				Ist GRADE (A)		IInd GRADE (B)				
45	104.04 (1.80)	140.32 (2.40)	80.80 (1.58)	89.43 (1.95)	73.44 (1.90)	**97.61**	132.09 (2.53)	158.62 (2.45)	106.99 (2.10)	95.76 (2.85)	95.52 (2.40)	62.06 (2.10)	**108.51**
75	442.54 (1.40)	828.06 (1.85)	429.54 (1.45)	548.31 (2.25)	237.11 (1.10)	**497.11**	595.12 (1.55)	863.58 (2.00)	536.56 (1.70)	424.02 (1.85)	523.42 (2.35)	303.09 (1.65)	**540.97**
105	1014.39 (1.30)	1526.85 (1.50)	1115.80 (1.70)	901.38 (1.60)	997.23 (2.10)	**1111.13**	1340.48 (1.60)	1602.40 (1.60)	1176.12 (1.65)	1114.73 (1.90)	1004.34 (1.90)	632.96 (1.60)	**1145.17**
140	1527.39 (1.35)	1806.87 (1.30)	1172.16 (1.20)	1037.82 (1.40)	1077.87 (1.55)	**1324.42**	1534.01 (1.35)	1940.29 (1.55)	1498.72 (1.45)	1425.78 (1.80)	1105.94 (1.68)	749.40 (1.50)	**1375.69**
MEAN (LOCATIONS)	**772.09**	**1075.53**	**699.58**	**644.24**	**596.41**		**900.43**	**1141.22**	**829.60**	**765.07**	**682.31**	**436.88**	
MEAN FOR GRADE	**923.81**		**646.74**				**1020.83**		**678.47**				

For comparing means of (only uptake)	S.Em±	CD (0.05)	For comparing grade means by contrast	F test		For comparing means of (only uptake)	S.Em±	CD (0.05)	For comparing grade means by contrast	F test
Locations (L)	79.04	233.16	A Vs. B	*		Locations (L)	53.69	156.78	A Vs. B	*
DAT	70.69	208.55				DAT	43.83	128.00		
L X DAT	158.07	466.32				L X DAT	107.39	313.60		

Figures in the parentheses indicate conc. (%) * Significant at 5 per cent. α - Drill sown locations

Table 16(a) : Magnesium concentration and uptake (mg/plant) by chilli (Cvs. Dyavnur and Byadgi dabbi) at different growth stages at various locations

Days after transplanting (DAT)	Cv. DYAVNUR					MEAN	Cv. BYADGI DABBI						MEAN
	LOCATIONS						LOCATIONS						
	Gudgeri	Devanur	Ganjigatti	Dharwad	Annigeri⊄		Gudgeri	Devanur	Yaliwal	Malligawad⊄	Saidapur⊄	Kurtkoti⊄	
	Ist GRADE (A)		IInd GRADE (B)				Ist GRADE (A)		IInd GRADE (B)				
45	88.20 (1.53)	77.22 (1.35)	55.14 (1.08)	45.93 (1.00)	39.42 (1.00)	**61.28**	82.41 (1.58)	107.49 (1.65)	64.91 (1.28)	57.69 (1.70)	60.79 (1.53)	32.69 (1.10)	**67.66**
75	350.21 (1.11)	494.43 (1.10)	224.12 (0.75)	220.90 (0.90)	144.97 (0.67)	**286.75**	479.66 (1.25)	606.72 (1.41)	364.82 (1.15)	333.62 (1.46)	302.32 (1.34)	207.54 (1.09)	**382.45**
105	1089.75 (1.40)	1389.85 (1.38)	528.20 (0.80)	664.53 (1.22)	415.85 (0.88)	**817.64**	1255.19 (1.50)	1549.23 (1.55)	1014.06 (1.43)	1099.88 (1.88)	938.09 (1.78)	576.82 (1.45)	**1072.21**
140	1379.20 (1.23)	1618.28 (1.17)	713.15 (0.73)	796.79 (1.08)	502.95 (0.73)	**1002.07**	1306.32 (1.15)	1843.26 (1.48)	1310.43 (1.28)	1326.43 (1.68)	1069.22 (1.63)	656.30 (1.33)	**1251.99**
MEAN (LOCATIONS)	**726.84**	**895.07**	**380.15**	**431.81**	**275.80**		**780.89**	**1026.67**	**688.55**	**704.40**	**592.60**	**368.34**	
MEAN FOR GRADE	**810.96**		**362.59**				**903.78**		**588.47**				

For comparing means of (only uptake)	S.Em±	CD (0.05)	For comparing grade means by contrast	F test		For comparing means of (only uptake)	S.Em±	CD (0.05)	For comparing grade means by contrast	F test
Locations (L)	27.18	80.19	A Vs. B	*		Locations (L)	33.46	97.70	A Vs. B	*
DAT	24.31	71.73				DAT	27.32	79.77		
L X DAT	54.37	160.38				L X DAT	66.92	195.40		

Figures in the parentheses indicate conc. (%) * Significant at 5 per cent. ⊄ - Drill sown locations

Both Ca and Mg uptake differed significantly at all growth stages in both cultivars. Ca uptake in Dyavnur and Byadgi dabbi cultivars increased from 97.61 (45 DAT) to 1324.42 (140 DAT) and 108.51 to 1375.69 mg per plant, respectively. Similarly Mg uptake for Dyavnur and Byadgi dabbi cultivars increased from 61.28 to 1002.07 and 67.66 to 1251.99 mg per plant respectively. There was almost five fold increase in both Ca and Mg uptake at 75 DAT from 45 DAT and three fold increase at 105 DAT from 75 DAT and only marginal increase at harvest.

Interaction effects were significant in influencing the uptake of both Ca and Mg by plants in both cultivars. However at 45 DAT, plants of all locations were on par with each other with respect to the uptake of both Ca and Mg and at all stages drill sown plants recorded lower uptake than transplanted plants. For both cultivars, plants of Gudgeri and Devanur locations recorded higher Ca and Mg uptake at all stages than plants of other locations.

4.6.6 Cu and Zn uptake

4.6.6(a) Byadgi kaddi cv. **Tables 17 and 18**

Significant difference existed between first, second and third grade locations with respect to the uptake of both Cu and Zn by plants. Highest uptake of Cu (1.30 mg/plant) and Zn (2.11 mg/plant) were observed in plants of first group locations whereas lowest value (0.20 and 0.58 mg/plant of Cu and Zn respectively) were observed in plants of third grade locations and plants of second grade locations were intermediate in uptake values (0.87 and 1.80 mg/plant of Cu and Zn uptake respectively).

It is observed that highest Cu (1.31 mg/plant) and Zn uptake (2.17 mg/plant) were observed in plants of Gudgeri and Devagiri locations, respectively. Plants of Gudgeri and

Table 17: Copper concentration and uptake (mg/plant) by chilli (Cv. Byadgi kaddi) at different growth stages at various locations

Days after transplanting (DAT)	LOCATIONS										
	Gudgeri	Devanur	Ganjigatti	Devagiri	Somanhalli	Dharwad	Savanur	Kalagond	Thimmenhalli	Asundi	MEAN
	Ist grade (A)		IInd grade (B)				IIIrd grade (C)				
45	0.04 (5.50)	0.05 (7.00)	0.04 (6.50)	0.04 (5.50)	0.04 (9.00)	0.03 (6.00)	0.02 (5.00)	0.02 (6.00)	0.03 (9.00)	0.01 (2.50)	**0.03**
75	1.01 (21.00)	0.91 (19.00)	0.85 (19.50)	0.46 (10.00)	0.90 (30.00)	0.46 (15.00)	0.41 (15.50)	0.20 (18.00)	0.51 (23.00)	0.20 (12.50)	**0.59**
105	1.38 (12.50)	1.24 (11.50)	1.53 (16.00)	1.07 (10.50)	0.99 (14.50)	0.64 (9.00)	0.32 (6.00)	0.08 (3.50)	0.21 (6.50)	0.05 (2.00)	**0.75**
140	2.81 (21.00)	2.96 (22.00)	1.69 (15.00)	1.70 (13.00)	1.58 (17.50)	1.79 (17.50)	0.54 (8.00)	0.16 (5.00)	0.39 (8.00)	0.12 (3.50)	**1.37**
MEAN (Locations)	**1.31**	**1.29**	**1.03**	**0.82**	**0.88**	**0.73**	**0.32**	**0.11**	**0.28**	**0.09**	
MEAN (for grade)	**1.30**		**0.87**				**0.20**				

For comparing means of (only uptake)	S.Em±	CD (0.05)	For comparing grade means by contrast	F test
Locations (L)	0.05	0.16	A Vs. B	*
DAT	0.03	0.10	A Vs. C	*
L X DAT	0.11	0.31	B Vs. C	*

Figures in the parentheses indicate concentration (ppm)
* Significant at 5%.

Table 18 : Zinc concentration and uptake (mg/plant) by chilli (Cv. Byadgi kaddi) at different growth stages at various locations

Days after transplanting (DAT)	LOCATIONS										
	Gudgeri	Devanur	Ganjigatti	Devagiri	Somanhalli	Dharwad	Savanur	Kalagond	Thimmenhalli	Asundi	MEAN
	Ist grade (A)		IInd grade (B)				IIIrd grade (C)				
45	0.07 (11.00)	0.18 (26.00)	0.12 (23.00)	0.09 (12.00)	0.07 (15.50)	0.07 (17.00)	0.05 (13.00)	0.04 (17.50)	0.04 (12.50)	0.02 (10.00)	**0.07**
75	0.99 (20.50)	1.17 (24.50)	1.69 (40.00)	0.90 (19.50)	1.18 (39.50)	0.87 (27.50)	0.98 (34.50)	0.31 (28.50)	0.56 (25.00)	0.30 (19.00)	**0.89**
105	2.22 (20.00)	2.40 (22.00)	2.05 (21.00)	2.20 (21.50)	1.20 (17.50)	2.01 (27.50)	1.30 (24.00)	0.47 (21.00)	0.75 (23.50)	0.45 (17.50)	**1.50**
140	5.07 (38.00)	4.78 (35.50)	3.31 (29.00)	5.49 (42.00)	3.89 (43.50)	3.67 (36.50)	1.60 (24.00)	0.70 (22.00)	1.07 (22.50)	0.62 (19.00)	**3.02**
MEAN (Locations)	**2.09**	**2.13**	**1.79**	**2.17**	**1.58**	**1.65**	**0.98**	**0.38**	**0.60**	**0.34**	
MEAN (for grade)	**2.11**		**1.80**				**0.58**				

For comparing means of (only uptake)	S.Em±	CD (0.05)	For comparing grade means by contrast	F test
Locations (L)	0.13	0.36	A Vs. B	*
DAT	0.08	0.22	A Vs. C	*
L X DAT	0.25	0.71	B Vs. C	*

Figures in the parentheses indicate concentration (ppm)
* Significant at 5%.

Devanur locations were on par with one another for both Cu and Zn uptake. In second grade locations, Cu and Zn uptake ranged from 0.73 to 1.03 and 1.58 to 2.17 mg per plant, respectively. It is found that all the four locations were on par with each other for both Cu and Zn uptake. Similarly among third grade locations, plants of Savanur location recorded highest Cu (0.32 mg/plant) and Zn uptake (0.98 mg/plant), while plants of Asundi location recorded lowest (0.09 and 0.34 mg/plant of Cu and Zn respectively) and significant difference existed between these two locations. Among the three red soil locations, plants of Thimmenhalli location recorded comparatively higher uptake than plants of other two red soil locations (Kalagond and Asundi).

Cu and Zn uptake by plants differed significantly at all growth stages and uptake of Cu and Zn ranged from 0.03 to 1.37 and 0.07 to 3.02 mg per plant,respectively.

Interaction effects of locations and growth stages influenced the Cu and Zn uptake significantly. However at 45 DAT, plants of all locations were on par with each other for Cu and Zn uptake which ranged from 0.01 to 0.05 and 0.02 to 0.18 mg per plant, respectively. At all the growth stages, plants of Gudgeri location were on par with plants of Devanur location and highest values (2.96 mg/plant of Cu uptake and 5.07 mg/plant of Zn uptake) were recorded in plants of Devanur and Gudgeri locations at 140 DAT, whereas plants of Asundi red soil location recorded lowest Cu and Zn uptake at all growth stages.

4.6.6(b) Dyavnur and Byadgi dabbi cvs.

Perusal of data presented in Tables 17(a) and 18(a) reveal that, significant difference existed between locations with respect to the uptake of both Cu and Zn by plants in both cultivars. In Dyavnur cultivar highest Cu (1.23 mg/plant) and Zn uptake (2.73 mg/plant) was observed in plants of Devanur location and differed significantly

Table 17(a) : Copper concentration and uptake (mg/plant) by chilli (Cvs. Dyavnur and Byadgi dabbi) at different growth stages at various locations

Days after transplanting (DAT)	Cv. DYAVNUR LOCATIONS					MEAN	Cv. BYADGI DABBI LOCATIONS						MEAN
	Gudgeri	Devanur	Ganjigatti	Dharwad	Annigeri α		Gudgeri	Devanur	Yaliwal	Malligawad α	Saidapur α	Kurtkoti α	
	Ist GRADE (A)		IInd GRADE (B)				Ist GRADE (A)		IInd GRADE (B)				
45	0.06 (9.50)	0.08 (12.00)	0.04 (8.00)	0.29 (13.00)	0.04 (10.50)	**0.10**	0.06 (11.50)	0.05 (8.00)	0.04 (8.00)	0.04 (12.00)	0.05 (11.00)	0.03 (9.50)	**0.04**
75	0.63 (20.00)	1.04 (23.00)	0.36 (12.00)	0.68 (28.00)	0.38 (18.00)	**0.62**	1.14 (29.50)	1.36 (31.50)	1.08 (34.00)	0.79 (34.00)	0.49 (22.00)	0.38 (20.00)	**0.87**
105	1.30 (16.50)	1.86 (18.00)	0.99 (15.00)	0.61 (11.00)	0.31 (6.50)	**1.01**	1.13 (13.50)	1.90 (19.00)	1.10 (15.50)	0.97 (16.50)	0.64 (12.00)	0.67 (16.50)	**1.07**
140	2.31 (20.50)	1.95 (14.00)	1.17 (12.00)	1.26 (17.00)	1.12 (16.00)	**1.56**	2.96 (26.00)	2.87 (23.00)	2.21 (21.50)	1.39 (17.50)	1.52 (23.00)	1.16 (23.00)	**2.02**
MEAN (LOCATIONS)	**1.07**	**1.23**	**0.64**	**0.71**	**0.46**		**1.32**	**1.55**	**1.11**	**0.79**	**0.67**	**0.56**	
MEAN FOR GRADE	**1.15**		**0.60**				**1.44**		**0.78**				

For comparing means of (only uptake)	S.Em±	CD (0.05)	For comparing grade means by contrast	F test		For comparing means of (only uptake)	S.Em±	CD (0.05)	For comparing grade means by contrast	F test
Locations (L)	0.08	0.23	A Vs. B	*		Locations (L)	0.07	0.21	A Vs. B	*
DAT	0.07	0.20				DAT	0.06	0.17		
L X DAT	0.15	0.46				L X DAT	0.14	0.42		

Figures in the parentheses indicate conc. (ppm), * Significant at 5 per cent. α - Drill sown locations

Table 18(a) : Zinc concentration and uptake (mg/plant) by chilli (Cvs. Dyavnur and Byadgi dabbi) at different growth stages at various locations

Days after transplanting (DAT)	Cv. DYAVNUR LOCATIONS					MEAN	Cv. BYADGI DABBI LOCATIONS						MEAN
	Gudgeri	Devanur	Ganjigatti	Dharwad	Annigeriα		Gudgeri	Devanur	Yaliwal	Malligawadα	Saidapurα	Kurtkotiα	
	Ist GRADE (A)		IInd GRADE (B)				Ist GRADE (A)		IInd GRADE (B)				
45	0.09 (15.00)	0.23 (35.00)	0.14 (26.00)	0.13 (26.50)	0.06 (15.50)	**0.13**	0.11 (20.50)	0.15 (22.00)	0.13 (23.50)	0.10 (29.00)	0.08 (19.50)	0.06 (19.00)	**0.10**
75	0.90 (28.50)	2.31 (49.50)	0.96 (32.00)	1.18 (47.50)	0.71 (33.00)	**1.21**	1.61 (42.00)	1.28 (29.50)	1.43 (44.50)	1.19 (51.50)	1.07 (47.00)	0.78 (41.50)	**1.22**
105	1.61 (20.50)	2.63 (26.00)	1.45 (22.00)	1.32 (24.50)	0.95 (19.50)	**1.59**	3.52 (42.00)	3.16 (31.50)	1.88 (26.50)	1.50 (25.50)	1.51 (28.50)	0.75 (19.00)	**2.05**
140	4.78 (42.50)	5.75 (41.50)	4.02 (41.00)	2.93 (39.50)	2.96 (42.50)	**4.09**	4.15 (36.50)	4.50 (36.00)	4.89 (47.50)	2.94 (37.00)	2.66 (40.50)	1.69 (33.50)	**3.47**
MEAN (LOCATIONS)	**1.84**	**2.73**	**1.64**	**1.39**	**1.17**		**2.35**	**2.27**	**2.08**	**1.43**	**1.33**	**0.82**	
MEAN FOR GRADE	**2.29**		**1.40**				**2.31**		**1.42**				

For comparing means of (only uptake)	S.Em±	CD (0.05)	For comparing grade means by contrast	F test		For comparing means of (only uptake)	S.Em±	CD (0.05)	For comparing grade means by contrast	F test
Locations (L)	0.23	0.68	A Vs. B	*		Locations (L)	0.14	0.40	A Vs. B	*
DAT	0.21	0.61				DAT	0.11	0.32		
L X DAT	0.46	1.36				L X DAT	0.27	0.79		

Figures in the parentheses indicate conc. (ppm), * Significant at 5 per cent. α - Drill sown locations

from plants of all other locations. Similarly in Byadgi dabbi cultivar also, highest Cu (1.55 mg/plant) and Zn uptake (2.35 mg/plant) were found in plants of Devanur and Gudgeri locations,respectively. Generally transplanted plants have higher uptake of both nutrients than drill sown plants in both cultivars.

Plants of first grade locations recorded higher uptake of both nutrients than plants of second grade locations and significant difference existed between them (F test by contrast).

In both cultivars, Cu and Zn uptake differed significantly at all growth stages and Cu uptake in Dyavnur and Byadgi dabbi cultivars at different stages ranged from 0.10 to 1.56 and 0.04 to 2.02 mg per plant respectively. Similarly Zn uptake in Dyavnur and Byadgi dabbi cultivar ranged from 0.13 to 4.09 and 0.10 to 3.47 mg per plant, respectively.

Interaction effects were significant in influencing the uptake of both Cu and Zn by plants in both cultivars. However at 45 DAT, plants of all locations were on par with one another. In Dyavnur cultivar, plants of Devanur location recorded highest uptake of both nutrients closely followed by plants of Gudgeri location at all stages except at 140 DAT, where cu uptake was more in Gudgeri than in Devanur location.

4.6.7 Fe and Mn uptake

4.6.7(a) Byadgi kaddi cv.

Perusal of data presented in Tables 19 and 20 reveal that, plants of Gudgeri, Devanur and Devagiri locations were on par with each other for the uptake of both Fe and Mn. It is found that, plants of Devanur and Gudgeri locations recorded highest uptake of Fe (26.26 mg/plant) and Mn (6.34 mg/plant) respectively, while plants of Asundi and

Table 19 : Iron concentration and uptake (mg/plant) by chilli (Cv. Byadgi kaddi) at different growth stages at various locations

Days after transplanting (DAT)	LOCATIONS										
	Gudgeri	Devanur	Ganjigatti	Devagiri	Somanhalli	Dharwad	Savanur	Kalagond	Thimmenhalli	Asundi	MEAN
	Ist grade (A)		IInd grade (B)				IIIrd grade (C)				
45	1.10 (168.50)	1.79 (272.50)	1.64 (270.00)	1.17 (170.00)	1.02 (226.50)	0.52 (132.50)	0.36 (105.00)	0.53 (212.50)	0.28 (107.50)	0.25 (104.50)	**0.86**
75	11.93 (247.00)	14.65 (306.00)	18.59 (432.50)	10.46 (230.00)	9.64 (317.50)	6.71 (215.00)	3.76 (155.00)	3.41 (297.50)	3.49 (160.00)	1.45 (94.00)	**8.41**
105	41.59 (377.50)	42.31 (388.50)	32.42 (336.00)	40.11 (388.00)	17.53 (256.50)	20.75 (277.00)	10.89 (199.00)	4.64 (206.50)	8.19 (255.50)	4.79 (192.50)	**22.32**
140	43.44 (326.00)	46.29 (344.50)	33.98 (300.50)	43.20 (325.00)	21.01 (234.50)	25.85 (250.50)	12.58 (187.50)	5.99 (187.50)	9.39 (197.50)	6.35 (197.00)	**24.81**
MEAN (Locations)	**24.51**	**26.26**	**21.65**	**23.73**	**12.30**	**13.45**	**6.90**	**3.64**	**5.34**	**3.21**	
MEAN (for grade)	**25.39**		**17.78**				**4.77**				

For comparing means of (only uptake)	S.Em±	CD (0.05)	For comparing grade means by contrast	F test
Locations (L)	1.28	3.65	A Vs. B	*
DAT	0.80	2.30	A Vs. C	*
L X DAT	2.55	7.29	B Vs. C	*

Figures in the parentheses indicate concentration (ppm)
* Significant at 5%.

Table 20 : Manganese concentration and uptake (mg/plant) by chilli (Cv. Byadgi kaddi) at different growth stages at various locations

Days after transplanting (DAT)	LOCATIONS										
	Gudgeri	Devanur	Ganjigatti	Devagiri	Somanhalli	Dharwad	Savanur	Kalagond	Thimmenhalli	Asundi	MEAN
	Ist grade (A)		IInd grade (B)				IIIrd grade (C)				
45	0.33	0.38	0.28	0.27	0.20	0.13	0.09	0.13	0.15	0.12	**0.21**
	(50.50)	(56.50)	(47.50)	(39.00)	(45.00)	(32.00)	(27.50)	(52.50)	(57.50)	(55.00)	
75	3.98	4.08	4.71	2.96	2.59	1.87	1.19	0.98	2.42	0.95	**2.57**
	(82.50)	(85.00)	(110.00)	(65.00)	(85.00)	(60.00)	(47.50)	(90.00)	(110.00)	(61.00)	
105	9.97	8.68	9.50	9.68	8.00	7.88	5.49	1.51	2.88	1.66	**6.52**
	(90.50)	(79.50)	(98.00)	(93.50)	(117.00)	(107.00)	(98.00)	(67.00)	(90.00)	(65.50)	
140	11.08	10.49	10.77	10.96	9.57	9.87	6.08	2.03	3.96	2.18	**7.70**
	(83.00)	(77.50)	(95.00)	(82.50)	(107.50)	(97.50)	(88.50)	(62.50)	(83.00)	(67.50)	
MEAN (Locations)	**6.34**	**5.90**	**6.31**	**5.96**	**5.09**	**4.94**	**3.21**	**1.16**	**2.35**	**1.22**	
MEAN (for grade)	**6.12**		**5.58**				**1.98**				

For comparing means of (only uptake)	S.Em±	CD (0.05)	For comparing grade means by contrast	F test
Locations (L)	0.41	1.17	A Vs. B	*
DAT	0.26	0.74	A Vs. C	*
L X DAT	0.82	2.35	B Vs. C	*

Figures in the parentheses indicate concentration (ppm)
* Significant at 5%.

Kalagond locations recorded lowest uptake of Fe and Mn, respectively. All the four locations that produced third grade fruits were on par with each other for Fe uptake and plants of Savanur location recorded higher uptake (6.90 mg/plant) than plants of Kalagond, Thimmenhalli and Asundi locations. Similarly, plants of Savanur location that recorded 3.21 mg per plant of Mn uptake differed significantly from plants of Kalagond (1.16 mg/plant) and Asundi (1.22 mg/plant) locations, but were on par with Thimmenhalli location (2.35 mg/plant). Further Fe and Mn uptake in second grade locations ranged from 12.30 to 21.65 and 4.94 to 6.31 mg per plant, respectively.

The three groups of locations, that produced first, second and third grade fruits differed significantly with respect to Fe and Mn uptake by plants (F test by contrast). Plants of first grade locations recorded highest uptake (25.39 and 6.12 mg/plant of Fe and Mn respectively) closely followed by plants of second group locations with 17.78 and 5.58 mg per plant of Fe and Mn uptake, respectively. Lowest uptake of both nutrients was found in plants of third group locations.

Growth stages differed significantly with respect to the uptake of both nutrients and Fe uptake ranged from 0.86 mg per plant at 45 DAT to 24.81 mg per plant at 140 DAT and Mn uptake ranged from 0.21 mg per plant to 7.70 mg per plant. Interaction effects were significant in influencing the uptake of both Fe and Mn. Highest uptake of Fe (46.29 mg/plant) and Mn (11.08 mg/plant) was found in plants of Devanur and Gudgeri locations at 140 DAT, respectively.

4.6.7(b) Dyavnur and Byadgi dabbi cvs. Tables 19(a) and 20(a)

In both cultivars, plants of first grade locations recorded higher uptake of both nutrients than plants of second group locations and significant difference existed between first and second grade locations with respect to uptake of both Fe and Mn (F-test by

Table 19(a) : Iron concentration and uptake (mg/plant) by chilli (Cvs. Dyavnur and Byadgi dabbi) at different growth stages at various locations

Days after transplanting (DAT)	Cv. DYAVNUR					MEAN	Cv. BYADGI DABBI						MEAN
	LOCATIONS						LOCATIONS						
	Gudgeri	Devanur	Ganjigatti	Dharwad	Annigeriα		Gudgeri	Devanur	Yaliwal	Malligawadα	Saidapurα	Kurtkotiα	
	Ist GRADE (A)		IInd GRADE (B)				Ist GRADE (A)			Iind GRADE (B)			
45	1.07 (185.00)	2.41 (405.00)	1.40 (272.50)	1.05 (231.00)	0.99 (256.50)	**1.38**	1.26 (240.00)	1.93 (298.50)	1.00 (194.50)	0.67 (199.50)	0.75 (187.50)	0.67 (225.00)	**1.05**
75	9.08 (287.50)	20.43 (457.50)	9.51 (322.50)	10.38 (425.00)	6.50 (302.50)	**11.18**	15.01 (391.00)	20.00 (465.00)	14.07 (442.50)	5.92 (258.50)	7.76 (350.00)	4.87 (260.00)	**11.27**
105	18.82 (242.00)	34.26 (337.00)	21.87 (331.50)	19.30 (356.00)	12.84 (266.50)	**21.42**	31.84 (379.50)	39.76 (397.50)	15.70 (220.50)	18.11 (309.00)	20.67 (391.00)	12.06 (308.00)	**23.02**
140	22.78 (202.50)	41.20 (296.50)	29.10 (298.50)	22.56 (324.50)	16.26 (233.00)	**26.38**	36.07 (317.50)	44.43 (355.00)	20.96 (204.00)	18.32 (231.50)	23.93 (363.50)	13.72 (280.50)	**26.24**
MEAN (LOCATIONS)	**12.93**	**24.57**	**15.47**	**13.32**	**9.15**		**21.04**	**26.53**	**12.93**	**10.76**	**13.28**	**7.83**	
MEAN FOR GRADE	**18.75**		**12.65**				**23.79**		**11.20**				

For comparing means of (only uptake)	S.Em±	CD (0.05)	For comparing grade means by contrast	F test		For comparing means of (only uptake)	S.Em±	CD (0.05)	For comparing grade means by contrast	F test
Locations (L)	0.75	2.21	A Vs. B	*		Locations (L)	0.57	1.66	A Vs. B	*
DAT	0.67	1.98				DAT	0.46	1.35		
L X DAT	1.50	4.43				L X DAT	1.14	3.32		

Figures in the parentheses indicate conc. (ppm), * Significant at 5 per cent. α - Drill sown locations

Table 20(a): Manganese concentration and uptake (mg/plant) by chilli (Cvs. Dyavnur and Byadgi dabbi) at different growth stages at various locations

Days after transplanting (DAT)	Cv. DYAVNUR LOCATIONS					MEAN	Cv. BYADGI DABBI LOCATIONS						MEAN
	Gudgeri	Devanur	Ganjigatti	Dharwad	Annigeriα		Gudgeri	Devanur	Yaliwal	Malligawadα	Saidapurα	Kurtkotiα	
	Ist GRADE (A)		IInd GRADE (B)				Ist GRADE (A)			IInd GRADE (B)			
45	0.26 (45.00)	0.41 (67.50)	0.25 (47.50)	0.31 (67.50)	0.22 (57.50)	**0.29**	0.39 (73.50)	0.53 (81.50)	0.46 (90.00)	0.30 (88.50)	0.35 (87.50)	0.12 (40.00)	**0.36**
75	3.32 (105.00)	6.29 (140.00)	2.15 (72.50)	3.50 (142.50)	1.67 (76.00)	**3.38**	2.70 (70.00)	4.54 (105.00)	4.11 (130.00)	2.39 (104.50)	2.62 (117.50)	1.07 (57.00)	**2.90**
105	9.24 (118.50)	14.48 (143.50)	5.02 (76.50)	5.38 (97.50)	4.66 (97.50)	**7.76**	6.61 (79.00)	6.27 (62.50)	7.45 (105.00)	6.95 (118.50)	5.58 (105.50)	4.65 (119.00)	**6.25**
140	10.38 (92.00)	16.99 (122.50)	5.88 (60.50)	5.95 (80.00)	6.00 (86.50)	**9.04**	8.53 (75.00)	8.18 (65.50)	9.47 (92.00)	8.03 (101.50)	5.96 (90.50)	5.11 (103.00)	**7.54**
MEAN (LOCATIONS)	**5.80**	**9.54**	**3.32**	**3.78**	**3.14**		**4.55**	**4.88**	**5.37**	**4.42**	**3.62**	**2.74**	
MEAN FOR GRADE	**7.67**		**3.41**				**4.72**		**4.04**				

For comparing means of (only uptake)	S.Em±	CD (0.05)	For comparing grade means by contrast	F test		For comparing means of (only uptake)	S.Em±	CD (0.05)	For comparing grade means by contrast	F test
Locations (L)	0.37	1.08	A Vs. B	*		Locations (L)	0.22	0.64	A Vs. B	*
DAT	0.33	0.97				DAT	0.18	0.53		
L X DAT	0.74	2.17				L X DAT	0.44	1.29		

Figures in the parentheses indicate conc. (ppm), * Significant at 5 per cent. α - Drill sown locations

contrast). Further, all growth stages differed significantly with respect to the uptake of both Fe and Mn in both cultivars.

In Dyavnur cv. plants of Devanur location recorded highest uptake of both nutrients (24.57 and 5.54 mg/plant of Fe and Mn respectively) and differed significantly from plants of all other locations. Similarly, in Byadgi dabbi cv., highest uptake of Fe (26.53 mg/plant) and Mn (5.37 mg/plant) was noticed in plants of Devanur and Yaliwal locations, respectively. Drill sown plants of Annigeri and Kurtkoti locations recorded lowest uptake of both nutrients in Dyavnur and Byadgi dabbi cultivars, respectively.

Interaction effects were significant in influencing the uptake of both Fe and Mn in both cultivars, however at 45 DAT, plants of all locations were on par with each other. At 75, 105 and 140 DAT in Dyavnur cultivar plants of Devanur location recorded highest uptake of both nutrients and differed significantly from plants of all other locations. Similarly in Byadgi dabbi cv., highest Fe uptake (44.43 mg/plant) and Mn uptake (9.47 mg/plant) was observed in plantsof Devanur and Yaliwal locations respectively at 140 DAT.

4.7 Physical characteristics of chilli fruits

Data pertaining to physical characteristics of chilli fruits (Byadgi kaddi, Dyavnur and Byadgi dabbi cultivars) recorded at different locations are presented in Tables 21 and 21(a).

4.7.1 Fruit length, breadth and L/B ratio

4.7.1(a) Byadgi kaddi cv. **Table 21**

Significant difference existed between first, second and third grade fruits with respect to fruit length and L/B ratio as shown by F test by contrast. Further, first grade fruits recorded highest fruit length (16.88 cm) and L/B ratio (32.34), where as third grade

Table 21. Physical characteristics of different grade chilli fruits (cv. Byadgi kaddi) recorded at harvest at various locations

Locations	Fruit grade	Fruit length (L) (cm)	Fruit breadth (B) (cm)	L/B ratio	Single fruit weight (gm)	Fruit components: Pericarp (%)	Seed (%)	Pedicel (%)
Gudgeri	Ist Grade (A)	16.75	0.55	30.67	1.01	49.02	41.89	9.09
Devanur		17.00	0.50	34.00	0.96	48.75	43.22	8.03
		16.88	**0.53**	**32.34**	**0.99**	**48.89**	**42.56**	**8.56**
Ganjigatti	IInd Grade (B)	13.25	0.75	17.73	0.79	43.70	42.80	13.50
Devagiri		16.75	0.65	25.95	1.00	48.52	40.78	12.70
Somanhalli		13.75	0.85	16.25	0.68	46.68	45.44	7.88
Dharwad		14.00	1.05	13.40	0.76	46.38	44.79	8.83
		14.44	**0.83**	**18.33**	**0.81**	**45.82**	**43.45**	**10.73**
Savanur	III Grade (C)	14.10	0.85	16.65	0.65	48.42	38.81	12.77
Kalagond		11.25	0.75	15.13	0.63	44.50	46.99	8.51
Thimmenhalli		11.60	0.75	15.50	0.67	41.25	43.55	15.20
Asundi		10.25	0.80	13.05	0.54	42.60	43.45	13.95
		11.80	**0.79**	**15.08**	**0.63**	**44.19**	**43.20**	**12.61**
For comparing locations	S.Em±	0.28	0.06	1.59	0.03	0.92	0.82	1.07
	C.D. (0.05)	0.88	0.19	5.09	0.10	2.93	2.62	3.42
	F-test							
For comparing grade means by contrast	A Vs B	*	*	*	*	*	NS	*
	A Vs C	*	*	*	*	*	NS	*
	B Vs C	*	NS	*	*	*	NS	*

Note: Figures in bold indicate grade means compared with F test by contrast
* Significant at 5 per cent.
NS – Non significant.

fruits recorded lowest (11.80 cm and 15.08). Second grade fruits were intermediate in their values of fruit length and L/B ratio. Further, Devanur location recorded maximum fruit length (17.00 cm) and L/B ratio (34.00) which were on par with fruits of Gudgeri and Devagiri locations with an exception of significant difference between Devanur and Devagiri locations for L/B ratio. Similarly, lowest fruit length (10.25 cm) and L/B ratio (13.05) were recorded in third grade fruits of Asundi red soil location which differed significantly from all other locations with regard to fruit length, but for L/B ratio, they were on par with all other locations except fruits of Gudgeri, Devanur and Devagiri locations. Among second grade locations, fruits of Ganjigatti, Somanhalli and Dharwad locations were on par with each other with regard to fruit length and L/B ratio, but they differed significantly from fruits of Devagiri location. Among the three red soil locations, fruits of Thimmenhalli location recorded higher fruit length (11.60 cm) and L/B ratio (15.50) than fruits of other two locations and differed significantly from fruits of Asundi location with respect to fruit length only, but were on par with fruits of Kalagond location.

Contrary to the higher values of fruit length and L/B ratio in first grade fruits, fruit breadth was lowest (0.53 cm) in these fruits, while second grade fruits recorded highest breadth (0.83 cm) and third grade fruits having lowest fruit length and L/B ratio were intermediate in fruit breadth value (0.79 cm). First grade fruits differed significantly from second and third grade fruits with regard to fruit breadth, but second grade fruits did not differ significantly from third grade fruits.

4.7.1(b) Dyavnur and Byadgi dabbi cvs. **Table 21(a)**

Length of Dyavnur and Byadgi dabbi fruit samples of study area ranged from 10.50 to 14.25 cm and 8.75 to 12.00 cm,respectively. Similarly, fruit breadth ranged from 1.35 to 1.75 and 1.75 to 2.05 cm for Dyavnur and Byadgi dabbi fruit samples respectively. In both cultivars, first grade fruits recorded higher length (13.50 and 11.75

Table 21(a). Physical characteristics of different grade chilli fruits (Cvs. Dyanrnur an Byadgi dabbi) recorded at harvest at different locations

Dyavnur Cv.

						Fruit components		
Locations	Fruit grade	Fruit length (L) (cm)	Fruit breadth (B) (cm)	L/B ratio	Single fruit weight (gm)	Pericarp	Seeds	Pedicel
							(%)	
Gudgeri	Ist Grade	12.75	1.45	8.81	1.09	50.67	40.77	8.56
Devanur	(A)	14.25	1.75	8.19	1.15	49.91	44.30	5.80
	Mean (A)	**13.50**	**1.60**	**8.50**	**1.12**	**50.29**	**42.54**	**7.18**
Ganjigatti	IInd Grade	10.50	1.45	7.59	1.09	49.77	43.85	6.39
Dharwad	(B)	11.75	1.65	7.20	1.08	47.21	45.03	7.77
Annigeri		12.25	1.35	9.09	1.07	51.55	39.42	9.04
	Mean (B)	**11.50**	**1.48**	**7.96**	**1.08**	**49.51**	**42.77**	**7.73**
Cal. 't' value		2.30	0.75	0.69	2.00	0.47	0.0.9	0.32
Table 't' (0.05) at 3df	3.18	NS	NS	NS	NS	NS	NS	NS

Byadgi dabbi Cv.

						Fruit components		
Locations	Fruit grade	Fruit length (L) (cm)	Fruit breadth (B) (cm)	L/B ratio	Single fruit weight (gm)	Pericarp	Seeds	Pedicel
							(%)	
Gudgeri	Ist Grade	12.00	1.85	6.50	1.83	54.23	38.99	6.79
Devanur	(A)	11.50	1.75	6.58	1.90	52.58	41.09	6.34
	Mean (A)	**11.75**	**1.80**	**6.54**	**1.87**	**53.41**	**40.04**	**6.57**
Yaliwal		10.25	1.95	5.26	1.71	53.76	39.06	7.19
Malligawad	IInd Grade	8.75	2.05	4.28	1.58	52.92	40.94	6.15
Saidapur	(B)	9.75	1.75	5.58	1.66	50.36	41.24	8.41
Kurtkoti		8.75	1.95	4.50	1.52	49.65	42.32	8.03
	Mean (B)	**9.38**	**1.93**	**4.91**	**1.62**	**51.67**	**40.89**	**7.45**
Cal. 't' value		4.65	1.31	3.54	3.57	1.11	0.71	1.15
Table 't' (0.05) at 4df	2.78	*	NS	*	*	NS	NS	NS

NS – Nonsignificant , * Significant at 5 per cent.

cm for Dyavnur and Byadgi dabbi fruits, respectively) than second grade fruits with 11.50 and 9.38 cm fruit length, respectively. T test showed significant difference between the two grades of fruits with regard to fruit length for Byadgi dabbi cultivar, while it was non significant for Dyavnur cultivar. Similarly, with respect to fruit breadth, non significant difference existed between first and second grade fruits in both cultivars, however second grade fruits of Byadgi dabbi cultivar recorded higher breadth (1.93 cm) than first grade fruits (1.80 cm) and it is vice-versa in fruits of Dyavnur cultivar.

L/B ratio of Dyavnur and Byadgi dabbi fruit samples ranged from 7.20 to 9.09 and 4.28 to 6.58 respectively and second grade fruits of Annigeri location recorded highest L/B ratio (9.09) in case of Dyavnur cultivar while in case of Byadgi dabbi cultivar first grade fruits of Devanur location recorded highest L/B ratio (6.58). Further, significant difference existed between first and second grade fruits with respect to L/B ratio in case of Byadgi dabbi cultivar, while it was non significant in case of Dyavnur cultivar (T test).

When all the three cultivars were compared, it can be concluded that, Byadgi kaddi fruits have highest length and L/B ratio, while dabbi fruits have lowest length and L/B ratio and Dyavnur fruits were intermediate in their values.

4.7.2 Single fruit weight

4.7.2(a) Byadgi kaddi cv.

First grade fruits recorded highest value of single fruit weight (0.99 g) and differed significantly from second (0.81 g) and third (0.63 g) grade fruits (F-test by contrast). Further, fruits of Gudgeri location, having maximum weight (1.01 g) were on par with those of Devanur (0.96 g) and Devagiri (1.00 g) locations, but differed significantly from fruits of other locations. Similarly, lowest value (0.54 g) was recorded in fruits of Asundi red soil location which differed significantly from fruits of other locations.

4.7.2(b) Dyavnur and Byadgi dabbi cvs.

Perusal of data presented in Table 21(a) reveal that, in both cultivars, fruits of Devanur location recorded highest single fruit weight (1.15 and 1.90 g) closely followed by fruits of Gudgeri location. Similarly lowest values (1.07 and 1.52 g) were recorded in fruits of Annigeri and Kurtkoti locations for Dyavnur and Byadgi dabbi fruits, respectively. Similar to the fruits of Byadgi kaddi cultivar, first grade fruits recorded higher fruit weight than second grade fruits and significant difference existed between two grades fruits in case of Byadgi dabbi cultivar, while it was non significant in Dyavnur cultivar (t-test).

Based on Tables 21 and 21(a), it can be inferred that, Byadgi dabbi fruits have highest single fruit weight while Byadgi kaddi fruits have lowest weight and Dyavnur fruits were intermediate in single fruit weight value.

4.7.3 Pericarp, seeds and pedicel per cent in whole fruit

4.7.3(a) Byadgi kaddi cv. **Table 21**

Significant difference existed between all the three grades of fruits with respect to pericarp and pedicel per cent, while with respect to seed content non significant difference existed. It is found that, first grade fruits recorded highest pericarp (48.89%) and lowest pedicel (8.56%) content, while third grade fruits recorded lowest pericarp (44.19%) and highest pedicel (12.61%) contents. Further, second and third grade fruits, recorded more seed content than first grade fruits (42.56%). Fruit samples of Gudgeri and Devanur locations were on par with each other with regard to all the three fruit components and fruits of Gudgeri location recorded highest pericarp per cent (49.02%). Similarly, lowest pericarp (41.25%) and seed contents (38.81%) were observed in third grade fruits of Thimmenhalli and Savanur locations. With regard to pedicel content, highest (15.20%) and lowest values (7.88%) were observed in fruits of Thimmenhalli and Somanhalli locations, respectively.

4.7.3(b) Dyavnur and Byadgi dabbi cvs. **Table 21(a)**

Nonsignificant difference existed between first and second grade fruits with regard to the distribution of all fruit components in both cultivars. However first grade fruits recorded higher pericarp content than second grade fruits while seeds and pedicel contents were higher in second grade fruits.

Pericarp content in Dyavnur and Byadgi dabbi fruit samples study area ranged from 47.21 to 51.55 and 49.65 to 54.23 per cent, respectively. Fruits of Gudgeri location recorded highest pericarp component (50.67 and 54.23%), while fruits of Dharwad and Devanur locations recorded lowest values (41.21 and 52.58 per cent for Dyavnur and Dabbi fruits, respectively). Among drill sown locations in Byadgi dabbi cultivar, fruits of Kurtkoti recorded lowest value (49.65%), while fruits of Malligawad location recorded highest (52.92%).

Similar to pericarp content, seed content in Dyavnur and Byadgi dabbi fruit samples ranged from 39.42 to 45.03 and 38.99 to 42.32 per cent, respectively. A cursory look at the data showed that, inverse relationship exist between pericarp and seed contents. Lastly, pedicel per cent ranged from 5.80 to 9.04 and 6.15 to 8.41 per cent as recorded in Dyavnur and Byadgi dabbi cultivars, respectively.

When all the three cultivars were compared for distribution of fruit components, it can be concluded that, Byadgi dabbi fruits have maximum pericarp component, while Byadgi kaddi fruits have minimum and Dyavnur fruits were intermediate in pericarp component. Similarly, seed and pedicel contents were minimum in Byadgi dabbi fruits, while Dyavnur and Byadgi kaddi fruits recorded almost same seed content.

4.8 Chemical characteristics of chilli fruits

Data pertaining to chemical characteristics of chilli fruit samples (Byadgi kaddi, Dyavnur and Byadgi dabbi cvs.) of study area are presented in Tables 22 and 22(a).

4.8.1 Moisture content of sundried fruits

4.8.1(a) Byadgi kaddi cv.

Sun dried fruit samples of different locations did not differ significantly with respect to moisture content and ranged from 9.76 to 11.22 per cent recorded in fruit samples of Asundi and Thimmenahalli locations, respectively. First grade fruits recorded slightly higher (10.87%) moisture content than second grade fruits (10.51%) and lowest moisture content (10.31%) was found in third grade fruits.

4.8.1(b) Dyavnur and Byadgi dabbi cvs.

Moisture content ranged from 12.13 to 13.83 and 12.44 to 15.00 per cent for sundried fruit samples of Dyavnur and Byadgi dabbi cultivars, respectively and non significant difference existed between first and second grade fruits (T-test). Among the three cultivars, fruits of Byadgi dabbi cultivar had comparatively higher moisture content than Dyavnur fruits and Byadgi kaddi fruits contain lowest moisture content.

Table 22 . Chemical characteristics of different grade chilli fruits (cvs. Byadgi kaddi) as influenced by various locations

Locations	Fruit grade	Moisture content of Sun dried fruit	Moisture content of fresh fruit	Protein	Total Ash	Non volatile ether extract (NVEE)	Volatile ether extract (VEE)	Total ether extract (TEE)
		Per cent						
Gudgeri	Ist Grade	10.75	78.91	10.69	6.60	15.75	0.24	15.99
Devanur	(A)	10.99	79.53	11.57	6.14	15.98	0.23	16.21
		10.87	**79.22**	**11.13**	**6.37**	**15.87**	**0.24**	**16.10**
Ganjigatti		10.43	74.95	10.50	6.11	14.43	0.24	14.67
Devagiri	IInd Grade	9.93	77.92	10.57	6.20	15.16	0.26	15.42
Somanhalli	(B)	10.90	70.88	10.35	5.99	14.85	0.31	15.16
Dharwad		10.76	75.10	10.44	6.08	14.73	0.27	15.00
		10.51	**74.71**	**10.47**	**6.10**	**14.79**	**0.27**	**15.06**
Savanur		10.01	66.89	9.78	5.90	14.60	0.28	14.88
Kalagond	IIIrd Grade	10.26	55.73	9.44	5.49	15.38	0.27	15.65
Thimmenhalli	(C)	11.22	62.68	9.69	5.26	15.93	0.28	16.20
Asundi		9.76	53.39	9.59	5.80	15.31	0.28	15.58
		10.31	**59.67**	**9.63**	**5.61**	**15.31**	**0.28**	**15.58**
For comparing locations	S.Em±	0.35	0.71	0.31	0.13	0.13	0.01	0.14
	C.D. (0.05)	NS	2.28	0.99	0.43	0.43	0.02	0.44
	F-test							
For comparing grade means by contrast	A Vs B	-	*	*	*	*	*	*
	A Vs C	-	*	*	*	*	*	*
	B Vs C	-	*	*	*	*	NS	*

Note: Figures in bold indicate grade means compared with F test by contrast
* Significant at 5 per cent.
NS – Non significant.

Table 22(a) . Chemical characteristics of different grade chilli fruits (Cvs. Dyavnur and Byadgi dabbi) as influenced by various locations

Dyavnur Cv.

Locations	Fruit grade	Moisture content of sun dried fruits	Moisture content of fresh fruits	Protein	Total ash	Non volatile ether extract (NVEE)	Volatile ether extract (VEE)	Total ether extract (TEE)
		Per cent						
Gudgeri	Ist Grade	13.23	77.07	10.81	6.37	14.57	0.21	14.78
Devanur	(A)	13.58	78.66	11.38	6.45	14.54	0.23	14.76
	Mean (A)	**13.41**	**77.87**	**11.09**	**6.41**	**14.56**	**0.22**	**14.77**
Ganjigatti		12.98	76.69	10.00	6.17	14.74	0.26	15.00
Dharwad	IInd Grade	12.13	76.74	9.91	6.15	14.60	0.23	14.83
Annigeri	(B)	13.83	74.06	9.69	6.36	14.49	0.25	14.74
	Mean (B)	**12.98**	**75.83**	**9.87**	**3.23**	**14.61**	**0.25**	**14.86**
Cal. 't' value		0.66	1.59	5.08	1.82	0.55	3.00	0.92
Table 't' (0.05) at 3df	3.18	NS	NS	*	NS	NS	NS	NS

Byadgi dabbi Cv.

Locations	Fruit grade	Moisture content of sun dried fruits	Moisture content of fresh fruits	Protein	Total ash	Non volatile ether extract (NVEE)	Volatile ether extract (VEE)	Total ether extract (TEE)
		Per cent						
Gudgeri	Ist Grade	13.18	80.88	10.60	6.73	14.78	0.20	14.97
Devanur	(A)	12.44	81.04	10.82	7.20	14.63	0.19	14.82
	Mean (A)	**12.81**	**80.96**	**10.71**	**6.97**	**14.71**	**0.20**	**14.90**
Yaliwal		15.00	80.39	10.53	6.55	14.54	0.21	14.75
Malligawad	IInd Grade	13.62	78.95	10.38	6.63	14.72	0.21	14.94
Saidapur	(B)	13.11	79.29	10.32	6.28	14.91	0.21	15.12
Kurtkoti		13.80	79.80	9.81	6.40	14.85	0.23	15.08
	Mean (B)	**13.88**	**79.86**	**10.26**	**6.47**	**14.76**	**0.22**	**14.897**
Cal. 't' value		1.67	1.98	1.88	2.63	0.38	2.08	0.54
Table 't' (0.05) at 4df	2.78	NS	NS	NS	NS	NS	NS	NS

NS – Nonsignificant , * Significant at 5 per cent.

4.8.2 Moisture content of fresh fruits

4.8.2(a) Byadgi kaddi cv.

Table 22 indicated that, fruits of Devanur location recorded maximum moisture content (79.53%) and were on par with fruits of Gudgeri and Devagiri locations. Similarly, lowest moisture content (53.39%) was found in fruits of Asundi red soil location and differed significantly from fruits other two red soil locations including those of Savanur location having 66.89 per cent moisture.

Further, first grade fruits had highest moisture content (79.22%) while third grade fruits had lowest (59.67%) and intermediate moisture content (74.71%) was found in second grade fruits. Contrary to the nonsignificant difference that existed between three grades of fruits for moisture content at sundried stage, significant difference existed between the three grades at freshly harvested stage.

4.8.2(b) Dyavnur and Byadgi dabbi cvs. Table 22(a)

Similar to Byadgi kaddi cultivar, here also fruits of Devanur location recorded maximum moisture content (78.66 and 81.04 per cent for Dyavnur and Byadgi dabbi fruits respectively) followed by fruits of Gudgeri location. Lowest moisture content for Dyavnur and Byadgi dabbi fruits was recorded in freshly harvested fruits of Annigeri and Saidapur locations. It is found that, fruits of drill sown plants recorded slightly less moisture than fruits of transplanted ones. Though moisture content in first grade fruits was slightly higher than second grade fruits, yet non significant difference existed between them as indicated by t-test in both cultivars.

4.8.3 Protein and total ash per cent

4.8.3(a) Byadgi kaddi cv. **Table 22**

In this cultivar, protein and total ash contents of fruit samples ranged from 9.44 to 11.57 and 5.26 to 6.60 per cent, respectively. First grade fruits of Devanur and Gudgeri locations recorded highest protein and total ash contents, respectively while third grade fruits of Kalagond and Thimmenhalli locations recorded lowest values.

All the four second grade fruit samples were on par for protein and total ash contents which ranged from 10.35 to 10.57 and 5.99 to 6.20 per cent, respectively. First grade fruits contained highest protein (11.13%) and total ash (6.37%), whereas third grade fruits contained lowest protein (9.63) and total ash (5.61%) and second grade fruits were intermediate (10.47% protein) and (6.10% total ash).

4.8.3(b) Dyavnur and Byadgi dabbi cvs. **Table 22(a)**

Protein content in Dyavnur and Byadgi dabbi fruit samples ranged from 9.69 to 11.38 and 9.81 to 10.82 per cent, respectively. In both cultivars, first grade fruits of Devanur location recorded highest protein content, whereas second grade fruits of Annigeri and Kurtkoti locations recorded lowest values in Dyavnur and Byadgi dabbi fruits, respectively. Similarly, total ash content in Dyavnur and Byadgi dabbi fruits samples ranged from 6.15 to 6.45 and 6.28 to 7.20 per cent, respectively, and again first grade fruits of Devanur location recorded highest ash content in both cultivars.

Significant difference existed between first and second grade fruits with respect to protein content in case of Dyavnur cultivar, while in Byadgi dabbi cv. non significant difference was observed. Similarly, for total ash content non significant difference existed between the two grades of fruits in both cultivars (t-test). But numerially, higher values were observed in first grade fruits both for protein and total ash.

4.8.4 NVEE, VEE and TEE contents

4.8.4(a) Byadgi kaddi cv. Table 22

NVEE, VEE and TEE contents in fruit samples of study area ranged from 14.43 to 15.98, 0.23 to 0.31 and 14.67 to 16.21 per cent, respectively. Highest NVEE, VEE and TEE contents were recorded in fruits of Devanur , Somanhalli and Devanur locations, respectively. Similarly lowest NVEE (14.43%) and TEE (14.67%) contents were found in fruits of Ganjigatti location that differed significantly from fruits ofother locations. Further, fruits of all red soil locations have a narrow range in VEE content (0.26 to 0.28%).

Significant difference was observed between the three grades of fruits for both NVEE and TEE contents (F test by contrast). First grade fruits recorded highest NVEE (15.87%) and TEE (16.10%) contents, whereas second grade fruits contained lowest (14.79% NVEE) and (15.06% TEE). With regard to VEE, first grade fruits recorded lowest value (0.24%) and differed significantly from second and third grade fruits.

4.8.4(b) Dyavnur and Byadgi dabbi cvs. Table 22(a)

NVEE, VEE and TEE contents in Dyavnur cv. fruit samples ranged from 14.49 to 14.74, 0.21 to 0.26 and 14.74 to 15.00 per cent, respectively. Similarly in Byadgi dabbi cultivar, the values of NVEE, VEE and TEE contents ranged from 14.54 to 14.91, 0.21 to 0.23 and 14.75 to 15.12 per cent, respectively. In both cultivars, the range was very narrow irrespective of the fruit grade and first grade fruits did not differ significantly from second grade fruits with respect to all the three constituents (t-test). When all the three cultivars were compared, it is found that Byadgi kaddi fruits contained highest NVEE and VEE, while Byadgi dabbi fruits contained lowest VEE.

4.9 Nutrient content of red chilli fruits

Red chilli fruits (Byadgi kaddi, Dyavnur and Byadgi dabbi) harvested at peak picking stage from different locations were sundried thoroughly and analysed for mineral composition. Results obtained are presented in Tables 23 and 23(a).

[a] Nitrogen

Perusal of data presented in Table 23 reveal that, first grade fruits of Devanur location recorded maximum N content (1.85%) and was on par with fruits of Gudgeri (1.71%) and Devagiri (1.69%) locations. N content in second and third grade fruit samples ranged from 1.67 to 1.69 and 1.51 to 1.57 per cent respectively and the four fruit samples were on par with each other in both grades of fruits.

Significant difference existed between first, second and third grade fruits with respect to N content (F test by contrast) and first grade fruits contained highest N (1.78%) followed by second and second grade fruits (1.68%) and third grade fruits (1.54%).

Similarly in Dyavnur and Byadgi dabbi cultivars, first grade fruits of Devanur location recorded maximum N content (1.82% in Dyavnur and 1.73% in Byadgi dabbi fruits) followed by fruits of Gudgeri location with 1.73 and 1.70 per cent N, respectively. Lowest N contents were recorded in second grade fruits of Annigeri and Kurtkoti locations for Dyavnur and Byadgi dabbi cultivars, respectively. In both cultivars, fruits of transplanted locations recorded higher N content than fruits of drill sown locations.

Table 23. Nutrient concentration in different quality whole red fruits (cv. Byadgi kaddi) as influenced by various locations (sun dry basis)

Locations	Fruit grade	N	P	K	S	Ca	Mg	Cu	Zn	Fe	Mn
		Per cent						ppm			
Gudgeri	Ist Grade	1.71	0.33	2.70	0.27	0.13	0.15	6.00	23.00	92.50	27.50
Devanur	(A)	1.85	0.35	3.00	0.25	0.11	0.18	9.00	20.00	77.50	39.00
		1.78	**0.34**	**2.85**	**0.26**	**0.12**	**0.17**	**7.50**	**21.50**	**85.00**	**33.25**
Ganjigatti		1.68	0.23	2.50	0.18	0.11	0.16	6.00	16.00	110.00	42.50
Devagiri	IInd Grade	1.69	0.57	2.05	0.23	0.19	0.21	8.00	26.00	123.00	30.00
Somanhalli	(B)	1.66	0.54	2.35	0.33	0.15	0.17	7.00	27.50	97.00	34.50
Dharwad		1.67	0.36	2.60	0.23	0.11	0.14	6.50	24.00	125.00	40.00
		1.68	**0.43**	**2.38**	**0.24**	**0.14**	**0.17**	**6.88**	**23.38**	**113.75**	**36.75**
Savanur		1.57	0.38	1.85	0.20	0.10	0.18	4.50	21.50	110.00	40.00
Kalagond	IIIrd Grade	1.51	0.43	1.80	0.35	0.14	0.20	7.00	11.50	110.00	35.00
Thimmenhalli	(C)	1.55	0.55	1.70	0.31	0.09	0.14	8.00	16.00	122.00	35.00
Asundi		1.54	0.49	1.90	0.35	0.09	0.16	2.50	12.50	65.00	30.00
		1.54	**0.46**	**1.81**	**0.30**	**0.11**	**0.17**	**5.50**	**15.38**	**101.75**	**35.00**
For comparing locations	S.Em±	0.05	0.08	0.08	0.04	0.02	0.03	1.47	1.99	7.45	8.66
	C.D. (0.05)	0.16	NS	0.27	NS	NS	NS	NS	6.38	23.84	NS
		F-test									
For comparing grade means by contrast	A Vs B	*	-	*	-	-	-	-	NS	*	-
	A Vs C	*	-	*	-	-	-	-	*	*	-
	B Vs C	*	-	*	-	-	-	-	*	*	-

Note: Figures in bold indicate grade means compared with F test by contrast
* Significant at 5 per cent.
NS – Non significant.

Table 23(a) . Nutrient concentration in different quality whole red fruits (Cvs. Dyavnur and Byadgi dabbi) as influenced by various locations (sun dry basis)

Dyavnur Cv.

Locations	Fruit grade	N	P	K	S	Ca	Mg	Cu	Zn	Fe	Mn
		Per cent						ppm			
Gudgeri	Ist Grade	1.73	0.50	3.30	0.30	0.22	0.21	11.00	25.50	85.00	42.50
Devanur	(A)	1.82	0.51	3.35	0.45	0.09	0.13	7.00	29.00	12.00	47.50
	Mean (A)	**1.78**	**0.51**	**3.33**	**0.38**	**0.16**	**0.17**	**9.00**	**27.25**	**102.50**	**45.00**
Ganjigatti		1.60	0.33	2.40	0.27	0.19	0.20	9.00	23.00	112.50	32.50
Dharwad	IInd Grade	1.59	0.37	2.35	0.20	0.12	0.16	10.00	26.50	67.50	22.50
Annigeri	(B)	1.55	0.47	2.60	0.25	0.13	0.14	8.00	22.50	106.00	37.50
	Mean (B)	**1.58**	**0.39**	**2.45**	**0.24**	**0.15**	**0.17**	**9.00**	**24.00**	**95.33**	**30.83**
Cal 't' value		5.12	2.40	8.80	2.33	0.18	0.00	0.00	1.56	0.32	2.36
Table 't' (0.05) at 3df	3.18	*	NS	*	*	NS	NS	NS	NS	NS	NS

Byadgi dabbi Cv.

Locations	Fruit grade	N	P	K	S	Ca	Mg	Cu	Zn	Fe	Mn
		Per cent						ppm			
Gudgeri	Ist Grade	1.70	0.48	3.50	0.25	0.15	0.18	8.00	17.50	172.50	37.50
Devanur	(A)	1.73	0.60	3.65	0.34	0.14	0.17	9.00	19.50	172.50	24.50
	Mean (A)	**1.72**	**0.54**	**3.58**	**0.30**	**0.15**	**0.17**	**8.50**	**18.50**	**172.50**	**31.00**
Yaliwal		1.69	0.47	2.95	0.29	0.12	0.17	14.50	26.00	177.50	30.00
Malligawad	IInd Grade	1.66	0.35	3.10	0.22	0.14	0.17	9.50	15.50	157.50	25.00
Saidapur	(B)	1.65	0.47	2.70	0.29	0.16	0.22	8.00	22.50	190.00	47.50
Kurtkoti		1.57	0.40	2.65	0.18	0.08	0.10	9.00	21.00	162.50	45.00
	Mean (B)	**1.64**	**0.42**	**2.85**	**0.25**	**0.13**	**0.17**	**10.25**	**21.25**	**171.88**	**36.88**
Cal 't' value		2.00	0.36	4.56	1.00	0.66	0.00	0.79	0.83	0.05	0.64
Table 't' (0.05) at 4df	2.78	NS	NS	*	NS	NS	NS	NS	NS	NS	NS

NS – Nonsignificant ,   * Significant at 5 per cent.

In Dyavnur cultivar, significant difference existed between the two grades of fruits for N content, whereas in Byadgi dabbi cv. nonsignificant difference exixted (t-test). However first grade fruits contain more N than second grade fruits.

When all the three cultivars were compared for N content in whole fruits, it is found that, variation in N content is negligible.

[b] Phosphorus

P concentration in Byadgi kaddi, Dyavnur and Byadgi dabbi fruit samples of study area ranged from 0.27 to 0.57, 0.33 to 0.51 and 0.35 to 0.60 per cent respectively. In Byadgi kaddi cultivar, nonsignificant difference was observed between fruit samples of different locations for P content and first grade fruits recorded lowest P concentration (0.34%), while third grade fruits recorded highest (0.46%) and second grade fruits were intermediate in P content (0.43%). In Dyavnur and Byadgi dabbi cultivars, first grade fruits did not differ significantly from second grade with respect to P content (t-test), however first grade fruits contain more P than second grade fruits.

[c] Potassium

Data presented in Tables 23 and 23(a) and reveal that, in all the three cultivars, first grade fruits of Devanur location recorded highest K content followed by fruits of Gudgeri location. In Byadgi kaddi cultivar, fruit samples of various locations differed significantly with respect to K content and it ranged from 1.70 to 3.00 per cent. K content in second grade fruits of this cultivar (Table 23) ranged from 2.05 to 2.60 per cent and fruits of Devagiri location recorded lowest K content and differed significantly from fruit samples of other three locations. All the four third grade fruit samples were on par with each other and K content in these samples ranged from 1.70 to 1.90 per cent.

In Dyavnur and Byadgi dabbi cultivars, K content in fruits ranged from 2.35 to 3.35 and 2.65 to 3.65 per cent, respectively [Table 23(a)]. In both cultivars, first grade fruits of Devanur location recorded highest values (3.35 and 3.65% K) while second grade fruits of Dharwad and Kurtkoti locations recorded lowest values (2.35 to 2.65% K in Dyavnur and Byadgi dabbi fruits respectively). T test showed that, significant difference existed between first and second grade fruits in both cultivars and first grade fruits have higher K content than second grade fruits. Similarly in Byadgi kaddi cultivar, significant difference existed between all the three grades of fruits (F test by contrast). First grade fruits contained highest K (2.85%), while third grade fruits contained lowest (1.81) and second grade fruits were intermediate in K content (2.38%).

Comparison among the three cultivars for K content in fruits revealed that, Byadgi dabbi fruits contained highest K, whereas Byadgi kaddi contained lowest and intermediate K content was observed in Dyavnur fruit samples.

[d] Sulphur, Calcium and Magnesium **Tables 23 and 23(a)**

Sulphur concentration in Byadgi kaddi, Dyavnur and Byadgi dabbi fruit samples ranged from 0.18 to 0.35, 0.20 to 0.45 and 0.18 to 0.34 per cent, respectively. In Byadgi kaddi cultivar, third grade fruits of Kalagond and Asundi locations recorded highest S content (0.35% each), whereas second grade fruits of Ganjigatti location recorded lowest (0.18%). Similarly Dyavnur and Byadgi dabbi fruit samples, first grade fruits of Devanur location recorded maximum S content whereas second grade fruit samples of Dharwad and Kurtkoti locations recorded lowest S content in Dyavnur and Byadgi dabbi cultivars, respectively. Though first grade fruits recorded high sulphur content in both cultivars, yet they did not differ significantly from second grade fruits as t test appeared to be nonsignificant. Not much variation was observed in S content of chilli fruits irrespective of the type of cultivar.

Calcium and magnesium contents in Byadgi kaddi fruit samples ranged from 0.09 to 0.19 and 0.14 to 0.21 per cent,respectively. Similar to S content, Ca and Mg contents also did not differ significantly in fruit samples of different locations. In Dyavnur and Byadgi dabbi fruit samples, Ca content ranged from 0.09 to 0.22 and 0.08 to 0.16 per cent, respectively while Mg content varied from 0.13 to 0.21 and 0.10 to 0.22 per cent, respectively. First grade fruits did not differ significantly from second grade fruits with respect to the content of both Ca and Mg in both cultivars (t-test). Irrespective of the fruit grade Ca and Mg contents did not vary much in all the three types of fruits. The concentration of these secondary elements in chilli fruits follow the order S>Mg>Ca.

[e] Cu, Zn, Fe and Mn

Copper content in Byadgi kaddi, Dyavnur and Byadgi dabbi cultivar fruit samples ranged from 2.50 to 9.00, 7.00 to 11.00 and 8.00 to 14.50 ppm, respectively. First grade fruits did not differ significantly from second grade fruits with respect to copper content in both Dyavnur and Byadgi dabbi cultivars as t-test appeared to be nonsignificant. It is found that, Byadgi kaddi fruits contained less copper, than Byadgi dabbi and Dyavnur cultivar fruits.

Table 23 reveal that, in case of Byadgi kaddi cv. third grade fruits which recorded lowest Zn content (15.38 ppm) differed significantly from first and second grade fruits which have 21.50 and 23.38 ppm of Zn,respectively. But first grade fruits did not differ significantly from second grade fruits as shown by F test by contrast. Further highest zinc content (27.50 ppm) was observed in second grade fruits of Ganjigatti location, while lowest value (11.50 ppm) was found in third grade fruits of Kalagond red soil location.

Similarly Zn content in Dyavnur and Byadgi dabbi fruit samples ranged from 22.50 to 29.00 and 15.50 to 26.00 ppm, respectively [Table 23(a)]. In both cultivars, first grade fruits did not differ significantly from second grade fruits (t- test nonsignificant).

Fe content in fruit samples of Byadgi kaddi cultivar ranged from 65.00 to 125.00 ppm and they differed significantly from one another. Similarly in Dyavnur and Byadgi dabbi fruit samples its content ranged from 67.50 to 120.00 and 157.50 to 190.00 ppm, respectively. In Byadgi kaddi cultivar(Table 23) first grade fruits with lowest Fe content (85.00 ppm) differed significantly from second grade fruits which have highest Fe content (113.75 ppm) and thsee two grades differed significantly from third grade fruit samples F-test by contrast. But in Dyavnur and Byadgi dabbi cultivars, first grade fruits did not differ significantly from second grade fruits with respect to Fe content in fruits as t-test was non significant. When all the three cultivars were compared for Fe status in fruits, it is seen that, Byadgi dabbi fruits contained more Fe than Dyavnur and Byadgi kaddi fruits.

Mn content in Byadgi kaddi fruit samples ranged from 27.50 to 42.50 ppm recorded in Gudgeri and Ganjigatti locations, respectively (Table 23). It is found that, nonsignificant difference existed between first, second and third grade fruit samples with respect to Mn content as shown by F test after contrast. Similarly in content in Dyavnur and Byadgi dabbi fruit samples Mn content ranged from 22.50 to 47.50 and 24.50 to 47.50 ppm, respectively [Table 23(a)]. T test showed that, first grade fruits did not differ significantly from second grade fruits in both cultivars as calculated t value is less than table t value.

The concentration of these micronutrients in chilli fruits irrespective of the fruit grade and cultivar follow the order Fe>Mn>Zn>Cu. Totally, the nutrient content in chilli fruits follow the order K>N>P>S>Mg>Ca>Fe>Mn>Zn>Cu.

4.9.1 Nutrient concentration in pericarp component of red chilli fruits

Sundried whole fruits collected from different locations of study area were partitioned into pericarp and seed components. Red pericarp component was analysed for proximate nutrient concentrations and results obtained are tabulated in Tables 24 and 24(a).

[a] Nitrogen

Perusal of data presented in Tables 24 and 24(a) reveal that, in all the three cultivars nitrogen content in pericarp component was lower than that found in respective whole fruit samples [Tables 23 and 23(a)].

In case of Byadgi kaddi cultivars, highest N content (1.72%) was recorded in pericarp component of Dharwad fruits where as lowest N content (1.18%) was recorded in pericarp component of Asundi and Ganjigatti fruit samples. It is found that, fruits of different locations differed significantly with respect to N content in pericarp. However, pericarp component of Dharwad location fruits was on par with pericarp component of Devagiri and Savanur locations. Similarly, fruits of Gudgeri location were on par with Devanur location with regard to N content in pericarp portion.

Nonsignificant difference existed between first, second and third grade fruits with respect to N content in pericarp portion (F-test). However, pericarp portion of second grade fruits contained highest N (1.47%), where as first grade fruits contained lowest N (1.40%) in pericarp component.

N content in pericarp component of Dyavnur and Byadgi dabbi cultivar fruit samples ranged from 1.19 to 1.54 and 1.23 to 1.44 per cent, respectively. Similar to N content in pericarp component of Byadgi kaddi fruits, in both Dyavnur and Byadgi dabbi

Table 24. Nutrient concentration in red pericarp component of different quality red chilli fruits (cv. Byadgi kaddi) of various locations (sun dry basis)

Locations	Fruit grade	N	P	K	S	Ca	Mg	Cu	Zn	Fe	Mn
		Per cent						ppm			
Gudgeri	Ist Grade	1.47	0.18	3.75	0.23	0.26	0.11	1.00	13.50	68.00	17.00
Devanur	(A)	1.33	0.27	3.80	0.25	0.15	0.13	0.50	15.50	59.50	14.00
		1.40	**0.23**	**3.78**	**0.24**	**0.21**	**0.12**	**0.75**	**14.50**	**63.75**	**15.50**
Ganjigatti		1.18	0.13	3.18	0.17	0.16	0.10	0.50	12.50	84.00	15.50
Devagiri	IInd Grade	1.70	0.21	3.10	0.13	0.23	0.13	1.00	16.50	75.00	16.50
Somanhalli	(B)	1.28	0.22	3.05	0.26	0.21	0.13	0.20	20.50	60.00	21.00
Dharwad		1.72	0.32	3.45	0.32	0.23	0.09	1.00	11.00	120.00	27.00
		1.47	**0.22**	**3.19**	**0.22**	**0.21**	**0.11**	**0.68**	**15.13**	**84.75**	**20.00**
Savanur		1.65	0.19	2.90	0.23	0.12	0.12	0.50	17.50	57.50	19.00
Kalagond	IIIrd Grade	1.53	0.24	2.90	0.24	0.16	0.15	0.20	8.50	52.50	25.50
Thimmenhalli	(C)	1.30	0.21	2.70	0.26	0.11	0.10	0.30	11.50	83.00	17.00
Asundi		1.18	0.25	2.80	0.15	0.11	0.11	1.00	6.00	31.00	20.00
		1.42	**0.22**	**2.83**	**0.22**	**0.13**	**0.12**	**0.50**	**10.88**	**56.00**	**20.38**
For comparing locations	S.Em±	0.06	0.03	0.07	0.03	0.02	0.02	0.21	0.97	58.55	2.10
	C.D. (0.05)	0.18	0.09	0.24	NS	0.05	NS	NS	3.09	NS	6.72
		F-test									
For comparing grade means by contrast	A Vs B	NS	NS	*	-	NS	-	-	NS	-	*
	A Vs C	NS	NS	*	-	*	-	-	*	-	*
	B Vs C	NS	NS	*	-	*	-	-	*	-	NS

Note: Figures in bold indicate grade means compared with F test by contrast
* Significant at 5 per cent.
NS – Non significant.

Table 24(a). Nutrient concentration in pericarp component of different grade red chilli fruits (Cvs. Dyavnur and Byadgi dabbi) of various locations (sun dry basis)

Dyavnur Cv.

Locations	Fruit grade	N	P	K	S	Ca	Mg	Cu	Zn	Fe	Mn
		Per cent						ppm			
Gudgeri	Ist Grade	1.54	0.39	4.60	0.32	0.27	0.16	5.50	14.00	67.50	26.50
Devanur	(A)	1.27	0.26	4.85	0.32	0.17	0.09	2.00	15.00	105.00	22.50
	Mean (A)	**1.41**	**0.33**	**4.73**	**0.32**	**0.22**	**0.13**	**3.75**	**14.50**	**86.25**	**24.50**
Ganjigatti	IInd Grade	1.19	0.20	.05	0.23	0.21	0.14	5.00	12.00	62.50	16.00
Dharwad	(B)	1.43	0.21	4.25	0.33	0.18	0.09	1.00	15.50	52.50	14.00
Annigeri		1.48	0.38	3.95	033	0.22	0.10	1.50	11.50	61.00	13.00
	Mean (B)	**1.37**	**0.26**	**4.08**	**0.30**	**0.20**	**0.11**	**2.50**	**13.00**	**58.33**	**14.33**
Cal 't' value		0.27	0.77	3.69	0.50	0.50	0.66	0.60	0.90	1.89	5.43
Table 't' (0.05) at 3df	3.18	NS	NS	*	NS	NS	NS	NS	NS	NS	*

Byadgi dabbi Cv.

Locations	Fruit grade	N	P	K	S	Ca	Mg	Cu	Zn	Fe	Mn
		Per cent						ppm			
Gudgeri	Ist Grade	1.27	0.18	4.85	0.15	0.20	0.12	4.00	10.50	145.00	25.50
Devanur	(A)	1.25	0.13	5.30	0.08	0.12	0.12	6.50	10.00	157.50	15.00
	Mean (A)	**1.26**	**0.16**	**5.08**	**0.12**	**0.12**	**0.12**	**5.25**	**10.25**	**151.25**	**20.25**
Yaliwal		1.23	0.25	4.20	0.33	0.12	0.12	9.50	12.50	137.00	15.50
Malligawad	IInd Grade	1.28	0.12	4.15	0.22	0.14	0.14	6.50	10.50	137.50	16.00
Saidapur	(B)	1.44	0.21	4.00	0.33	0.13	0.13	4.50	20.50	160.00	40.00
Kurtkoti		1.32	0.26	405	0.29	0.20	0.07	1.50	13.50	143.50	30.50
	Mean (B)	**1.32**	**0.21**	**4.10**	**0.29**	**0.59**	**0.11**	**5.50**	**14.75**	**144.35**	**25.50**
Cal 't' value		0.89	1.00	6.53	4.25	0.43	0.43	0.09	1.37	0.75	0.55
Table 't' (0.05) at 4df	2.78	NS	NS	*	*	NS	NS	NS	NS	NS	NS

NS – Nonsignificant , * Significant at 5 per cent.

cultivars, first grade fruits did not differ significantly from second grade fruits with respect to N content in pericarp component. When pericarp component of all the three types of fruits were compared for N status, it is found that, Byadgi kaddi fruits contained more N in pericarp than Dyavnur fruits, while, lowest N was found in pericarp of Byadgi dabbi fruits.

[b] Phosphorus

Phosphorus content in pericarp component of Byadgi kaddi samples ranged from 0.13 to 0.32 per cent. All the four locations that produced third grade fruits were on par with each other with regard to P content in pericarp portion (Table 24) which ranged from 0.19 to 0.25 per cent. But in fruits of second group locations only fruits of Dharwad location differed significantly from fruits of other three locations.

P content in pericarp component of Dyavnur and Byadgi dabbi fruit samples ranged from 0.20 to 0.39 and 0.12 to 0.26 per cent, respectively and first grade fruits did not differ significantly from second grade fruits (t-test). Similarly, in Byadgi kaddi cultivar, nonsignificant difference existed between first, second and third grade fruits with respect to P content in pericarp (F-test by contrast).

Irrespective of the cultivar and fruit grade, P content in pericarp portion is less than that is found in respective whole fruit sample and Byadgi dabbi fruits contained comparatively less P in pericarp than Byadgi kaddi and Dyavnur fruits.

[c] Potassium

Contrary to N and P contents, which were low in pericarp compared to whole red fruits, K content was very high in pericarp portion compared to their respective red fruit samples in all the three cultivars. In Byadgi kaddi cultivar (Table 24), fruit samples of different locations differed significantly with respect to K content in pericarp portion. Data presented in Tables 24 and 24(a) reveal that, in all the three cultivars, first grade fruits of Devanur location recorded highest K in pericarp portion (3.80, 4.85 and 5.30% in Byadgi kaddi, Dyavnur and Byadgi dabbi fruits respectively) and closely followed by fruits of Gudgeri location with 3.75, 4.60 and 4.85 per cent K. These two locations were on par with each other but differed significantly from other locations (Table 24) in Byadgi kaddi cultivar. Similarly among second grade locations fruits of Dharwad location contained highest K (3.45%) in pericarp component (Table 24) which differed significantly from fruits of other three locations. Lowest K content (2.70%) was found in samples of Thimmenhalli location which was on par with samples of Savanur, Kalagond and Asundi locations which produced third grade fruits (Table 24).

Contrary to N and P contents which did not differ significantly in the pericarps of three grades of Byadgi kaddi fruits, K content differed significantly between pericarp of first, second and third grade fruits as shown by F test by contrast (Table 24). Pericarp component of first grade fruits contained highest K (3.78%) while lowest K (2.83%) was in third grade fruits and intermediate K content (3.19%) was noticed in pericarp of second grade fruits.

For Dyavnur and Byadgi dabbi cultivars [Table 24(a)], lowest K content in pericarp component was observed in fruits of Annigeri and Saidapur locations with 3.95 and 4.00 per cent K, respectively. Contrary to the nonsignificant difference between first and second grade fruits with respect to N and P contents in pericarp portion in both cultivars, K content differed significantly between first and second grade fruits as t test was found to be significant [Table 24(a)] and pericarp portion of first grade fruits contained more K (4.73 and 5.08%) than second grade fruits (4.08 and 4.10%).

Tables 24 and 24(a) reveal that, pericarp component of Byadgi dabbi fruits contained highest K, followed by that of Dyavnur and Byadgi kaddi fruits.

[d] Sulphur, Calcium and Magnesium

Sulphur content in pericarp component of Byadgi kaddi, Dyavnur and Byadgi dabbi fruit samples ranged from 0.13 to 0.32, 0.23 to 0.33 and 0.08 to 0.33 per cent, respectively. Fruits of Byadgi dabbi cultivar have wide variation in S content in pericarp portion, while Dyavnur fruits have narrow range. In Byadgi dabbi cultivar, pericarp component of second grade fruits contained more S (0.29%) than first grade fruits (0.12%) and significant difference existed between them as (t-test). But in Dyavnur cultivar, non significant difference existed between first and second grade fruits and the three grades of Byadgi kaddi fruits contained almost same amount of sulphur in pericarp component (0.22 to 0.24%).

Calcium content in pericarp portion of Byadgi kaddi, Dyavnur and Byadgi dabbi fruit samples ranged from 0.11 to 0.26, 0.17 to 0.27 and 0.13 to 0.23 per cent, respectively [Tables 24 and 24(a)].

In Byadgi kaddi cultivars, highest Ca (0.26%) content was noticed in first grade fruits of Gudgeri location, which differed significantly from third grade fruits of Thimmenhalli and Asundi locations who recorded lowest Ca content (0.11%). First grade fruits did not differ significantly from second grade fruits with respect to Ca concentration in pericarp component of all the three cultivars as shown by F-test by contrast and t-test. But third grade fruits of Byadgi kaddi cultivar differed significantly from first and second grade fruits (Table 24). Ca content in pericarp portion is almost same in all the three types of fruits.

Mg content in pericarp portion of Byadgi kaddi, Dyavnur and Byadgi dabbi fruit samples ranged from 0.09 to 0.15, 0.09 to 0.16 and 0.07 to 0.14 per cent,respectively. Mg content did not vary much between different grades of fruits, as such F and t tests carried out to test for the significant difference between different grades of fruits were found to be non significant.

[e] Cu, Zn, Fe and Mn **Tables 24 and 24(a)**

Copper content in pericarp component of Byadgi kaddi, Dyavnur and Byadgi dabbi cultivar fruit samples ranged from 0.20 to 1.00, 1.00 to 5.50 and 1.50 to 9.50 ppm, respectively. It is found that, pericarp component of Byadgi dabbi fruits contain highest Cu, while lowest Cu was found in Byadgi kaddi fruits and fruits of Dyavnur cultivar were intermediate in Cu content.

In Byadgi kaddi cultivar. fruit samples of different locations differed significantly with respect to Zn and Mn content in pericarp portion (Table 24). Highest Zn (20.50 ppm) and Mn contents (27.00 ppm) were observed in pericarp component of Somanahalli and Dharwad location fruits,respectively, while lowest contents (6.00 ppm Zn) and (14.00 ppm Mn) were recorded in fruits of Asundi and Dyavnur locations,respectively. The two first grade fruit samples of Gudgeri and Devanur locations were on par with each other with regard to Mn content in pericarp portion.

Results of F test by contrast reveal that, third grade fruits differed significantly from first and second grade fruits with respect to Zn content in pericarp, whereas first grade fruits did not differ significantly from second grade fruits (Table 24). Similarly, first grade fruits differed significantly from second and third grade fruits with respect to Mn content in pericarp, where as non significant difference existed between second and third grade fruits.

Zn and Mn contents in pericarp component of Dyavnur fruit samples ranged from 11.50 to 15.50 and 13.00 to 26.50 ppm, respectively. T- test showed that, nonsignificant difference existed between first and second grade fruits with respect to Zn content whereas with respect to Mn content, significant difference existed between two grades of fruits [Table 24(a)].

Similarly in Byadgi dabbi cultivar, Zn and Mn content in pericarp component of fruit samples ranged from 10.00 to 20.50 and 15.00 to 40.00 ppm, respectively. Though, first grade fruits contained higher amounts of Zn and Mn in pericarp portion than second grade fruits, yet nonsignificant difference existed between them (t-test).

Fe content in pericarp component of Byadgi kaddi, Dyavnur and Byadgi dabbi fruit samples ranged from 31.00 to 120.00, 52.50 to 105.00 and 137.00 to 160.00 ppm, respectively. In case of Byadgi kaddi cultivar (Table 24), nonsignificant difference existed between different locations with respect to Fe content in pericarp and highest Fe content (120.00 ppm) was in second grade fruits of Dharwad location and lowest (31.00 ppm) in third grade fruits of Asundi location. It is found that, first grade fruits did not differ significantly from second grade fruits with respect to Fe content in pericarp although first grade fruits contain more Fe than second grade fruits in both Dyavnur and Byadgi dabbi cultivars as shown by 't' test.

Tables 24 and 24(a) reveal that, pericarp portion of Byadgi dabbi fruits contained highest Fe, followed by fruits of Dyavnur cultivar and Byadgi kaddi fruits contained lowest Fe.

4.9.3 Nutrient concentration in chilli seeds

Sundried whole fruit samples collected from different locations of study area were separated into pericarp and seeds component. Seed component of whole fruit samples that were analysed for nutrient status are tabulated and presented in Tables 25 and 25(a).

Table 25. Nutrient concentration in seed component of different grade red chilli fruits (cv. Byadgi kaddi) of various locations (sundry basis)

Locations	Fruit grade	N	P	K	S	Ca	Mg	Cu	Zn	Fe	Mn
		Per cent						ppm			
Gudgeri	Ist Grade	1.74	0.44	0.95	0.28	0.10	0.24	5.50	40.50	120.50	42.00
Devanur	(A)	1.89	0.57	0.90	0.29	0.04	0.23	12.50	37.00	114.00	52.50
		1.82	**0.51**	**0.93**	**0.29**	**0.07**	**0.24**	**9.00**	**38.75**	**117.25**	**47.25**
Ganjigatti		1.91	0.35	0.35	0.26	0.06	0.30	11.00	31.00	131.00	61.50
Devagiri	IInd Grade	1.85	0.65	0.96	0.32	0.05	0.35	11.00	36.00	163.00	44.50
Somanhalli	(B)	1.82	0.68	0.45	0.33	0.08	0.27	19.50	36.50	137.00	50.00
Dharwad		1.84	0.45	1.00	0.32	0.09	0.27	11.50	33.00	140.00	64.00
		1.86	**0.53**	**0.69**	**0.31**	**0.07**	**0.30**	**13.25**	**34.13**	**142.75**	**55.00**
Savanur		2.07	0.53	1.05	0.26	0.04	0.27	13.50	38.50	135.00	53.50
Kalagond	IIIrd Grade	1.80	0.51	0.90	0.34	0.06	0.21	14.00	15.50	142.50	50.00
Thimmenhalli	(C)	1.73	0.73	1.20	0.20	0.01	0.31	8.50	21.50	155.00	54.00
Asundi		1.60	0.63	1.00	0.14	0.05	0.28	5.00	17.50	87.50	42.50
		1.80	**0.60**	**1.04**	**0.24**	**0.04**	**0.27**	**10.25**	**23.25**	**130.00**	**50.00**
For comparing locations	S.Em±	0.08	0.06	0.07	0.02	0.02	0.03	0.97	3.14	7.29	8.49
	C.D. (0.05)	NS	0.20	0.24	0.07	NS	NS	3.10	10.04	23.34	NS
		F-test									
For comparing grade means by contrast	A Vs B	NS	*	NS	-	-	*	NS	NS	*	-
	A Vs C	NS	NS	*	-	-	NS	*	*	NS	-
	B Vs C	NS	*	*	-	-	*	*	*	*	-

Note: Figures in bold indicate grade means compared with F test by contrast
* Significant at 5 per cent.
NS – Non significant.

Table 25(a). Nutrient concentration in seed component of different grade red chilli fruits (Cvs. Dyavnur and Byadgi dabbi) of various locations (sun dry basis)

Dyavnur Cv.

Locations	Fruit grade	N	P	K	S	Ca	Mg	Cu	Zn	Fe	Mn
		Per cent						ppm			
Gudgeri	Ist Grade	1.85	0.68	0.85	0.21	0.07	0.24	16.50	43.50	122.50	60.00
Devanur	(A)	1.88	0.66	1.40	0.32	0.06	0.26	13.00	44.00	147.50	60.00
	Mean (A)	**1.87**	**0.67**	**1.13**	**0.27**	**0.07**	**0.25**	**14.75**	**43.75**	**135.00**	**60.00**
Ganjigatti	IInd Grade	1.73	0.49	0.55	0.36	0.08	0.26	11.00	32.50	147.50	50.00
Dharwad	(B)	1.96	0.48	0.45	0.19	0.03	0.26	14.00	34.50	92.50	39.00
Annigeri		1.78	0.67	0.70	0.23	0.08	0.24	16.50	30.50	137.50	46.50
	Mean (B)	**1.82**	**0.55**	**0.57**	**0.26**	**0.06**	**0.25**	**13.83**	**32.50**	**125.83**	**45.17**
Cal 't' value		0.55	1.50	2.54	0.12	0.50	0.00	0.38	7.50	0.38	3.55
Table 't' (0.05) at 3df	3.18	NS	NS	NS	NS	NS	NS	NS	*	NS	*

Byadgi dabbi Cv.

Locations	Fruit grade	N	P	K	S	Ca	Mg	Cu	Zn	Fe	Mn
		Per cent						ppm			
Gudgeri	Ist Grade	1.81	0.61	0.60	0.18	0.02	0.23	11.50	25.50	210.00	57.50
Devanur	(A)	1.86	0.70	0.65	0.16	0.03	0.26	13.50	27.50	222.50	47.50
	Mean (A)	**1.84**	**0.66**	**0.63**	**0.17**	**0.03**	**0.25**	**12.50**	**26.50**	**216.25**	**52.50**
Yaliwal)		1.69	0.63	0.50	0.11	0.08	0.32	16.00	33.00	255.00	35.00
Malligawad	IInd Grade	1.72	0.51	0.65	0.18	0.03	0.27	16.50	23.50	292.50	40.00
Saidapur	(B)	1.68	0.58	0.75	0.17	0.07	0.34	11.00	29.00	215.00	60.00
Kurtkoti		1.73	0.53	0.55	0.23	0.05	0.23	20.00	29.50	300.00	58.00
	Mean (B)	**1.71**	**0.56**	**0.61**	**0.17**	**0.06**	**0.29**	**15.88**	**28.75**	**265.63**	**48.25**
Cal 't' value		6.50	2.00	0.24	0.00	1.76	1.00	1.19	0.75	1.67	0.43
Table 't' (0.05) at 4df	2.78	*	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS – Nonsignificant , * Significant at 5 per cent.

[a] Nitrogen

Nitrogen content in seed component of Byadgi kaddi, Dyavnur and Byadgi dabbi fruit samples ranged from 1.60 to 2.07, 1.73 to 1.96 and 1.68 to 1.86 per cent respectively. Invariably seeds contained more nitrogen than respective pericarp components in all the three cultivars. In Byadgi kaddi cultivar, non significant difference existed between seed samples of different locations with respect to N content (Table 25) and seeds of second grade fruits contained slightly higher N (1.86%) than seeds of first (1.82%) and third grade fruits (1.80%).

Similarly in Dyavnur cultivar, seeds of first grade fruit did not differ significantly from seeds of second grade fruits with respect to N content (t-test) whereas in Byadgi dabbi cv. significant difference existed between seeds of first and second grade fruits [Tables 25 and 25(a)]. Seed samples of these cultivars did not vary much with respect to N content.

[b] Phosphorus

Data presented in Table 25 reveal that, seed samples of different locations differed significantly with respect to P content and highest value (0.73%) was noticed in seeds of Thimmenhalli location while lowest (0.35%) was in seeds of Ganjigatti location. The three grades of fruits did not differ significantly from one another with respect to P content in seeds as revealed by F test by contrast. However, seeds of third grade fruits contained more P (0.60%) than seeds of first and second grade fruits (Table 25).

P content in seed samples of Dyavnur and Byadgi dabbi cultivars ranged from 0.48 to 0.68 and 0.51 to 0.70 per cent respectively. In both cultivars, seeds of first grade fruits did not differ significantly from seeds of second grade fruits as t-test is nonsignificant [Table 25(a)]. However, first grade fruits contain more P than second grade fruits in seeds.

[c] Potassium

Perusal of data presented in Table 25 reveal that, seeds of Thimenahalli fruits contain highest K (1.20%), while seeds of Ganjigatti fruits contain lowest K (0.35%) and significant difference existed between them. F test by contrast reveal that, first grade fruits differed significantly from second grade fruits with respect to K content in seeds, but non significant difference existed between first and third grade fruits. Similarly significant difference existed between second and third grade fruits also. Seeds of third grade fruit samples recorded highest K (1.04%), while seeds of second grade fruit sample contain intermediate K (0.93%).

Table 25(a) reveal that, K content in seed samples of Dyavnur and Byadgi dabbi cultivars ranged from 0.45 to 1.40 and 0.50 to 0.75 per cent,respectively. As per t-test, first grade fruits did not differ significantly from second grade fruits with respect to K content in seeds.

Contrary to N and P concentrations, which were high in seeds compared to their respective pericarps, K content in seeds was less compared to respective pericarp components in all the three cultivars.

[d] Sulphur, Calcium and Magnesium

Sulphur content in seed samples of Byadgi kaddi, Dyavnur and Byadgi dabbi fruits ranged from 0.14 to 0.34, 0.19 to 0.36 and 0.11 to 0.23 per cent,respectively. In case of Byadgi kaddi cultivar (Table 25),all locations that produced first and second grade fruits were on par with each other with regard to S content in seeds (ranged from 0.26 to

0.33%), but in third grade fruit samples, seeds of Asundi location having lowest S (0.14%) differed significantly from seeds of all other locations except seeds of Thimmenhalli location (0.20% S). Seeds of third grade fruit samples having lowest S (0.24%) differed significantly from seeds of first and second grade fruits (Table 25) which were on par with each other (F-test). Similarly, for Dyavnur and Byadgi dabbi cultivars, non significant difference existed between first and second grade fruits with respect to S content in seeds (t-test). It is found that, seeds of Byadgi dabbi cultivar contained less sulphur compared to seeds of Dyavnur cultivar and those of Byadgi kaddi cultivar contain highest S.

Ca and Mg contents in seed samples of Byadgi kaddi fruits ranged from 0.01 to 0.10 and 0.21 to 0.35 per cent, respectively (Table 25). Similarly Ca content in seed samples of Dyavnur and Byadgi dabbi fruits [Table 25(a)] ranged from 0.03 to 0.08 per cent while Mg content ranged from 0.24 to 0.26 and 0.23 to 0.34 per cent respectively. In both cultivars, seeds of first grade fruits did not differ significantly from seeds of second grade fruits as t test was nonsignificant [Table 25(a)].

[e] Cu, Zn, Fe and Mn

Copper content in seeds of Byadgi kaddi, Dyavnur and Byadgi dabbi fruit samples ranged from 5.00 to 19.50, 11.00 to 16.50 and 11.00 to 20.00 ppm, respectively. Seeds of second grade fruits with highest Cu (13.25 ppm) differed significantly from seeds of first and third grade fruits (F-test by contrast) and nonsignificant difference existed between seed samples of first and third grade fruits (Table 25). Similarly for Dyavnur and Byadgi dabbi cultivars, nonsignificant difference existed between first and second grade fruits with respect to Cu content in seeds (t-test). Tables 25 and 25(a) reveal that seeds of Byadgi dabbi and Dyavnur cultivar contained more copper than Byadgi kaddi cultivar.

Seeds invariably contained more copper than respective pericarp components irrespective of fruit grade and cultivar.

Zn content in seed samples of Byadgi kaddi fruits ranged from 15.50 to 40.50 ppm recorded in Kalagond and Gudgeri location fruits respectively, which differed significantly from one another (Table 25). Similarly in Dyavnur and Byadgi dabbi cultivars, it ranged from 30.50 to 44.00 and 23.50 to 33.00 ppm, respectively [Table 25(a)]. In Byadgi kaddi cultivar, seeds of third grade fruits having lowest Zn (23.25 ppm) differed significantly from seeds of first and second grade fruits which were on par with each other (F-test). Similarly, in Dyavnur cultivar significant difference existed between seeds of first and second grade fruits, whereas in Byadgi dabbi cultivar, non significant difference was observed as revealed by t-test [Table 25(a)]. Invariably seeds contained more Zn than respective pericarp components [Tables 24(a) and 25(a)].

Fe content in seeds of Byadgi kaddi, Dyavnur and Byadgi dabbi fruit samples ranged from 87.50 to 163.00 ppm, 92.50 to 147.50 and 210.00 to 300.00 ppm, respectively. Significant difference existed between seeds of first and second grade fruits and also between second and third grade fruits with regard to Fe content in seeds, whereas nonsignificant difference existed between first and third grade fruits (Table 25). Similarly in Dyavnur and Byadgi dabbi cultivars [Table 25(a)], t-test showed nonsignificant difference between first and second grade fruits with respect to Fe content in seeds.

Seeds of Byadgi dabbi cultivar contained highest Fe, while those of Byadgi kaddi cultivar contained lowest and intermediate Fe was found in seeds of Dyavnur cultivar. Seeds contain more Fe than respective pericarps.

Mn content in seed samples of Byadgi kaddi cultivar (Table 25) ranged from 42.00 to 64.00 ppm and nonsignificant difference existed between different locations.

Similarly in Dyavnur and Byadgi dabbi cultivars it ranged from 39.00 to 60.00 and 35.00 to 60.00 ppm, respectively [Table 25(a)]. Seeds contain more Mn than respective pericarp component in all the three cultivars.

4.10 Quality attributes of different grade chilli fruits

Chilli fruits harvested at peak picking stage from different locations were sundried and destalked. These fruits were analysed for quality attributes viz., capsaicin, colour value and oleoresin. But for ascorbic acid estimation, freshly harvested green and turning red fruits were utilised, since sundrying of fruits leads to substantial loss of ascorbic acid and results are not reliable.

4.10.1 Ascorbic acid

4.10.1(a) Byadgi kaddi cv. **Table 26**

Significant difference existed between fruit samples of different locations with respect to ascorbic acid content. Fruits of Devanur location recorded highest value (230.55 mg/100 g), where as those of Asundi red soil location recorded lowest (113.40 mg/100 g) and they differed significantly. Fruits of Devanur location were on par with fruits of Gudgeri and Devagiri locations for ascorbic acid content. Similarly, fruits of Asundi location with lowest ascorbic acid content were on par with fruits of Savanur, Kalagond and Thimmenhalli locations which have 146.09, 124.99 and 128.81 mg per 100 g of ascorbic acid, respectively.

Turning red fruits recorded higher ascorbic acid (175.39 mg/100 g) than green coloured fruits (156.32 mg/100 g) and significant difference existed between them.

Table 26 : Ascorbic acid content (mg/100 g) of fresh chilli fruits (Cv. Byadgi kaddi) at 'green' and 'turning red' stages at various locations.

Fruit stage	LOCATIONS										
	Gudgeri	Devanur	Ganjigatti	Devagiri	Somanhalli	Dharwad	Savanur	Kalagond	Thimmenhalli	Asundi	MEAN
	Ist grade (A)		IInd grade (B)				IIIrd grade (C)				
GREEN FRUIT	206.53	215.00	162.58	186.13	144.04	167.15	134.09	122.05	122.41	103.17	**156.32**
TURNING RED FRUIT	231.96	246.09	170.83	229.21	159.69	171.20	158.10	127.93	135.21	123.63	**175.39**
MEAN (Location)	**219.24**	**230.55**	**166.71**	**207.67**	**151.87**	**169.18**	**146.09**	**124.99**	**128.81**	**113.40**	
MEAN (for grade)	**224.90**		**173.86**				**128.32**				

For comparing means of	S.Em±	CD (0.05)	For comparing grade means by contrast F test	
Locations (L)	13.61	40.16	A Vs. B	NS
Fruit stage	6.09	17.96	A Vs. C	*
L X Fruit stage	19.25	NS	B Vs. C	*

* Significant at 5%
NS – Nonsignificant.

Though first grade fruits recorded higher ascorbic acid (224.90 mg/100 g) content than second grade fruits (173.86 mg/100 g), yet non significant difference existed between them (F-test by contrast). But third grade fruits with lowest ascorbic acid (128.32 mg/100 g) differed significantly from first and second grade fruits.

Interactions were non significant in influencing the ascorbic acid content, which implies that, at a particular fruit stage (Green or turning red stage) non significant difference existed between fruit samples of different locations. However in green fruits, ascorbic acid ranged from 103.17 mg 100 per g to 215.00 mg per 100 g found in fruits of Asundi and Devanur locations respectively. Similarly in turning red fruits, it ranged from 123.63 to 246.09 mg per 100 g found in fruit samples of Asundi and Devanur locations, respectively.

4.10.1(b) Dyavnur and Byadgi dabbi cultivars **Table 26(a)**

Ascorbic acid content in Dyavnur and Byadgi dabbi fruits samples ranged from 137.01 to 212.99 and 70.45 to 146.33 mg per 100 g and fruits of Devanur location recorded highest value in both cultivars, which were on par with those of Gudgeri location (170.15 and 141.76 mg/100 g). In Dyavnur cultivar, fruits of Annigeri location with lowest ascorbic acid (137.01 mg/100 g) differed significantly from other locations. But in Byadgi dabbi cultivar, fruits of Kurtkoti location (70.48 mg/100 g) were on par with those of Saidapur location (74.46 mg/100 g) but differed significantly from fruits of other locations.

Generally first grade fruits contain higher ascorbic acid (191.57 and 144.05 mg/100 g for Dyavnur and Byadgi dabbi fruits respectively) than second grade fruits and in Dyavnur cultivar significant difference was observed between first and second grade fruits, while in Byadgi dabbi cultivar nonsignificant difference was observed.

Table 26(a) : Ascorbic acid content (mg/100 g) of fresh chilli fruits (Cvs. Dyavnur and Byadgi dabbi) at `green' and `turning red' stages at various locations

FRUIT STAGE	Cv. DYAVNUR					MEAN	Cv. BYADGI DABBI						MEAN
	LOCATIONS						LOCATIONS						
	Gudgeri	Devanur	Ganjigatti	Dharwad	Annigeri α		Gudgeri	Devanur	Yaliwal	Malligawadα	Saidapur α	Kurtkoti α	
	Ist GRADE (A)		IInd GRADE (B)				Ist GRADE (A)		Iind GRADE (B)				
GREEN FRUIT	163.78	196.34	147.60	160.16	133.53	**160.28**	132.44	136.64	83.88	91.77	70.55	61.95	**96.21**
TURNING RED FRUIT	176.51	229.64	159.20	176.03	140.48	**176.37**	151.08	156.02	122.76	124.45	78.37	79.01	**118.62**
MEAN (LOCATIONS)	**170.15**	**212.99**	**153.40**	**168.09**	**137.01**		**141.76**	**146.33**	**103.32**	**108.11**	**74.46**	**70.48**	
MEAN FOR GRADE	**191.57**		**152.83**				**144.05**		**89.09**				

For comparing means of	S.Em±	CD (0.05)	For comparing grade means by contrast	F test		For comparing means of	S.Em±	CD (0.05)	For comparing grade means by contrast	F test
Locations (L)	9.56	30.12	A Vs. B	*		Locations (L)	5.69	17.55	A Vs. B	NS
Fruit stage	6.05	19.05				Fruit stage	3.29	10.13		
L X Fruit stage	13.52	NS				L X Fruit stage	8.06	24.82		

Significant at 5 per cent
NS – Non significant
α - Drill sown locations.

In both cultivars, fruits at turning red stage contained higher ascorbic acid than at green stage. Further, interactions were nonsignificant in case of Dyavnur cultivar, while they were significant in Byadgi dabbi cultivar. This implies that in Dyavnur cultivar, fruits of different locations did not differ significantly with respect to ascorbic acid content analysed at a particular fruit stage, while in Byadgi dabbi cultivar fruits of different locations differed significantly. However in both cultivars, fruits of Devanur location recorded highest ascorbic acid at both stages, followed by those of Gudgeri location.

4.10.2 Capsaicin

4.10.2(a) Byadgi kaddi, Sankeshwari and Guntur (G-3) cvs. Table 27

Pungency as indicated by capsaicin content in chilli fruits ranged from 0.11 to 0.21 per cent and nonsignificant difference existed between fruit samples of different locations. It is found that, first grade fruits of Devanur location contained highest capsaicin (0.21%) closely followed by fruits of Devagiri (0.20%), Gudgeri (0.19%) and Ganjigatti (0.17%) locations and is being depicted by HPLC [chromatograms 2,4,1,3 (Fig. 3)]. Capsaicin content in second and third grade fruit samples ranged from 0.15 to 0.20 and 0.11 to 0.14 per cent, respectively. It is found that, lowest capsaicin (0.11%) content was found in third grade fruits of Kalagond red soil location (chromatogram-8), while fruits of Savanur location (mixed red and black soil) recorded slightly higher value (0.14%, chromatogram-7). The other two fruit samples of red soil locations (Thimmenhalli and Asundi) recorded 0.13 and 0.12 per cent capsaicin respectively (chromatograms 9 and 10).

Table 27. Quality attributes of different grade red chilli fruits (cv. Byadgi kaddi) of various locations (sundry fruits)

Locations	Fruit grade	Capsaicin(%)	Colour value **ASTA** units	Oleoresin (%)	Scoville Heat Units (SHU) ⊗
Gudgeri	Ist Grade	0.19	205.60	17.84	29000
Devanur	(A)	0.21	216.40	19.64	32000
		0.20	**211.00**	**18.74**	
Ganjigatti		0.17	140.10	16.39	25000
Devagiri	IInd Grade	0.20	152.90	16.81	30000
Somanhalli	(B)	0.15	131.20	16.14	22000
Dharwad		0.16	123.30	16.50	24000
		0.17	**136.88**	**16.46**	
Savanur		0.14	104.60	15.66	21000
Kalagond	IIIrd Grade	0.11	69.10	13.46	16000
Thimmenhalli	(C)	0.13	91.00	15.71	20000
Asundi		0.12	88.40	15.12	18000
		0.13	**88.28**	**14.99**	
For comparing locations	S.Em±	0.02	14.15	1.14	
	C.D. (0.05)	NS	45.24	NS	
Sankeshwari cv.		0.48	127.40	15.32	72000
Guntur (G-3) cv.		0.37	144.50	13.60	56000
	F-test				
For comparing grade means by contrast	A Vs B	-	*	-	⊗ Calculated from the
	A Vs C	-	*	-	Standard 0.66% Capsaicin
	B Vs C	-	*	-	Gives 1,00,000 SHU.

Note: Figures in bold indicate grade means compared with F test by contrast

* Significant at 5 per cent.

NS – Non significant.

CHROMATOGRAMS

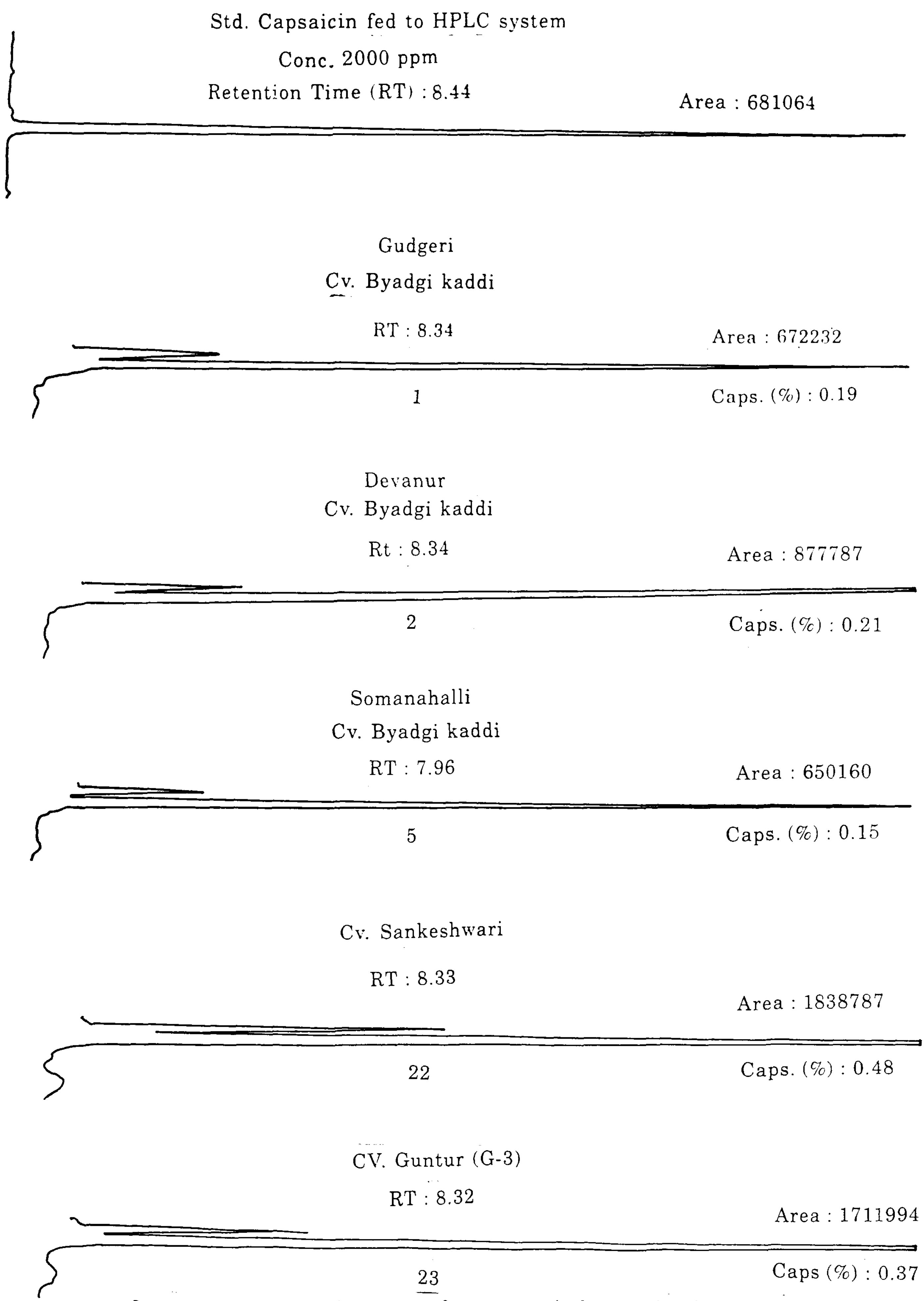


Fig. 3 : HPLC chromatograms for capsaicin content of chilli fruit samples (Cv. BYADGI KADDI)

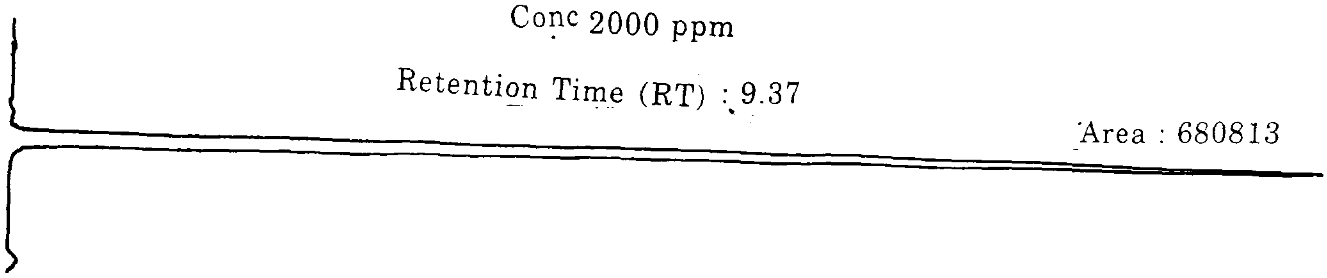
CHROMATOGRAMS

Std. capsaicin fed to HPLC system

Conc 2000 ppm

Retention Time (RT) : 9.37

Area : 680813

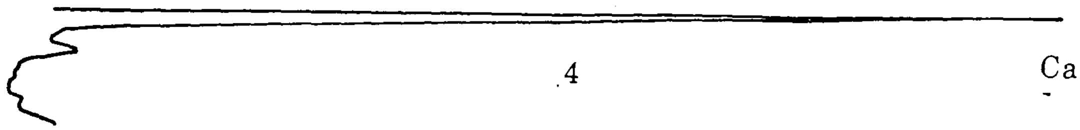


Devagiri

Cv. Byadgi kaddi

RT : 8.73

Area : 614372



.4

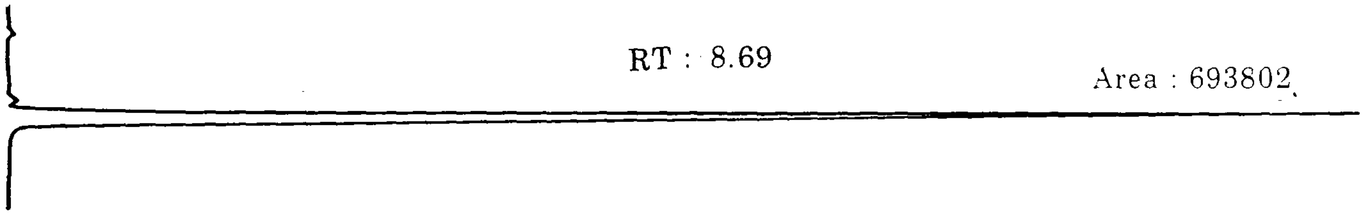
Caps. (%) : 0.18

Std. Capsaicin fed to HPLC system

Conc 2000 ppm

RT : 8.69

Area : 693802

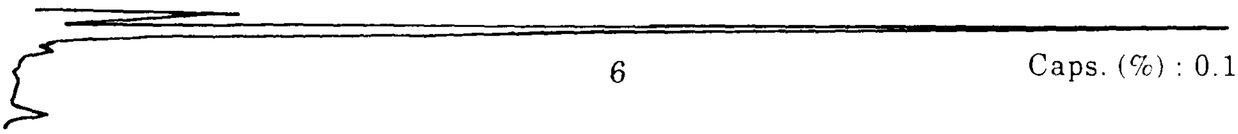


Dharwad

Cv. Byadgi kaddi

RT : 8.64

Area : 608289



6

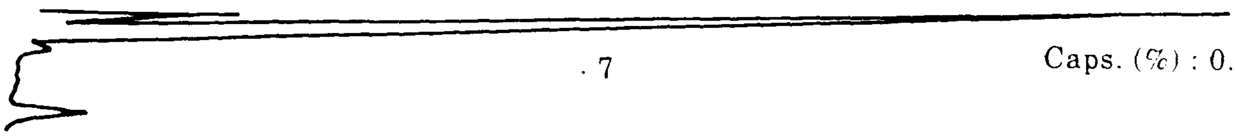
Caps. (%) : 0.16

Savanur

Cv. Byadgi kaddi

RT : 8.26

Area : 599060



7

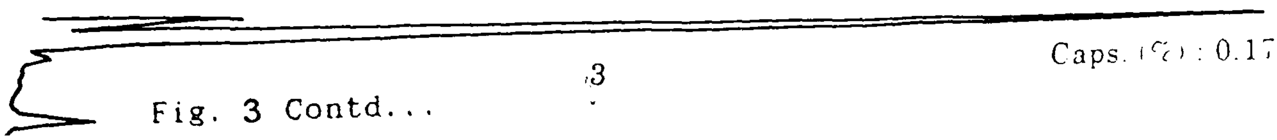
Caps. (%) : 0.14

Ganjigatti

Cv. Byadgi kaddi

RT : 8.73

Area : 608950



Caps. (%) : 0.17

3

Fig. 3 Contd...

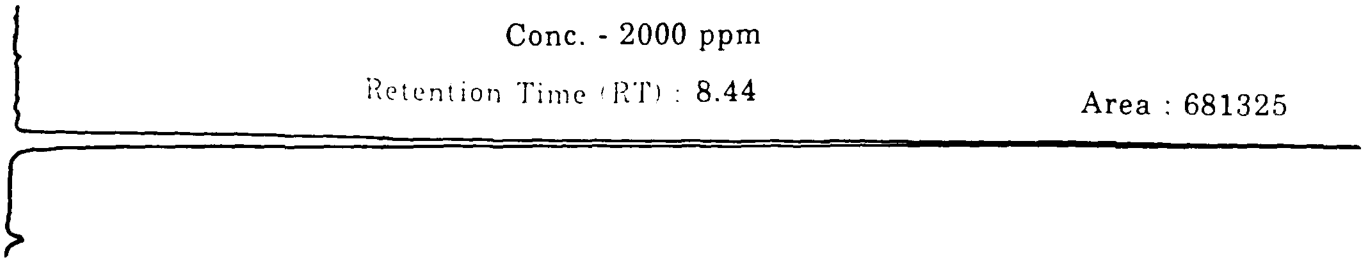
CHROMATOGRAMS

Std. Capsaicin fed to HPLC system

Conc. - 2000 ppm

Retention Time (RT) : 8.44

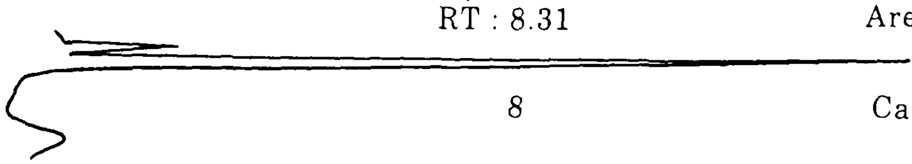
Area : 681325



Kalagond
Cv. Byadgi kaddi

RT : 8.31

Area : 434034



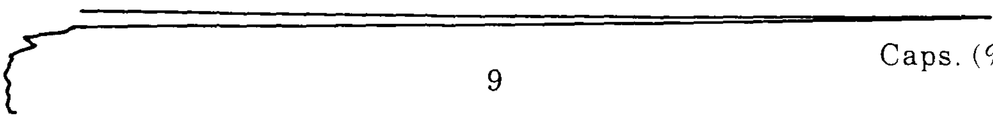
8

Caps. (%) 0.11

Thimmenahalli
Cv. Byadgi kaddi

RT : 8.37

Area : 517355



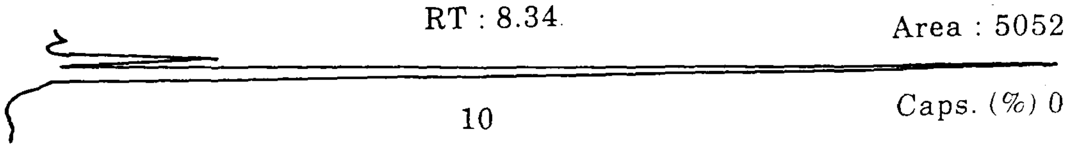
Caps. (%) : 0.13

9

Asundi
Cv. Byadgi kaddi

RT : 8.34

Area : 505251



Caps. (%) 0.12

10

Fig. 3 Contd...

A cursory look at the data presented in Table 27 reveal that, first grade fruits contained comparatively higher amount of capsaicin (0.20%) than second grade fruits with 0.17 per cent capsaicin and third grade fruits contained lowest capsaicin (0.13).

These different grade Byadgi kaddi cultivar fruits were compared with fruits of Sankeshwari and Guntur (G-3) varieties in order to know the extent of variation in pungency between three varieties that are extensively cultivated in the state. It was found that (Fig.3), fruits of Sankeshwari variety have maximum capsaicin (0.48%) as shown in chromatogram-22 closely followed by fruits of Guntur (G-3) variety with 0.37 per cent capsaicin (chromatogram- 23). Byadgi kaddi fruits contained very low amount of capsaicin with a range of 0.11 to 0.21 per cent.

4.10.2(b) Dyavnur and Byadgi dabbi cultivars **Table 27(a)**

Capsaicin content in fruit samples of Dyavnur and Byadgi dabbi cultivars ranged from 0.10 to 0.14 and 0.10 to 0.15 per cent, respectively. In both cultivars, first grade fruits of Devanur location recorded highest capsaicin (0.14 and 0.15%) closely followed by fruits of Gudgeri location with 0.13 per cent capsaicin [chromatograms 12,15,16 and 17 and Figs. 3(a) and 3(b)]. Second grade fruits of Ganjigatti, Dharwad, Yaliwal and Malligawad locations recorded same amount of capsaicin (0.12%) and the same is shown by HPLC chromatograms.

Fruits of Annigeri and Kurtkoti locations recorded lowest capsaicin (0.10%) content for Dyavnur and Byadgi dabbi cultivars, respectively [Fig.3(a) and 3(b)]. Though first grade fruits contained higher amount of capsaicin (0.14%) than second grade fruits (0.11%), yet nonsignificant difference existed between them (t-test). Among the three Byadgi cultivars, fruits of Byadgi kaddi fruits were highly pungent due to high capsaicin content than Dyavnur and Byadgi dabbi fruits [Tables 27 and 27(a)].

Table 27(a). Quality attributes of different grade red chilli fruits (Cvs. Dyavnur and Byadgi dabbi) of various locations (sundry fruits)

Dyavnur Cv.

Locations	Fruit grade	Capsaicin [%]	Colour value (ASTA units)	Oleoresin [%]	Scoville heat ⊗ units (SHU)
Gudgeri	Ist Grade	0.13	239.80	16.13	20000
Devanur	(A)	0.14	255.50	16.53	21000
	Mean (A)	**0.14**	**247.65**	**16.33**	
Ganjigatti		0.12	176.60	12.01	18000
Dharwad	IInd Grade	0.12	177.10	15.20	18000
Annigeri	(B)	0.10	188.10	15.47	15000
	Mean (B)	**0.11**	**180.60**	**14.23**	
Cal 't' value		3.00	8.85	1.46	
Table 't' (0.05) at 3df	3.18	NS	*	NS	

Locations	Fruit grade	Capsaicin [%]	Colour value (ASTA units)	Oleoresin [%]	Scoville heat ⊗ units (SHU)
Gudgeri	Ist Grade	0.13	277.40	15.00	20000
Devanur	(A)	0.15	280.10	15.11	22000
	Mean (A)	**0.14**	**278.75**	**15.06**	
Yaliwal		0.12	239.90	12.50	18000
Malligawad	IInd Grade	0.12	231.30	14.97	18000
Saidapur	(B)	0.11	235.70	12.29	16000
Kurtkoti		0.10	206.70	11.87	15000
	Mean (B)	**0.11**	**228.23**	**12.91**	
Cal 't' value		2.50	4.55	2.05	
Table 't' (0.05) at 4df	2.78	NS	*	NS	

⊗ - Calculated from the standard 0.66% capsaicin = 1,00,000 SHU.

NS – Nonsignificant , * Significant at 5 per cent.

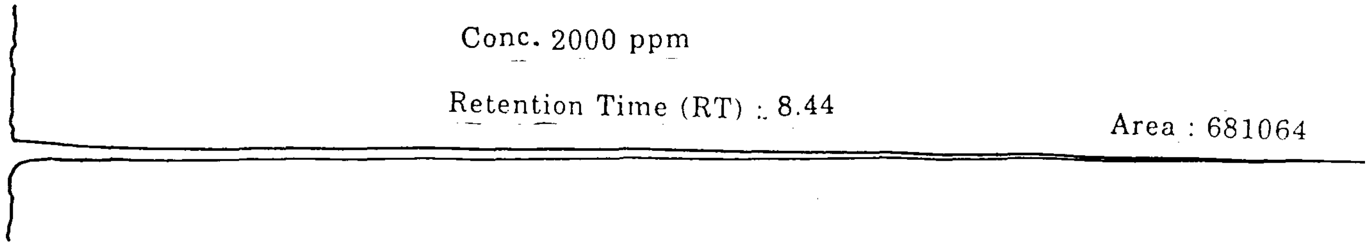
CHROMATOGRAMS

Std. Capsaicin fed to HPLC system

Conc. 2000 ppm

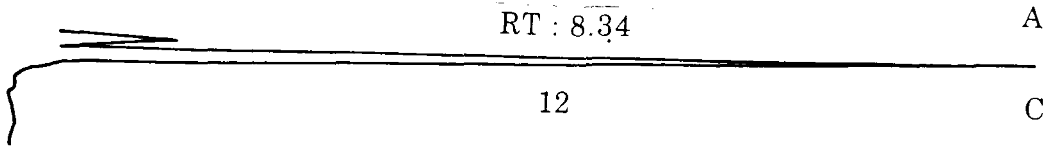
Retention Time (RT) : 8.44

Area : 681064



Gudgeri
Cv. Dyavnur
RT : 8.34

Area : 507885

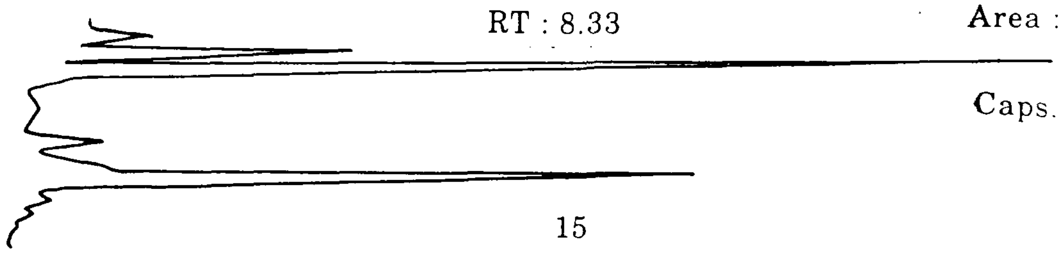


12

Caps. (%) : 0.13

Dharwad
Cv. Dyavnur
RT : 8.33

Area : 505251

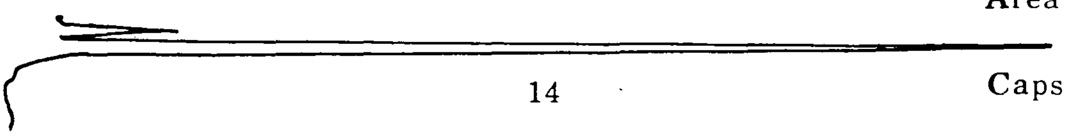


Caps. (%) : 0.12

15

Ganjigatti
Cv. Dyavnur
RT : 8.33

Area : 505251



14

Caps. (%) : 0.12

Fig. 3(a): HPLC chromatograms for capsaicin content of chilli fruit samples (Cv. DYAVNUR)

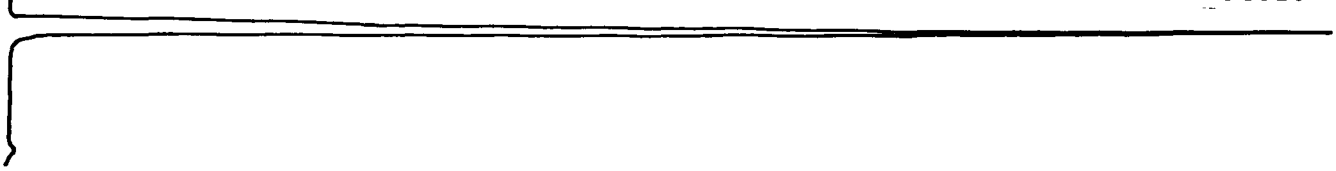
CHROMATOGRAMS

Std. Capsaicin fed to HPLC system

Conc - 2000 ppm

Retention Time (RT) : 9.39

Area : 684610

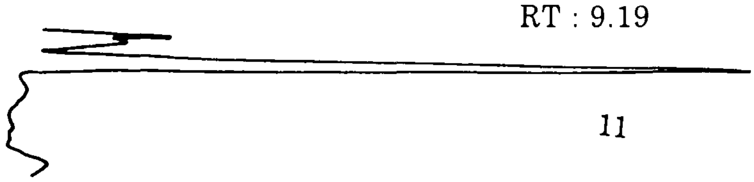


Annigeri

CV. Dyavnur

RT : 9.19

Area : 397047



11

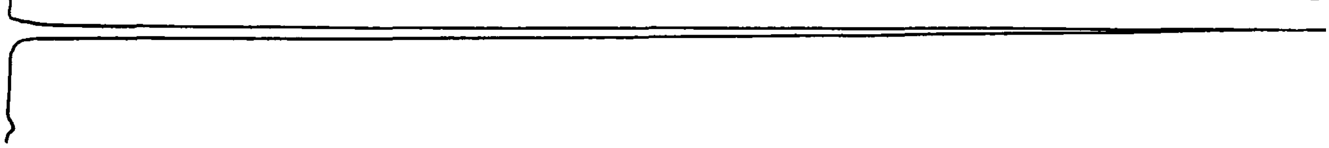
Caps. (%) : 0.10

Std. Capsaicin fed to HPLC system

Conc. - 2000 ppm

RT : 8.43

Area : 675021

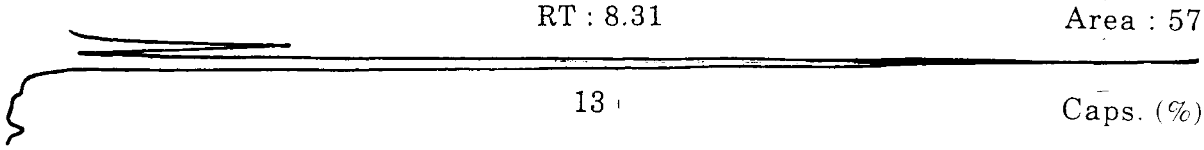


Devanur

Cv. Dyavnur

RT : 8.31

Area : 572351



13

Caps. (%) : 0.14

Fig. 3(a) Contd...

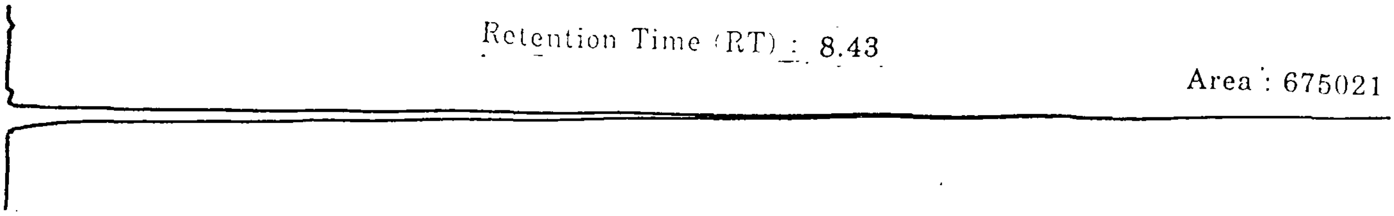
CHROMATOGRAMS

Std. Capsaicin fed to HPLC system

Conc. - 2000 ppm

Retention Time (RT) : 8.43

Area : 675021

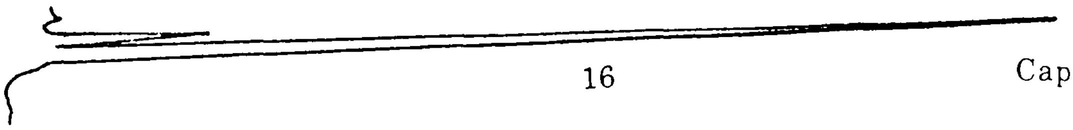


Gudgeri

Cv. Byadgi dabbi

RT : 8.34

Area : 638032



16

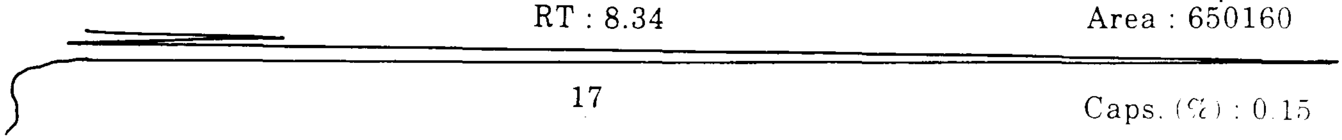
Caps. (%) : 0.12

Devanur

Cv. Byadgi dabbi

RT : 8.34

Area : 650160



17

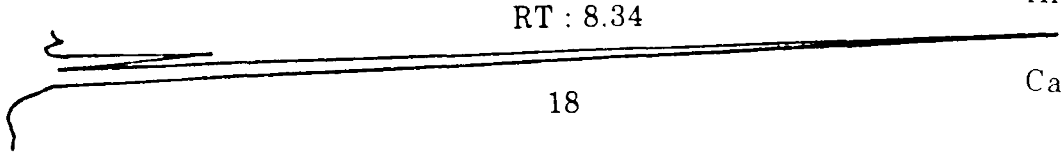
Caps. (%) : 0.15

Yaliwal

Cv. Byadgi dabbi

RT : 8.34

Area : 638032



18

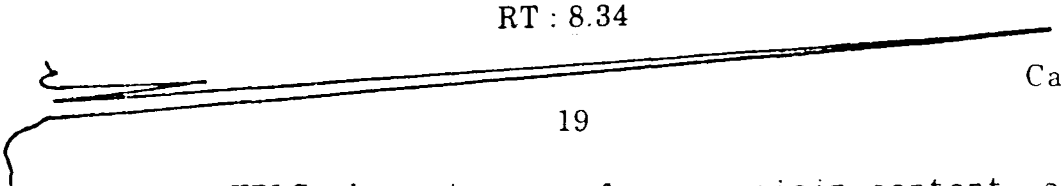
Caps. (%) : 0.12

Malligawad

Cv. Byadgi dabbi

RT : 8.34

Area : 638032



Caps.(%) : 0.12

19

Fig. 3(b) : HPLC chromatograms for capsaicin content of chilli fruit samples (Cv. BYADGI DABBI)

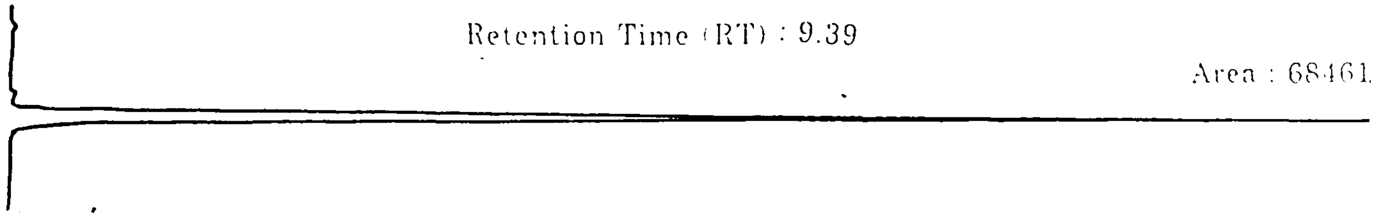
CHROMATOGRAMS

Std. Capsaicin fed to HPLC system

Conc. 2000 ppm

Retention Time (RT) : 9.39

Area : 68461

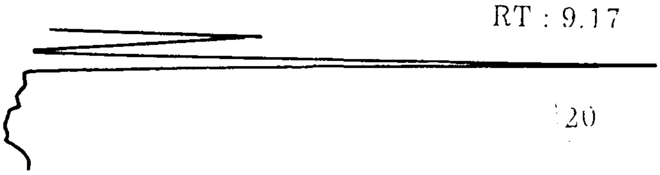


Saidapur

Cv. Byadgi dabbi

RT : 9.17

Area : 321827



20

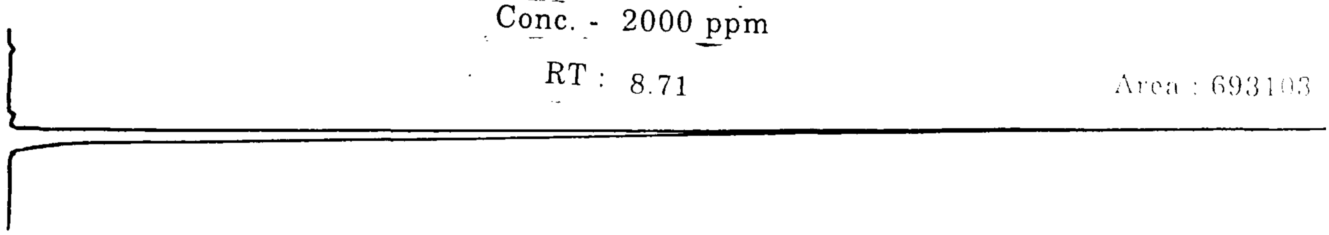
Caps. (%) : 0.11

Std. Capsaicin fed to HPLC system

Conc. - 2000 ppm

RT : 8.71

Area : 693103

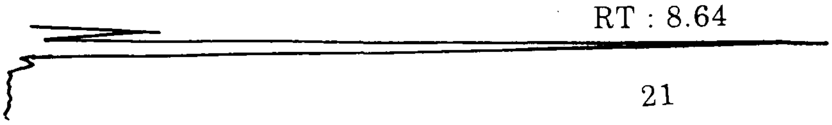


Kurtkoti

Cv. Byadgi dabbi

RT : 8.64

Area : 422206



21

Caps. (%) : 0.10

Fig. 3(b)contd...

4.10.3 Colour value

4.10.3(a) Byadgi kaddi cv. Table 27

First grade fruits of Devanur location recorded highest colour value (216.40 ASTA units) and were on par with fruits Gudgeri location (205.60 ASTA units) but these two locations differed significantly from fruits all other locations (Fig.4). Colour value in second grade fruit samples ranged from 123.30 to 152.90 ASTA units recorded in fruits of Dharwad and Devagiri locations,respectively. All the four locations that produced second grade fruits were on par with each other with respect to colour value. Similarly in third grade fruit samples, colour value ranged from 69.10 to 104.60 ASTA units recorded in fruits of Kalagond and Savanur locations,respectively. All the four third grade fruit samples were on par with each other. Among the red soil locations (Kalagond, Thimmenahalli and Asundi) fruits of Thimmenhalli location recorded comparatively higher colour value (91.00 ASTA units) than fruits of Asundi location with 88.40 ASTA units and fruits of Kalagond location recorded lowest (69.10 ASTA units) colour value (Fig. 4).

F test by contrast reveal that, significant difference existed between first, second and third grade fruits with respect to colour value and first grade fruits recorded highest colour value (211.00 ASTA units) while third grade fruits recorded lowest (88.28 ASTA units) and second grade fruits were intermediate in their colour value (136.88 ASTA units).

Colour value of these Byadgi kaddi fruits was compared with fruits of Sankeshwari and Guntur (G-3) varieties to know the variation in colour units between varieties. Data presented in Table 27 reveal that, fruits of Sankeshwari variety have lowest colour value (127.40 ASTA units) compared to fruits of Guntur variety (144.50

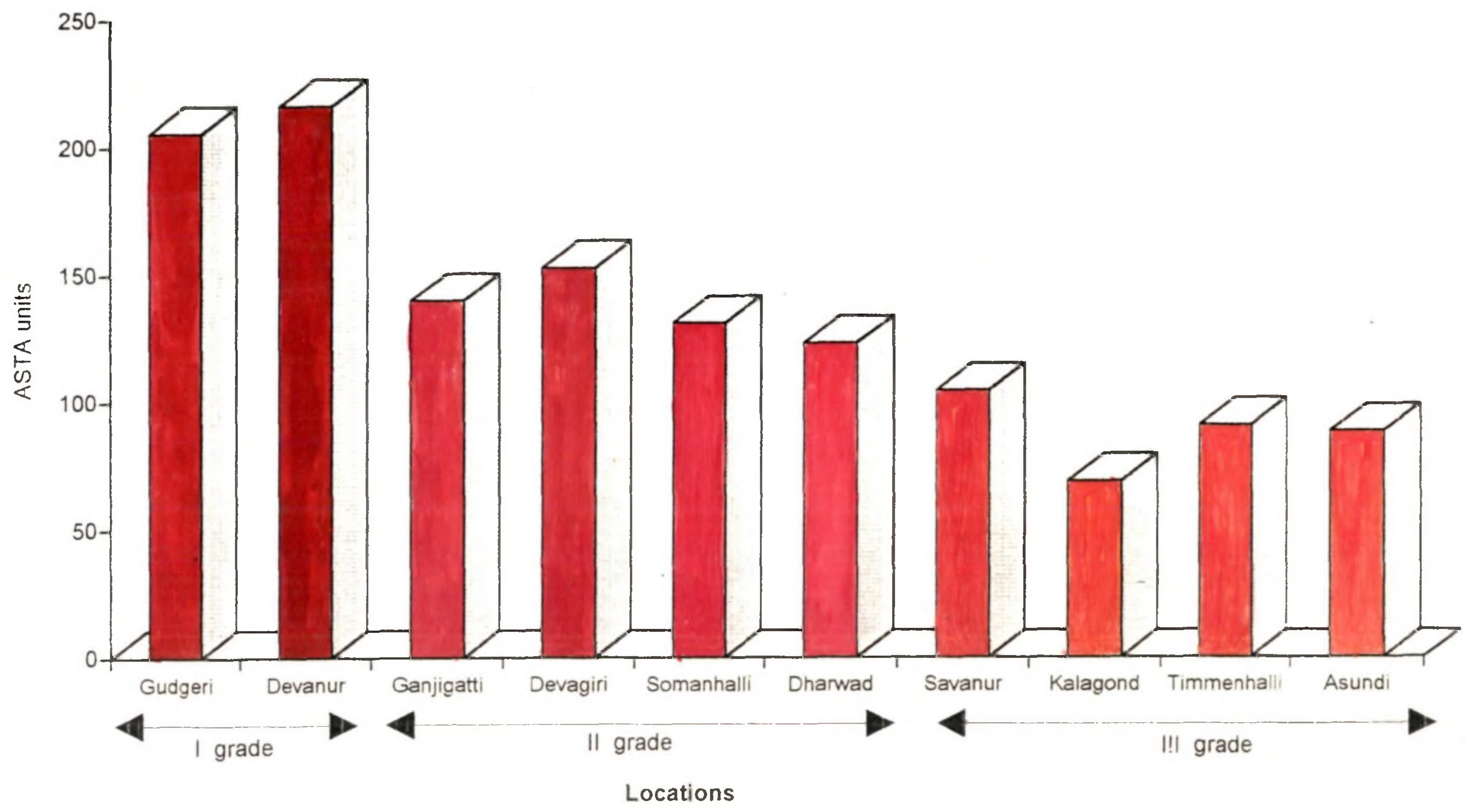


Fig. 4. Colour value of different grade Byadgi kaddi chilli fruits at various locations

ASTA units) and fruits of both varieties in general have less colour value than first grade fruits of Byadgi kaddi variety (211.00 ASTA units).

4.10.3(b) Dyavnur and Byadgi dabbi cvs. **Table 27(a)**

Colour value of Dyavnur and Byadgi dabbi fruit samples of different locations ranged from 176.60 to 255.50 and 206.70 to 280.10 ASTA units, respectively. In both cultivars, first grade fruits of Devanur location recorded highest colour value (255.50 and 280.10 ASTA units), closely followed by the same grade fruits of Gudgeri location (Fig.5). Among second grade locations in Dyavnur cultivar fruits of Annigeri location recorded slightly higher colour value (188.10 ASTA units) than fruits of other two locations (Ganjigatti and Dharwad). Similarly in Byadgi dabbi cultivar (second grade locations), fruits of Yaliwal loation recorded higher colour value (239.90 ASTA units) than fruits of other three locations (Malligawad, Saidapur and Kurtkoti) with lowest value of 206.70 ASTA units found in fruits of Kurtkoti location.

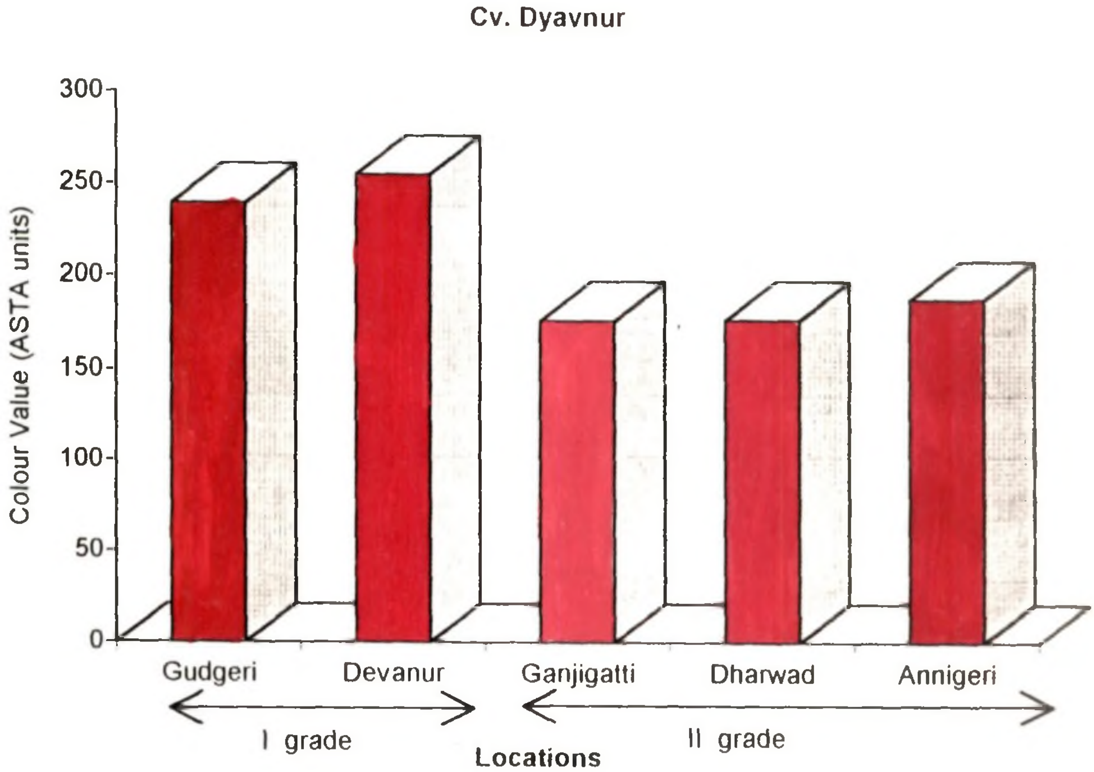
T test carried out to test for the significant difference between means of first and second grade fruits indicated a significant difference between means and first grade fruits recorded higher colour units than second grade fruits in both cultivars.

Comparison among the three Byadgi cultivars for colour value of fruits indicated, highest value for fruits of Byadgi dabbi cultivar, while lowest for Byadgi kaddi and medium colour units for fruits of Dyavnur cultivar.

4.10.4 Oleoresin

4.10.4(a) Byadgi kaddi cv. **Table 27**

Non significant difference existed between fruit samples of different locations with respect to oleoresin content which ranged from 13.46 to 19.64 per cent. First grade fruits of Devanur location yield highest oleoresin (19.64%) closely followed by fruits of Gudgeri and Devagiri locations with 17.84 and 16.81 per cent oleoresin, respectively.



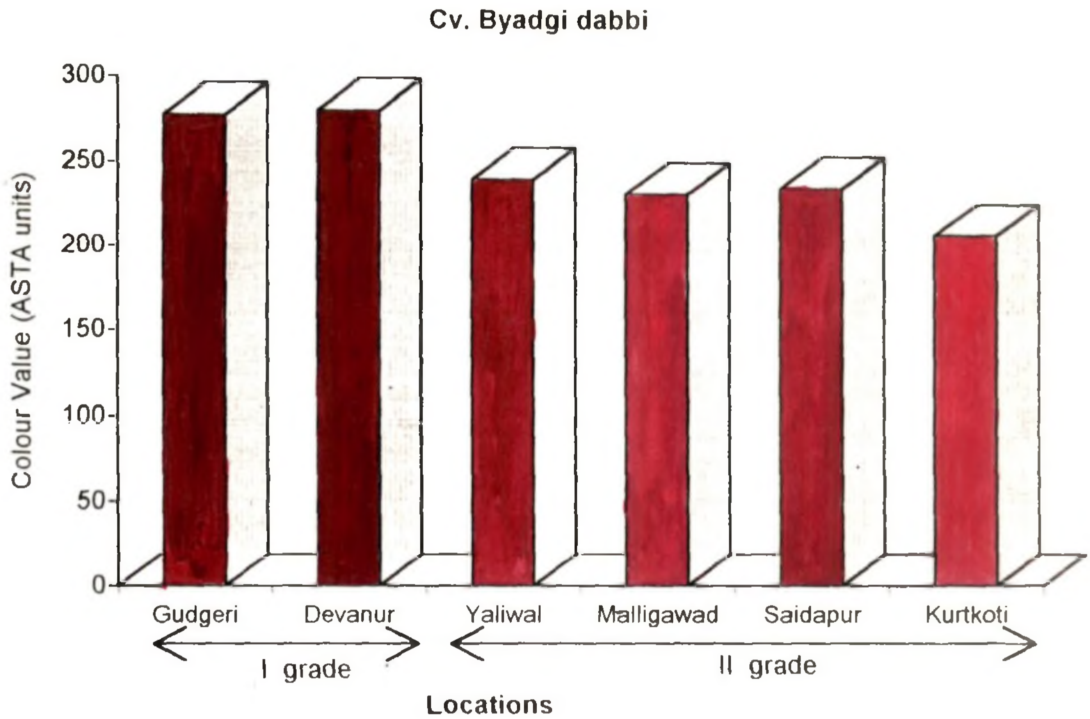


Fig. 5. Colour value of first and second grade chilli fruits (Cvs. Dyavnur and Byadgi dabbi) at various locations

Second grade fruit samples have narrow variation in oleoresin content (16.14 to 16.81%) compared to third grade fruit samples which have a range of 13.46 to 15.71 per cent. It is found that, third grade fruits of Kalagond location yield lowest oleoresin (13.46%). Generally, first grade fruits yielded highest oleoresin (18.74%), while third grade fruit yielded lowest (14.99%) and second grade fruits were medium in oleoresin yield (16.46%). Comparison of these different grade Byadgi kaddi cv. fruits with fruits of Sankeshwari and Guntur varieties for oleoresin yield revealed, low oleoresin yield in Sankeshwari (15.32%) and Guntur variety fruits (13.60%) which are comparable with oleoresin yield of third grade fruits.

4.10.4(b) Dyavnur and Byadgi dabbi cvs. Table 27(a)

In both cultivars, first grade fruits of Devanur location recorded maximum oleoresin (16.53 and 15.11%) closely, followed by fruits of Gudgeri location (16.13 and 15.00%). Among second grade fruit samples in Dyavnur cultivar, fruits of Annigeri location yielded more oleoresin (15.47%) than fruits of Ganjigatti location which yielded lowest (12.01%). Similarly in Byadgi dabbi cv. fruits of Malligawad location yielded highest oleoresin (14.97%) while those of Kurtkoti location yield lowest (11.87%) oleoresin.

Though first grade fruits recorded highest oleoresin yield than second grade fruits in both cultivars, yet the difference between first and second grade fruits with respect to oleoresin yield was nonsignificant as shown by t-test.

Scoville Heat Units (SHU)

These are the international units followed by American Spice Trade Association (ASTA) to assess the extent of pungency in chillies and grading. Pungency in chillies is determined based on the scoville heat units (SHU) liberated by standard pure capsaicin chemical used in HPLC column as a standard. It is found that, 0.66 per cent pure capsaicin solution liberates one lakh SHU.

Perusal of data presented in Tables 27 and 27(a) reveal that, for all the three Byadgi cultivars, fruits of Devanur location recorded maximum SHU (32000, 21000 and 22000 for Byadgi kaddi, Dyavnur and Byadgi dabbi fruits respectively) closely followed by fruits of Gudgeri location. Lowest SHU (15,000) were found in second grade fruits of Annigeri and Kurtkoti locations for Dyavnur and Byadgi kaddi cultivars respectively.

Comparison of different grade Byadgi cultivar fruits with fruits of Sankeshwari and Guntur varieties revealed that, fruits of Sankeshwari variety have maximum scoville heat units (72,000) due to high capsaicin content (0.48%) followed by fruits of Guntur variety with 56,000 SHU (0.37% capsaicin). Lowest SHU (15,000) were recorded in second grade fruits of Byadgi dabbi cultivar due to low capsaicin (0.10%) content.

4.11 Correlation studies

Results on the relationship of soil physical and physico-chemical properties at surface (0-15 cm) and sub surface (15-30 cm) depths with yield and quality attributes of chilliies (Byadgi kaddi cv.) are presented in Table 28.

Correlations could not be worked out for Dyavnur and Byadgi dabbi cultivars due to less pairs (5 and 6 pairs) of observations and correlation coefficient(r) values obtained in such small samples are not reliable.

4.11.1 Soil physical properties Vs. Yield and quality **Table 28**

Significant negative correlation was observed between bulk density at both depths and yield/quality attributes of chilli, but significant positive relationships were

Table 28: Relationship between soil physical, chemical properties and yield/quality attributes of Byadgi kaddi cultivar

Soil property	'r' value							
	Yield		Capsaicin		Color value		Oleoresin	
Bulk density	-0.94*	-0.89*	-0.92*	-0.81*	-0.90*	-0.83*	-0.84*	-0.74*
Per cent pore space	0.87*	0.79*	0.87*	0.70*	0.81*	0.72*	0.72*	0.78*
Available moisture	0.88*	0.86*	0.90*	0.89*	0.92*	0.90*	0.86*	0.83*
Per cent clay	0.80*	0.79*	0.83*	0.80*	0.79*	0.77*	0.70*	0.69*
Per cent silt + clay	0.50	0.77*	0.37	0.81*	0.53	0.77*	0.33	0.70*
Soil pH	0.24	-0.39	0.33	-0.26	0.34	-0.42	0.38	-0.27
Cation exch. capacity (CEC)	0.71*	0.72*	0.77*	0.75*	0.72*	0.76*	0.75*	0.74*
Exch. K.	0.82*	0.79*	0.39	0.49	0.75*	0.74*	0.34	0.40
Exch. Ca + Mg	0.13	0.33	0.29	0.47	0.14	0.35	0.18	0.37
Organic carbon	0.93*	0.08	0.92*	0.27	0.91*	0.11	0.89*	0.24
Free $CaCo_3$	0.07	0.52	0.20	0.39	0.04	0.55	0.17	0.34
Soluble Ca + Mg	0.45	0.17	0.59	0.07	0.46	0.23	0.50	0.01
Soluble sulphate	-0.44	0.00	-0.43	0.18	-0.42	0.04	-0.49	0.14

Note : Underlined figures indicate 'r' value for subsurface depth (15-30 cm).
* Significant at 5%.

observed between yield/quality attributes of chilli and per cent pore space, available moisture and per cent clay contents at both depths. Similarly per cent silt plus clay of only subsurface depth (15-30 cm) has direct relationship with yield (0.77*) and quality attributes (0.81*, 0.77* and 0.70*) of chilli, while it's content at surface depth has no relationship with yield and quality attributes.

4.11.2 Soil physico-chemical properties Vs yield and quality attributes of chilli

Correlation values presented in Table 28 reveal that, yield and all quality attributes bear significant positive relationship with CEC of soils at both depths. Similarly yield and colour value had significant positive relations with soil exchangeable K^+ at both depths, but capsaicin and oleoresin contents were not related to exchangeable K^+. Organic carbon content of only surface soil (0-15 cm) influenced the yield and quality attributes significantly, whereas no rèlationship existed between organic carbon content of subsurface soil and yield/quality attributes. Other physico-chemical properties have not influenced the yield/quality attributes significantly as indicated by very low 'r' values.

4.11.3 Fertility status of soils and their relation to yield and quality attributes of chilli

Results on the relationship of available nutrient status in soils at surface (0-15 cm) and sub surface (15-30 cm) depths with yield and quality attributes of chillies as obtained after correlation studies are presented in Table 29.

4.11.3(a) Available nitrogen Vs.yield and quality attributes

Significant positive relationships existed between yield/quality attributes of fruits and soil nitrogen content at both surface and subsurface depth with an exception of

Table 29: Relationship between soil available nutrient status and yield /quality of Byadgi kaddi, chilli.

Available nutrient	'r' value			
	Yield	Capsaicin	Colour value	Oleoresin
Nitrogen	0.62*	0.68*	0.65*	0.64*
	(0.64*)	(0.61*)	(0.71*)	(0.55)
Phosphorus	0.40	0.55	0.49	0.50
	(0.11)	(0.28)	(0.13)	(0.25)
Potassium	0.66*	0.37	0.95*	0.23
	(0.55)	(0.44)	(0.89*)	(0.38)
Sulphur	0.33	0.49	0.37	0.41
	(-0.11)	(-0.27)	(-0.13)	(-0.37)
Copper	-0.22	-0.36	-0.28	-0.21
	(0.83*)	(-0.77*)	(0.87*)	(0.78*)
Zinc	0.64*	-0.69*	0.61	0.74*
	(-0.69*)	(-0.71*)	(-0.68*)	(-0.64*)
Iron	-0.38	-0.46	-0.36	-0.37
	(-0.29)	(-0.36)	(-0.37)	(-0.49
Manganese	0.39	0.32	0.26	0.14
	(0.34)	(0.34)	(0.25)	(0.20)

Note : Figures in the parentheses indicate 'r' value for subsurface depth .
* Significant at 5%.

nonsignificant relationship between oleoresin content and available N at subsurface depth (r = 0.55).

4.11.3(b) Available phosphorus Vs. yield and quality attributes

Available p content at both depths, has no relationship with yield and quality attributes as given by very low correlation coefficient values (Table 29).

4.11.3(c) Available potassium Vs. Yield and quality attributes

A cursory look at the correlation coefficient values presented in Table 29 reveal that, among the three quality attributes, colour value of fruits was significantly and positively correlated with available K content soils at both surface ($r = 0.95^*$) and sub surface ($r = 0.89^*$) depths. But, capsicum and oleoresin contents of fruits have no relationship with soil available K content at both depths.

4.11.3(d) Available sulphur Vs. yield and quality attributes

Available sulphur content of these pedons at both depths could not influence the yield and quality attributes of this cultivar either positively or negatively.

4.11.3(e) Micronutrients Vs. yield and quality attributes

Yield and quality attributes bear significant positive correlation with copper content of soil at sub surface depth with the exception of negative correlation (r = -0.77*) observed between capsaicin and soil copper, whereas no relationship existed between soil copper at surface depth and yield/quality attributes. With respect to zinc, significant negative correlations were observed between zinc content at subsurface depth and yield/quality attributes (r =-0.69*, -0.71*, -0.68*, -0.64*). But yield and oleoresin content of fruits were significantly and positively correlated with zinc content of soil at surface depth. Capsaicin was negatively correlated (r = -0.69*) while no relationship exist between colour value and zinc content of soil at surface depth (r = 0.71*).

Yield and quality attributes were not related to available iron content in soils at both depths. Most of the correlation coefficient values are negative as indicated in Table 29. Similarly manganese content in soils at both depths has no relationship with yield and quality attributes.

4.11.4 Nutrient uptake Vs. yield and quality attributes

Results pertaining to relationship between uptake of nutrients at different periods and yield/quality attributes of chill are presented in Table 30.

Correlation coefficient values presented in Table reveal that, yield and all the three quality attributes have significant positive correlation with N uptake by plants at all the three stages. The values of correlation coefficient(r) for yield, capsaicin, colour value and oleoresin as influenced by N uptake at 75, 105 and 140 DAT range from 0.95 to 0.97, 0.98 to 0.99, 0.93 to 0.96, 0.87 to 0.91, respectively.

Phosphorus and potassium uptake at 75 and 140 DAT, have significant positive correlation with yield and quality attributes, whereas uptake at 105 DAT, has no relationship with yield and quality attributes. The values of correlation coefficient for yield, capsaicin, colour value and oleoresin versus P uptake by chilli plants at 75 DAT were 0.92*, 0.89*, 0.96* and 0.89*, respectively. Similarly the values for K uptake at 75 DAT were 0.90*, 0.94*, 0.94* and 0.91* for yield, capsaicin, colour value and oleoresin respectively. The values of 'r' for showing the relationship of P and K at 140 DAT with yield and capsaicin content were 0.96 and 0.95, respectively.

Table 30 : Relationship between nutrient uptake at different stages growth and yield/quality of chilli (Cv. Byadgi kaddi)

Nutrient uptake	'r' value											
	Yield			Capsaicin			Colour value			Oleoresin		
	75	105	140	75	105	140	75	105	140	75	105	140
Nitrogen	0.97*	0.96*	0.95*	0.99*	0.98*	0.98*	0.96*	0.94*	0.93*	0.91*	0.87*	0.87*
Phosphorus	0.92*	0.32	0.96*	0.89*	0.45	0.95*	0.96*	0.31	0.96*	0.89*	0.36	0.89*
Potassium	0.90*	0.19	0.96*	0.94*	0.32	0.95*	0.94*	0.21	0.97*	0.91*	0.29	0.88*
Sulphur	0.81*	0.66*	0.92*	0.82*	0.67*	0.61*	0.86*	0.74*	0.91*	0.78*	0.58	0.87*
Calcium	0.96*	0.34	0.98*	0.96*	0.50	0.96*	0.94*	0.39	0.95*	0.92*	0.44	0.89*
Magnesium	0.96*	0.48	0.98*	0.95*	0.63	0.94*	0.95*	0.53	0.97*	0.86*	0.59	0.88*
Copper	0.74*	0.51	0.95*	0.77*	0.39	0.96*	0.82*	0.54	0.96*	0.75*	0.34	0.90*
Zinc	0.52	-0.38	0.90*	0.68*	-0.28	0.91*	0.59	-0.45	0.87*	0.58	-0.48	0.79*
Iron	0.74*	-0.15	0.96*	0.82*	-0.02	0.97*	0.76*	-0.21	0.93*	0.68*	-0.23	0.86*
Manganese	0.78*	0.15	0.81*	0.83*	0.23	0.89*	0.80*	0.13	0.82*	0.74*	-0.00	0.77*

Significant at 5 per cent.

Similar to the relationship between N uptake and yield/quality attributes, sulphur uptake also had significant positive correlation with yield and quality attributes with the exception of relationship between oleoresin content in fruits and sulphur uptake at 105 DAT (r = 0.58). Calcium and magnesium uptake at 75 and 140 DAT also had significant positive relationship with yield and all quality attributes. But their uptake at 105 DAT had no relationship with yield and quality attributes.

With regard to the relationship between uptake of micronutrients and yield/quality attributes, it was found that, yield and quality attributes were significantly and positively correlated with uptake of copper, iron and manganese at 75 and 140 DAT, whereas their uptake at 105 DAT had no relationship with yield and quality attributes. Uptake of zinc by chilli plants at 140 DAT had significant positive relationship with yield and quality attributes, while it's uptake at 75 and 105 DAT had no relationship with yield and quality attributes except for capsaicin content in fruits and Zn uptake at 75 DAT ($r = 0.68^*$).

4.11.5 Nutrient content of whole red fruit or pericarp component and quality attributes

In order to know, whether any relationship existed between nutrient concentration in whole red fruits or pericarp component and quality attributes of fruits, correlation coefficient values were worked out separately for three Byadgi cultivars and results are presented in Table 31.

All the three quality attributes have significant positive correlation ($r = 0.96^*$, 0.94^* and 0.94^*) with N content of whole red fruit. It was found that, quality attributes have no relationship with N content of pericarp component. Similarly phosphorus content of whole red fruits or pericarp component had no relationship with quality attributes.

Table 31: Relationship of nutrient concentration of whole red fruit and pericarp component with quality attributes of chilli fruits (Cv. Byadgi kaddi,)

Nutrient	'r' value		
	Capsaicin	Colour value	Oleoresin
Nitrogen	0.96*	0.94*	0.94*
	(0.08)	(-0.01)	(-0.04)
Phosphorus	-041	-0.39	-0.32
	(-0.07	(-0.08)	(0.06)
Potassium	0.85*	0.86*	0.83*
	(0.87*	(0.90*)	(0.83*)
Sulphur	-0.61	-0.45	-0.47
	(-0.02	(0.01)	(0.09)
Calcium	0.27	0.22	0.04
	(0.52	(0.52)	(0.34)
Magnesium	0.03	-0.08	0.17
	(-0.14	(-0.06)	(-0.25)
Copper	0.48	0.41	0.43
	(0.34	(0.32)	(0.30)
Zinc	0.56	0.51	0.50
	(0.48	(0.45)	(0.44)
Iron	-0.10	-0.27	-0.26
	(0.20	(0.04)	(0.07)
Manganese	0.05	-0.10	0.05
	(-0.58	(-0.59)	(-0.62)

Note : Figures in the parentheses indicate correlation values between pericarp nutrient concentration and quality attributes.
* Significant at 5%.

Potassium content in whole red fruit or pericarp component had significant positive correlation with quality attributes of fruits and among the three quality attributes, colour value of fruits appeared to highly positively correlated with K content of both whole red and pericarp component. Similarly, capsaicin content was significantly and positively related to K content of both whole fruits and pericarp portion ($r = 0.92^{*}$). With regard to the relationship between oleoresin content and K content of fruits significant positive relationship was observed between oleoresin content and K content of whole red fruit ($r = 0.69^{*}$) as well as pericarp (0.64^{*}).

With regard to the relationship between quality attributes of fruits and concentration of secondary and micronutrients in whole fruits or pericarp component, it can be inferred that, no definite relationship existed between quality attributes of fruits and concentration of or micronutrients.

DISCUSSION

V. DISCUSSION

Byadgi chilli is being grown extensively in the transitional belt of Dharwad district in Karnataka state. Though,the entire chilli growing area falls under one agroclimatic region, yet different locations of this region differ widely in yield levels and quality attributes. This wide variation in yield levels and quality attributes of locations may be attributed to different soil types and cultivation practices followed by farmers. From many years it has been reported that, the Byadgi chilli grown in few villages of Kundagol taluk is of best quality and the yield levels are high, thereby fetch highest price than chillies grown in other taluks of the district. The present investigation was carried out to understand how the yield levels and quality attributes of fruits in different locations are influenced by soil properties and management practices.

Based on the yield levels and quality of chilli produced in the region, the entire chilli growing area was divided into three regions. A cluster of soil bodies from each of these three regions were choosen and it accounted to fifteen soil pedons spread over in eleven taluks. Out of fifteen pedons, two pedons fall in the first region, where yield levels were high and first grade fruits were produced, nine pedons fall in the second region where yields were medium and second grade fruits were produced and four pedons belong to third region where yields were low and third grade fruits were produced. These fifteen pedons were examined for morphological, physical, chemical and fertility characteristics. Byadgi cultivars (Byadgi kaddi, Dyavnur and Byadgi dabbi) grown in these fifteen locations for two seasons were examined for growth attributes, nutrient uptake, yield and quality attributes to establish few relationships with soil properties. The results obtained are discussed under the following headings.

5.1 Morphological features of soil pedons

5.2 Physical and chemical properties of soil pedons

5.3 Fertility status of soils

5.4 Nutrient uptake by plants in different locations

5.5 Growth and yield attributes as influenced by soil properties

5.6 Physical and chemical characteristics of different grade chilli fruits in different locations

5.7 Nutrient status of whole chilli fruits and fruit components in different locations

5.8 Quality attributes of chilli fruits in different locations

5.9 Correlation studies.

5.1 Morphological features of soil pedons

Black soil pedons that produced first and second grade fruits were deep and red soil pedons were shallow to medium in depth. More depth in black soil pedons is attributed chemical weathering as reported by Krishnamoorthy and Govindarajan (1977). The red soil pedons (VIII, IX and X) exhibited wide variation in solum depth because of differential weathering of rocks constituting the Dharwad rock system and pedon-IX having sandstone as the parent rock was more deep due to easy weatherability than other two pedons which have quartzite rock.

The dominant colour in black soil pedons was dark grayish brown to very dark grayish brown and in red soil pedons it was yellowish red to dark red and this variation in colour is due to organic carbon and free iron content in soils (Singh, 1956).

Structure in black soil pedons varied from granular to subangular and angular blocky, while in red soil pedons it was coarse to very coarse and granular to subangular blocky. Angular blocky structure in sub soil horizons of black soil pedons was due to slickensides formation in these soils. Abundance and intensity of slickensides was more in the middle of solum because of maximum swelling pressure generated there as described by Yaalon and Kalmar (1978). Slickensides are absent in red soil pedons (VIII, IX and X) and also in mixed red and black soil pedon (VII).

5.2 Physical and chemical properties

5.2.1 Physical properties

All black soil bodies were clays whereas red soil pedons were sandy clay to clay loam and loam in texture. The clay content increased with depth in all pedons except in pedons I, III, IV, VII, X and XV where no definite trend was observed in it's distribution. The increase or decrease in clay content with depth was gradual and was not significant. Increase in clay content with depth may be due to pronounced cracking, self mulching and pulverizing nature of these soils (Bhargava *et al.*, 1973 and Boul, 1965). Red soil pedons (VIII, IX and X) and pedon VII have more sand fraction than other black soil pedons because of more coarser fractions due to less chemical weathering (Krishnamoorthy and Govindarajan, 1977). High sand content in red soil pedons is also related to nature of parent rock as the pedons were developed on quarzite and sandstone complexes, while black soil pedons have chlorite-schist, granite gneiss and weathered basalt rock system.

There was marked difference in the bulk density values of black and red soil pedons. Deep black soil pedons (pedons I and II) that produced first grade fruits and high yields have lower bulk density values (1.30 to 1.40 Mg m^{-3}) than other black soil pedons (1.33 to 1.52 Mg m^{-3}) that produced second grade fruits and medium yields. High clay content in pedons I and II resulted in low bulk density values. Ghildyal and Satyanarayana (1965) reported inverse relationship between clay content and bulk density. High bulk density values in red soil pedons (pedons VIII, IX and X) and pedon VII that is due to low clay content and more of coarser fractions.

Black soil pedons have higher pore space (42.58 to 49.81%) than red soil pedons (39.54 to 43.98%) and not much variation was observed between deep black and medium black soil pedons. Similarly black soil pedons have higher moisture retention capacity than red soil pedons and the trend in moisture retention at 33 kPa and 1500 kPa followed the clay content. Very low moisture content in red soil pedons (VIII, IX and X) was due to low clay content, weak structure and more coarse fractions. The findings of moisture retention characteristics and it's relation to soil texture are in agreement with the findings of Ali *et al.* (1966).

Deep black soil pedons (I and II) have maximum cumulative available soil moisture (31.17 and 33.75 cm), whereas red soil pedons (VIII, IX and X) including pedon VII recorded lowest (4.24 to 20.47 cm) and medium black soil pedons (pedons III, IV, V, VI, XI, XII, XIII, XIV and XV) were intermediate in available total moisture content. This variation in total available soil water content of pedons was due to depth of solum, texture and structure of soils.

5.2.2 Chemical properties of soil pedons

Black soil pedons were neutral to alkaline in reaction, whereas red soil pedons (Pedons VIII, IX and X) were acidic to neutral. High pH in black soil pedons is due to calcareous nature and accumulation of bases in the solum as they were poorly leached (Satyanarayana and Biswas, 1970) and low pH in red soil pedons is due to leaching of bases on account of well drained conditions leaving behind iron and aluminium oxides (Manjunathaiah, 1981).

Black soil pedons have higher soluble salts than red soil pedons may be due to restricted drainage in black soils which causes accumulation of salts in the soils. Low EC in red soil pedons (pedons VIII, IX and X) signifies extensive leaching.

Black soil pedons recorded higher CEC values when compared to red soil pedons including pedon VII (mixed red and black soil pedon). These are in line with the findings of Alase (1977) who also observed high CEC values in black soils, low in red soils and intermediate in alluvial soils. Usually deep black soil pedons (pedons I and II) have higher CEC values than medium black soil pedons (pedons III, IV, V, VI, XI, XII, XIII, XIV and XV). It is found that, CEC is largely governed by nature and amount of clay and high CEC values in black soil pedons is attributed to high clay content. No definite trend in CEC values with depth was observed in black soil pedons, may be due to movement and accumulation of clay.

Among exchangeable cations, Ca^{2+} + Mg^{2+} were dominant over sodium and potassium in both black and red soil pedons. Black soil pedons have two and half to three times higher exchangeable Ca^{2+} + Mg^{2+} than red soil pedons. This variation between black and red soil pedons is attributed to the type and amount of clay, present in these soils. The distribution of exchangeable Ca^{2+} + Mg^{2+} in red soil pedons (pedons VIII, IX and X) with depth followed the extent of clay distribution with depth. These results are in confirmity with the findings of Krishnamurthy (1993) and Alur (1994). Higher values of CEC and exchangeable Ca^{2+} + Mg^{2+} in black soil pedons give an indication of dominance of smectite type of clay mineral as reported earlier by Nandi and Dasog (1992).

Black soil pedons invariably contain more exchangeable Na^{+} and K^{+} than red soil pedons and this is attributed to high clay content and 2:1 type of clay mineral present in black soils than red soils having low clay content and 1:1 type of clay mineral. Exchangeable sodium content increased with depth due to its solubility and leaching to lower layers (Subbaiah and Manickam, 1992), however in some pedons it increased only upto third depth or fourth depth and later decreased. No definite trend in the distribution of potassium with depth was observed irrespective of the type of soil pedon.

Data on organic carbon (Table 5) content indicated that, black soil pedons have higher organic carbon content than red soil pedons. Among the black soil pedons, pedons I and II that produced first grade fruits contained highest organic carbon than other black soil pedons that produced second grade fruits. Very high organic carbon content in pedons I and II was due to intensive cultivation of chilli coupled with heavy application of organic manures every year as mentioned in Tables 3, 3(a) and 3(b). Low organic carbon content in mixed red and black (pedon VII) and red soil pedons (VIII, IX and X) was due to rapid oxidation of organic matter facilitated by high temperature regimes and coarse textured nature of soils further enhances the oxidation process (Bhargava *et al.*, 1973). Further less application of organic manures to the crop pronounced low organic carbon status of such red soils. In all the pedons, organic carbon content decreased with depth indicating the maturity of pedons (Sahu *et al.*, 1990).

All the black soil pedons including pedon VII (mixed red and black soil pedon) were calcareous in nature where as red soil pedons (VIII, IX and X) were noncalcareous. In black soil pedons, calcium carbonate content increased with depth possibly due to accumulation of displaced calcium from exchange complex from the upper layers (Pathak and Patel, 1980), while in red soil pedons and pedon VII, no definite trend in its distribution with depth was noticed, may be due to low base saturation in these soils.

Among soluble cations, Na^+ dominated over Ca^{2+} + Mg^{2+} and soluble K^+ content was lowest in all the pedons. The concentration of soluble sodium increased with depth in all pedons as sodium salts are more mobile and hence accumulate at lower depths. These results are in confirmity with Talbot *et al.* (1971) ; Kaushik and Shukla (1977) and Deshpande (1985).

Among soluble anions, bicarbonates dominated over chlorides and sulphates and black soil pedons contain more bicarbonates than red soil pedons. The trend in the distribution of HCO_3 and Cl^- anions in all the pedons was irregular, but sulphates increased with depth in all black soil pedons, while in red soil pedons irregular distribution was observed. Similar results were reported by Manjunathaiah (1981).

5.3 Fertility status of soils

Data on fertility status of soil pedons are presented in Table 6.

5.3.1 Available nitrogen

The available nitrogen content in the soil bodies studied was low to medium and decreased with depth in all soil bodies. Deep black soil pedons (I and II) contained higher available nitrogen than other medium black soil pedons (pedons III, IV, V, VI, XI, XII, XIII, XIV and XV) producing second grade fruits and medium yields. Pedon II has highest available N may be due to heavy application of organic manures and fertilizers every year to get high yields and first grade fruits. High N content in deep black soil pedons might be due to very fine textured nature on account of high clay content, which results in less leaching of applied N compared to medium black soil pedons. Red soil pedons (VIII, IX and X) producing third grade fruits and low yields were low in N status, this might be due to coarse textured nature of these soils coupled with high temperature, that results in rapid loss of applied N due to leaching (Ramamoorthy and Velayutham, 1976). These conditions were further pronounced by low application of organics and fertilizers to chilli crop in these soils. In general, black soil pedons contained more nitrogen than red soil pedons due to fixation of applied nitrogen in the form of organo-mineral complexes of humic substances in fine textured soils. Jenny and Raychaudhury (1960) reported nitrogen content in some Indian soils as closely related to clay content. Black soil pedons have high adsorption capacities for organic molecules because of montmorillonitic clays and higher exchangeable calcium in such pedons helps to preserve humic substances by forming calcium humate and organo mineral compounds, which are less available to microbial attack. Further, poor drainage and low microbial activity in black soils lead to accumulation of N in such soils. High N content in surface soil is due to incorporation of organic manures and fertilizers in this depth.

5.3.2 Available phosphorus

The available phosphorus content in the soil bodies studied was low to medium. Deep black soil pedons (I and II) contain higher available P than other medium black soil pedons (pedons III, IV, V, VI, XI, XII, XIII, XIV and XV). This may be due to weak organic acids produced in deep black soils during decomposition of heavy doses of organic manures applied by farmers before planting that dissolve native phosphorus present in soils. Further, the added complex fertilizer containing P may also lead to higher available P in these soils. But in medium black soil locations, solubility of native P was less compared to pedons I and II, may be due to low organic matter content in soils. In general low phosphorus content in few black soil pedons was due to the presence of excess calcium carbonate which forms insoluble compounds of calcium and phosphorus leading to reduction in P availability. Such results were obtained by Raut (1962) for black soils of Nagpur region. Not much variation was observed with respect to the distribution of phosphorus with depth in both black and red soil pedons. Generally, phosphorus content decreased with depth in all the pedons with few exceptions. Pearson *et al.* (1940) reported that, readily available P decreased with depth to a minimum in lower A horizon or upper B horizon and then increased markedly in subsequent layers of US soils. Wide variation in the vertical distribution of this element have been reported earlier by different workers.

5.3.3. Available potassium

Since major portion of potassium requirement of crop is met through the process of diffusion, it is of great importance to know the depthwise distribution of available K in any soil body. All the black soil bodies were high in available K content, whereas red soil pedons

(pedons VIII, IX and X) were medium to high in K status. The available potassium content decreased with depth in all the pedons except in pedons I and VIII. Rajukkannu *et al.* (1970) studied K status of red and alluvial soils and reported the decreasing trend of available K with depth. Among black soil pedons, pedons I and II recorded highest available K in surface layer than other black soil pedons. Red soil pedons contained slightly lower available K than black soil pedons. High available K in surface layers was due to the release of potassium from organic matter and application of potassic fertilizer to the crop which lead to more of exchangeable K in surface horizon (Chahal *et al.*, 1976). This exchangeable K is the major contributor for available K in soil and intensive weathering in surface horizon also enhances exchangeable K indirectly governing available K content in soil.

5.3.4 Available sulphur

Available sulphur in surface layer (0-15 cm) ranged from 3.50 to 32.50 ppm found in pedons VIII and II, respectively. Black soil pedons contained more sulphur than red soil pedons (VIII, IX and X). This might be due to gypsiferous nature of black calcareous soils as reported by Balasubramaniam and Kothandaraman (1985). Low sulphur content in red soils including mixed red and black soil (pedon VII) might be due to high leaching losses, because of coarse textured nature and heavy rainfall. Dolui and Saha (1983) reported similarly for lateritic soils of West Bengal. In all the soil bodies, sulphur content increased with depth, which may be due to leaching of soluble sulphates to deeper layers and precipitation as gypsum crystals. Hogg (1966) reported leaching to the extent of 85 to 100 per cent of applied sulphur.

If 10 ppm is taken as critical limit for available sulphur in soil (Kanwar, 1963), then all the black soil pedons were high in sulphate sulphur, whereas red soil pedons were deficit in available sulphur and pedon VII (mixed red and black soil) is marginal.

5.3.5 Available micronutrients

5.3.5.1 Available copper

Available copper content in surface layer of pedons ranged from 1.10 to 2.10 ppm. In some pedons (VI, VIII, X and XIII), it's content decreased with depth, while in other pedons, no definite pattern of distribution was observed. It is found that pedon-VIII had highest available copper than other black soil pedons. This might be due to acidic pH of this pedon which led to increased solubility of copper compounds (Lindsay, 1979). Low copper content in black soil pedons compared to red soil pedons (VIII, IX and X) including pedon VII was due to high calcium carbonate and clay content as reported by Rai *et al.* (1972) and Tekale and Ghonsikar (1977).

5.3.5.2 Available zinc

The concentration of DTPA extractable zinc in black soil pedons ranged from 0.24 to 2.14 ppm found in 30 to 60 and >110 cm depths of pedons VI and XV, respectively. Appavu and Sreeramulu (1981) reported that, DTPA extractable zinc varied from 0.16 to 5.14 ppm and no consistent distribution pattern was observed in soil bodies. In red soil pedons, available Zn ranged from 0.20 to 0.84 ppm found >30 and 15-30 cm depths of pedons VIII and X, respectively.

5.3.5.3 Available iron

The concentration of available iron in soil bodies ranged from 1.38 to 13.34 ppm found in >30 and 0-15 cm depths of pedons X and VIII, respectively. Red soil pedons (pedon VIII) have higher available Fe than black soil pedons, this may be due to acidic pH of soil leading to greater solubility and availability. The results of available iron are in agreement with values of DTPA extractable iron for calcareous soils of Marathwada region as reported by Malewar and Randhawa (1977). In all the black soil bodies, DTPA extractable iron did not follow any definite pattern. Based on the critical limits suggested by Sakal *et al.* (1985) for calcareous soils (6.95 ppm), except soils of pedon VIII, all other soil bodies were found to be deficient in available iron.

5.3.5.4 Available manganese

The concentration of DTPA extractable manganese in soils varied from 7.50 to 45.70 ppm and its distribution in soil pedons did not follow any definite pattern. Very high value in surface layer of pedon VIII may be due to acidic pH as reported by Biswas (1951). Under such conditions, the soluble manganese compounds precipitated as higher oxides of manganese and thus becoming unavailable. High pH values of black calcareous soils coupled with semi arid conditions decrease the availability of Mn by converting into unavailable forms (Mn^{++} converted to Mn^{+++}) as reported by Arora and Sekhon (1981).

5.4 Nutrient uptake by chilli cultivars in different locations

Chilli being an exhaustive crop, plant nutrition is of vital importance in growing it successfully. Among the several agro techniques that can enhance the production of chillies, adequate nutrition ranks first. The fertilizer application is usually based on nutrient uptake since the crop yields are directly related to the amount of nutrient absorbed. The nutrient uptake behaviour is useful in determining the peak period of its uptake for maximising the efficiency of applied fertilizers (Mehrotra *et al.*, 1968). Results pertaining to uptake of nutrients at different growth stages in different locations for the three Byadgi cultivars are discussed below.

5.4.1 N uptake

The data on N uptake by chilli cultivars are presented in Tables 11 and 11(a).

All the three cultivars, grown on deep black soil locations (Gudgeri and Devanur) recorded highest N uptake (Figs. 6 to 8) and differed significantly from plants grown on medium black soil locations. All the soil properties in deep black soil locations are highly favourable for better root spread and nutrient uptake by plants because of better aggregation, increased porosity and high available moisture. Further continuous application of organics to chilli crop every year in these locations resulted in high organic matter status that led to slow break down of nitrogenous compounds making steady supply of N throughout the growth period and subsequent uptake. Results obtained are in agreement with the findings of Chavan *et al.* (1997). Thomas and Heilman (1967) reported higher N availability and uptake in deep black soils as closely related to available soil moisture. Plants grown on red soils (Third group locations in case of Byadgi kaddi cv.) had low N uptake and this is attributed to low N availability on account of low organic matter content, shallow depth and coarse textured nature resulted in higher leaching losses. Further, higher compaction of red soils on account of high bulk density resulted in limited root spread leading to reduced N uptake.

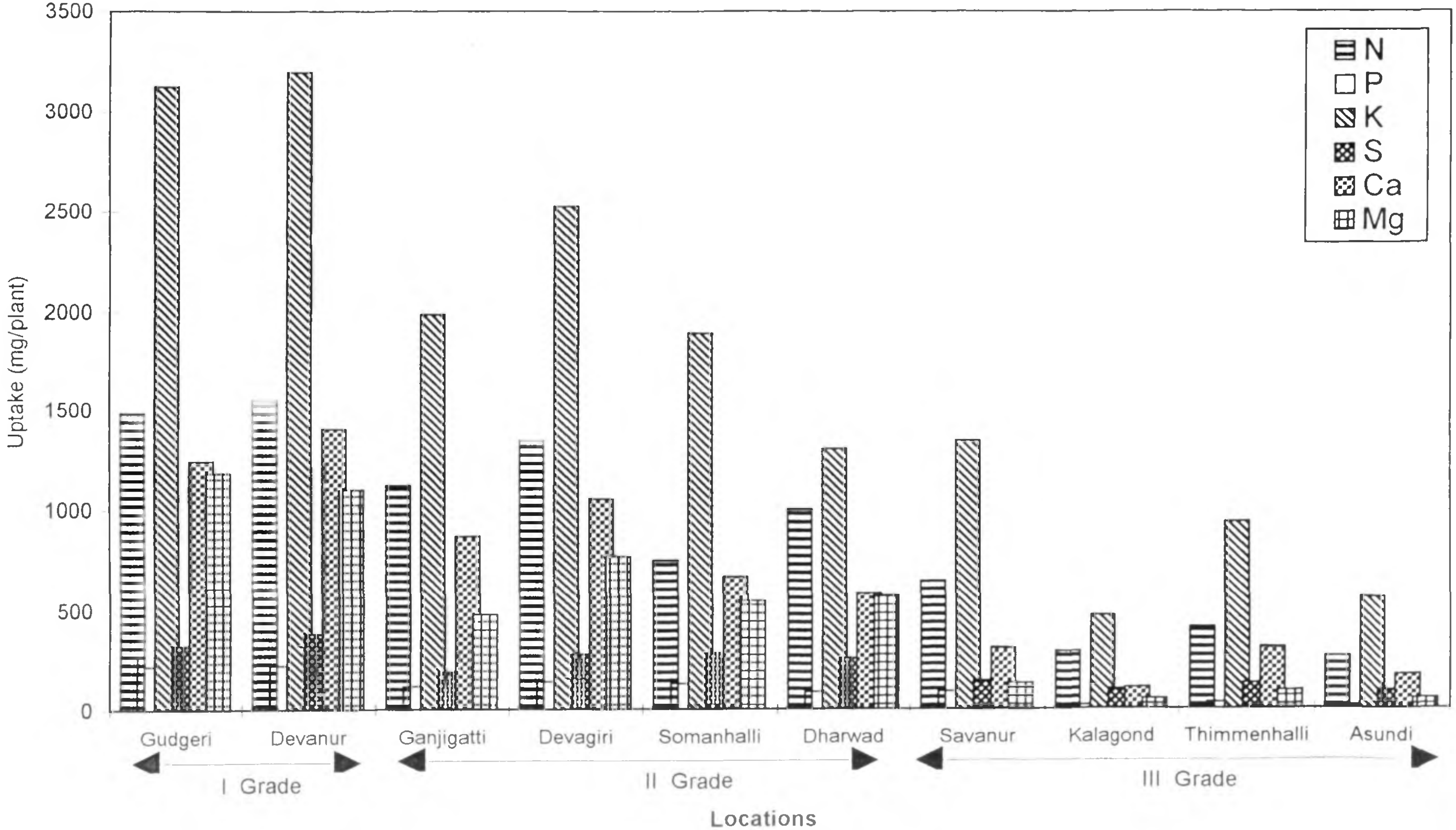


Fig. 6. Major and secondary nutrient uptake (mg/plant) by Byadgi kaddi cv. Chilli at various locations

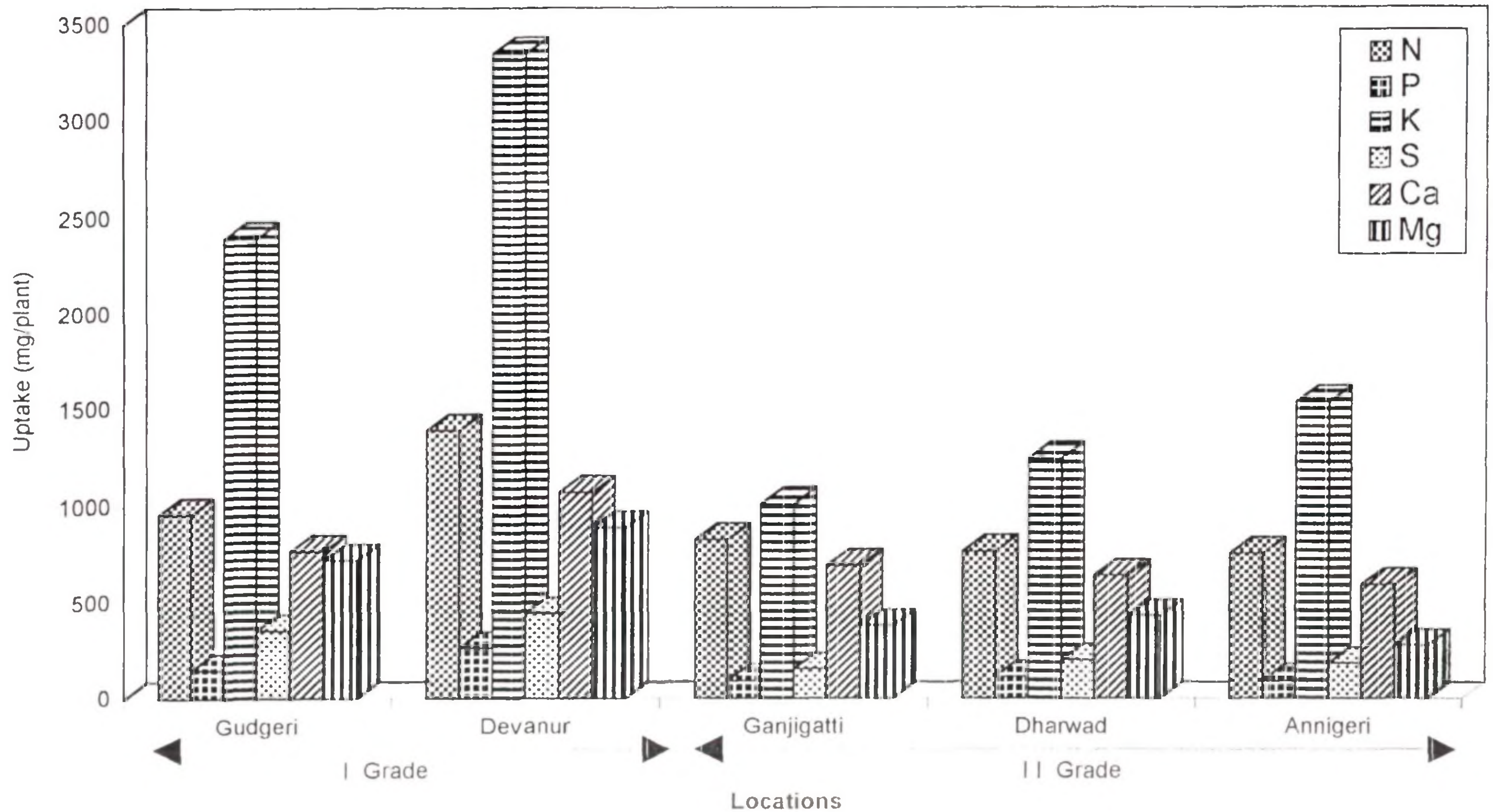


Fig. 7. Major and secondary nutrient uptake (mg/plant) by Dyavnur cv. chilli at various locations

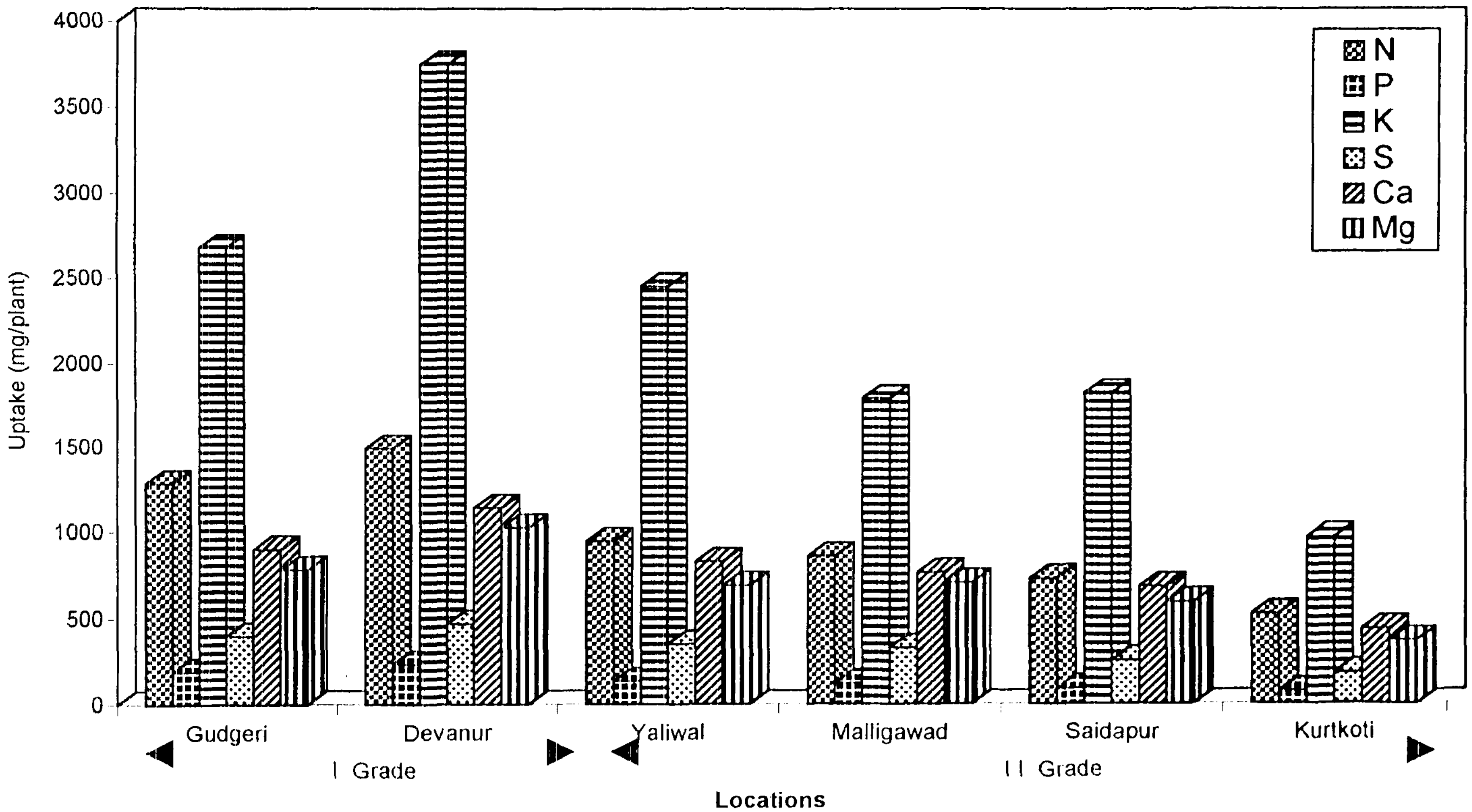


Fig. 8. Major and secondary nutrient uptake (mg/plant) by Byadgi dabbi cv. chilli at various locations

In Dyavnur and Byadgi dabbi cultivars, drill sown plants recorded comparatively lesser uptake (Figs. 7 and 8) than transplanted plants. This might be due to lack of competition free environment in drill sown locations and lesser root development because of high plant population which resulted in reduced uptake of nitrogen. Usha Rani (1996) related N uptake to rooting habit in chillies and attributed low N uptake by plants to limited root system. She further stated that, in chillies, transplanted crop develops a distinct root system unlike drill sown crop and this variation in rooting habit of plants results in differential uptake of moisture and nutrients.

Irrespective of the cultivar, growth stages differed significantly with respect to N uptake and there was a steep increase in N uptake during the peak vegetative growth to flowering (45 to 75 DAT) period with a marginal increase at final harvest time. Rajendraprasad and Subramaniam (1978) reported similar results with experiment on Guntur variety of chilli. Similarly Wankhade *et al.* (1997) studied the uptake behaviour of field crops and reported that, nutrient uptake and plant growth are closely parallel to each other.

Interaction effects were significant in influencing the N uptake by plants, which implies that, at a particular growth stage (either at 45 DAT or 75 or 105 or 140 DAT) plants of various locations differed significantly with respect to N uptake. This is attributed to variation in N status of soils along with moisture and organic matter content that influenced the N uptake by plants in different locations significantly. However at 45 DAT, N uptake by plants at all locations were on par with each other, this might be due to root system at this stage may not be in a position to absorb enough N to meet the growing needs of plant on account of transplanting shock suffered by young seedlings. Apart from this N requirement of crop might be very low at this stage, , on account of less shoot growth. Once new roots are produced, uptake becomes very fast and during peak vegetative growth (75 DAT) significant difference between plants of different locations was observed. Similarly at 105 and 140 DAT also, significant difference between locations with respect to N uptake was observed. Uptake at 105 and 140 DAT depends upon the partitioning of absorbed N between developing fruit and growing shoot because of indeterminate nature of chilli crop. Due to wide variation in source sink relationship of plants in different locations, differential uptake of N was observed. Results obtained are in agreement with the findings of Rajendraprasad and Subramaniam (1978) and Wankhade *et al.* (1997).

5.4.2 P uptake

Perusal of data presented in Tables 12, 12(a) and Figs. 6 to 8 reveal that, irrespective of cultivar, plants grown on deep black soil locations (Gudgeri and Devanur) recorded significantly higher P uptake than plants grown on medium black soil locations. This is attributed to extensive root system of plants in deep black soil locations that possess high available moisture, high organic matter higher porosity which encourage higher P uptake.

Further high organic matter content of deep black soil locations led to solubilisation of native phosphate due to the action of various organic acids liberated during decomposition of organic matter. This process contributes to higher P availability and subsequent uptake. Results obtained are in agreement with the findings of Subbiah *et al.* (1982). Relwani (1962) reported that high organic matter content in soil reduces fixation and greater quantity of soil P is made available for crop uptake. P uptake was very low in plants of red soil locations and this might be due to low P availability on account of shallow depth, less available moisture and limited root development on account of greater compaction. Thomas and Heilman (1967) related P uptake by sweet peppers to moisture regime in soil and concluded that P availability gets reduced under dry moisture regime and rooting habit of plants was greatly influenced by moisture status of soil. Generally enhanced P uptake in any locations irrespective of the cultivar and quality of chilli produced is associated with higher P availability, favourable soil moisture, root spread and high organic matter status. Further drill sown plants and transplanted plants did not differ significantly with respect to P uptake [Table 12(a)] which suggests that, plant population has not influenced the P uptake considerably.

Similar to N uptake, P uptake also increased significantly from 45 DAT to 140 DAT in all the cultivars. This is expected because of increased root growth which absorbed higher quantities of P at latter growth stages to meet the needs of developing branches, leaves, flowers, fruits etc. Barooah and Zaman Ahmed (1964) reported higher P uptake at latter growth stages in pungent peppers.

Similar to the interaction effects of N uptake. P uptake was also influenced by interaction of growth stages and locations. This is attributed to variation in soil depth, available moisture, available P status, organic matter content, bulk density, and root development in different locations that play major role in influencing the P uptake in different locations. Further, cultivation practices particularly the quantum of fertilizers and manures applied by farmers also influenced the P uptake in different locations.

5.4.3 K uptake

Similar to N and P uptake, K uptake also differed significantly between locations that grow Byadgi cultivars. For all the three cultivars, plants of Devanur location recorded highest uptake closely followed by those of Gudgeri location both produced first grade fruits and high yields. This is attributed to high available K content in soil pedons (Table 6) and extensive root system of plants in these deep black soils absorbed more K from deeper layers also. Further, K fertilizer applied in split doses in these two locations [Tables 3, 3(a) and 3(b)] might have synchronised with crop requirement and hence higher uptake. This is in conformity with observations of Rajput and Singh (1991) who reported higher K uptake by Turnip crop grown in deep black soils. Weaver (1926) reported higher nutritional uptake in any crop as closely related to expansion of root system. Very low K uptake in plants of Asundi and Kalagond red soil locations (Fig. 6) is attributed to shallow depth of red soils along with limited root development on account of high bulk density and low moisture status. Further, K availability in such red soils is very low due to less moisture. However, plants of Thimmenhalli location recorded significantly higher K uptake than plants of Asundi and Kalagond locations. This might be due to more depth of red soil (>90 cm) in Thimmenhalli location because it is situated at the foot hills and greater root development on account of more depth might have enhanced K uptake.

In case of Dyavnur and Byadgi dabbi cultivars, lowest K uptake was observed in plants of Ganjigatti and Kurtkoti locations, respectively (Figs. 7 and 8). This might be due to low available K content in pedons along with less available moisture and less root development on account of medium black soil nature. Root development in any crop is governed by K status of soil and low K content in soil restricts the root growth. Hence medium black soils on account of low K content, limit the root growth. These observations lend support to the findings of Widders and Lorenz (1979) who reported that, in tomato plants, root length is the primary parameter and is mainly governed by K status of soil, which influences the capacity of root system to absorb mineral nutrients.

Irrespective of the cultivar, plants grown on deep black soil locations (Gudgeri and Devanur) recorded higher K uptake than plants grown on medium black soil locations. Extensive root system, high K availability, higher availability of moisture, high clay content, low bulk density and high CEC are some of the reasons for higher K uptake in deep black soils than in medium black soils. Very low K uptake in red soil locations is attributed to limited root development in these soils on account of greater compaction, shallow depth, low moisture status and lower K availability.

K uptake increased significantly from 45 DAT to 140 DAT. This is due to increased dry matter production at latter stages and K appears to have role in enlarging fruit size, because of its role in the translocation of photosynthates and metabolites as reported by Dod *et al.* (1983) and Parminder Singh *et al.* (1986).

Interaction effects were significant in influencing the K uptake. This is attributed to wide variation in soil properties of different locations along with cultivation practices that influence K uptake.

5.4.4 Sulphur uptake

Irrespective of the cultivar, plants grown on Devanur deep black soil location recorded highest uptake [Figs.6 to 8] and this is attributed to higher concentration of sulphate sulphur in soil solution which is related to adsorbed sulphur. Fox (1982) related sulphur uptake by plants in any soil to adsorbed sulphur and concluded that in clay soils (deep black soils), high sulphur uptake by plants on account of extensive root system is controlled by replenishment of solution sulfur from absorbed sulphur. Among third grade locations in case of Byadgi kaddi cultivar, plants of Savanur location recorded significantly higher uptake than plants of other three red soils. This might be due to more fine textured soil nature of Savanur location than other three red soils where there is higher availability of solution sulphur due to more of adsorbed sulphur. But red soil locations due to their coarse textured nature, shallow depth and less of solution and adsorbed sulphur may not supply adequate sulphur resulting in less uptake.

Irrespective of the cultivar plants grown on deep black soil locations recorded higher sulphur uptake than plants grown on medium black soil locations. This might be due to more of adsorbed sulphur in deep black soils that replenish the solution sulphur constantly so that plants can have constant source of sulphur. But medium black soils due to their lesser depth and clay content may not have enough adsorbed sulphur to replenish solution sulphur. Tabatabai (1986) reported that, plants grown in different textured soils vary widely in their sulphur uptake and this is governed by amount of solution sulphur and adsorbed sulphur. In addition to this, higher available moisture, extensive root system and high solution sulphur in deep black soils contribute for high sulphur uptake.

Sulphur uptake differed significantly at all growth stages and uptake at 75 DAT was almost 8 to 9 fold from 45 DAT and only marginal increase was observed as plant approaches maturity. Increased sulphur uptake at peak vegetative growth (75 DAT) might be due to its role in energy transformation and activation of enzymes in carbohydrate metabolism which are highest at 75 DAT. Jat *et al.* (1998) reported similar observations in case of fenugreek. Once the partitioning of photosynthates in the formation of yield and yield attributes starts, then marginal increase in sulphur uptake was noticed (at 105 and 140 DAT).

Interaction effects of locations and growth stages influenced the sulphur uptake significantly. This is mainly due to variation in available sulphur status of soils in different locations coupled with variation in rooting habit of plants. However at 45 DAT, plants of all locations were on par with each other with regard to S uptake and this might be due to low sulphur requirement of crop at this stage and primitive root system of plants.

5.4.5 Ca and Mg uptake

Based on the results it can be inferred that, plants of Gudgeri and Devanur locations recorded highest uptake of these secondary nutrients. This is attributed to higher concentration of exchangeable Ca + Mg in these soils on account of high clay content and high CEC. Further, highly branched root system and higher availability of moisture favoured the uptake of Ca + Mg in these soils. Sharma *et al.* (1996) reported similar findings and stated that, Ca and Mg uptake is related to growth rate of roots rather than shoots and highly branched root system as found in black soils is favourable for Ca and Mg uptake. In addition to this, high organic matter content of deep black soils also influenced the Ca and Mg uptake by solubilisation of Ca and Mg bearing minerals by decomposing organic matter as well as chelating effect, resulting in enhanced uptake. The present findings lend credence to earlier observations reported by Subbiah *et al.* (1982). Lowest uptake of Ca and Mg was observed in plants of red soil locations. This might be due to low exchangeable Ca + Mg content of these soils on account of low clay content and acidic to neutral pH. Further, intense leaching, high bulk density, shallow depth and less moisture content limit the root development in such soils lead to low uptake of Ca and Mg.

In Dyavnur and Byadgi dabbi cultivars, drill sown plants differed significantly from transplanted plants with respect to only Mg uptake, where as for Ca uptake, they were on par with each other [Tables 15(a) and 16(a)]. The probable reason for this is, the association of Mg with chlorophyll content of leaves and transplanted plants might have more number of leaves than drill sown plants due to uniform population and higher number of branches, whereas drill sown plants have less number of branches and less number of leaves and hence low uptake of Mg. But Ca is usually associated with cell wall and plant population of drill sown and transplanted locations might not have influenced the Ca uptake significantly.

Uptake of both Ca and Mg differed significantly at all growth stages and there was almost 5 to 6 fold increase in uptake at 75 DAT from 45 DAT and 3 fold increase at 105 DAT from 75 DAT, only marginal increase at harvest (140 DAT). Increased uptake of Ca and Mg at latter stages is attributed to increased dry matter production on account of increased root growth. Sharma *et al.* (1996) reported that, root growth and root branching are important in providing sites for Ca and Mg uptake where casparian strip is not fully developed at the tip of the root. As the plant grows, root system becomes more branched and there is enhanced uptake of Ca + Mg.

Interaction of locations and growth stages influenced the Ca and Mg uptake significantly. This might be due to variation in exchangeable Ca + Mg content of soils in different locations along with variation in rooting habit of plants. Generally plants grown on black soils had higher uptake at all stages than plants grown on red soils. This might be due to highly branched root system in black soils on account of more depth, high available moisture, less BD and as reported earlier, uptake of Ca and Mg is more related to root growth rather than shoot growth are some of the reasons such high uptake.

5.4.6 Uptake of micronutrients

Nutrient uptake is a continuous process in chillies as the plant is indeterminate and long duration one. Chilli being an exhaustive crop needs heavy application of fertilizers to put forth good growth and yield heavily. Now-a-days due to continuous and heavy application of chemical fertilizers, which are devoid of micronutrients, led to the appearance of micronutrient deficiency symptoms which influence the yield and quality of crop to some extent. The study of micronutrient uptake is very essential in order to know their possible role in influencing the yield and quality attributes of chillies. In the present study, micronutrient mixtures or sprays were not applied by farmers in all the locations, because of inadequate information about their role in chillies and awareness. The uptake of micronutrient cations by chilli plants in different locations is discussed below in the light of observations recorded at different stages and uptake is mainly based on soil properties and dry matter yield.

5.4.6(a) Cu and Zn uptake

Plants grown on deep black soil locations (Gudgeri and Devanur) recorded higher uptake than plants grown on medium black soil locations. In deep black soil, high organic matter content enhanced the availability of native micronutrient cations through the transformation of solid phase to soluble metal complexes. Further, extensive root system and high available moisture enhanced the uptake of Cu and Zn in such soils. Krishnan and Christopher (1997) reported that in deep black soils, due to higher levels of N and in presence of organic matter, activity of microorganism might be more which release various organic compounds. The associated processes of soil microorganisms lead to formation of stable complexes and reduce adsorption/fixation/precipitation reactions and make Cu and Zn more available to chilli plant. Similar observations were reported by Hegde and Dwivedi (1992). Plants grown on red soil locations (Tables 17 and 18) in Byadgi kaddi cv. recorded very low uptake of Cu and Zn. This might be due to low mobility of these elements in red soils on account of low moisture content and chelation of these nutrients appeared to be very less due to less organic matter content in such soils. In addition to this, high Mn and Fe content in these red soils might have some antagonistic effect on the uptake of Cu and Zn.

Uptake of both Cu and Zn increased significantly with the advancement in the age of crop. Increased copper uptake at latter stages is attributed to its role in retention of flowers on plants and zinc uptake to its role in inducing pollen growth for pollination. Both the processes are at peak at 75 and 105 DAT. Hence, there might be higher uptake of Cu and Zn at 75 and 105 DAT. Mallick and Muthukrishnan (1980) reported similar observations on tomato. Similarly, Pillai (1967) reported that, Cu and Zn play role in enhancing flower production in chillies, a process that begins after 45 DAT and continues upto 105 DAT or even more. Similar observations were made by Sharma *et al.* (1980) on Japanese mint and Wankhade *et al.* (1997) on the nutrient uptake behaviour of field crops.

Interaction of locations and growth stages influenced the Cu and Zn uptake significantly. This might be due wide variation in the soil properties of different locations along with variation in cultural practices particularly organic matter application and rooting habit of plants. The present findings lend credence to earlier observations made by Prasad *et al.* (1984).

5.4.6(b) Fe and Mn uptake

Plants of Devanur deep black soil location recorded highest uptake of both nutrients and this is attributed to high organic matter that forms stable complex with native Fe and Mn and make them more soluble and available. Similar results of increase in the uptake of iron with high organic matter were reported by Thomas and Mathers (1979), Parsa and Wallace (1979) and Prasad *et al.* (1984).

Plants grown on red soil locations in Byadgi kaddi cultivar (Table 19), recorded lowest uptake of both Fe and Mn. This is attributed to low dry matter production on account of less moisture and limited root development due to greater com-paction. Further, low organic matter in these red soils limit the formation of chelates and availability gets reduced. Although DTPA-Fe and Mn contents were high in Kalagond red soil location (Table 6), yet uptake was less, might be due to less mobility of these elements on account of less moisture. Further, limited root development and less dry matter production might have further pronounced the low uptake.

There was a steep increase in the uptake of both nutrients from 45 DAT to 75 DAT. This might be due to the role of Fe in the synthesis of chlorophyll in leaves, which are very active at 75 DAT and the role of Mn is, it delays the senescence of chloroplast. Results obtained are in agreement with the findings of Elabdeen and Metwally (1982) and Wankhade *et al.* (1997).

Interaction effects were significant in influencing the uptake of Fe and Mn. This might be due to variation in DTPA-Fe and Mn content of soils in different locations along with rooting habit of plants, dry matter yield and other soil physical and chemical properties that influenced the uptake.

Nutrient uptake summarised

Finally, considering the uptake of major, secondary and micronutrients as a whole, it can be concluded that, irrespective of cultivar, the uptake of nutrients follow the order K>N>Ca>Mg>S>P≥Fe>Mn>Zn>Cu (Fig. 9). Secondary nutrients uptake is more than P uptake and it needs further investigation to know the specific role of Ca and Mg in influencing the yield and quality of chillies.

5.5 Growth and yield attributes of chilli cultivars as influenced by soil properties and management practices

It is needless to stress the paramount importance of growth parameters which have a profound bearing on yield and yield components of a crop. Thus, any variation in the latter could be very well documented and elucidated on the basis of events that have occurred earlier in growth. A better plant architecture resulting from favourable edaphic and climatic conditions signifies better growth and hence, a higher yield and vice versa. This justifies the measurement of growth attributes like plant height, number of branches and dry matter production. Following is an account of how these growth characteristics fared in different soils and the possible reasons for such a performance when most of the locations come under one agro-climatic zone and the climatic factors for the two years of study (96-97 and 97-98) were almost identical. Results on growth attributes for the three Byadgi cultivars (Byadgi kaddi, Dyavnur and Byadgi dabbi) presented in Tables 7, 7(a), 8, 8(a) and 9, 9(a) are discussed here combinedly, so that the three cultivars can be compared effectively.

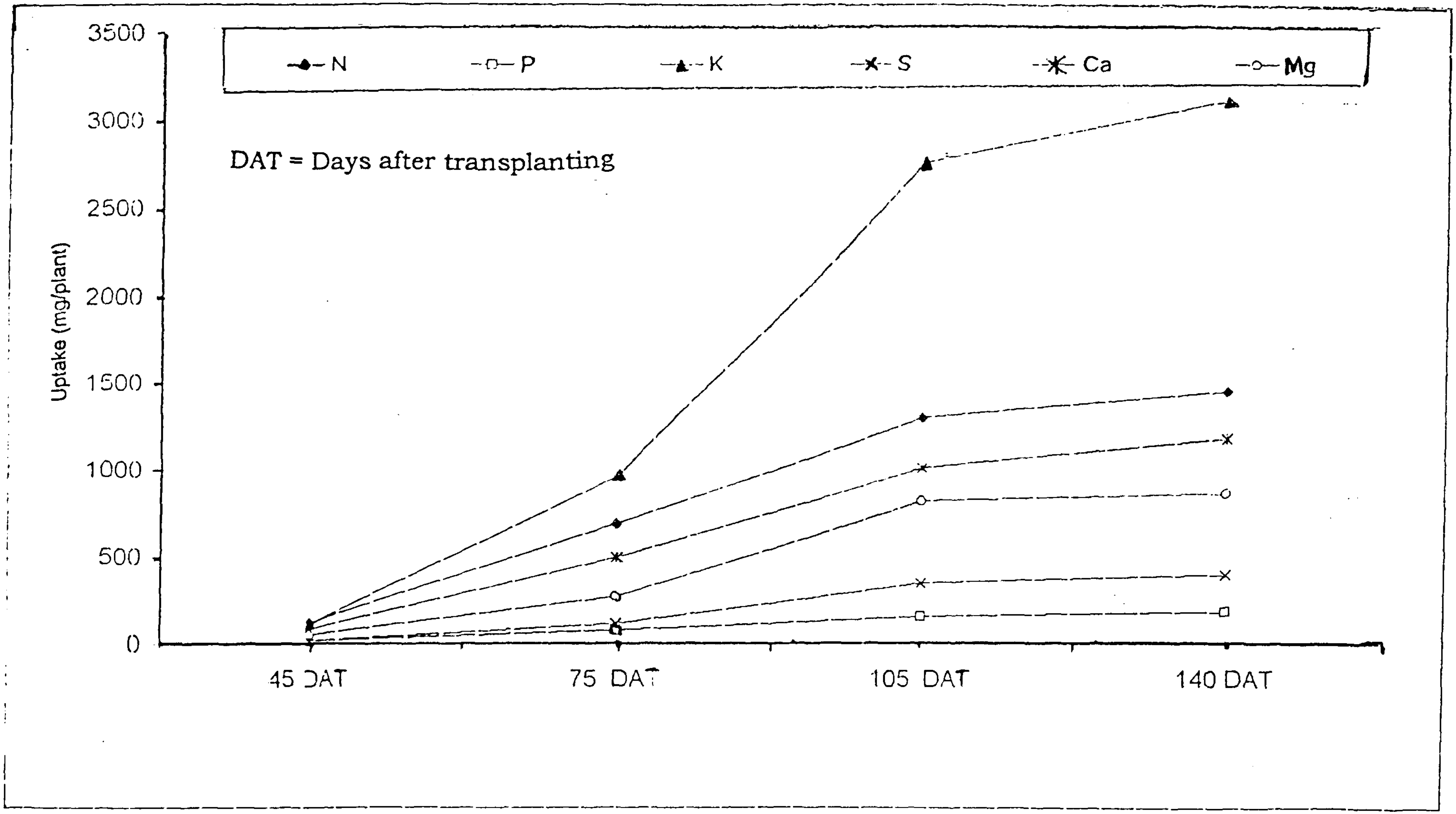


Fig. 9. Major and secondary nutrient uptake (mg/plant) by chilli (Cv. Byadgi kaddi) at different growth stages.

5.5.1 Plant height, number of branches and total dry matter yield

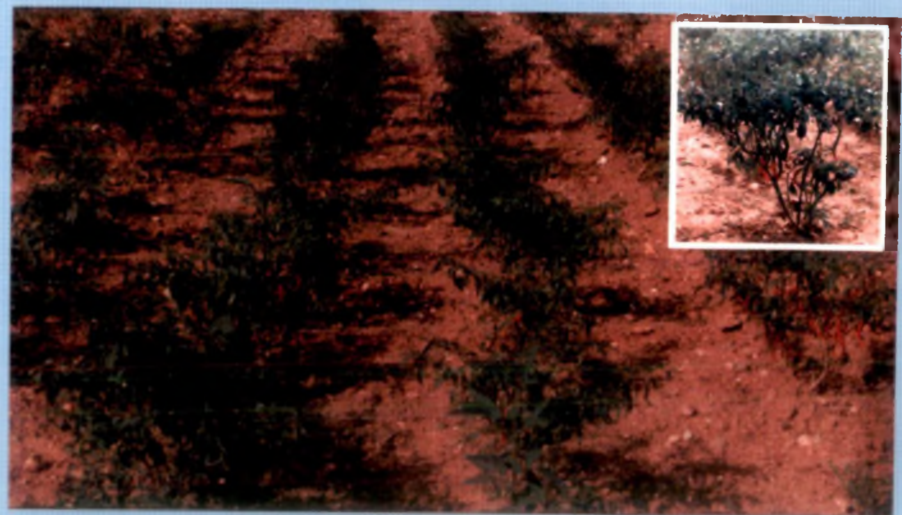
Irrespective of the cultivar, plants grown on deep black soil locations in general and in particular plants of Devanur location recorded highest growth attributes and differed significantly from plants of medium black soil locations (Plate I). This is mainly due to higher availability and uptake of moisture and nutrients by the growing plant in deep black soil coupled with extensive root system that led to increased uptake. In turn, this helps in elongation of cells, multiplication of cells and better translocation of soluble ions in plants leading to production of more number of branches, flowers and fruits. All these contribute to higher growth attributes and ultimately total dry matter yield. Nathulal and Pundrik (1971) reported that, moisture and nutrient availability in soils greatly influence the growth attributes of chilli plants and higher uptake of moisture and nutrients pronounced by favourable soil physico-chemical properties in black soils lead to enhanced growth attributes. Parminder Singh *et al.* (1986) reported the growth attributes of chilli as directly related to N availability in soils. Similar findings were reported by Roychoudhury *et al.* (1990) and Barooah and Zaman Ahmed (1964).

Significant differences were observed between locations that produced a particular grade fruits, this may be due to variation in management practices followed by farmers particularly manure/ fertilizer application and also spacing. Among the three red soil locations (Tables 7, 8 and 9), plants of Thimmenhalli location recorded higher growth attributes than plants of other two locations. This might be due to more depth and higher availability of moisture and nutrients in this soil compared to other two locations causing better expression of growth attributes.

DEEP BLACK SOIL

MEDIUM BLACK SOIL

MIXED RED & BLACK SOIL



RED SOIL

PLATE- I Chilli crop [Cv.BYADGI KADDI] at grand growth stage in different soils

In Dyavnur and Byadgi dabbi cultivars, lowest growth attributes were observed in drill sown plants of Annigeri and Kurtkoti locations, respectively. This might be due to presence of medium black soil in these locations which had comparatively less available moisture and nutrients than deep black soil location. Generally drill sown plants had lower growth attributes than transplanted plants. This is due to lack of competition free environment prevailing in drill sown locations due to high plant population leading to lesser uptake of moisture and nutrients.

Plants grown on red soil locations (Byadgi kaddi cv.) recorded lowest growth attributes (Plate I). This is attributed to lesser uptake of moisture and nutrients in red soils coupled with restricted root system of plants which is fibrous on account of high bulk density. Shaykewich and Warkentin (1970) reported similar observations in tomato plants grown on different textured soils and concluded that, all growth attributes were higher in fine textured soils than in medium and coarse textured soils. Similar observations were reported by Flocker and Menary (1960), Ivanov (1970, Menary and Kruger (1966) and Bunt (1961). Thomas and Heilman (1967) reported that, in sweet peppers, growth attributes have a direct relationship with moisture availability in soils.

In all the three cultivars, growth attributes increased significantly from 45 DAT to 140 DAT. This is quite obvious because of increased root growth which led to increased uptake of moisture and nutrients that were utilized for enhancing plant height and for producing more number of branches resulting in increased dry matter yield. Rate of increase in growth attributes from 45 to 75 DAT was very sharp, there after only marginal increase in at 105 and 140 DAT were observed. This might be due to, plants attain peak flowering at 70 to 75 DAT and part of moisture and nutrients particularly N responsible for vegetative growth absorbed by plants were utilized for flower and fruit formation, there by less nutrients were diverted for vegetative growth. Hence only marginal increase in growth attributes at 105 and 140 DAT was observed. Similar observations were reported by Dass and Mishra (1972), and Rajendraprasad and Subramaniam (1978).

Interaction effects of locations and growth stages influenced the growth attributes significantly, which suggests that, at a particular growth stage (45 or 75 or 105 or 140 DAT), plants of various locations differed significantly with respect to growth attributes. This might be due to wide variation in fertility status of soils along with physical and physico-chemical properties that influence the uptake of moisture and nutrients from soils. However at 45 DAT, plants of all locations were on par with each other. This might be due to lesser uptake of moisture and nutrients at 45 DAT on account of lesser root development as the seedlings were young and have to withstand the transplanting shock. Once the seedlings produce new roots, then uptake becomes very fast and growth attributes increase sharply.

Plants of Byadgi kaddi cultivar have higher growth attributes than plants of Dyavnur and Byadgi dabbi cultivars. This might be due to genetic make up of the cultivar and soil environment or cultivation practices that might have altered these growth attributes to some extent. Further chilli being an indeterminant plant, fruits mature regularly over a period and to get high yields farmers are in the practice of picking these fruits once in 10 to 15 days particularly in Byadgi kaddi cultivar. This led to increased number of branches and plant height and such practice being absent in Byadgi dabbi cultivar.

5.5.2 Root weight

Growth and yield attributes of any crop depends on the rooting pattern of plants. The study of rooting habit in different textured soils helps to elucidate the possible reasons for variation in yield and nutrient uptake. Root weight and rooting habit of Byadgi chilli cultivars grown in different locations are discussed below [Tables 10 and 10(a)].

Plants grown on first grade locations (deep black soils) recorded highest root weight and have more number of basal and lateral roots than plants of second grade locations (medium black soil). This is attributed to varying depth of these soils. Further, high available moisture, low bulk density, higher porosity of deep black soils favour the root growth. In addition to favourable physical properties high N and K status of soils also appeared to stimulate root growth. Similar observations on the effect of N and K status of soils that stimulate root growth and branching in field grown tomatoes were reported by Jackson and Bloom (1990) and also by Widders and Lorenz (1979) and Leskovar *et al.* (1989) and Flocker and Nielsen (1962). Plants grown on third grade locations (red soil) that produced third grade fruits and low yields in Byadgi kaddi cv. recorded lowest root weight and root branching. This might be due to less favourable soil environment like shallow depth , high bulk density and low moisture content that limit root growth. Bunt (1961) reported similar observations on the root growth of tomato plants in red soils. Further in red soils due to high infiltration rate, moisture is depleted beyond the root zone and very little amount of moisture is present very nearer to tap root, as such root spread is very nearer to tap root and is more fibrous (Plate II). But in black soils due to more of horizontal movement of moisture, root spread is extensive for away from tap root. Further low N and K status of red soils also limit the root growth.

Results of root weight presented in for the three Byadgi cultivars were slightly higher than reported earlier by Usha Rani (1996). She reported that, root weight (RW) and root

DEEP BLACK SOIL — Transplanted crop

MEDIUM BLACK SOIL — Transplanted crop

RED SOIL — Transplanted crop

MEDIUM BLACK SOIL — Drill sown crop

PLATE-II Rooting pattern of chilli plants in different soils volume (RV) in chillies was greatly influenced by soil type, nutrient supply, moisture status and spacing.

It is found that, drill sown plants in case of Dyavnur and Byadgi dabbi cultivars [Table 10(a)] recorded less root weight compared to transplanted plants. This might be due to high plant population in drill sown locations that led to competition between roots for moisture, nutrients and also lesser translocation of photosynthates to growing roots on account of shading effect. Stoffella *et al.* (1988) reported similar observations in bell peppers, where root growth was closely related to source sink relationship influenced by plant population. Similarly Mckea (1981) reported that, transplanted crop develops a distinct root system caused by early modification of tap root and subsequent development of lateral and basal roots, which lead to more root weight than drill sown plants.

5.5.3 Yield and yield attributes

In chillies, fruit yield is directly related to yield attributes like number of fruits, hundred fruit weight and fruit weight per plant, besides growth attributes indirectly influence the fruit yield. Yield and yield attributes of Byadgi chilli grown in different locations of Dharwad, Haveri and Gadag districts are discussed below in the light of observations made on soil properties and cultivation practices.

Plants grown on first grade locations recorded higher yield and yield attributes than plants of second grade locations (Figs. 10 and 11). Higher yield and yield attributes in first grade locations were attributed to higher uptake of moisture and nutrients by plants due to favourable physico-chemical properties and high nutrient status of deep black soils coupled with extensive root system. Dass and Mishra (1972) reported higher fruit weight and higher

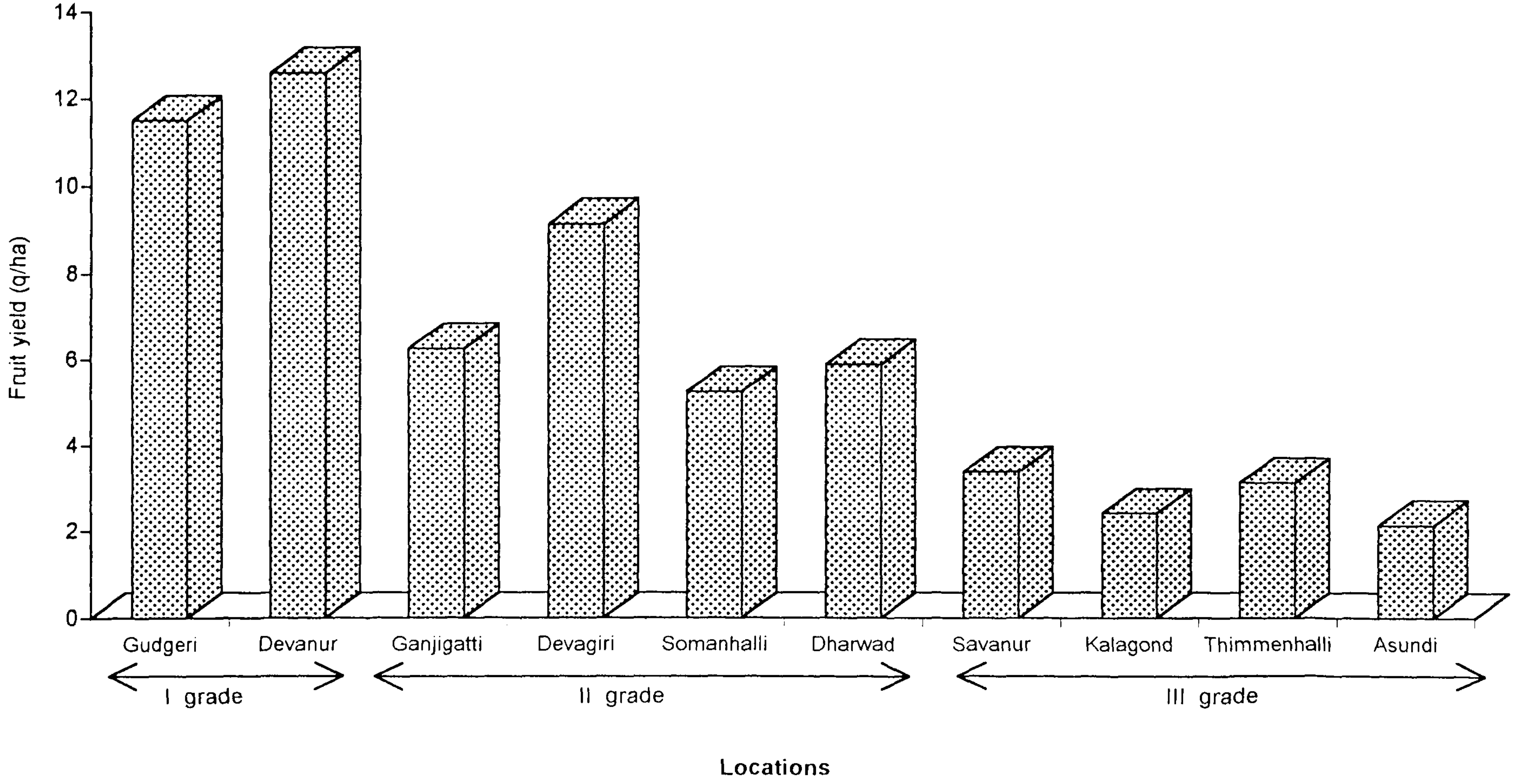
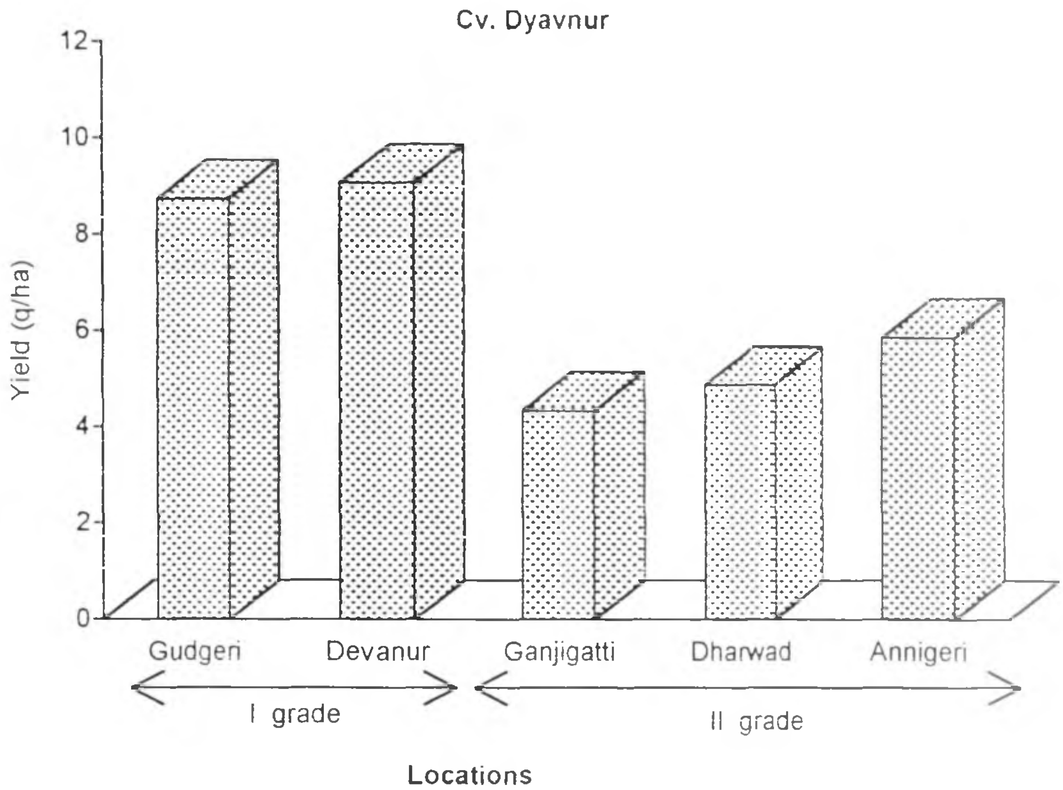


Fig10. Fruit yield (q/ha) of Byadgi kaddi cv. chilli at various locations



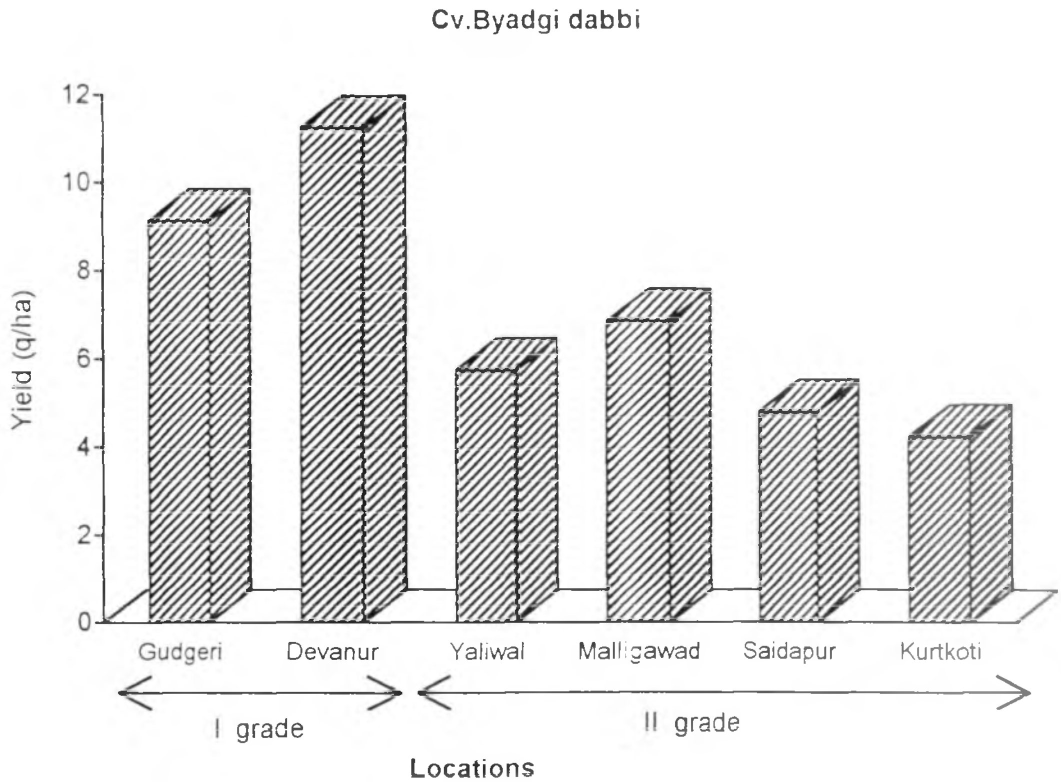


Fig. 11 Fruit yield (q/ha) of Dyavnur and Byadgi dabbi cultivar chillies at various locations

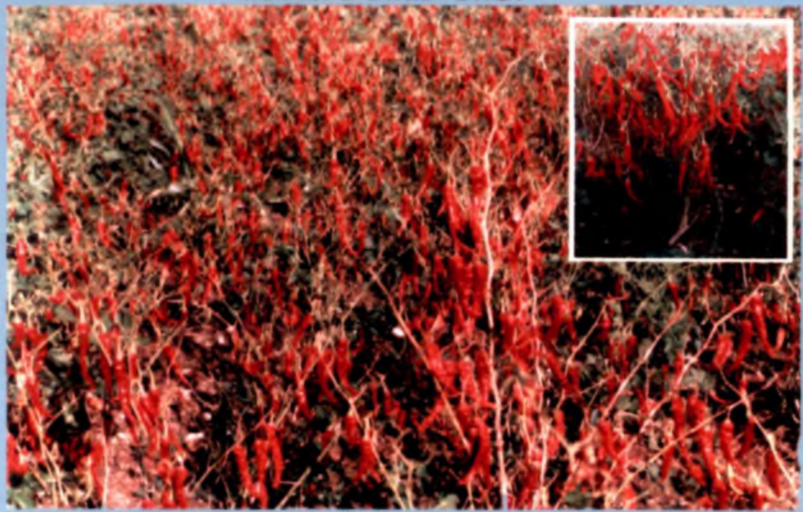
number of fruits as closely related to high N and P status of soils. Further, high N availability in deep black soils results in increased vegetative growth which leads to enhanced carbohydrate synthesis.

Plants grown on red soil locations (third grade) recorded lowest yield and yield attributes (Fig. 10 and Plate IV). This is due to less favourable soil properties as compared to deep black soils, that limit root growth and subsequent uptake of moisture and nutrients. Similar observations on low yield of chilli in sandy soils due to coarse textured nature and low organic matter were reported by Sambasiva Rao and Ankaiah (1968), Mohamed Kunju and George (1969) and Barooah and Zaman Ahmed (1964). Rama Rao *et al.* (1988) attributed poor yields of chilli in red soils under rainfed conditions to intense leaching and non availability of adequate nutrients during flowering and fruiting.

It is observed that, plant population also influenced the yield and yield attributes. Drill sown plants of Dyavnur and Byadgi dabbi cultivars recorded lower yield attributes compared to transplanted plants [Table 10(a)]. This might be due to high plant population in drill sown locations on account of closed intra row spacing that led to competition for moisture, nutrients and sunshine. Further, shading effect is more pronounced in drill sown locations, which results in poor translocation of photosynthates to developing fruit, as such fruit weight per plant is reduced. On the whole, drill sown plants have lesser number of branches, fruits and fruit weight than transplanted plants resulted from reduced uptake of nutrients and moisture coupled with less photosynthesis. Castillo *et al.* (1996) reported similar observations in Garlic, where high plant density reduced the nutrient and moisture uptake. But, the final fruit yield in drill sown locations is being compensated by higher plant

TRANSPLANTED CROP

DRILL SOWN CROP

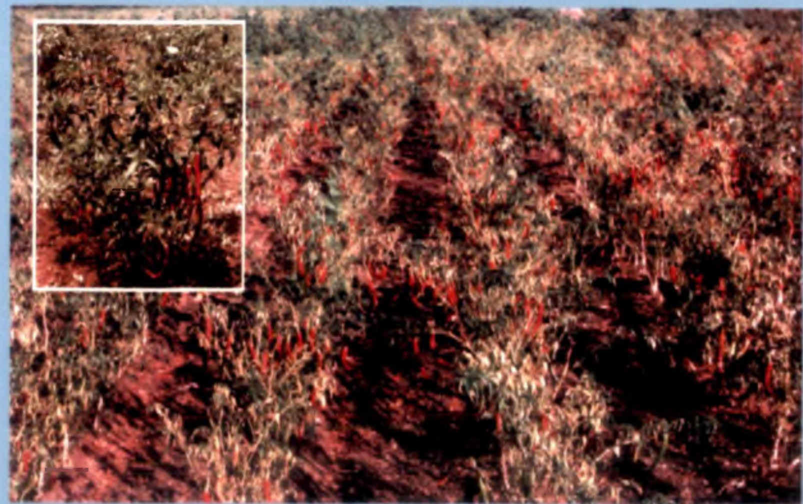


Deep black soil

Medium black soil

Cv.BYADGI DABBI

Deep black soil



Medium black soil

Cv. DYAVNUR

PLATE-III Chilli crop at peak harvesting stage in different soils

Deep black soil

Medium black soil

Mixed red & black soil

Red soil

PLATE-IV Chilli plant [Cv. BYADGI KADDI] at peak harvesting stage in different soils population, as such not much variation between yields of drill sown and transplanted locations was noticed.

Significant differences observed between locations within a particular group that produced a specific quality of fruit were attributed to variation in initial soil fertility and cultivation practices followed by farmers, particularly quantum and time of fertilizers applied along with organics. It is found that, plants of Devanur deep black soil location recorded highest yield and yield attributes (Plates III and IV). This was due to initial rich nutrient status of soil along with heavy application of fertilizers and organics in both years of study [Tables 3, 3(a) and 3(b)] coupled with split application, (particularly N and K) which has synchronized with crop requirement. Subhani *et al.* (1990) reported similar findings indicating the effect of split N and K application on yield and yield attributes. Nair and Peter (1990) reported the beneficial effects of FYM in improving soil physical properties in terms of better root penetration and chelation of micronutrients there by enhancing yield attributes by increased uptake. Similar observations pertaining to the effect of combined application of fertilizers and manures were reported by Subbiah *et al.* (1982), Chavan *et al.* (1997), Relwani (1962), Nathulal and Pundrik (1971), Rahimkhan and Suryanarayan (1977), Selvaraj *et al.* (1973) and Iruthayaraj and Kulandaivelu (1973).

Comparison between cultivars for yield and yield attributes revealed that, plants of Byadgi kaddi cv. have more number of fruits than Dyavnur or Byadgi dabbi cultivars, but with respect to final fruit yield not much variation was observed between cultivars.

5.6.1 Physical characteristics of chilli fruits

Fruit samples of different locations vary widely in their physical characteristics as revealed by data presented in Tables 21 and 21(a). It is found that, first grade fruits produced from deep black soil locations recorded higher fruit size and fruit weight than second grade fruits produced from medium black soil locations. This is attributed to greater synthesis and translocation of photosynthates to developing fruits in deep black soils on account of high available moisture, nutrients, and favourable physical properties that support plants to grow vigorously and manufacture greater amount of photosynthates. All these contribute for increased fruit size and weight. Similar findings were reported by Nathulal and Pundrik (1971), Subhani *et al.* (1990), Rahimkhan and Suryanarayana (1977), Mallick and Muthukrishnan (1980) and Shibhila Mary and Balakrishnan (1990).

Third grade fruits of Byadgi kaddi cv. produced from red soil locations including mixed red and black soil location recorded lowest fruit size and fruit weight. This is attributed to lesser uptake and translocation of nutrients to developing fruits on account of low moisture supply and limited root system. Consequently enlargement of cells and translocation of photosynthates to developing fruits is being reduced in red soil locations, that lead to lesser fruit size and weight. Results of fruit length, breadth and L/B ratio presented in Table 21 for Byadgi kaddi cv. agree with the results of Pankar and Magar (1978a).

Wide variation was observed between these Byadgi cultivars for L/B ratio which is mostly due to genetic factor and highest L/B ratio in Byadgi kaddi fruits is due to more length than breadth and lowest in Byadgi dabbi fruits is due to more breadth than length. Maurya *et al.* (1984) reported that, shape of fruits is genetically controlled and little alterations in size of fruits can be attributed to translocation of photosynthates and nutrients to developing fruits. Similarly, comparison among the three Byadgi cultivars for single fruit weight revealed that, fruits of Byadgi dabbi cultivar recorded highest value, may be due to thick pericarp, where as fruits of Byadgi kaddi cultivar recorded lowest due to thin pericarp and intermediate values were observed for fruits of Dyavnur cultivar. Pankar and Magar (1978a) noticed similar observations for few varieties of chilli extensively cultivated in India. Within a particular grade, fruit samples harvested from different locations exhibited some variation in physical characteristics in all the three cultivars. These variations were mostly due to differences in the quantity of photosynthates and nutrients translocated to developing fruits, influenced by cultivation practices followed by farmers, and such variations are quite common in chilli fruits harvested from different locations.

Partitioning of whole fruit into individual components revealed that (Fig.12), irrespective of cultivar and fruit grade, weight of pericarp is maximum and accounts for 40 to 55 per cent of whole fruit weight, where as weight of pedicel is minimum which accounts for only 5 to 15 per cent and seed component accounts for 35 to 45 per cent of whole fruit weight. Rajput *et al.* (1991) reported similar observations for few genotypes of Maharashtra and Teotia and Raina (1987) for few genotypes of Haryana. Values of pericarp, seed and pedicel content presented in Table 21 for Byadgi cultivar closely agree with the findings of Pankar and Magar (1978a).

Higher weight of pericarp than seed in chillies might be due to greater partitioning of photosynthates into pericarp portion that contribute for quality attributes. Pankar and Magar (1978a) attributed higher weight of pericarp component than seed in few varieties of chilli fruits to ash, crude fibre and carbohydrate. It is found that, pungency, colour, ascorbic acid

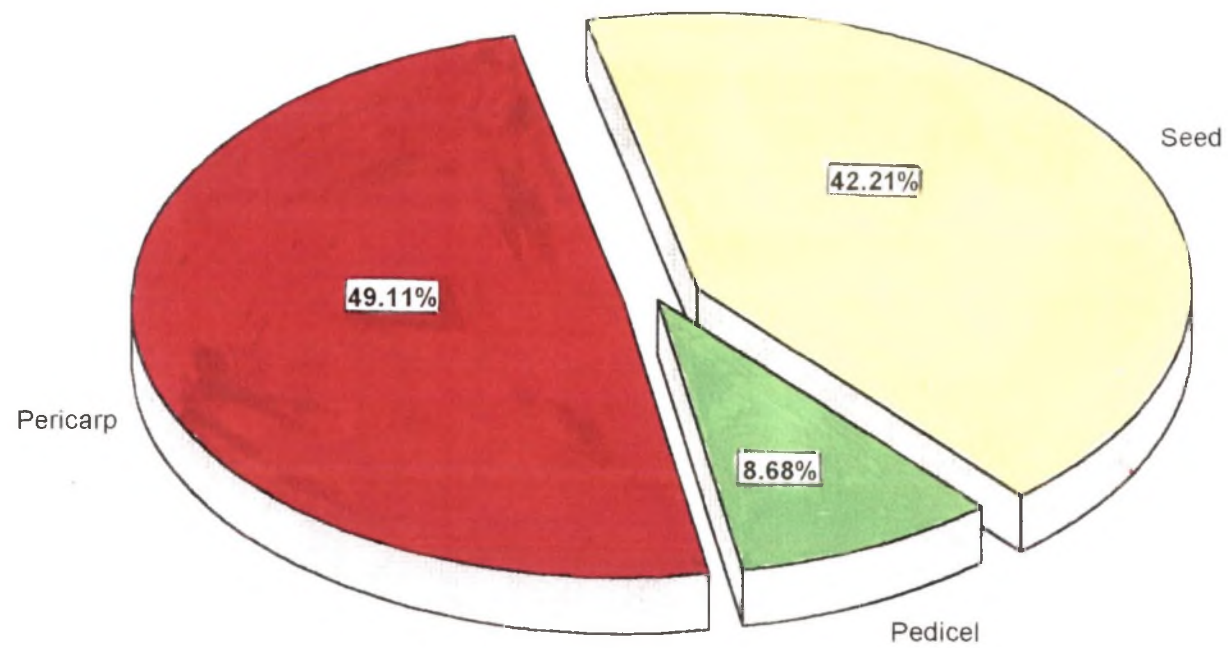


Fig.12. Per cent share of fruit components to whole fruit weight

and oleoresin are highly concentrated in pericarp portion and seeds entirely lack these attributes Natarajan *et al.* (1968) reported similar observations for few varieties of chillies cultivated in Kerala, Tamil Nadu and Andhra Pradesh. Low pedicel weight is due to translocation of photosynthates and nutrients to pericarp and seed portions.

Comparison among the three cultivars revealed that (Fig.13), fruits of Byadgi dabbi cultivar recorded highest pericarp weight followed by fruits of Dyavnur and Byadgi kaddi cultivar. This variation in pericarp weight between cultivars is attributed to thickness of pericarp and fruits of Byadgi dabbi cultivar have very thick pericarp where as Byadgi kaddi fruits have thin pericarp. Similarly Byadgi kaddi fruits have highest seed weight because of more number of seeds, whereas Byadgi dabbi fruits recorded lowest seed weight due to less number of seeds. Byadgi kaddi fruits have comparatively higher pedicel weight than dabbi fruit due to higher pedicel length.

5.6.2 Chemical characteristics of chilli fruits

Sundried fruit samples of different locations did not vary much with respect to moisture content whereas freshly harvested fruit samples of different locations differed significantly. This indicates that after uniform sun drying, moisture content in fruits comes to a minimum level irrespective of the location or soil type where they were grown. But freshly harvested first grade fruits contained higher moisture than second grade fruits. This is attributed to first grade fruits being produced from deep black soil locations where high moisture retention and availability resulted in increased uptake of moisture and nutrients. Third grade fruits of Byadgi kaddi cultivar contained lowest moisture because they were produced from red soil locations. Results of moisture content in sundried fruits and fresh

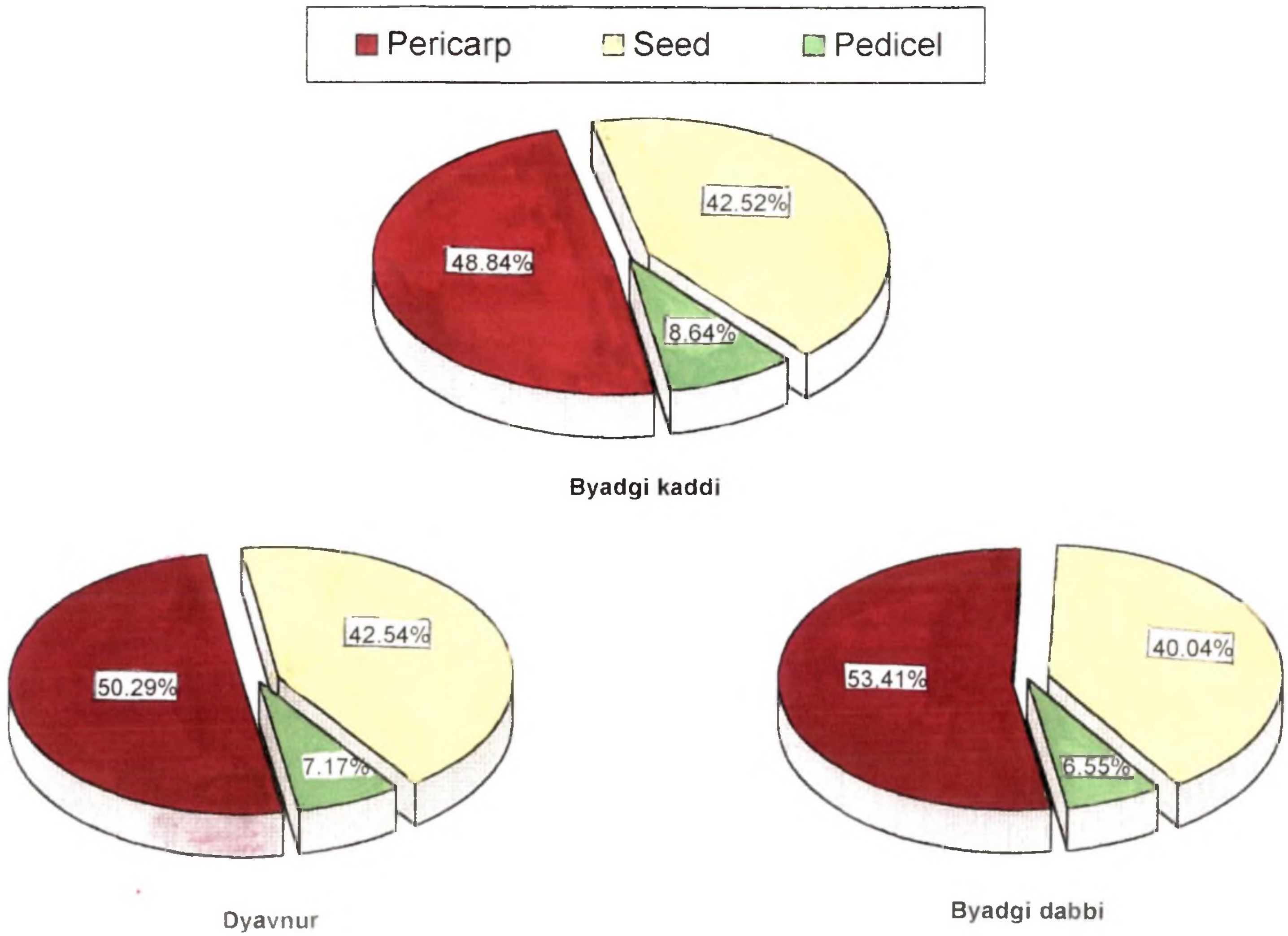


Fig13. Per cent share of fruit components to whole fruit weight for different Byadgi cultivar chillies

fruits are in agreement with the findings of Dass and Mishra (1972) and Pankar and Magar (1978a).

Comparison among the three Byadgi cultivars for moisture content in fruits revealed that, fruits of Byadgi dabbi cultivar contained highest moisture which may be due to thick pericarp which prevents moisture loss, whereas fruits of Byadgi kaddi cultivar contained lowest moisture which may be due to thin pericarp and fruits of Dyavnur cv. were intermediate in moisture content.

Irrespective of the cultivar, first grade fruits contained highest protein due to high N content in fruits because of increased uptake of N from deep black soils which have high available N. Lowest protein content (9.63%) in third grade fruits of Byadgi kaddi cultivar is attributed to low N content in fruits because of low N uptake due to low N availability in red soil locations coupled with poor physical and chemical properties that limit the uptake. Values of protein content as reported in Tables 22 and 22(a) and for the three Byadgi cultivars are lower than the average value (16.09%) given for Indian varieties and the values are lower than results reported earlier by Pankar and Magar (1978a), Natarajan *et al.* (1968) and Desai and Patil (1984). Similarly, the total ash content in different grade fruits follow the same trend as that of protein but the values of total ash closely agree with values reported earlier by Pankar and Magar (1978a) and Desai and Patil (1984) for few Indian varieties.

Total ether extract (TEE) of fruits indicates the fat content and the values of TEE for fruit samples of three Byadgi cultivars are within the range (13.92 to 24.5%) as given by Natarajan *et al.* (1968) for fruits of few Indian varieties. Volatile ether extract (VEE) responsible for flavour and aroma was low in first grade fruits compared second grade fruits whereas nonvolatile ether extract (NVEE) which represents non volatile fatty oil concentrated in seeds was high in first grade fruits than in second grade fruits. High seed content in first grade fruits due to higher fruit size might be the probable reason for high NVEE in first grade fruits. Further, fruits of Byadgi kaddi cultivar contained highest TEE due to high seed content, where as fruits of Byadgi dabbi cultivar contained lowest TEE because of low seed content. Pankar and Mayar (1978a) reported similar observations for fruits of few Indian varieties, which vary in size and seed content.

5.7.1 Nutrient concentration of whole red fruits

Nutrients absorbed by plant roots will be translocated to different organs, where they are utilized for biochemical processes leading to production of branches, leaves, flowers and fruits. It is a known fact that, the quality attributes in case of chillies are concentrated in fruits and the study of nutrient composition in different quality red fruits is helpful in establishing few correlations between quality attributes and nutrient concentration. This further adds in manipulating nutrient application, so that quality attributes can be improved.

5.7.1.1 N content

Fruit samples of different locations vary widely with respect to N content and particularly in fruits of Byadgi kaddi cultivar significant difference was observed between locations. This variation is attributed to differential uptake and translocation of N on account of variation in N status of soils along with other soil physical and chemical properties.

Irrespective of cultivar, first grade fruits invariably contained more N (1.76%) than second grade fruits and this is attributed to first grade fruits being produced from plants grown on black soil locations where high N status, extensive root system and favourable soil moisture along with other properties enhanced the uptake of N and its further translocation to developing fruit (Fig.14). Lowest N content (1.54%) was observed in third grade fruits of Byadgi kaddi cv. since these were produced from red soil locations. First grade fruits of Devanur location contained highest N, this might be due to heavy application of organic matter and N containing fertilizer every year and uptake is pronounced by favourable soil physical and physico-chemical properties. Results of N content in fruits are in consonance with values reported by Dass and Mishra (1972).

5.7.1.2 P content

Irrespective of cultivar, different quality fruit samples did not differ significantly with respect to P content in whole fruits (Fig. 14). This might be due to low P uptake by plants because of low to medium P availability in soils and greater P fixing capacity due to their fine textured nature and calcareousness. Further, the role of P in influencing the quality attributes of fruits is not exactly known and only small amount of absorbed P might have been translocated to fruits. Values of P content in fruits are in consonance with the results reported earlier by Pankar and Magar (1978a) and Farrell (1990).

5.7.1.3 K content

Unlike P content, K concentration appeared to differ significantly in different grades of fruits. It is found that, first grade fruits invariably contained higher potassium than second grade fruits and third grade fruits of Byadgi kaddi cultivar contained lowest potassium (Fig.14). High K content in first grade fruits is attributed to high K uptake on account of high K availability in deep black soils. Pronounced by favourable soil protein leading to extensive root development and increased K uptake. Further, K appears to have a significant role in influencing the quality attributes and hence its concentration is highest in fruits. Low K

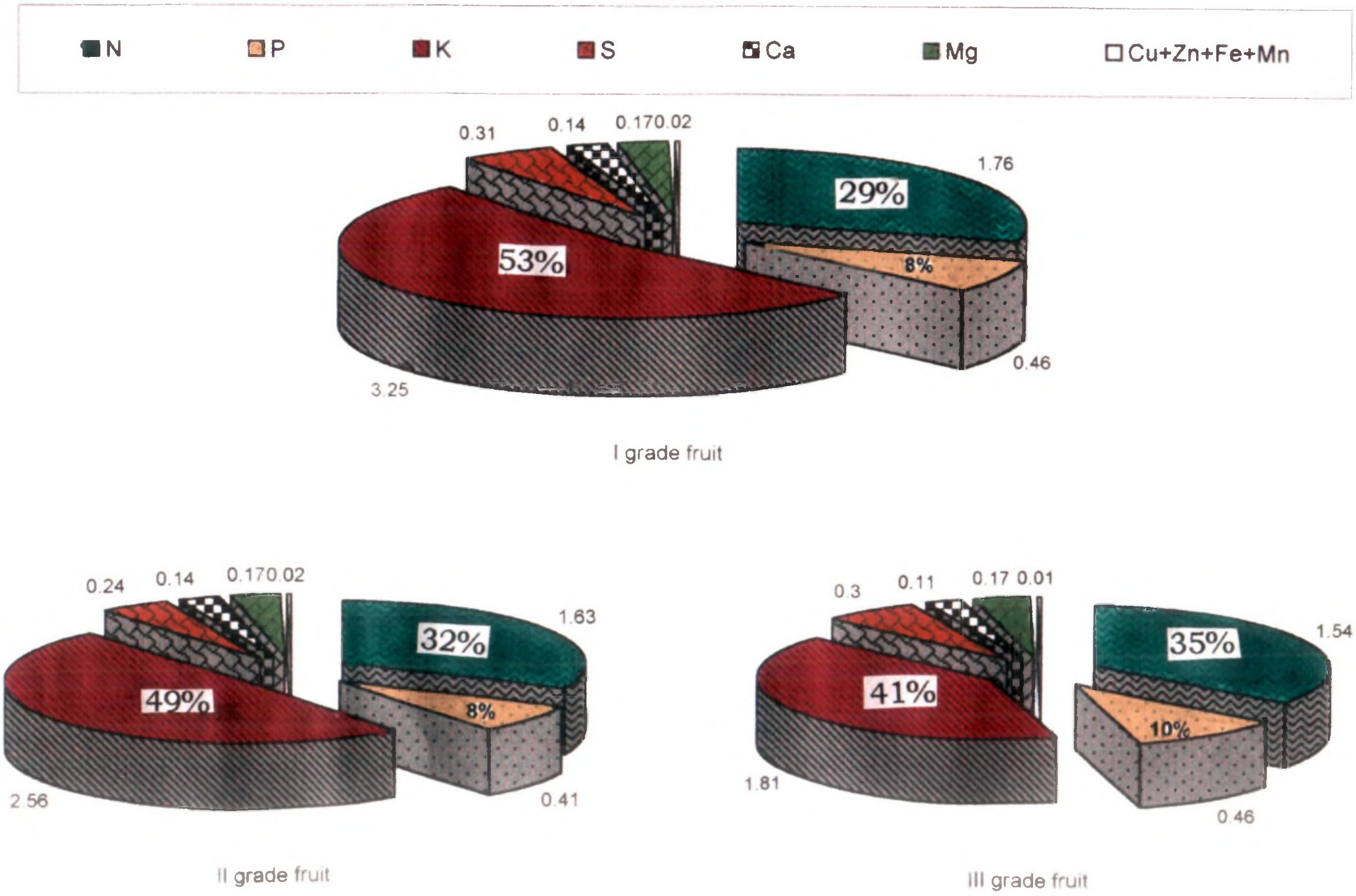


Fig. 14 : Nutrient concentration (%) and their per cent contribution to total nutrient status of different grade chilli fruits

uptake content in third grade fruits attributed to reduced K uptake by plants on account of low K status of red soils coupled with restricted root system.

Among the three Byadgi cultivars, fruits of Byadgi dabbi cultivar contain highest K, followed by fruits of Dyavnur cultivar and lowest K content was observed in fruits of Byadgi kaddi cultivar (Fig. 15). This variation in K content might be attributed to size and weight of fruits along with distribution of pericarp and seeds in whole fruits. Similar observations were reported by Pankar and Magar (1978a) and Farrell (1990).

5.7.1.4 Sulphur, Calcium and Magnesium

First grade fruits did not differ significantly from second grade fruits with respect to the concentration of these secondary nutrients (Fig. 14). This implies that, though uptake of these nutrients in deep black and medium black soil locations differed significantly, yet their further assimilation into developing fruits is negligible. Probably these secondary nutrients might have a minor role to play in influencing the quality attributes and mostly they may be utilized to produce more number of branches and leaves, since chilli is an indeterminate plant. There is a narrow range of variation in the concentration of these secondary nutrients in all the three cultivars and magnesium content was more than calcium irrespective of fruit grade and cultivar. Results of Ca and Mg content in fruits are in close agreement with values reported earlier by Pankar and Magar (1978a) and also Farrell (1990).

5.7.1.5 Cu, Zn, Fe and Mn

In chillies, the role of micronutrients in influencing the quality attributes is not well understood although they have a role to play in enhancing the fruit yield. Among these micronutrients, iron content is maximum irrespective of cultivar and fruit grade. This might be due to its preferential absorption by plants and its possible role in the development of red

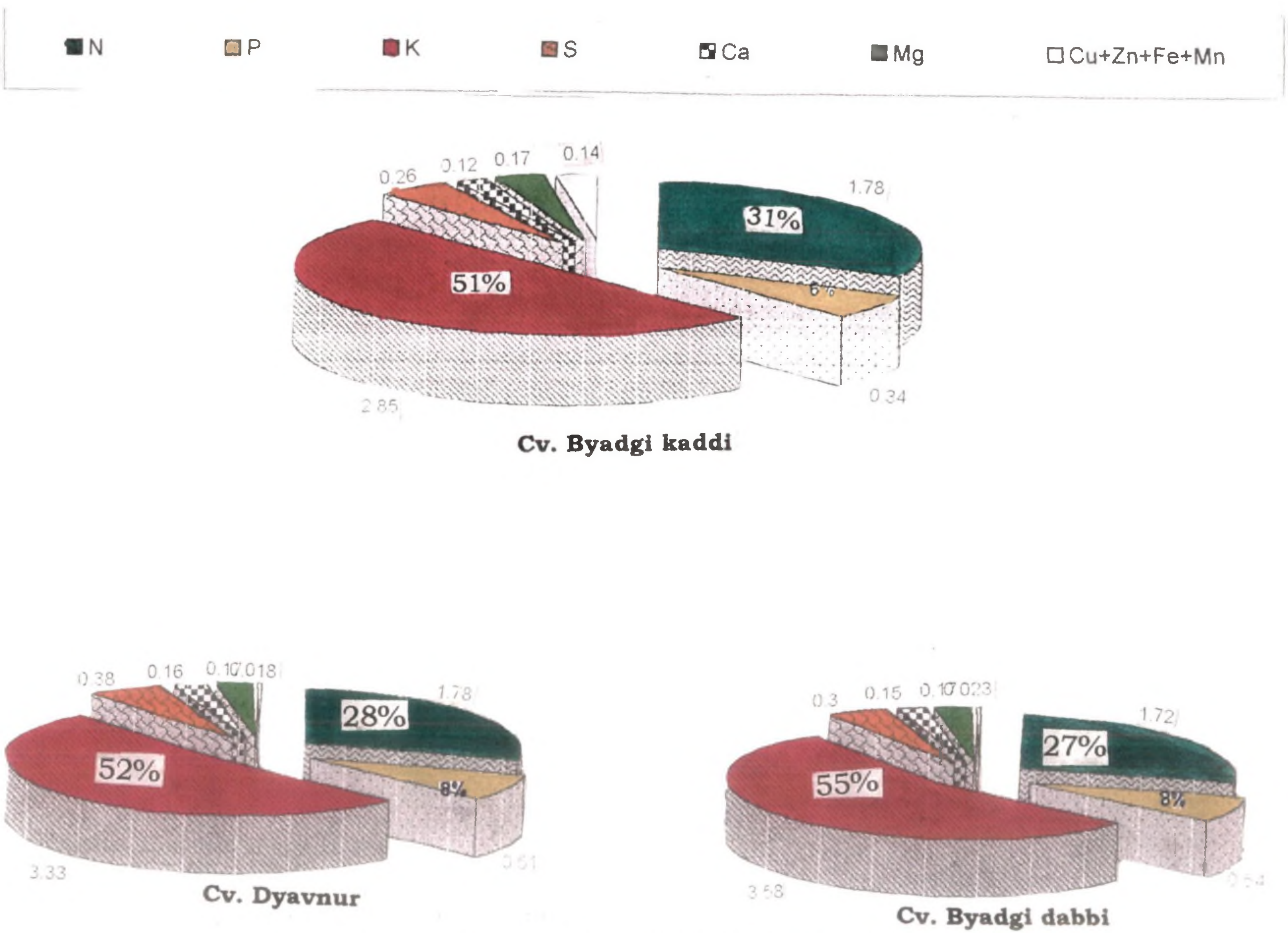


Fig. 15 : Nutrient concentration (%) and their per cent contribution to total nutrient composition of whole chilli fruits (Byadgi cultivars)

colour in fruits by activating few enzymes. Similar findings were reported by Martinez *et al.* (1990) in case of paprika. Low Mn content in fruits compared to Fe content might be due to slightly lower uptake of Mn although soils have higher DTPA-Mn than Fe and absorbed Mn might have limited role in influencing the quality attributes. Mallick and Muthukrishnan (1980) reported that, Mn plays greater role in the synthesis of carbohydrates in tomato rather than its role in improving ascorbic acid content or lycopene (colour) pigment. These observations lend support to present investigation of low Mn content in chilli fruits.

Zinc content follows Fe and Mn contents in fruits. Low Zn content in fruits might be due to its limited role in influencing the quality attributes Mallick and Muthukrishnan (1980) reported low Zn content in tomato fruits to its role in inducing pollen growth which results in increased fruit set and ultimately yield. Hence, its role in improving the quality of fruits is negligible as such its content is less in fruits. Mehrotra *et al.* (1977) reported similar observations in mustard where influence of zinc is more on yield rather on improving oil content in seeds. Subrahmanyam *et al.* (1991) attributed low Zn content in Japanese mint to low Zn uptake by plants because of antagonistic effects of Zn-P interactions and also Zn-Mn interactions. Such interactions might have taken place in chilli growing soils also because of heavy application of fertilizers by cultivators resulting in reduced uptake of Zn and subsequently low Zn content in fruits.

Copper content was lowest in fruits compared to other micronutrients, may be due to its limited role in influencing the quality attributes. Results obtained are in conformity with findings of Mallick and Muthukrishnan (1980) who stated that, in tomato, absorbed Cu plays role in influencing the retention of flowers and fruits on plants rather than in influencing the juice and ascorbic acid.

The concentration of nutrients in whole fruits irrespective of quality and cultivar followed the order K > N > M g > C a > S ≥ P > Fe > Mn > Zn > Cu. The present findings and the order of nutrient concentration in whole chilli fruits are in accordance with earlier observations reported by Farrell (1990).

5.7.2 Nutrient status of fruit components viz., pericarp and seed

It is an well established fact that, pericarp portion of whole fruit contains 95 per cent pungency and 99 per cent colour, while seeds entirely lack these attributes. In order to prepare a best quality oleoresin, the food industry prefers to use only pericarp portion. Nutrient analysis of pericarp and seed components of different grade fruit samples was carried out to know the extent of nutrient concentration and distribution in these components (Figs.) and its relationship with quality attributes. This study helps in manipulating the nutrient needs of plants for quality improvement. Different grade red chilli fruits of the three Byadgi cultivars collected from various locations of study area were separated into pericarp and seed components. These fruit components were analysed for nutrient status and results presented in Tables 24, 24(a), 25 and 25(a) are discussed.

5.7.2.1 Major nutrients

It is observed that, irrespective of cultivar, fruit grade and location, N and P contents were low in pericarp portion compared to their respective seed components (Fig. 16), whereas K content was very high in pericarp component than found in seed portion. This indicates the differential partitioning of nutrients between the two fruit components. Observations recorded on partitioning of nutrients between the two fruit components are in conformity with the findings of Pankar and Magar (1978a). Low N and P contents in pericarp

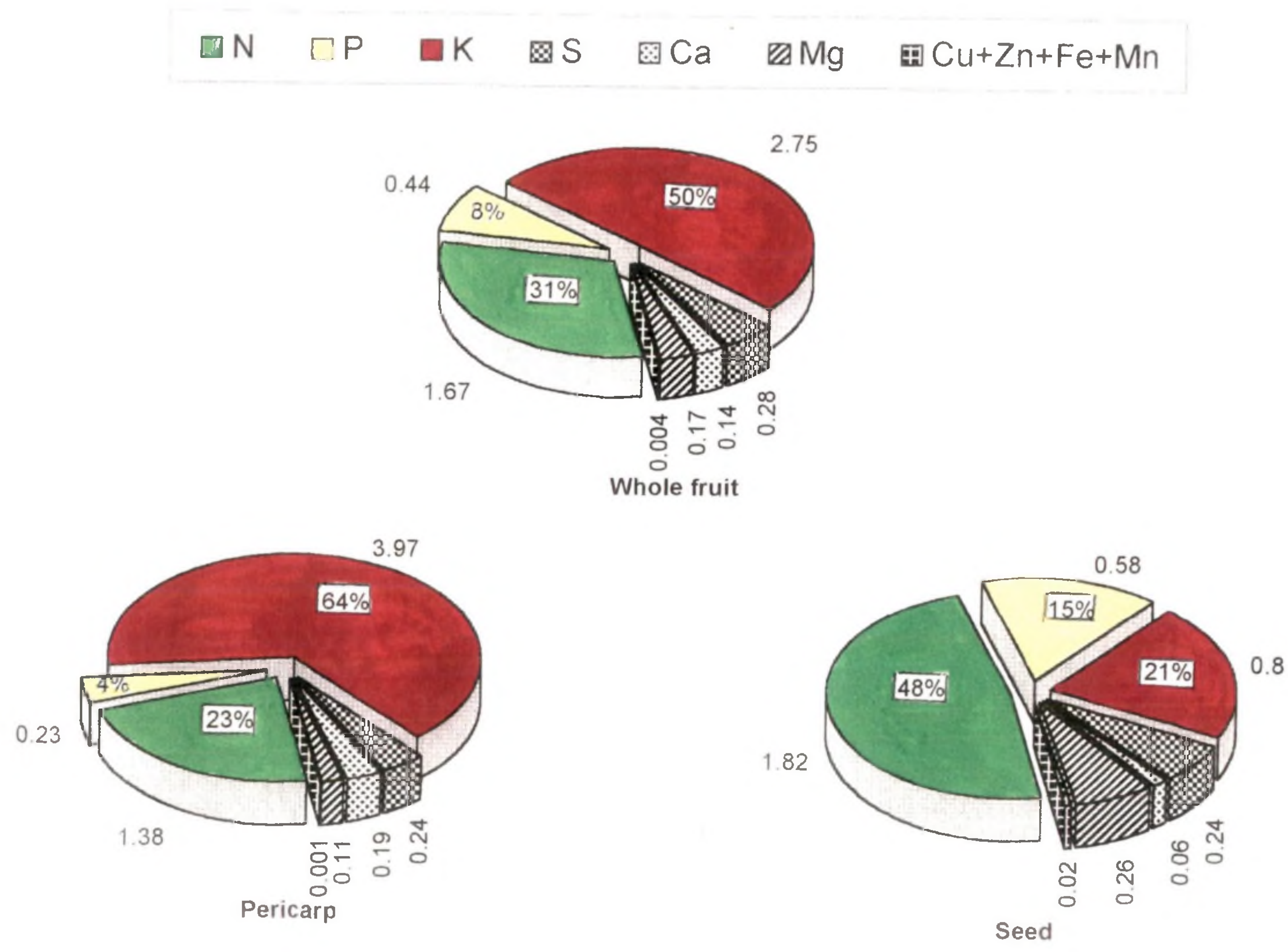


Fig 16. Per cent share of nutrients to total nutrient composition of whole fruit, pericarp and seed components

portion compared to respective seed components might be due to greater partitioning of assimilated N and P content of fruits towards developing seeds to meet the immediate needs of embryo in the event of germination and to support vegetative growth of seedlings. High K content in pericarp portion is attributed to its probable role in the development of red colour. Cazi (1961) reported that, deep red colour, glossiness and lustre are brought about by increased K uptake and its subsequent translocation to developing fruit. Similarly Subhani *et al.* (1990) reported significant increase in K uptake particularly at fruit maturation, thus indirectly K plays role in the development of red colour. Gross (1991) reported that, the biosynthesis of red pigments viz., capsanthin and capsorubin in chillies and lycopene in tomato is enzymatic process and potassium supply may catalyse the biosynthesis process by activating enzymes. These observations appeared to give some clue about greater uptake and subsequent partitioning of absorbed K into pericarp portion after translocation to fruits. However, further investigation is needed to know the exact role of K in the synthesis of red colour and greater partitioning of fruit K into pericarp rather than seeds.

Comparison between the three Byadgi cultivars for NPK content in pericarp portion revealed that, not much variation was observed between three cultivar with respect to N and P contents, but with respect to K content wide variation existed between pericarp components. It is found that, pericarp portion of Byadgi dabbi fruits contained highest K may be due to thick pericarp and intense red colour, whereas pericarp portion of Byadgi kaddi fruits contained lowest K may be due to thin pericarp and light red colour. Similarly intermediate K content was observed in pericarp portion of Dyavnur cultivar fruits due to medium thickness of pericarp. Further greater partitioning of fruit K into pericarp may also be one of the reason for such wide variation in K content. Narrow variation in N and P contents is attributed to their greater partitioning into seeds rather than pericarp and may have lesser role to play in influencing the quality attributes of fruits unlike potassium.

Irrespective of cultivar, pericarp and seed components of first grade fruits did not differ significantly from respective components of second and third grade fruits with respect to N and P contents with few exceptions. This showed that, the quality of fruit had no influence over partitioning of N and P between pericarp and seed portions. But, K content in pericarp portion was significantly influenced by fruit grade or quality. Irrespective of the cultivar, pericarp portion of first grade fruits contain more K than second grade fruits, while lowest K concentration was found in pericarp portion of third grade fruits in case of Byadgi kaddi cultivar. This showed that, the intensity of red colour in fruits is directly and linearly related to K concentration of pericarp and first grade fruits having dark red colour recorded highest K concentration in pericarp, while third grade fruit in Byadgi kaddi cv. having light red colour or orange colour recorded lowest K content.

But seed components of different grade fruits irrespective of the cultivar, did not differ significantly with respect to K content, this might be due to very low K content in seed and greater partitioning of fruit K into pericarp rather than seed.

5.7.2.2 Sulphur, Calcium and Magnesium

Based on the results presented in Tables 24, 24(a), 25 and 25(a), it can be inferred that, seed component contains higher concentration of sulphur and magnesium than respective pericarp components, whereas calcium was more in pericarp than in seeds (Fig. 16). These observations are in corroboration with the results reported by Pankar and Magar (1978a). Since Ca is a constituent of cell wall and middle lamella, it's association with cell wall imparts resistance to decay by pathogens, probably this is the reason for greater partitioning of Ca into pericarp than into seeds (Sharma *et al.*, 1996). Marcelle (1995) reported higher Ca content in skin of apple fruit than in fruit pulp. Similar results of high Ca content in pericarp of tomato fruits were reported by Aloni *et al.* (1994).

High sulphur content in seeds than respective pericarp component is attributed to it's probable role in the synthesis of fatty oil present to the extent of 25.7 per cent in chilli seeds and this oil is more unsaturated than groundnut or mustard oil. The present results are supported by observations made earlier by Tandon *et al.* (1964). But in Byadgi dabbi cultivar, very low seed content in fruits might not have partitioned enough sulphur for synthesis of fatty oil, hence seeds of this cultivar contain less sulphur than pericarp portion.

Irrespective of cultivar, pericarp and seed components of first grade fruits did not differ significantly from respective fruit components of second grade fruits with respect S, Ca and Mg concentrations. This implies that, deep black soils and medium black soils that produced first and second grade fruits,respectively did not influence concentration of these secondary nutrients in fruit components, even though the quality of fruits is different. But second grade fruits differed significantly from third grade fruits with respect to concentration of S and Ca in fruit components. This might be due to wide variation in uptake of S and Ca by plants grown in medium black soil and red soil locations that produced second and third grade fruits, respectively. Finally the concentration of secondary nutrients in pericarp component follows the order S>Ca>Mg but in seeds the order is S>Mg>Ca.

5.7.2.3 Cu, Zn, Fe and Mn

Irrespective of the cultivar and fruit quality, seed component contains higher concentration of micronutrients than respective pericarp component. This indicates the greater partitioning of micronutrients into seeds rather than into pericarp. Results closely agree with the findings of Pankar and Magar (1978a). Based on the present observations, it is difficult to assess the reasons for greater partitioning of micronutrients into seeds rather than into pericarp because of their low concentration in whole fruit and may have limited role to play in influencing the quality attributes. Future work in this line will help to know the specific role of micronutrients in influencing the quality attributes of chillies.

5.8 Quality attributes of chilli fruits

The study of quality attributes in fruits of different locations helps to establish some relationship between quality attributes and soil properties. Based on these relationships, the possible reasons for the yield of best and poor quality fruits under one agro climatic region can be identified. Based on this work, the cultivation practices can be modified in those locations where poor quality fruits are being produced, so that quality of fruits can be improved and were on par with locations that produced best quality fruits. In the present investigation, fruits collected from different locations were analysed for ascorbic acid, capsaicin, colour value and oleoresin content. Results obtained are discussed below.

5.8.1 Ascorbic acid

Green chillies and turning red (unripe) chillies are valuable on account of their richness in ascorbic acid. Data presented in Tables 26 and 26(a) showed that, fruit samples of

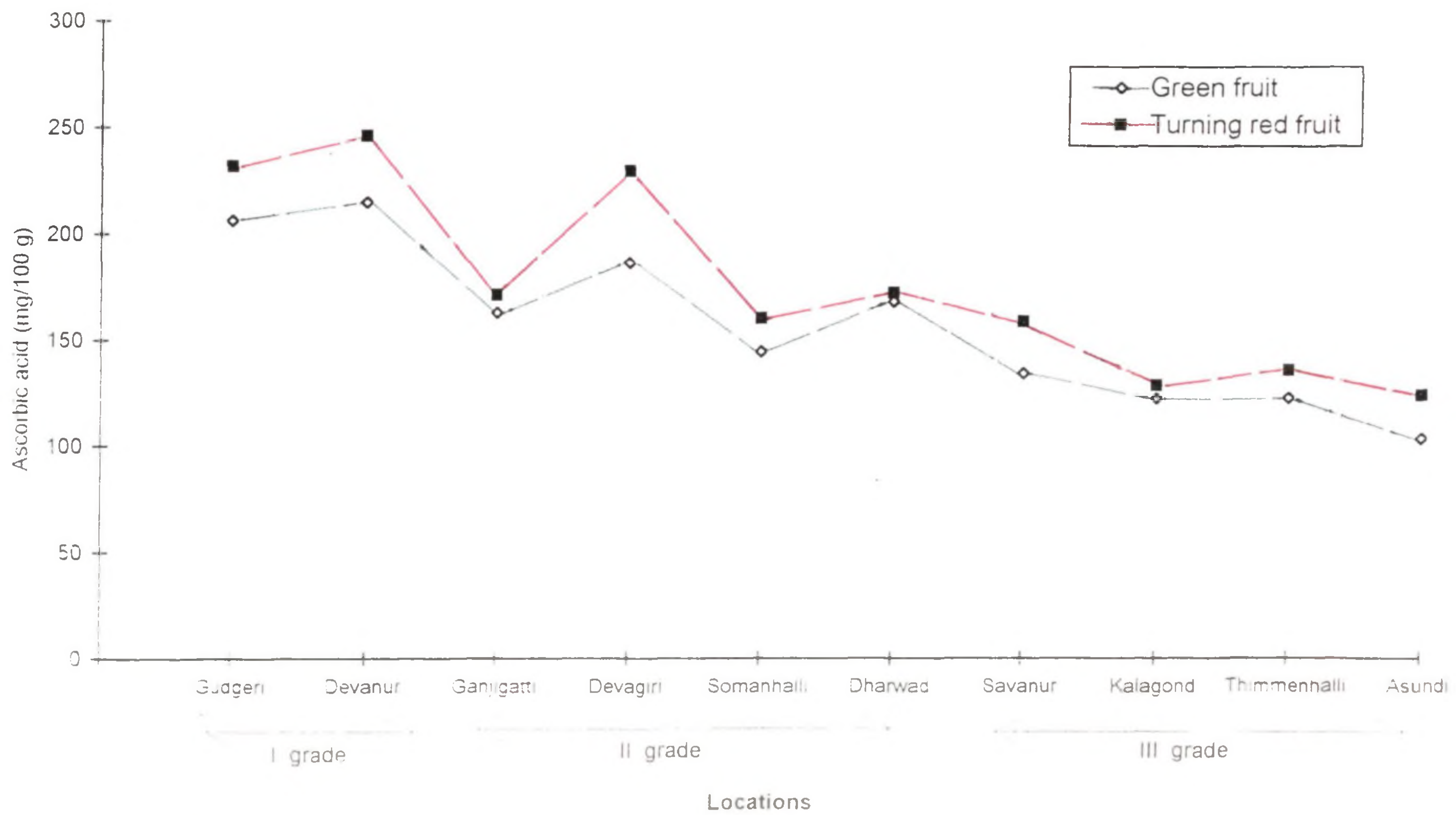


Fig. 17. Ascorbic acid content (mg/100 g) of green and turning red coloured chilli fruits (Cv.Byadgi kaddi) at various locations

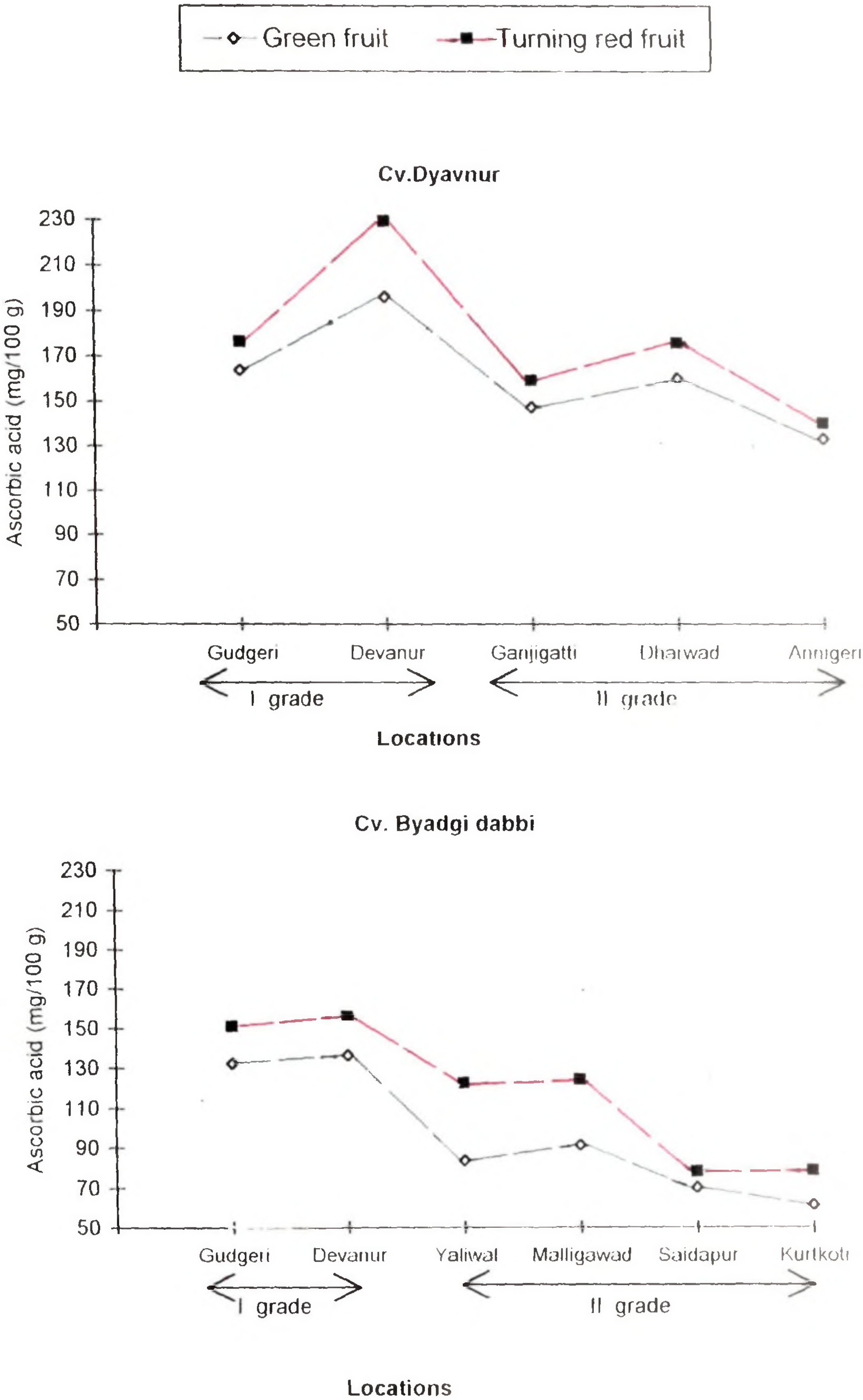


Fig18 Ascorbic acid content of green and turning red coloured chilli fruits (Cvs. Dyavnur and Byadgi dabbi) at various locations

various locations differed significantly with respect to ascorbic acid content in all the three cultivars. This is attributed to variation in nutrient status of soils coupled with uptake as influenced by soil properties. First grade fruits recorded higher ascorbic acid compared to second and third grade fruits (Figs. 17 and 18) produced from medium black and red soil locations,respectively. High N uptake by plants in deep black soils due to high N availability might have increased enzymatic activities leading to increased ascorbic acid synthesis in fruits. Shibhila Mary and Balakrishnan (1990) reported that, high N uptake enhanced the enzymatic activities for amino acid synthesis and increased ascorbic acid content in fruits. Similar results were also reported by Parminder Singh *et al.* (1986), Dass and Mishra (1972), Niranjana and Suseela Devi (1990) and Chavan *et al.* (1997).

It is interesting to note that, fruits at "turning red" stage contain significantly higher ascorbic acid than at "green" stage. Bajaj *et al.* (1977) reported higher ascorbic acid content in pink coloured fruits than in green fruits for few varieties of chillies cultivated in Punjab. Similar results were reported by Saimbhi *et al.* (1972), Awasthi and Singh (1979) and Rahman *et al.* (1978).

Interaction effects showed that, fruits of deep black soil locations did not differ significantly from fruits of medium black soil locations irrespective of the stage at which they were harvested. But in case of Byadgi kaddi cultivar, third grade fruits of red soil locations including mixed red and black soil location differed significantly first and second grade fruits at both fruit stages. This might be due to wide variation in properties of red and black soil locations that influence the uptake of nutrients particularly N responsible for amino acid synthesis leading to ascorbic acid.

Among the three cultivars, fruits of Byadgi kaddi cultivar contained highest ascorbic acid, while fruits of Byadgi dabbi cultivar contained lowest and fruits of Dyavnur cultivar were intermediate. This variation in ascorbic acid content is attributed to size of fruits and seed content. Fruits having more length and more number of seeds contained high ascorbic acid due to more placenta, than fruits having less length and less number of seeds as observed in fruits of Byadgi dabbi cultivar. Awasthi and Singh (1979) reported that, a direct relationship exist between length of fruits and ascorbic acid content. It appears ascorbic acid content of fruits is influenced by the genetic make up of the plants, however its content in fruits can be altered to some extent by nutrient supply.

5.8.2 Capsaicin

As mentioned in previous chapters, pungency in chillies is due to an alkaloid viz., capsaicin and it is a vanillyl amide of isodecyclenic acid. Any cultural practices or soil property that influence the synthesis of capsaicin indirectly alters the extent of pungency.

Irrespective of cultivar, first grade fruits contained more capsaicin than second grade fruits [Figs. 19 and 20]. This is attributed to higher N uptake by plants in deep black soils favoured by high N availability, extensive root system along with favourable soil properties. This absorbed N appeared to play role in the formation of amide molecule present in the side chain of capsaicin structure that is responsible for pungency. The present findings are in accordance with the report of Ananthakrishna and Govindarajan (1975) who reported the synthesis of amide (NH_2) molecule in capsaicin structure as closely related to N uptake. Further high N uptake by plants resulted in increased size of plant canopy and leaf, and it is reported by Bennett and Kirby (1968) that, a direct relationship exist between leaf area and capsaicin content in fruits, because capsaicin gets synthesized from photosynthates like phenylalanine, valine and leucine which are manufactured in leaves as shown in biochemical

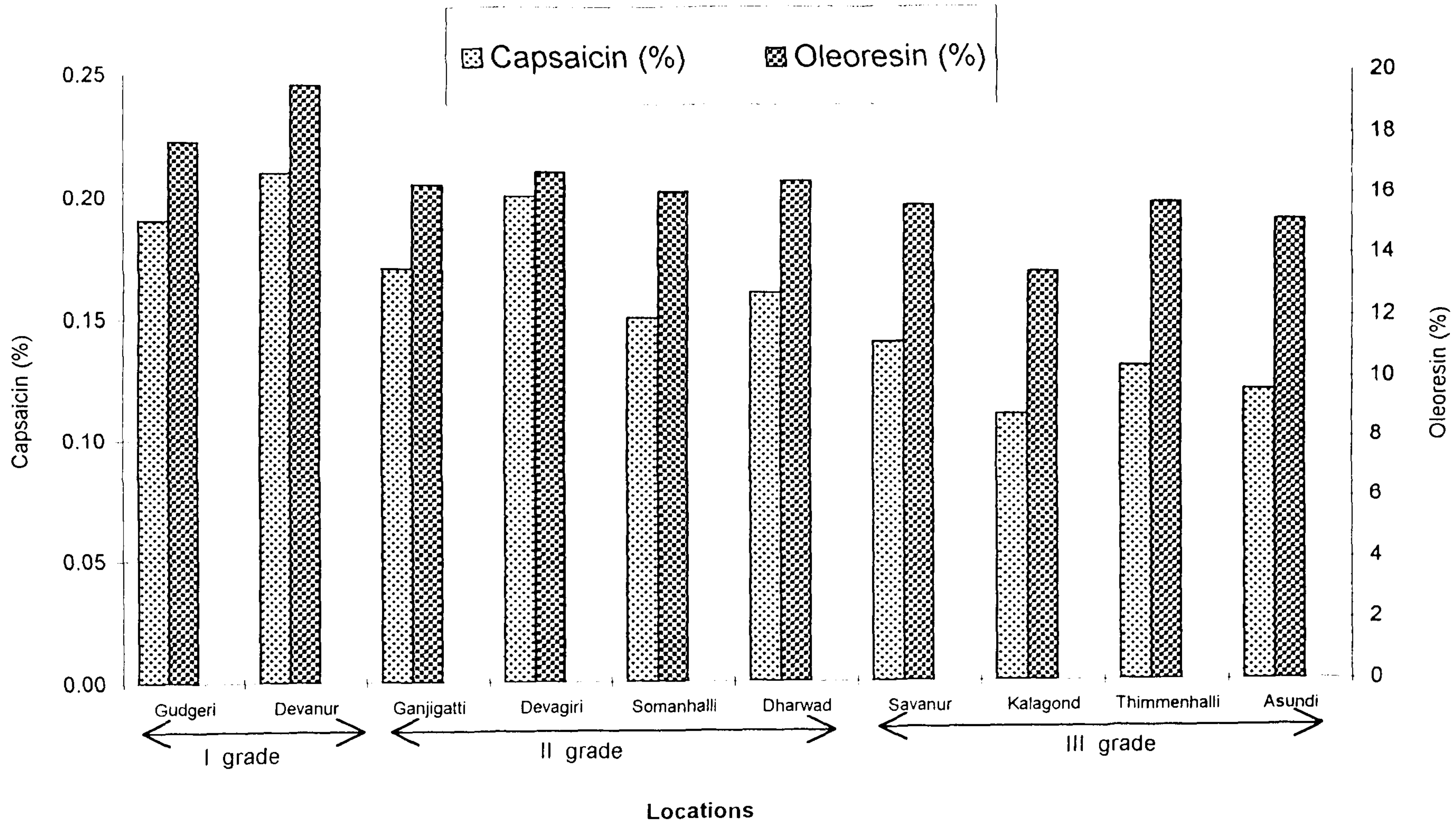


Fig19 Capsaicin and oleoresin content of different grade Byadgi kaddi chilli fruits at various locations

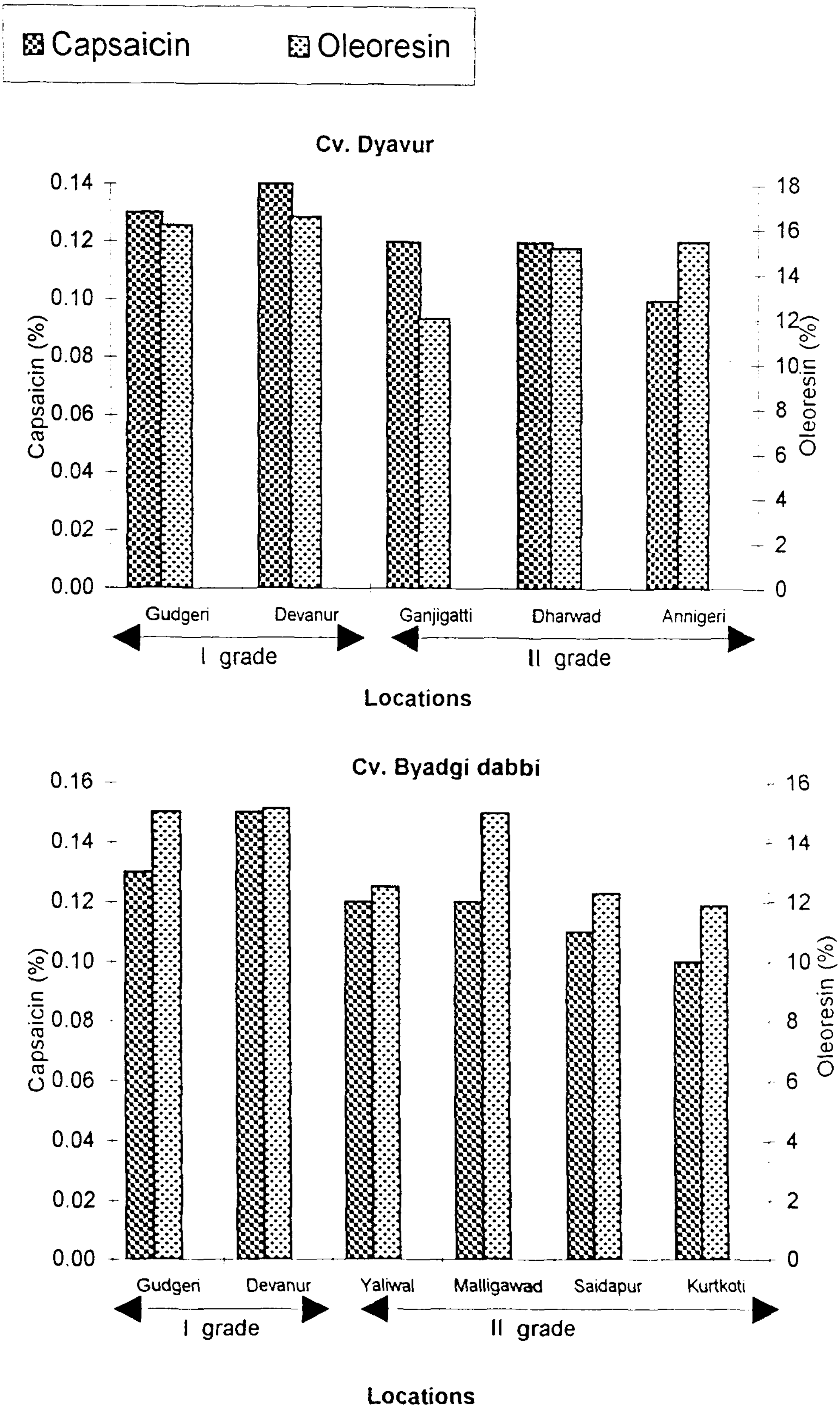


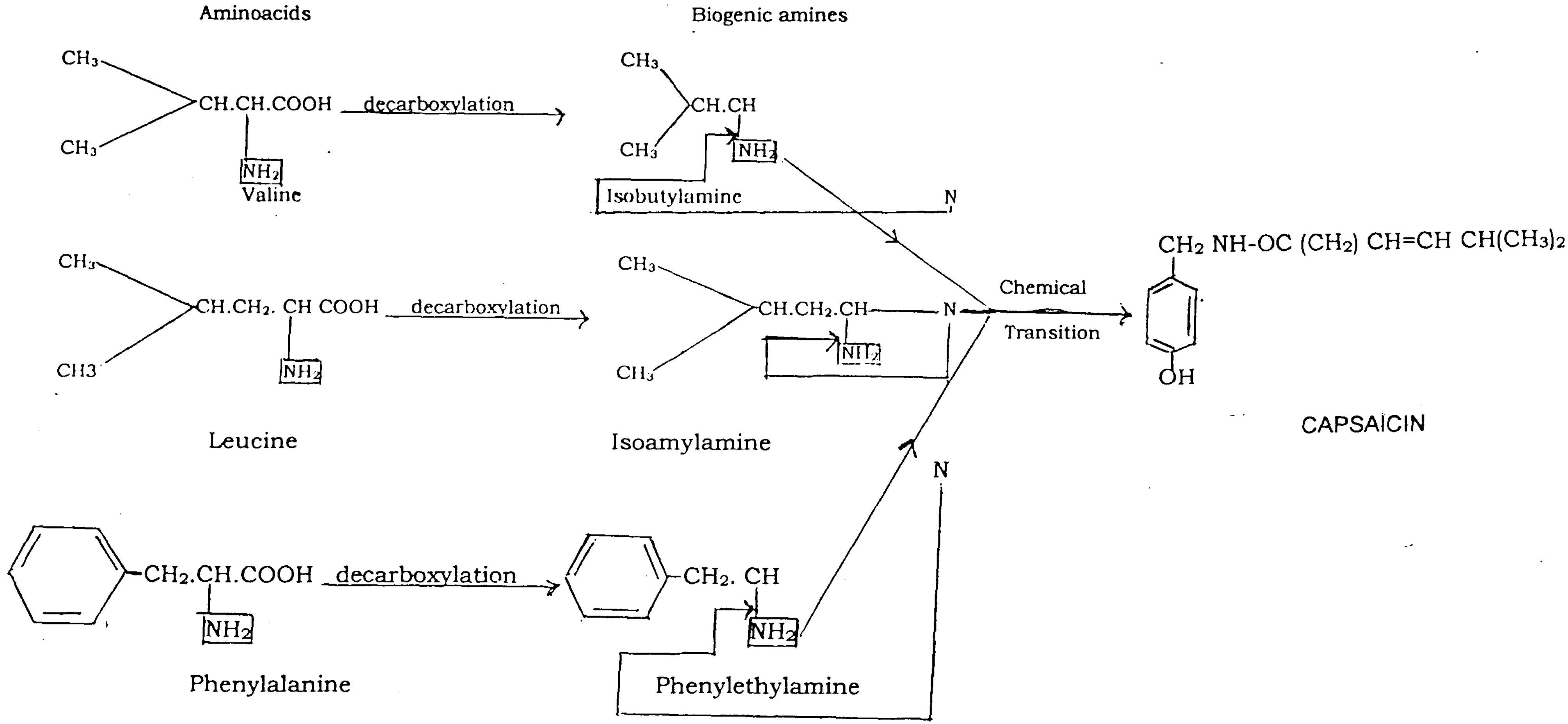
Fig20 Capsaicin and Oleoresin content of first and second grade chilli fruits (Cvs.Dyavnur and Byadgi dabbi) at various locations

pathway. Similar observations were reported by Lette and Louden (1968), Suzuki *et al.* (1981) and Balasubramanian *et al.* (1982).

Third grade fruits of red soil locations in Byadgi kaddi cultivar contained lowest (0.13%) capsaicin (Fig. 19). This might be due to low N uptake by plants in red soil locations on account of low N status and limited root system along with poor soil properties. This low N uptake results in reduced size of plant canopy and also leaf area where the photosynthates responsible for manufacture of capsaicin are synthesized. These observations are in accordance with the findings of Bennett and Kirby (1968) and also Balasubramanian *et al.* (1982).

Though, some variation was observed in the capsaicin content of different grade fruits, yet nonsignificant difference existed between different quality fruits irrespective of the cultivar. This showed that, although these different quality fruits were produced from different soil types which have wide variation in nutrient status and nutrient uptake differed significantly between locations, yet capsaicin content did not vary much. This might be due to inherent narrow range (0.10 to 0.26%) of variation in the capsaicin content of fruits and cultural practices or soil properties may alter the capsaicin content of fruits within the specified range. Rowland *et al.* (1983) reported that capsaicin content in fruits is a conserved character and is synthesized in specialized gland cells on the cross walls of capsicums and is genetically controlled.

Among the three cultivars, fruits of Byadgi kaddi cultivar contained highest capsaicin may be due to cylindrical shape, thin pericarp and more number of seeds that connect inner placenta to pericarp, while fruits of Byadgi dabbi cultivar contain lowest capsaicin because of



NH$_2$-radical responsible for pungency

Biochemical pathway for capsaicin synthesis

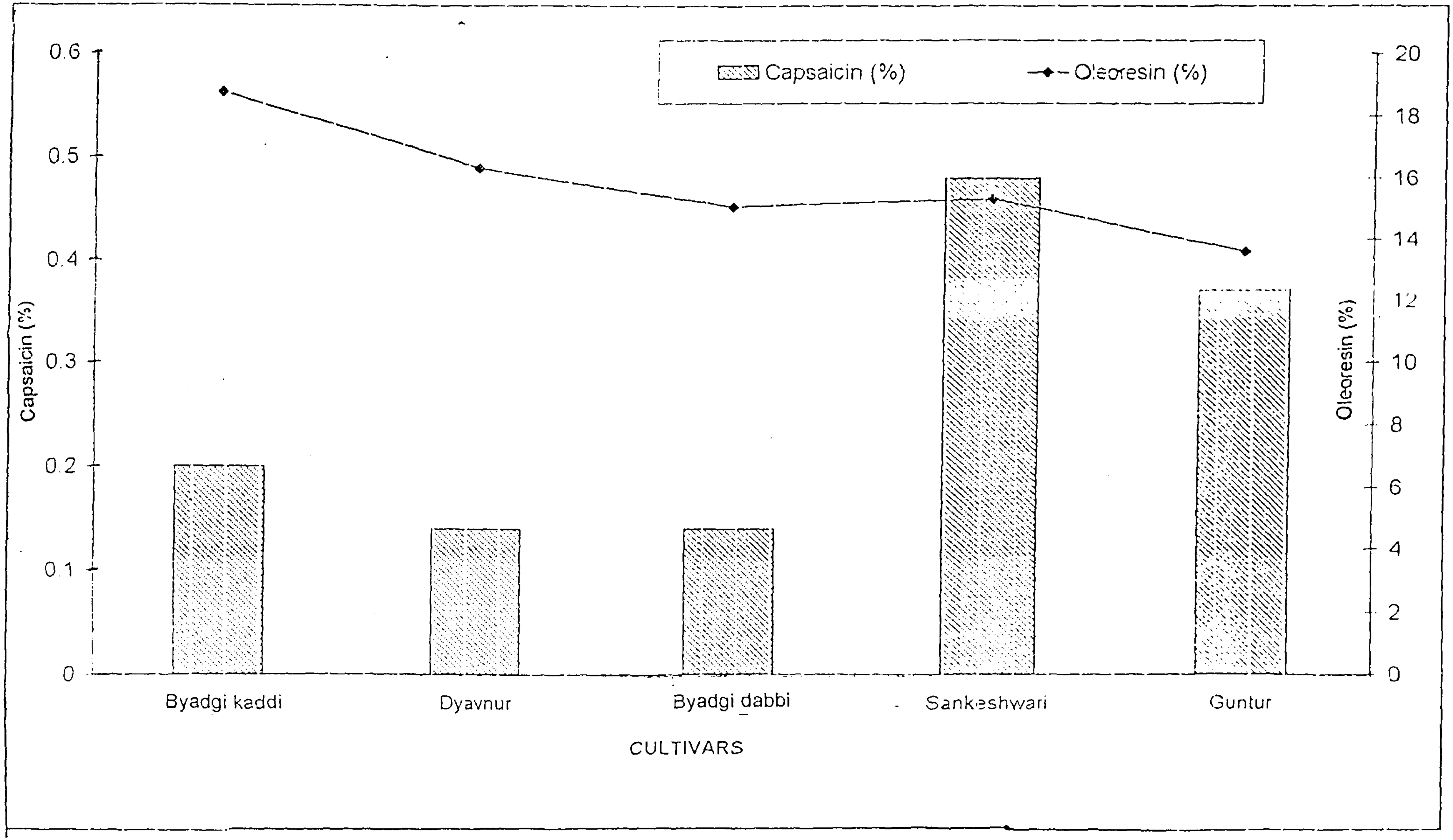


Fig. 21. Comparison of Byadgi chilli cultivars with Sankeshwari and Guntur (G-3) cultivars for capsaicin and oleoresin contents

globular shape, thick pericarp and less number of seeds. These observations are in line with the findings of Balasubramanian *et al.* (1982) who stated that, globular varieties had lower capsaicin than cylindrical varieties due to less number of seeds and less placenta. Similar observations were reported by Ananthasamy *et al.* (1960) and Sooch *et al.* (1977).

Comparison of these three cultivars with fruits of Sankeshwari and Guntur (G-3) varieties revealed that (Fig. 21), fruits of Sankeshwari variety have highest capsaicin (0.48%) may be due to cylindrical shape, very thin pericarp and highest number of seeds that lead to more placenta. Fruits of Guntur variety (G-3) contained slightly less capsaicin (0.37%) compared to Sankeshwari variety, this may be due small sized fruits and less number of seeds along with thin pericarp. Capsaicin content of the cultivars studied is in line with the findings of Pankar and Magar (1978b), Hosmani (1993), Sooch *et al.* (1977), Sumathykutty and Mathew (1984) and Sankarikutty *et al.* (1978).

5.8.3 Colour value

Irrespective of cultivar, first grade fruits recorded maximum colour value where as third grade fruits of Byadgi kaddi cultivar recorded lowest colour value (Plates V and VI). High colour value in first grade fruits is attributed to increase in uptake of nutrients in deep black soil locations and colour value is closely related to K content of fruits. In deep black soils, there is increase in uptake of K because of high K availability and favourable soil properties.

Subhani *et al.* (1990) reported that, adequate K supply to plant results in rapid transformation of green colour to pink and then to red colour. It is found that, K brings about equilibrium between acids and sugars in fruits, which results in good ripening and

FIRST GRADE — Deep black soil

SECOND GRADE — Medium black soil

THIRD GRADE — Red soil

PLATE-V Different grade chilli fruits[Cv. BYADGI KADDI]

First grade

Cv.DYAVNUR

Second grade

First grade

Cv.BYADGI DABBI

Second grade

PLATE-VI Different grade chilli fruits [Cvs.Dyavnur & Byadgi dabbi] development of red colour. These observations lend support to the results of high colour value in first grade fruits produced from deep black soil locations. Similarly, Marcelle (1995) reported that, plants well supplied with K enhance the synthesis of carbohydrates in leaves and further translocate these carbohydrates to developing fruits so as to balance the acids. Hence, K indirectly plays role in the development of colour by altering acid sugar ratio in fruits. Cazi (1961) reported a direct relationship between colour value of fruits and K supply to plants. Similarly, Trudel and Ozbun (1971) reported enhance carotenoid or lycopene pigment formation in tomato fruits as closely related to K supply. Apart from the properties of these deep black soils that favour colour development, the cultural practices followed by farmers in these two locations (Gudgeri and Devanur), particularly application of potassic fertilizers in split doses (Tables 3, 3(a) and 3(b)], might have synchronized with crop requirement and enhanced the colour development. These observations are in conformity with the findings of Nathulal and Pundrik (1971) who advocated split application of potassic fertilizers to enhance colour.

Lowest colour value was observed in third grade fruits of Byadgi kaddi cultivar produced from red soil locations. This might be due inadequate K supply in red soils on account of low K availability and restricted root system in such red soils may limit the K uptake. Generally fruits harvested from red soil locations were of light red colour, whereas those of deep black soils had blood red colour. It seems calcium being a constituent of cell wall is of high concentration in pericarp and may play some role in the development of red colour along with potassium. Hence K/Ca ratio in fruit pericarp may influence the intensity of red colour in fruits. So black soils rich in exchangeable Ca might have produced dark red colour fruits unlike red soils which are very low in exchangeable Ca. However further investigation is needed in this line. On the whole, it can be inferred that, K supply to plant mainly governs the colour value of fruits and there is a direct relationship between K uptake and colour value of fruits.

Unlike capsaicin content, whose concentration in fruits cannot be altered to a great extent by nutrient supply, but colour value of fruits can be altered to some extent by manipulating cultural practices. Hence low colour value in fruits of red soil locations can be improved to match with colour value of fruits produced from black soil locations by supplying adequate and timely application of nutrients. Further investigation in this direction is needed.

Among the three cultivars, fruits of Byadgi dabbi cultivar contained highest colour value (Fig. 22) because of thick pericarp and highest K content, whereas fruits of Byadgi kaddi cultivar contained lowest colour value may be due to thin pericarp and low K content. So K concentration of fruits is directly related to colour value of fruits. Fruits of Sankeshwari and Guntur (G-3) varieties have comparatively less colour value than fruits of Byadgi kaddi variety and this might be due to thin pericarp and low K content in fruits. It is found that, colour value of third grade fruits of Byadgi kaddi cv. is comparable with colour value of Sankeshwari or Guntur (G-3) varieties.

5.8.4 Oleoresin

Oleoresin is a viscous, semi solid gel like substance which contains essential oil as well as non-volatile constituents extracted from chillies. Oleoresin permits better and uniform distribution of flavour to food stuffs and it is added to the food in a diluted form. Oleoresin content of different grade chilli fruits presented in Tables 27 and 27(a) are discussed below.

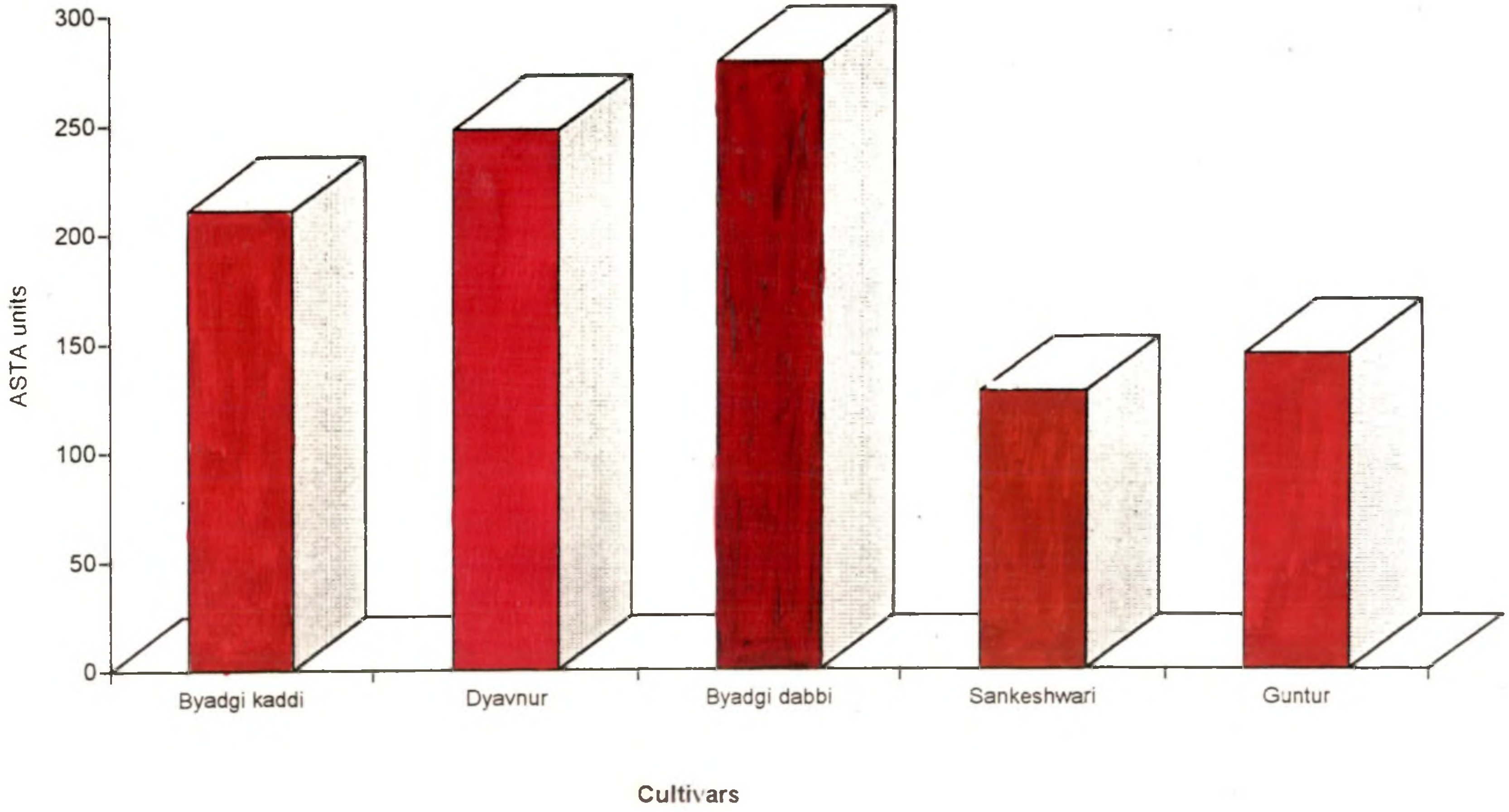


Fig22 Comparison of Byadgi chilli cultivars with Sankeshwari and Guntur (G-3) cultivars for colour value of fruits (I grade)

First grade fruits invariably yield higher amount of oleoresin than second grade fruits (Figs. 19 and 20). High oleoresin content in first grade fruits is attributed to big fruit size and fruit weight because of greater synthesis and translocation of photosynthates to developing fruits on account of increased uptake of moisture and nutrients from deep black soil locations. Second grade fruits in case of Byadgi dabbi cultivar contained lowest oleoresin (12.91%) because of less fruit size and less number of seeds that contained essential oil. Within a particular grade, fruits of different locations vary in their oleoresin content and this is attributed to difference in growth and yield attributes of plants in different locations that result in variation of fruit size and fruit weight. Apart from this, cultivation practices particularly quantum of fertilizers and manures applied by cultivators also influence indirectly the oleoresin content of fruits by altering the yield attributes. Oleoresin content of fruit samples for the three Byadgi cultivars including Sankeshwari and Guntur varieties are in close agreement with the values reported earlier by Natarajan *et al.* (1968), Narayanan *et al.* (1980), Tandon *et al.* (1964), Sumathykutty and Mathew (1984).

Third grade fruits of Byadgi kaddi cultivar yielded lowest oleoresin, because of less fruit size and less fruit weight on account of reduced uptake of nutrients and moisture in red soil locations pronounced by limited root system.

Among the three cultivars, fruits of Byadgi kaddi cv. yielded highest oleoresin (Fig. 21) may be due to more number of seeds in these fruits that contain essential fatty oil which contributes to higher weight of oleoresin. But fruits of Byadgi dabbi cv. yielded less oleoresin may be due to less number of seeds in fruits that contribute lesser amount of fatty oil to oleoresin weight. Tandon *et al.* (1964) reported similar observation and concluded that, oleoresins extracted from whole fruit are of poor quality due to greater quantity of fatty oil contributed by seeds and to get best quality oleoresin, it is preferred to use only pericarp portion. Hence, fruits of Byadgi dabbi cv. may yield maximum and best quality oleoresin if only pericarp portion is used for extraction because of thick and high pericarp weight coupled with intense red colour, whereas fruits of Byadgi kaddi cv. may yield low oleoresin due to thin pericarp and light red colour. The present observations lend credence to earlier observations made by Natarajan *et al.* (1968), Narayanan *et al.* (1980) and others.

Comparison of Byadgi cultivars with Sankeshwari and Guntur (G-3) varieties for oleoresin yield revealed that, fruits of Sankeshwari and Guntur (G-3) varieties yielded slightly lower oleoresin than first grade fruits of the these Byadgi cultivars (Fig. 21). It is found that, the fruits of these two varieties (Sankeshwari and Guntur) were comparable with the third grade fruits of Byadgi kaddi cultivar with respect to oleoresin yield. This may be due to small fruit size in Guntur variety and thin pericarp in Sankeshwar variety coupled with less number of seeds that contribute lesser amount of oil for oleoresin weight. The results of oleoresin content in Sankeshwari and Guntur variety fruits are in agreement with the results reported earlier by Natarajan *et al.* (1968).

5.9 Correlation studies

In order to findout the factors that influence the yield and quality of chillies, simple correlations were worked out between soil properties, uptake of nutrients and yield/quality of chilli fruits. Correlations were also worked out between nutrient composition of red fruits and quality attributes, as this study can serve as data base for the purpose of crop improvement and based on such correlations, nutrient needs of plants can be manipulated by fertilizer application so that best quality fruits can be produced by maximizing the efficiency of nutrient applied. In the present investigation correlations were worked out only for Byadgi kaddi cultivar (10 pairs of observations) and less number of observations in case of Dyavnur (5 pairs) and Byadgi dabbi (6 pairs) cultivars limit the computation of correlation coefficient (r) because in small samples 'r is not reliable. However, 'r' values obtained for Byadgi kaddi cv. can be extrapolated to other two cultivars also if large number of observations were taken.

5.9.1 Physical and physico-chemical properties of soils Vs yield and quality attributes

Yield and quality attributes have significant negative correlation with bulk density. This indicates that, soils of higher bulk density are not fit for chilli cultivation because of greater compaction that limit root growth. But per cent pore space showed significant positive correlation with yield and quality attributes. This implies that, higher pore space as found in black soils favour root development because of well drained condition and proper ratio between capillary and noncapillary pores. Available moisture, per cent clay and silt plus clay showed significant positive correlation with yield and quality attributes. This may be due to greater adsorption capacity of nutrients on clays and higher uptake of moisture. Similar correlations were worked out by Vijayakumar *et al.* (1992) in turmeric (*Curcuma longa* L.).

Among the physico-chemical properties, CEC, exchangeable K and organic carbon showed significant positive correlation with yield and quality attributes. High CEC indicates higher adsorption of nutrient cations on clays which can be absorbed by plant roots either by contact exchange theory or through soil solution. The presence of organic matter in higher quantities improves the physical environment of soil which is conducive for better root development and subsequent uptake of nutrients resulting in increased yield and quality. Exchangeable K in higher quantities improves the yield and quality by it's role in the synthesis of carbohydrates and it maintains equilibrium between acids and sugars in fruits resulting in enhanced colour value. Similar observations were reported by Vijayakumar *et al.* (1992) in turmeric where yield and curcumin content of rhizomes is positively related to organic matter.

5.9.2 Nutrient status of soils Vs. yield and quality

Based on the correlation coefficient (r) values, it can be concluded that, nitrogen and potassium had significant positive correlation with yield and colour value of fruits (Fig. 23). Further, colour value of fruits had significant positive correlation (0.95^* and 0.89^*) with available K content of soils at both depths (0-15 cm and 15-30 cm). This underlines the importance of K and plants may take up K not only from surface but also from sub surface depth (15-30 cm) to meet their requirement. Similarly capsaicin content of fruits had significant positive correlation with available N status of soils. This can be attributed to increased leaf area brought about high N availability and increased manufacture of photosynthates in leaves viz., phenylalanine, valine and leucine that synthesise capsaicin in fruits and absorbed N appears to form amide molecule present in the side chain of capsaicin structure that is responsible for pungency in chillies. Vijayakumar *et al.* (1992) made similar observation in case of turmeric where curcumin content of rhizomes was significantly and positively correlated with available N status of soils.

Among the micronutrients, copper and zinc content showed significant relationship with yield and quality attributes. Further investigations under controlled conditions are

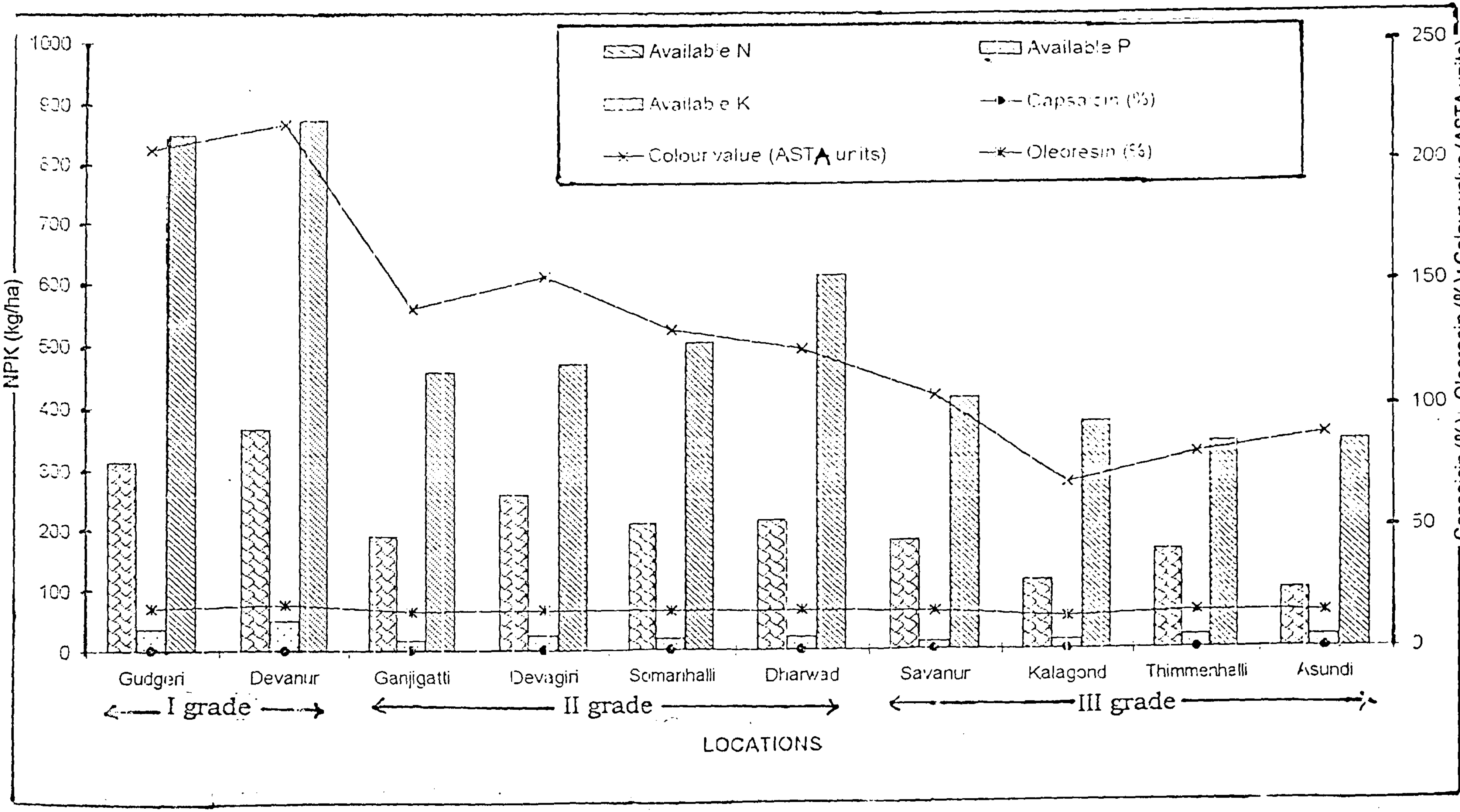


Fig. 23. Relationship between available NPK status of soils (0-15 cm) and quality attributes of fruits (Cv. Byadgi kaddi).

essential to understand to role of micronutrients in influencing the yield and quality attributes of chillies.

5.9.3 Nutrient uptake Vs yield and quality attributes

Correlation coefficient (r) values presented in Table 30 reveal that, yield and quality attributes have significant positive correlation with uptake of all nutrients. Particularly, uptake at 75 and 140 DAT had significant positive correlation with yield and all quality attributes, where as uptake of at 105 DAT had no relationship with yield and quality attributes except for nitrogen and sulphur uptake. Such differential uptake of nutrients by chilli crop at different growth stages is very difficult to interpret because of its indeterminate nature and variability on yield and quality attributes. Further investigations in the study of uptake pattern by imposing fertilizer treatments will help to understand such differential uptake and their relationship with yield and quality attributes.

5.9.4 Nutrient concentration in red fruits and pericarp Vs. quality attributes

Based on the results presented in Table 31, it can be inferred that, nitrogen and potassium content of whole fruits appeared to and have significant positive relationship with quality attributes and nitrogen content of pericarp alone had no relationship with quality attributes but, K content of pericarp was significantly and positively correlated with quality attributes (Fig. 24). Vijayakumar *et al.* (1992) reported significant positive relationship between N content of rhizome and curcumin content of turmeric. This finding lend support to the relationship that existed between N content of whole fruits and quality attributes in case chillies. Poor relationship between quality attributes and N content of pericarp might be attributed to lower N content of pericarp because of greater partitioning of whole fruit N into

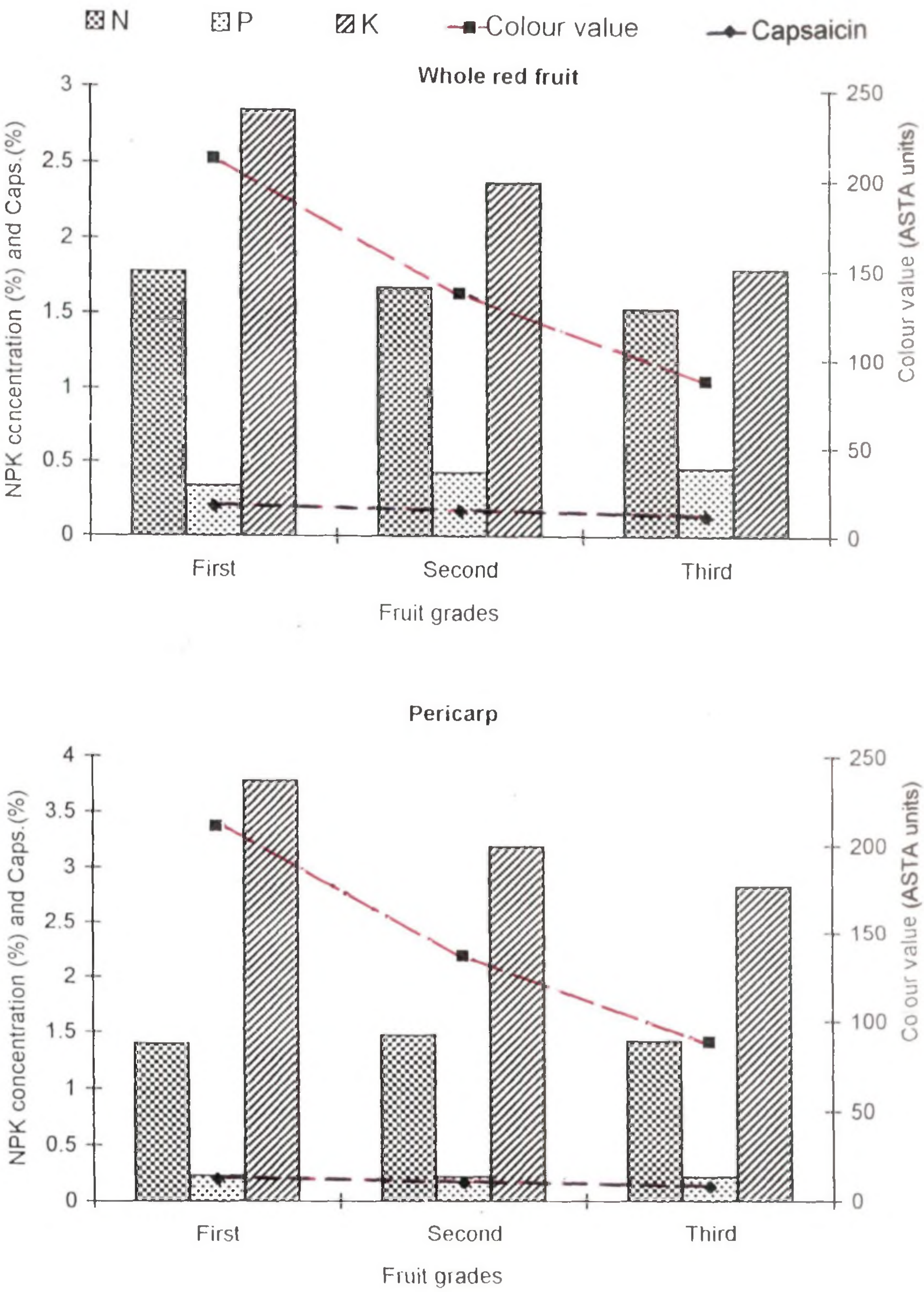


Fig 24 Relationship of NPK concentrations of different grade red fruits and pericarp component Vs quality attributes (Cv.Byadgi kaddi)

seeds to meet the needs of embryo in the event of germination as already discussed earlier. But K content of either whole fruit or pericarp component had significant positive correlation with quality attributes and this might be due to greater partitioning of fruit K into pericarp portion rather than into seeds. However there is a need to initiate biochemical and physiological investigations to understand the mechanism of capsaicin and pigment synthesis (capsanthin and capsorubin) vis-a-vis soil and plant properties.

RESULTS OF PRACTICAL UTILITY

The present investigation generated the following results of practical utility.

1. Profile studies and soil properties, of different locations served as data base for occurrence of wide variation in yield and quality of Byadgi chillies produced from different locations in Dharwad, Haveri and Gadag districts.

2. Based on this data, causes for medium and low yields in medium black and red soil locations were identified and suitable nutrient management practices to be adopted in such locations can be finalised so that yield and quality of fruits can be improved.

3. Studies on nutrient uptake at different growth stages and the order of nutrient uptake (K>N>Ca>Mg>S>P>Fe>Mn>Zn>Cu) gives hint for fertilizer application (time and quantum of fertilizer). So that there is maximum efficiency of fertilizer applied.

4. Application of organic matter in heavy doses appeared to enhance the yield and also quality, since the crop is mostly grown under rainfed conditions where organic matter conserves the moisture for long period and makes steady supply throughout the growing season.

5. Rooting habit of chillies in different soil types indicated the depth of rooting, root spread and root weight. This study helps in fertilizer placement to ensure effective uptake of nutrients and increase the efficiency of fertilizers applied.

6. Pungency and colour in chillies are influenced by N and K supply. Hence plants should have adequate supply of these nutrients particularly at the time of synthesis of capsaicin (after 75 DAT) and development of colour (after 90 or 105 DAT). In this respect, split application of not only N, but also K will be helpful to get attractive, bright red coloured fruits. Two to three split doses of K are essential as chilli is a long duration and indeterminate plant and colour development is a continuous process.

7. First grade fruits yield highest oleoresin because of their larger size and higher fruit weight. This finding identifies the reason for low yield of oleoresin in second and third grade fruits. Hence to enhance the yield of oleoresin from these fruits there is a need to increase the fruit size and fruit weight. This can be brought about by increased fertilizer and organic matter application in medium black and red soil locations.

8. Partitioning of nutrients of whole red fruits into pericarp and seed components revealed that, among major nutrients, N and P were very low in pericarp where as K was very high in pericarp and K content of either whole fruit or pericarp had significant positive correlation with colour and capsaicin. This signifies the importance of K in influencing the quality attributes, as such plants should be well supplied with K although soils have enough K.

9. Among the three Byadgi cultivars, fruits of Byadgi dabbi cultivar are best suited for oleoresin extraction because of thick pericarp, low seed content and shining blood red

colour. While fruits of Byadgi kaddi cultivar are suitable for domestic food preparation due to high pungency and thin pericarp and fruits of Dyavnur cultivar are suitable for both oleoresin extraction as well as domestic food preparation depending upon the colour of pericarp. Based on this, choice of cultivar can be decided depending upon the purpose for which the fruits have to used.

FUTURE RESEARCH PRIORITIES

1. Since chilli is a long duration and indeterminate plant, there is wide scope for testing slow release fertilizers to increase the fertilizer use efficiency and to make steady supply of nutrients.

2. It is possible to enhance the yield and quality of fruits produced from red soil locations. Hence, field experiments may be conducted in red soil locations by imposing treatments, and yield/quality attributes of fruits are studied.

3. There is a need to initiate biochemical and physiological investigations to understand the mechanism of capsaicin and pigment synthesis vis-a-vis soil and plant properties.

4. The role of micronutrients in influencing the yield and quality of fruits needs further investigation with the help of pot culture experiments under controlled conditions.

5. DRIS norms may be derived for different pairs of nutrients based on survey data of locations and grouping them into high and low yielding groups.

6. Information pertaining to third grade fruits of Dyavnur and Byadgi dabbi cultivar is lacking, hence these cultivars may be tried in red soil locations also.

7. Studies on the effect of N and K on quality attributes viz.,pungency, colour, ascorbic acid and oleoresin may be done by conducting field experiments in different locations.

8. Correlation studies may be strengthened further by enhancing the number of observations for all the three cultivars and also for Guntur (G-3) and Sankeshwari varieties.

9. Such studies may be initiated for other regions also (Bellary, Raichur and UKP Area), where chilli is being extensively grown under irrigation.

SUMMARY

VI. SUMMARY

A study was undertaken in the transitional zone (Zone-8) and part of northern dry zone (Zone-3) of Dharwad, Haveri and Gadag districts where Byadgi chilli is extensively cultivated as an important commercial crop during kharif season. Soils of these districts show wide variation in morphological, physical, chemical properties and also fertility status. Chilli crop grown in different locations of these districts under similar climatic conditions exhibit wide variation in yield and quality attributes. In order to ascertain the reasons for such wide variation in yield and quality of Byadgi chilli produced from different locations, where rainfall is sufficient and well distributed, the present investigation was carried out.

The entire chilli growing area was divided into three regions and totally 15 soil bodies were selected based on preliminary discussion with chilli growers in different locations with regard to yield and quality produced. These 15 soil bodies are such that, first region comprises two deep black soil pedons where yields were high and first grade fruits were produced, second region comprises nine medium black soil pedons where yields were medium and second grade fruits were produced and third region comprises four red soil pedons (including one mixed red and black soil pedon) where yields were low and third grade fruits were produced. These pedons were examined for morphological, physical, physico-chemical and fertility properties. The three Byadgi chilli cultivars (Byadgi kaddi, Dyavnur and Byadgi dabbi) grown in these 15 locations for two years during kharif were examined for growth, yield/yield attributes and quality parameters. Periodical observations on growth attributes were recorded in all these locations, besides nutrient uptake, yield/yield attributes and quality attributes of fruits

collected from different locations were also studied to establish few relationships with soil properties. The salient features of the present investigation are summarised below.

Black soil pedons are deeper than red soil pedons and structure in black soil pedons varied from granular to subangular and angular blocky and in red soil pedons it was coarse to very coarse and granular to subangular blocky. All black soil pedons were clays, whereas red soil pedons were sandy clay to clay loam and loam. As expected bulk density, per cent pore space, moisture retention capacity, organic matter content, CEC, exchangeable cations and free lime were higher in black soil pedons compared to red soil pedons. Black soil pedons were neutral to alkaline in reaction, whereas red soil pedons were acidic to neutral.

Pedons producing first grade fruits (I and II) recorded higher N and P content than pedons producing second grade fruits and pedons producing third grade fruits (VII, VIII, IX and X) recorded lowest N and P status. Black soil bodies were high in available K and S, whereas red soil pedons were medium to high.

With regard to available micronutrients status, the red soil pedon (pedon VIII) having acidic pH has higher concentration of micronutrients than black soil pedons and not much variation was observed between deep black and medium black soils with regard to status of micronutrients. Finally, irrespective of soil type, the concentration of these micronutrients in soils follow the order Mn>Fe>Cu>Zn and no definite trend in distribution with depth was observed.

Generally, pedons producing first grade fruits and highest yields have highly favourable soil properties for plant growth compared to pedons that produce second and third grade fruits with medium and low yields.

Nutrient uptake studies revealed that, irrespective of cultivar, plants grown on deep black soil locations that produced first grade fruits and high yields recorded higher uptake of nutrients, than plants grown on medium black soil locations that produced second grade fruits. Plants grown on red soil locations showed lowest uptake of nutrients. Nutrient uptake increased significantly from 45 DAT to 140 DAT and the peak period of uptake is at 75 DAT. Uptake of nutrients is influenced by soil properties like soil moisture, nutrient status, organic matter content, soil pH, CEC, clay content etc. Further, root spread, plant population and cultural practices also influenced the uptake significantly.

Plants of deep black soil locations recorded higher growth attributes than those of medium black soil locations which influenced the yield and yield attributes significantly and plants of red soil locations recorded lowest growth attributes.

Yield and yield attributes of chilli cultivars in different locations revealed that, plants of deep black soil locations recorded highest yield and yield attributes whereas, those of red soil locations recorded lowest. This variation in yield and yield attributes of plants in different locations is attributed to variation in nutrient status, moisture availability, organic matter content, rooting habit and other soil properties that influenced the growth attributes, which are responsible for the yield and yield attributes. There was not much variation between transplanted and drill sown locations with respect to final fruit yield. Due to high plant population in drill sown plants eventhuogh lesser yield attributes were observed in these locations.

Among the cultivation practices, quantum of fertilizers applied along with organics and split application of N and K appeared to have a significant effect in influencing the yield and quality attributes.

Rooting habit of plants studied in different locations showed that, in deep black soils, root spread was extensive and plants have highest root weight, whereas in red soils, there was limited root development along with less root weight and roots were more fibrous. It is found that, root spread and root weight were mainly influenced by soil depth, bulk density, moisture and nutrient status, (particularly N and K). Further, the pattern of root development in drill sown plants and transplanted plants was slightly different with transplanted plants have more root weight caused by early modification of tap root than drill sown plants.

Physical characteristics of fruits harvested from different locations indicated that, irrespective of cultivar, first grade fruits produced from deep black soil locations recorded higher fruit size (L/B ratio) and fruit weight than second grade fruits produced from medium black soil locations and third grade fruits of red soil locations recorded lesser size and lower fruit weight. Higher fruit size and fruit weight in black soil locations was attributed to greater synthesis and translocation of photosynthates to developing fruits on account of higher availability of moisture, nutrients and other favourable soil properties that enhance the uptake of nutrients leading to increased growth attributes. Comparison among the three cultivars for fruit weight and fruit size revealed that, fruits of Byadgi kaddi cultivar have highest size (L/B ratio), whereas those of Byadgi dabbi cv. have lowest and intermediate L/B ratio was observed for fruits of Dyavnur cultivar. With respect to single fruit weight, fruits of Byadgi dabbi cv. recorded highest value, whereas fruits of Byadgi kaddi cv. recorded lowest and intermediate value was noticed for Dyavnur cultivar fruits.

Partitioning of whole fruit into individual components (pericarp, seed and pedicel per cent) revealed that, irrespective of fruit grade and cultivar, pericarp weighs more than seed and pedicel weighs lowest. The contribution of pericarp, seed and pedicel to whole fruit weight was to the extent of 40 to 55 per cent, 35 to 45 per cent and 5 to 15 per cent, respectively. Within a cultivar, first grade fruits invariably recorded maximum pericarp per cent and lowest pedicel per cent, whereas third grade fruits have highest pedicel per cent and lowest pericarp per cent. Comparison among three cultivars revealed that, fruits of Byadgi dabbi cv. recorded highest pericarp weight and lowest seed weight, whereas in Byadgi kaddi cultivar, the values were vice-versa and intermediate values were observed for fruits of Dyavnur cv.

Chemical characteristics of different grade chilli fruits revealed that, different quality sundried fruits did not vary much with respect to moisture content, whereas freshly harvested different grade fruits showed significant variation in moisture content being highest in first grade fruits followed by second and third grade fruits. Such variation in moisture content of freshly harvested fruits is attributed to moisture status of soils and soil texture along with organic matter content and root spread in different locations. Among the three cultivars, fruits of Byadgi dabbi cultivar fruits contain highest moisture either at sundried stage or at freshly harvested stage whereas Byadgi kaddi fruits contain lowest moisture. Numerically though first grade fruits contain highest protein and total ash than second and third grade fruits, yet the range between different grades of fruits was narrow. It appears soil properties and cultural practices have marginal influence in altering these chemical properties.

Proximate nutrient composition of different grades of whole red fruits revealed that, first grade fruits had significantly higher N and K concentration than second grade fruits and not much variation was observed between these two grades of fruits with respect to the concentration of other nutrients (P, S, Ca, Mg, Cu, Zn, Fe and Mn).

Irrespective of the cultivar and fruit quality, the order of nutrient concentration in whole fruits followed the order K>N>Mg>Ca>S>P>Fe>Mn>Zn>Cu. Third grade red fruits contain very low concentration of N and K and they differed significantly from first and second grade fruits.

Among the three cultivars, fruits of Byadgi dabbi cv. contain highest K, whereas fruits of Byadgi kaddi cv. contain lowest and intermediate K content was found in fruits of Dyavnur cultivar. Not much variation was observed between the cultivars with respect to concentration of other nutrients in whole fruits.

Partitioning of nutrients of whole red fruits into pericarp and seed components revealed that, irrespective of fruit grade and cultivar, K concentration is very high in pericarp, whereas seeds contain very low K. Contrary to K, N and P contents are more in seeds than the respective pericarps. With regard to the partitioning of secondary and micronutrients, it was observed that, seeds contain higher concentration of all micronutrients including S and Mg than respective pericarps, whereas Ca concentration was slightly higher in pericarp than respective seed components. This differential partitioning of nutrients between seeds and pericarp components is attributed to their probable role in influencing the quality attributes and also due to genetic factors.

It is found that, pericarp component of first grade fruits contain significantly higher K than pericarp component of second grade fruits. Pericarp component of third grade fruits contain significantly lowest K compared to first and second grade fruits. Seed components of different grade fruits did not vary much with respect to the concentration of all nutrients and similar trend was observed for nutrient concentration in pericarps also except for K concentration. The nutrient concentration in pericarp follows the order K>N>Ca>Mg>S>P>Fe>Mn>Zn>Cu and in seeds the order is N>K>P>S>Mg>Ca>Fe>Mn>Zn>Cu.

The study of quality attributes revealed that, first grade fruits recorded higher quality attributes than second grade fruits and third grade fruits of Byadgi kaddi cv. recorded lowest quality attributes. Among the quality attributes, pungency, colour value and oleoresin yield are very important than ascorbic acid content which is of more value in fresh green fruits only. It is found that, ascorbic acid content did not vary much between first and second grade fruits in all the three cultivars, while it was low in third grade fruits of Byadgi kaddi cultivar. Among the three cultivars, fruits of Byadgi kaddi cv. contain highest ascorbic acid followed by fruits of Dyavnur and Byadgi dabbi cultivars. Further, fruits at turning red stage contain higher ascorbic acid than at green stage.

With respect to other three quality attributes, it is found that, though first grade fruits produced from deep black soil locations contained highest capsaicin and oleoresin, yet they did not differ significantly from second grade fruits produced from medium black soil locations. But with respect to colour value, significantly higher values were observed in first grades fruits than in second grade fruits. Similarly third grade fruits (Byadgi kaddi cv.) produced from red soil locations recorded lowest capsaicin and colour value and they differed significantly from first and second grade fruits with respect to colour value only and not for capsaicin and oleoresin. This suggests that, soil properties and cultivation practices influenced the colour value of fruits significantly, whereas capsaicin and oleoresin content were not much influenced by soil properties. It is found that, capsaicin synthesis is genetically controlled and marginal alterations in capsaicin content of fruits can be brought about by cultivation practices. The size and weight of fruit decides the oleoresin yield of fruits. Hence first grade fruits owing to their big size and weight yielded maximum oleoresin whereas, second grade fruits in Byadgi dabbi cv.

yielded very less oleoresin. Among the three cultivar, Byadgi kaddi fruits contain highest capsaicin and oleoresin whereas Byadgi dabbi fruits contained lowest and fruits of Dyavnur cv. were intermediate in capsaicin and oleoresin contents. With regard to colour value, fruits of Byadgi dabbi cv. contained highest colour value, whereas fruits of Byadgi kaddi cv. contained lowest and intermediate colour value was found for Dyavnur cultivar fruits. Comparison of these three cultivars with Sankeshwari and Guntur varieties revealed that, fruits of these two varieties contain higher capsaicin compared to Byadgi kaddi fruits. But, colour value of Sankeshwari and Guntur fruits was lower than that of Byadgi kaddi fruits.

Correlation studies revealed that, there exist negative relationship between soil bulk density and yield/quality of fruits, whereas significant positive relationship exist between yield/quality attributes and porespace, clay content, available moisture, silt + clay, CEC , exch K and organic carbon. With regard to nutrient status of soils and yield/quality attributes, available N and K status have significant positive correlation with yield and quality attributes. Particularly, capsaicin and colour value of fruits had significant positive relationship with available N and K of soils, respectively. Among micronutrients Cu and Zn had some significant relationship with yield and quality attributes.

Yield and quality attributes have significant positive relationship with uptake of all nutrients particularly at 75 and 140 DAT, whereas uptake at 105 DAT has no relationship yield and quality attributes except for N and S uptake.

With regard to the relationship between nutrient concentration in whole red fruit/pericarp and quality attributes, it was observed that, N content of whole fruits had significant positive relationship with all quality attributes while no relationship exist between N content of pericarp and quality attributes. But K content of both red fruit as well as pericarp had significant positive relationship with quality attributes particularly with colour value of fruits.

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* Original not seen.

APPENDIX

Appendix
DESCRIPTION OF SOIL PEDONS
Pedon-1

(Gudgeri deep black, Kundagol Tq., Dharwad dist.)

Location : Pedon is located 2.5 km away from Gudgeri village towards Saunshi village on the left side of railway line connecting Hubli and Kundagol town. Pedon occurs on nearly level topography and deep to very deep. Sy.No. 1/12.

Parent material : Gneiss

Depth (cm)	Description
0-15	Dark brown ((10YR 3/3 dry), very dark grayish brown (10YR 3/2 moist), moderate, medium subangular blocky structure, slightly hard, firm, sticky, plastic, smooth boundary, lime nodules.
15-30	Very dark grayish brown (10 YR 3/2 dry), black (10 YR 3/1 moist), moderate, firm, subangular blocky, sticky, plastic, many plentiful roots, gradual and diffused boundary
30-60	Very dark grayish brown (10YR 3/2 dry) and black (10 YR 3/1 moist), clay, moderate, medium subangular blocky, very hard, firm, sticky, slight effervescence with dilute HCl, slickensides few with gradual and smooth boundary, few roots.
60-110	Black (10 YR 3/1 moist and dry), clay, strong angular blocky, moist, firm, sticky wet and plastic, strong effervescence with dilute HCl, prominent intersecting slickensides, gradual and smooth boundary
>110	Black (10 YR 3/1 moist and dry), clay, angular blocky, firm, moist, wet, sticky and slickensides prominent and intersecting, shining, soft, effervescence with dilute HCl..

Additional notes : Byadgi chilli is being grown in this area for the last seven to eight years continuously.

Pedon 2

(Devanur deep black, Kundagol Tq., Dharwad dist.)

Location : Pedon is located about one km away from Devanur village towards Kamadolli village on the way Kundagol to Kamadolli.

Parent material : Gneiss

Depth (cm)	Description
0-15	Dark brown ((10 YR 3/3 dry), very dark grayish brown (10 YR 3/2 moist), clay, moderate, medium, subangular blocky, slightly hard, firm, sticky, plastic, slight effervescence with dilute HCl, smooth boundary
15-30	Very dark grayish brown (10 YR 3/2 dry), black (10 YR 3/1 moist), moderate coarse, subangular blocky, hard, firm, sticky, plastic, many fine roots, slight effervescence with dilute HCl, gradual and smooth boundary.
30-60	Very dark grayish brown (10 YR 3/2 dry) and black (10 YR 3/2 moist), clay, moderate, medium, angular blocky structure, very hard, firm, sticky, plastic, slight effervescence with dilute HCl, slicken sides, gradual smooth boundary
60-110	Black (10 YR 3/1 moist and dry), clay, strong, medium, angular blocky, moist, firm, sticky and plastic, strong effervescence with dilute HCl, intersecting slicken sides, gradual and smooth boundary, soft.
>110	Black (10 YR 3/1 moist and dry), clay, strong angular blocky structure, moist, firm, wet, sticky and plastic, slickensides intersected prominently, effervescence with dilute HCl.

Additional notes : Byadgi chilli is being grown in this area for the last five to six years continuously.

Pedon 3

(Ganjigatti medium black, Shiggaon Tq., Haveri dist.)

Location : Pedon is located half km. away from Ganjigatti village towards Hulagur town in . Sy No. 18/4. Pedon is located on slightly undulating land.

Parent material : Chlorite-schist

Depth (cm)	Description
0-15	Very dark grayish brown (10 YR 3/2 moist and dry), friable, sticky, fine roots, many lime nodules, effervescence with dilute HCl, smooth boundary, hard, wide cracks
15-30	Very dark grayish brown (10 YR 3/2 moist), dark grayish brown (10 YR 3.5/2 dry), sub angular blocky, plastic, lime nodules, effervescence with dilute HCl, clear and smooth boundary
30-60	Very dark grayish brown (10 YR 3/2 dry and moist), sub angular blocky, sticky and plastic, lime nodules, strong effervescence with dilute HCl, few roots, fine and hard.
60-110	Very dark grayish brown (10 YR 3/2 dry and moist), angular blocky with intersecting slicken sides, sticky, firm, medium sized nodules, strong effervescence with dilute HCl.
>110	Light gray and dark yellowish brown (10 YR 7/2) and 4/4 dry and moist), lime nodules, strong effervescence with dilute HCl, coarse, moist and no roots.

Additional notes : Chilli is being grown for the last three years.

Pedon 4

(Devagiri medium black, Haveri Tq., Haveri dist.)

Location : Pedon is located eight km away from Haveri town towards Shiggaon town on National Highway-4 near Devagiri cross on the right side.

Parent material : Chlorite schist.

Depth (cm)	Description
0-15	Very dark grayish brown (10 YR 3/2 moist and dry), friable, sticky, many fine and coarse roots, lime nodules, strong effervescence with dilute HCl, smooth boundary, granular structure, wide cracks, hard etc.
15-30	Very dark grayish brown (10 YR 3/2 moist), dark grayish brown (10 YR 3.5/2 dry), strong medium to coarse, sub angular blocky, sticky and plastic, very fine to coarse roots, lime nodules irregular in shape, strong effervescence with dilute HCl, clear and smooth boundary
30-60	Very dark grayish brown (10 YR 3/2 moist and dry), clay, angular blocky, very sticky, plastic, lime nodules, strong effervescence with dilute HCl, gradual wavy boundary, moist.
60-110	Very dark grayish brown (10 YR 3/2 dry and moist), gravelly, clay, angular blocky, few intersecting slickensides, sticky, firm, plastic, few roots inside peds, strong effervescence with dilute HCl, smooth boundary and coarse structure
>110	Dark yellowish brown (10 YR 4/4 moist) and light grey (10 YR 7/2 dry), gravelly, lime nodules, strong effervescence with dilute HCl, weak, slightly hard, moist and no roots.

Pedon 5

(Somanhalli medium black, Hirekerur Tq., Haveri dist.)

Location : Pedon is located half km away from Somanhalli village on the left side of road between Hirekerur and Somanhalli village. Pedon is located on nearly levelled land in Sy No. 23/3.

Parent material : Chlorite schist

Depth (cm)	Description
0-15	Very dark grayish brown (10 YR 3/2 dry and moist), clay, moderate coarse, sub angular blocky, slightly hard, friable, sticky and plastic, effervescence with dilute HCl.
15-30	Very dark grayish brown (10 YR 3/2 dry), very dark gray (10 YR 3/1 moist), clay moderate, coarse, subangular blocky, hard, sticky, plastic, strong effervescence with dilute HCl.
30-60	Very dark gray (10 YR 3/1 dry and moist), clay, coarse, angular blocky, hard, firm, sticky and plastic, few slicken sides, effervescence with dilute HCl.
60-110	Very dark gray (10 YR 3/1 dry and moist), clay, coarse, angular blocky, firm, sticky, strong effervescence with dilute HCl, few lime nodules, few slicken sides intersecting with each other
>110	Dark yellowish brown (10 YR 4/4 moist), light gray (10 YR 7/2 dry), gravelly, weak, slightly hard, effervescence with dilute HCl, few lime nodules.

Additional notes : Byadgi chilli is being grown in this location for the last two years.

Pedon 6

(Dharwad medium black, Dharwad Tq., Dharwad dist.)

Location : Pedon is located in D-block of Main Research Station, UAS., Dharwad in plot no. 96. Topography is nearly levelled land.

Parent material : Dharwad shale.

Depth (cm)	Description
0-15	Dark brown (10 YR 4.5/2 dry and 10 YR 4/2 moist), clay, strong, medium subangular blocky, hard, firm, sticky, plastic, medium roots, clear smooth boundary, slight effervescence with dilute HCl
15-30	Dark grayish brown (10 YR 4/2 dry), clay, dark grayish brown to very dark grayish brown (10 YR 3.5/2 moist), strong medium, subangular blocky, hard, very firm, sticky and plastic, fine roots, slight effervescence with dilute HCl, gradual and smooth boundary.
30-60	Greyish brown to dark grayish brown (10 YR 4.5/2 dry) clay, dark grayish brown (10 YR 4/2 moist), strong, medium, subangular blocky, prominent slickensides, hard, firm, sticky and few roots, diffuse, smooth boundary strong effervescence with dilute HCl.
60-110	Dark grayish brown (10 YR 4/2 dry), very dark grayish brown (10 YR 3/2 moist), medium subangular blocky, prominent intersecting slicken sides, very sticky, firm, hard, plastic, few fine roots, diffuse and wavy boundary, strong effervescence with dilute HCl.
>110	Yellowish brown (10 YR 5/4 dry), gravelly, clay, dark yellowish brown 10 YR 4/4 moist) weak, subangular blocky, slightly hard, sticky, plastic, medium lime nodules, strong effervescence with dilute HCl.

Pedon 7 :

(Savanur mixed red and black soil, Savanur Tq., Haveri dist.)

Location : Pedon is located three kms. Away from Savanur town towards Savanur raiway station on the left side of road. Pedon is situated at the foot hills with undulating topography. Sy. No. 106/1.

Parent material : Quartzite

Depth (cm)	Description
0-15	Reddish brown (5YR 4/4 dry) clay ; dark reddish brown (5YR ¾ moist) ; moderate, medium subangular blocky, slightly hard, slightly sticky, common coarse roots, smooth boundary
15-30	Dark reddish brown (5YR 3/4dry and moist) clay, weak, medium subangualr blocky, sticky and plastic, smooth boundary, slight effervescence with dilute HCl.
30-60	Dark grayish brown (2.5YR 3/4 dry and moist), weak, medium subangular blocky, hard, slightly sticky and plastic, few roots, coarse fragments, smooth boundary, moderate effervescence with dilute HCl.
60-110	Dark reddish brown (2.5 YR 5/4 dry and moist), fine subangular blocky, very hard, sticky, coarse fragments wavy boundary.
>110	Very hard, light reddish brown (2.5 YR 6/4 dry and moist), coarse fragments, slightly plastic, no effervescence with dilute HCl, subangular blocky

Present land use : Chilli and Jowar.

Pedon 8

(Kalagond shallow red soil, Hirekerur Tq., Haveri dist.)

Location : Pedon is located five km. away from Hirekerur town towards Ranebennur town and is situated at the foot hills on slightly undulating land, Sy. No. 53.

Parent material : Haematitic quartzite

Depth (cm)	Description
0-15	Yellowish red (5 YR 5/8 dry and 5 YR 4/6 moist), coarse, gravelly, sandy loam, moist, friable, non plastic, fine roots, common, diffused and smooth boundary. No effervescence with dilute HCl.
15-30	Reddish (5 YR 4/6 dry), gravelly, sandy clay loam, weak, slightly sticky and plastic (wet), few fine roots, smooth boundary, hard.
>30	Yellowish red (5 YR 5/8 dry), gravelly, non sticky, no effervescence with dilute HCl, sandy, coarse, non plastic.

Additional note : Byadgi chilli is being grown on this land for the last 2 years.

Pedon 9

(Thimmenhalli red soil, Byadgi Tq., Haveri dist.)

Location : Pedon is located five km. away from Byadgi town towards Belakeri village adjoining the main road. It is situated at the foot hills on a slopy land. Sy No. 22/3.

Parent material : Sandstone.

Depth (cm)	Description
0-15	Yellowish red (5 YR 5/6 dry), dark reddish brown (5 YR 3/4 moist) sandy, soft (dry), friable (moist), slightly sticky and non plastic (wet, many fine roots, diffuse and smooth boundary, no effervescence with dilute HCl.
15-30	Red (2.5 YR 4/6 dry), sandy clay, darkened (2.5 YR 3/6 moist), weak, fine, loose, subangular blocky, friable, few fine roots, diffuse boundary, no effervescence with dilute HCl.
30-60	Brown (7 YR 5/4 dry) ; dark brown (7.5 YR 3/4 moist), sub angular blocky, friable (moist), slightly sticky and plastic (wet), clear and smooth boundary
60-90	Dark brown (7.5 YR 4/4 dry and moist), fine subangular blocky structure, friable (moist), soft (dry), slightly sticky and plastic (wet), no roots, abrupt and smooth boundary, sand particles intermixed with clay in clods.
>90	Dark brown (7.5 YR 4/4 dry and moist), subangular blocky, moist friable, slightly sticky (wet), no roots, smooth boundary, flakes etc.

Pedon 10

(Asundi red soil, Ranebennur Tq., Haveri dist.)

Location : Pedon is located on fairly levelled land about one km. away from Asundi village towards Hanumanamatti, approaching national highway, Sy. No. 248.

Parent material : Dharwad schist.

Depth (cm)	Description
0-15	Dark red (2.5 YR 3/6 dry and moist), sandy clay loam, moderate, very hard, friable (moist), slightly sticky, few fine roots, no effervescence with dilute HCl
15-30	Reddish brown (2.5 YR 4/4 dry and moist), sandy clay loam, moderate, medium and subangular, hard, friable, no effervescence with dilute HCl.
>30	Gravelly, reddish brown (2.5 YR 4/4 dry) and red (2.5 YR 4/6 moist), loose, no structure etc.

Additional notes : Chilli crop being grown in this location for the last two years.

Pedon 11

(Annigeri medium black soil, Navalgund Tq., Dharwad dist.)

Location : Pedon is located on nearly levelled land about one and half km away from Annigeri town towards Navalli village

Parent material : Granite gneiss

Depth (cm)	Description
0-15	Dark gray (10 YR 4/1 dry) and very dark gray (10 YR 4/1 moist) ; clay, strong, medium, subangular blocky, slightly hard, friable, very sticky, very plastic, few fine roots, strong effervescence with dilute HCl.
15-30	Very dark gray (10 YR 3/1 dry and moist), clay, strong, medium, subangular blocky, hard, firm, very sticky, very plastic, very fine roots, strong effervescence with dilute HCl.

30-60	Dark gray (10 YR 4/1 dry and moist) ; clay medium, subangular blocky, slicken sides on ped surface, friable, sticky, plastic, strong effervescence with dilute HCl, few roots.
60-110	Very dark gray (10 YR 3/1 dry and moist), clay, medium, strong, subangular blocky, hard, firm sticky, plastic, slickensides on ped surface, strong reaction with dilute HCl.
>110	Very dark gray (10 YR 3/1 dry and moist) clay, strong, sub angular blocky, hard, plastic, firm, strong effervescence with dilute HCl.

Additional notes : Byadgi chilli (Dyavnur cv.) is being grown in this location for the last three years.

Pedon 12

(Yaliwal medium black soil, Kundagol Tq., Dharwad dist.)

Location : Pedon is located half km away from Yaliwal village on the left side of road connecting Yaliwal village and National highway Sy No.224/3

Parent material : Chlorite schist.

Depth (cm)	Description
0-15	Very dark grayish brown (10 YR 3/2 dry), very dark gray (10 YR 3/1), moist, coarse subangular blocky, slightly hard, friable, sticky and plastic, effervescence with dilute HCl, plentiful roots, lime nodules irregular shaped.
15-30	Very dark grayish brown (10 YR 3/2 dry) ; very dark gray (10 YR 3/1 moist) ; clay, moderate, subangular blocky, hard, firm sticky, plastic, strong effervescence with dilute HCl, plenty of roots.

30-60 Very dark gray (10 YR 3/1 dry and moist), clay, angular blocky, hard, firm, sticky and plastic, prominent slickensides, violent effervescence with dilute HCl.

60-110 Very dark gray (10 YR 3/1 dry and moist) ; coarse angular blocky, hard, firm, sticky, strong effervescence with dilute HCl, lime nodules, medium sized, white powdered parent material intermixed with soil.

>110 Very dark gray (10 YR 3/1 dry and moist), coarse, subangular blocky, loose, sticky, strong effervescence with dilute HCl, no roots.

Additional notes : Byadgi chilli (Dabbi cv.) is being grown in this location for the last five years.

Pedon 13

(Malligawad medium black soil, Hubli tq., Dharwad dist.)

Location : Pedon is located about two km. away from Malligawad village towards Gadag on the left side of road. It is situated on slightly sloping land (1 to 2%).

Parent material : Granite.

Depth (cm)	Description
0-15	Dark gray (10 YR 4/1 dry and moist) ; medium, weak, subangular blocky, slightly hard, friable, slightly sticky, plastic strong effervescence with dilute HCl, fine roots, lime nodules plenty.
15-30	Dark gray (10 YR 4/1 dry and moist) ; clay, subangular blocky, hard, friable, sticky, plastic, effervescence with dilute HCl, roots many, medium sized lime nodules
30-60	Very dark gray (10 YR 3/1 dry and moist) ; clay, medium, subangular blocky, hard, firm, sticky, plastic, slickensides on ped surface, strong effervescence with dilute HCl, few roots, few lime nodules

60-110	Very dark grey (10 YR 3/1 dry and moist) ; clay, medium, strong, subangular blocky, hard, firm, sticky, plastic, violent reaction with dilute HCl, no roots.
>110	Very dark grey (10 YR 3/1 dry and moist) ; clay, medium, subangular blocky, hard, firm sticky and plastic, violent reaction with dilute HCl.

Additional notes : Byadgi dabbi cv. is being grown in this location regularly for the last five years.

Pedon 14

(Saidapur medium black soil, Navalgund Tq., Dharwad dist.)

Location : Pedon is located one km. away from Saidapur village towards Gadag town on the right side of road.

Parent material : Granite gneiss.

Depth (cm)	Description
0-15	Very dark gray (10 YR 3/1 dry and moist) ; clay loam, moderate, medium, subangular blocky, slightly hard (dry), moist, sticky and plastic, lime concretions sparse, violent reaction with dilute HCl, diffused boundary
15-30	Very dark gray (10 YR 3/1 dry and moist) ; medium, subangular blocky, hard, dry, very firm, moist, very sticky, medium roots, clear and smooth boundary, strong reaction with dilute HCl.
30-60	Very dark gray (10 YR 3/1 dry and moist), clay, angular blocky, very hard dry, very firm, moist, very sticky, prominent, slickensides, strong reaction with dilute HCl, clear and smooth boundary
60-110	Very dark gray (10 YR 3/1 dry and moist), clay, moderate, angular blocky, very hard, dry very firm, moist, very sticky, very plastic, few fine roots, prominent slicken sides.

>110	Very dark gray (10 YR 3/1 dry and moist) ; gravelly, clay, sub angular blocky, moderate, very hard, firm, moist, few slickensides, strong reaction with dilute HCl, no roots.

Additional notes : Byadgi dabbi cv. is being grown in this location for the last 5 years.

Pedon 15

(Kurtkoti medium black soil, Gadag tq.,Gadag dist.)

Location : Pedon is located two km. away from Kurtkoti village towards Hulkoti on the right side of road connecting Kurtkoti and Hulkoti.

Parent rock : Granite

Depth (cm)	Description
0-15	Very dark gray (10 YR 3/1 dry and moist), weak, fine granular, loose, dry, firm, moist, sticky, plastic, strong effervescence with dilute HCl, clear and smooth boundary
15-30	Very dark gray (10 YR 3/1 dry and moist) ; moderate, medium and subangular blocky, slightly hard, firm, dry, sticky, few lime nodules strong reaction with dilute HCl.
30-60	Verydark gray (10 YR 3/1 dry and moist), moderate, medium, subangular blocky, strong reaction with dilute HCl, gradual and smooth boundary
60-110	Very dark gray (10 YR 3/1 dry and moist), coarse, angular blocky, very firm, moist, plastic, slight reaction with dilute HCl, gradual and smooth boundary.
>110	Yellowish brown (10 YR 5/4 dry), gravelly, dark yellowish brown (10 YR 4/4 moist), weak, hard, slightly sticky, loose, white coloured patches intermixed with soil particles in clods, slight effervescence with dilute HCl, loose structure.

Additional notes : Byadgi dabbi cv. is being grown in this location for the last two years.

STUDIES ON YIELD AND QUALITY OF BYADGI CHILLI (*Capsicum annuum* L.) IN RELATION TO SOIL PROPERTIES IN TRANSITIONAL ZONE AND PART OF DRY ZONE OF NORTH KARNATAKA

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ABSTRACT

Studies made on yield and quality of Byadgi chillies in relation to soil properties in Dharwad, Haveri and Gadag districts of Karnataka indicate that, deep black soils produced highest yield and first grade fruits, while red soils produced lowest yield and third grade fruits and medium black soils were intermediate in influencing the yield and quality of fruits. Nutient status of soils, moisture availability and other soil properties influenced the root growth and nutrient uptake by plants leading to variation in the yield and quality of Byadgi chillies.

Different grade Byadgi chilli fruits were analysed for physico-chemical characters, quality attributes and mineral composition. Further, pericarp and seed components were also analysed for minerals separately, to study their partitioning in fruit components and to establish relationship between quality attributes and mineral status of whole fruits/fruit components. Non significant difference existed between different grades of fruits for capsaicin and oleoresin contents, but significant difference existed for colour value of fruits with first grade fruits recording highest quality attributes followed by second and third grade fruits.

Mineral concentration in whole red fruits followed the order K>N>Ca>Mg>S>P>Fe>Mn>Zn>Cu and significant difference existed between different fruit grades for K concentration in whole fruit/pericarp component with highest concentration in the first grade fruits. Partitioning of minerals in fruit components revealed that, irrespective of fruit grade, all minerals except K and Ca gets partitioned more in seed than in pericarp.

Correlation studies revealed that, yield/quality attributes of chillies are negatively related to bulk density of soil, while other soil physico-chemical properties are positively related. Similarly, organic carbon, available N and K had significant positive correlation with yield/quality of fruits. Significant positive relationship between colour value of fruits and K concentration in whole fruit/pericarp component was observed.