1 INTRODUCTION

The horticulture sector contributes 14 percent to the agricultural GDP (Thapa, 1998). The share of horticulture to the agricultural GDP is increasing in recent years. Agricultural diversification and commercialization have drawn attention of the planners and policy makers in terms of generating major income, employment opportunities and biodiversity conservation (Gautam and Sara, 1995). The horticultural sector is more important than cereal particularly in hills farming system of Nepal and it helps in arresting the deteriorating hill economy and natural environment (APROSC, 1989). Commercial horticulture particularly citrus production in the mid-hills of Nepal is characterized by high altitude Citriculture.

Cultivation of fruit in homestead area in Nepalese agriculture is a traditional practice. It is grown in almost everywhere in the mid-hills (Shrestha and Verma, 1998). Among the other fruits, mandarin orange (*Citrus reticulata*, Blanco) is one of the most important species of genus citrus.

The agro-climatic condition of mid-hill regions of Nepal (MHR) account about 1.5 millions hectors is stretching from east to west ranging from 750 to 1350 m msl, characteristically rain fed agro-ecosystem, is favorable for the cultivation of citrus. The economic condition of the people in mid-hills can be raised significantly by bringing more area under citrus fruits and can also improve the present practices of fruit cultivation. Among the fruit crops for cultivation in mid-hills, citrus fruits received priority (APP, 1995). The total and productive area under citrus in Nepal are estimated to be 27,022 and 15,206 hectares, respectively and total production of fruits is estimated to be 1,64,075 m tones (FDD, 2006). Among the citrus, mandarin orange (*Citrus reticulato*, Blanco) is the most important fruit species of genus *Citrus*, (Joshi *et al*., 1995) which occupies 61% of total areas under citrus. Mandarin is successfully grown in about 50 districts stretching from Mechi to Mahakali zone of mid-hill districts and the cultivated area and fruit production is sharply increasing every year specially in the mid-hills of Western Development Region (NCDP, 1989; Chitrakar, 1990). Mandarin is very popular fruit of mid-hills with semi-commercial scale of production.

Mandarin orange is one of the major cash generating fruit enterprises in the mid-hills of Nepal along with staple crops such as maize, millet and wheat. Mandarin orange contributes to augmenting food availability, improvements in nutrition, employment generation and household income support along with maintaining the environment (Shrestha 1997; Aryal, 2001). It is also because most of the lands in the hills are suitable for fruits rather than cereal crops due to unique types of terrain and climatic condition (Chitrakar, 1990, Aryal, 2001).

Although, citrus is a major cash generating fruit enterprise in the mid-hill of Nepal, its production scale is still subsistence in nature (Subedi *et al*., 2000). The national productivity of existing orchard is very low (9 t/ha) as compared to 43 t/ha of other citrus growing countries (Ranjeet and G.C. 1997). However, in the recent years, production from subsistence level is shifting to commercial scale. The production and post-production problems are soaring up lately, affecting productivity and quality of mandarin and also discouraging to growers (Budathoki *et al*., 1989; Gurung *et al*., 1992).

The ideal deep, well drained, and sandy-loam soils have become increasingly inaccessible to citrus growing due to competition with other grain and vegetable crops. Therefore, the marginal, rainfed slopy, uplands of low productivity must be utilized to increase the areas under citrus. The expansion of acreages under citrus has brought under wide ranges of soil conditions but the production has not recorded a proportionate increase. Because of such a diverse soils suitability of citrus, there is a wide difference in productivity level from one soils to another even under similar management level. The differences in soil conditions caused variation in yield and orchard efficiency. So, far the soil is concerned, the most important condition influencing citrus growth and production is chemical environment such as maintenance of sufficient nutrients, and avoidance of excess of nutrients or other harmful conditions. Such soils constraints need to be wisely managed to get the best fruit yields for a given soil type.

Multiple problems and constraints in mandarin orchards in Nepal have been identified. The Inconsistent manuring practices are the most serious problems in mandarin growing pockets in the Central and Western Development Region (Budathoki *et al*., 1989); Gurung *et al*., 1992; Joshi *et al*., 1995). Most recently, a survey in mandarin growing pockets in Tanahun, Lamjung and Gorkha Districts has also identified several problems (Devkota *et al*., 2002). Among them, soil fertility management was the most prioritized problems ranked by the farmers. The plants producing performance have been declined over the last 10 years because of not following proper manuring practices and other general care and management.

Since citrus fruits are well-adapted to a wide range of soil types under varying climatic conditions that they need adequate nutrients for better productivity and quality. Mandarin like other fruit trees require a number of balanced mineral nutrients for its proper growth and development. A balance of essential nutrients both in the soils and in the plants is essential for high level of fruit production with better quality. Inadequacy of the nutrients leads to drastic reduction in yield and quality of fruits.

Farming systems in the hills are complex, diverse and predominantly resource poor. The hill soils are particularly vulnerable to losses of organic matter and nutrients through a combination of natural factors, heavy monsoon rainfall, the erosion prone nature of the soils, steep topography and people related activities involving a reduction in ground cover

(Tripathi, 1996). Citrus fruits are generally cultivated in the marginal upland, rainfed-agro-ecosystem where the returns are low and are not suitable for annual crops. In some areas of the hills, increasing cropping intensities, declining livestock numbers and low rate of FYM/compost application have contributed to a poor soil productivity (Tripathi, 1996). However, with the high demand of citrus fruits the use of organic sources are no longer adequate to replenish nutrients removed from the soil. The use of chemical fertilizers is an important option in order to sustain the increasing demand of citrus fruit. But, the continuous use of chemical fertilizers increases the soil acidity and decreases the availability of some of the micronutrients and hence, the imbalances of nutrient uptake by plant is created.

Since the mandarin is adapted under various soil conditions, soil fertility is affected with the variation in altitudes. Change in altitude determines the consequent fluctuations in climate, which could affect the growth of citrus. The climatic parameters are directly or indirectly influenced by altitude. Soil fertility is also equally affected by the variation in altitude in North-Eastern Region of India (Singh *et al*., 1989; Singh and Datta, 1983; Singh and Datta, 1989; Avasthe and Avathe, 1995). Altitudes act as fertility moderator.

Several efforts have been made to understand and recognize soil fertility problems in the hills (Sthapit, 1988; Subedi, 1989; Shah, 1991; Carson, 1992, Tamang, 1993; Joshi, 1995). Low and declining soil fertility has long been recognized as the most crucial problem by various workers (Hobbsal and Giri, 1992; Pandey, 1991; World Bank, 1990; Joshy and Deo, 1976). Therefore, management of soil fertility and plant nutrition is the key factor for sustaining agricultural productivity and environmental stability. Association of crop productivity trend with altitudes are expected. All of these factors may have significant relationship with soil fertility trends. A significant relation exists between fertility trends of khet and bari land and agroecological zones (Pradhan *et al*., 1992).

The deteriorating condition of citrus orchards in Nepal and abroad has been attributed mainly to soils related nutritional factors. Foliar and soil analyses of mandarin orchards are expected to affect by orchard performance namely healthy/unhealthy and bearing/non-bearing orchards and citrus growing belts located at different altitudes. These foliar and soil diagnostic techniques may be moderated by altitudinal variation and the orchard performances are utilized to assess the nutrient status realistically in the Mid-Hills of Western Regions (MHWR) of Nepal. However, more information on Local Mandarin varieties grown under a wide range of altitudes and orchard performances in MHWR's condition are needed to throw further light on nutritional dynamisms. With the agricultural intensification, the use of chemical fertilizer is increasing and the availability of manure and compost is decreasing. The organic sources are no longer adequate to replenish nutrients removed by crop from the soil.

There is awareness among the farmers that soil fertility is one of the major issues that governs the poverty and future production capacity of soil in the Western Middle Hill Region (WMHR) (Dhakal and Khanal, 2003). The most important issue is to maintain soil fertility with sufficient and balanced use of inputs especially chemical fertilizers (Shrestha, 1998; Ghale, 1996).

Among the factors responsible for citrus decline nutrient deficiencies, particularly N is majorly involved. This problem is more serious in low citrus growing altitudes (500-700 m msl.) facing southern slope compared to northern and high altitudes (Subedi *et al*., 1998).

The soils of mid-hills of Western region are poor in nitrogen requiring frequent yet split doses of fertilizer N (Dhakal and Khanal, 2003) applications.

Among the nutrients required for plant growth, N is usually required most often, due to high rate of depletion by plant use, leaching, volatilization, denitrification and N losses and assimilation by micro-organisms (Brradbent and Carlton, 1978; Volk, 1961). The Nitrogen fertilizer is generally required in greater amount by citrus than any other nutrients fertilizers. The N fertilizer amount, its methods of application and its interactions with other nutrients are known to affect the vegetative growth, yields and quality of citrus.

Nitrogen is found to be the most problematic nutrient for mandarin cultivation all over the world which affect the growth, yield and quality. One of the techniques for determining the relationship is to compare growth, yield and quality parameters with the N-fertilization practices. Mandarin though a major fruit crops in Nepal has received a little systematic research on nutritional requirements for optimum production and quality. A very little reliable literature is available about inorganic nutrition interactions with growth, yield and quality. Nitrogen fertilizer recommendation is highly variable and speculative. The N-requirement of citrus varies with the crop edaphic as well as atmospheric factors. Thus, it makes difficult to precise recommendation. Since mandarin has tremendous response potential of N-fertilization for quality and yield of crop therefore, its detailed study is imperative.

Optimum dose of N has not-yet been established based on scientific research for making judicious application of N to citrus in Nepal. Experimental evidences on N-fertilization are lacking.

In the second phase, nitrogen fertilization was found to be the most problematic nutrient based on literatures reviews and findings of the first phase of the study for mandarin cultivation.

Keeping aforementioned problems in view, this study was directed to find out the soils and plant nutritional dynamisms as affected by altitudes, bearing/non-bearing and healthy /unhealthiness of trees and to elucidate the roles of N on growth, yield and quality in the farmer’s mandarin orchards in the Mid-Hills of Western Region of Nepal.

Objectives

General objective of this study was to assess the plant and soils nutritional dynamisms at different altitudes, bearing and non-bearing, healthy/unhealthiness of trees and to suggest efficient N-fertilization practices of mandarin for optimal production with quality fruits under farmer's field conditions in MHWR of Nepal. The specific objectives were:

i) To assess plant and soils nutritional dynamisms of mandarin orange at different altitudes, bearing/non-bearing and healthy/unhealthy trees

ii) To correlate tissue test data with the soil test.

iii) To determine the nutritional status (constraints) of the mandarin orchard at different altitudes.

iv) To find out the balanced package for judicious N-fertilizer use in mandarins under farmers field conditions.

v) Overall, to suggest efficient fertilizer needs and practices for mandarin cultivation.

2 REVIEW OF LITERATURE

2.1 Part I: Survey of soil and foliar tissue of mandarin orange under farmer's field condition at different altitude, age and health of orchards in Tanahun, Lamjung and Gorkha districts.

2.1.1 Physical introduction to Nepal

As a Himalayan country, it exhibits a wide variation in its geographic settings so that the country has divided into three parallel ecological zones running from east to west – the Terai, the hills and the mountains. The northern high altitude belt referred to as the mountain region covers almost 35 percent of the total area and 1.7 percent of the area is under cultivation. This region at an altitude above 3,353 masl has an alpine climate with a considerably lower temperature in winter and includes perpetual snow, glaciers and high altitude river valleys where human habitation is sparse. The middle region called the hilly region or known as 'Pahad' in Nepal is a broad zone between Mahabharat Lekh' and main Himalayas. It covers 42 percent of the total area of Nepal in which 10.04 percent of the area is under cultivation. This region has a pleasant climate ground the year and the mornings and nights are cool. The region is quite extensive in west in comparison to central and eastern part of the country. This is a zone of innumerable North-South and East-West running valleys and mountains spars and ridges radiating in different directions. The region has average breadth from 50 to 100 km and elevation ranging from 6000 m to 3000 m. This is a complex region of low to medium hills and mountains, river basins and tectonic valleys. The southern region, most portion is low-lying plains know as Terai and it covers 23 percent of total area of the country in which 8.37 percent of the area is under cultivation. Terai region of the country has a hot humid climate.

There is marked variation in climate and rainfall due to the diverse topographic structure of the country. It encompasses almost all-climatic zones of the world ranging from tropical through temperate to alpine climate. In such a small country, the vertical variation causes a stark contrast in Nepal's meteorological variables, namely, temperature, moisture, wind and precipitation. Owing to altitude and locational setting intricate variations in climatic condition occur within a short distance. The mean annual temperature of the country is 15.5^{o}C, this decrease sharply as elevation increases from south to north. In the mid hills, the average maximum temperature is recorded as 12 deg.C which drops to a minimum of below freezing point (Silwal, 1993).

Similarly, the distribution of rainfall varies according to topography, an important controlling factor for precipitation. Since, the annual average rainfall for the country as a whole is 1000 mm, the volume of rainfall varies greatly from the northern mountain region to southern Terai ranging from 250 to 5000 mm annually while the northern mountain is the driest part. The central hill receives the highest rainfall. Almost 80 percent of the total rainfall is received during June to September and the rest mainly in winter. There is uncertainty of monsoon rainfall from year to year in the country.

2.1.2 Physical condition of western hills

Administratively and statistically, the middle hills are best defined as 35 districts out of 75 in Nepal, stretching from Dadeldhura in the West to Ilam in the East. It covers 62 percent of the total area. This region is pleasant all the year round and the mornings and nights are cool.

The western hills, the focus of the study, consist of the Mahabharat Lekh and lower foothills of Himalayas, which has an area of rugged mountain topography. The geomorphology is very complex and dominated by extreme relief provided by hills and valleys with continuous hill slopes from 600 to 3500 masl. The slopes of many of these hills are carved into innumerable terraces where agriculture is largely undertaken. Arable agriculture is practiced largely at elevation below 2000 m. Much of the area is dissected by north-south drainage system. In areas where rivers are passing, the river valleys are wide and topography is largely stabilized: in areas where medium to smaller rivers are flowing, river cutting in deep, erosion is high and landslides occur.

The hills of Nepal form a part of the Himalayan tectonic belt. The area is structurally complex. The hills and ridges are usually composed of hard rock, whilst in the valleys deposits of the soil weathered rock have been exposed (Wyatt-Smith, 1982). In the valleys below 800 m the soils are a thin layer of silt overlying a textural sandy loam. The soils are weak acid (pH 6.0-7.0) with a low cation exchange capacity but high base saturation, indicating that are reasonably fertile (LRMP, 1986).

There are wide microclimatic variations within the area resulting from the interaction of elevation with aspect, air movement and shading. So, the extreme microclimatic variation to the data available from weather stations are of little value, except where work is being carried out adjacent to a weather station site. Generally, the climate of this region is monsoonal in characters with 80-90 percent of annual precipitation occurring from June to September (HMG/N, 2000). The region also experiences non-monsoon rains. The contribution of this type of rainfall to total annual rainfall is very small, but is important. The upper portion of Gandaki catchment of Western hills occurs up to 10 percent of the rainfall during the winter months (Nelson *et al*., 1980).

The temperature displays seasonal variation, the coldest month being January and warmest May/June. Frost can be expected from the first week on December to the third week in February. Temperature is strongly modified by altitude and aspect. South facing slopes receive more sunshine than north facing. Slopes and temperature on the former can be expected to be higher. The climate is warm and moist.

The basic feature of the hills' resource base and production environment is referred to as mountain specificity, which mainly includes inaccessibility, fragility, marginality, diversity and human adaptations. In response to these characteristics, the western hill farming systems are complex, diverse and risk prone (Jodha *et al*., 1992). The land use pattern in the western hill is influenced by relief, climate and distribution of population. In general, the steeper the slope, the more the proportion of forest preserved; the higher the rainfall, the more the agricultural activity. Sal forest remains as a pure community on these lower hill slopes and in the valleys.

2.1.3 Agro-climatic diversity and citrus

There are three basic requirements for successful cultivation of citrus, namely, climate relatively free from frost hazards, good quality of irrigation water, and a reasonably deep and uniform fertile soil with good internal drainage (Nemec, 1986). Of these climate is the most important component of commercial Citriculture which determines the difference in growth, yield and quality due to differential behaviour of citrus in relation to climate-soil nexus (Cooper *et al*., 1963; Jones and Cree, 1964; Reuther, 1973a; Yelenosky, 1985; Cherkezishvill, 1987). However, citrus is well adapted to a wide range of climate from humid tropical to desert (Levy and Syvertsen, 1981).

Grigg (1969) advocated the climatic criteria as the best indicator of agricultural potentialities when world as a whole is being dealt with. But, in smaller areas, soil types and morphology, drainage conditions, and slope assume greater significance**.** Citrus is grown under a wide range of agroclimatic diversity, and continuous recurring efforts to exploit commercial cultivation of citrus may fail, if these exercises are not well substantiated by sound adaptability tests, and developing technology suitable for specific agroeco - situation. Citrus tree growth and fruit quality both are conditioned by climate in growing area (Cooper *et al*., 1966; Grierson and Ting, 1978).

Climate plays a very important role in yield and especially in fruit size, which is the single most important factor in determining the export value of various commercial citrus cultivars (Plessis, 1982, 1983; Sys *et al*., 1993) suggested various climatic norms for citrus. Sakamoto and Okuchi (1969) observed greater influence of meteorological features than fertilizers in Satsuma mandarin in Japan.

Quantification analysis regarding the contribution of environment and soil management factors on yield of Satsuma mandarin revealed that yield was more affected by physiographic environment than either climate or even fertilizer application (Egashira *et al*., 1990). But, Jones and Cree (1964) reported that high temperature (during the June drop period May to June) could be very detrimental to the crop size of Navel Orange.

2.1.4 Effects of altitude and soil fertility relationships on citrus culture

Citrus culture for the commercial purposes is being practiced at an altitude as high as 2400 m above seal level (Ding *et al*., 1990). Changes in altitude determine the consequent fluctuations in climate, which could affect the growth of citrus. The climatic parameters such as rainfall, wind, humidity, and light intensity are directly or indirectly influenced by altitude. Regardless of the altitude, the climate at a given site close to equator in the tropical areas differs from sites located at different latitudes in two major ways. First, the photoperiod of day length, which includes the number of hours with sunlight based on the time of sunrise, sunset is affected (Francis, 1972). And second, climatic factor that changes with the altitude is the seasonal variation in temperature.

The vegetational changes observed at various altitudes that occur, because the altitudinal gradients determine environmental gradients.

Soil fertility is also equally affected by the variation in altitude (Nakahara and Hada, 1963; Khera and Pradhan, 1976; Chakraborty, 1976; Ram *et al*., 1987; Lahiri and Chakravarty, 1989; Singh *et al*., 1990a; Walla and Chamuah, 1993; Lyngdoh and Shukla, 1993; Avasthe and Avasthe, 1995; Lahiri and Chakravarty, 1995; Dass *et al*., 1996; Singh *et al*., 1997b; Raychaudhuri *et al*., 1999a). Singh *et al*. (1989) observed altitude variation had little influence on pH, but strongly influenced the accumulation of organic matter and available P. While studying the changes in soil fertility under varying altitudes in Khasi hills of Meghalaya, organic carbon was deficient in 13 percent soils, P in 83 percent soils, and K. in 5.5 percent soils below 1300 m altitude. But, above 1300 m altitude, 55 percent, 48 percent, and 19 percent soils registered deficient levels of organic carbon, available P, and K, respectively. Relationship of changes in soil properties with altitudes showed that organic matter content decreased with fall in altitude. Low organic matter in valley soils was due to relatively higher temperature in lower reaches of the hills and regular cultivation. Better available water capacity under high elevation in strongly acidic soils of Mizoram, India has been reported by Singh and Datta (1983). The contents of SiO_2, K_2O, and P_2O, in these soils decreased with increasing of altitudes, whereas Fe_2O_3, Al_2O_3, TiO_2, CaO, and MgO content increased with decreasings altitude (Singh *et al*., 1991).

Singh and Datta (1989) observed decrease in pH, bulk density, soil depth, and porosity with altitude, while other soil properties like clay content in B horizon, silt content, and moisture retention increased with increasing altitude from 250 m to 1700 m in acidic hill soils of Mizoram, India. Avasthe and Avasthe (1995) showed much higher organic carbon, CEC, and sand at an altitude of more than 2700 m compared to 300-500m. While other properties viz., pH, silt, EC, exchangeable Ca, and exchangeable Mg recorded comparatively lower in soils at more than 2700 m against 300-500 m altitude in some acidic soils of Sikkim, India.

The critical limit has been evaluated for the soils of Meghalaya under the altitude range of 1000 to 1900m above mean sea level. The organic carbon content below 1.5, 1.5 to 2.25, and above 2.25 percent are rated as low, medium, and high, respectively, for evaluating N responsiveness. The above limits suggested that the existing limits (<0.5 percent as low, 0.5-0.75 percent as medium, and >0.75 percent as high) did not hold good for the soils of higher altitudes (Prasad *et al*., 1981). Minhas and Bora (1982) suggested various limits of organic C, less than 1.14 percent as low, 1.14-2.27 percent medium, and beyond 2.27 percent as high for high altitude hill soils. The soils fertility rating proposed by Mohr *et al*., (1965) has been quite useful in identifying the fertility constraints of horticultural crops including citrus grown in high altitude soils of Nainital (Divakar *et al*. (1989). Another soil fertility rating (Anonymous, 1994a) used for fertility evaluation of citrus growing soils of Nepal can also be used for fertility evaluation of high altitude soils.

Agroecological zones are synonymous with altitude and the sites are classified as high (>1100m), middle (700-1100m) and low (500-700m) sites in the citrus growing ranges. A significant relation exists between fertility trends on **Khet** and **Bari** land and agroecological zones. The incidences of increasing and decreasing soil fertility trends are higher in the low hills and more stagnant in the mid-hills. Decreasing trends are the highest in high hills (Shah, 1995). The pH shows the greatest response to elevation/aspect viz. the pH is low in the upper elevation.

Losses of Ca and Mg due to excess rain are high in the hills of Nepal. High leaching rates of basic cations (Ca, Mg, and K) have been reported by several researchers. (Shah, 1985; Shah *et al*., 1991). At high altitude of Nepal, soils are darker with high organic matter content. They are usually more acidic due to high rainfall which removes bases from the soil. With the oxidation of organic matter, acidity becomes a stronger limiting factor. Pine and pine litters have a tendency to acidify the soil (Shah, 1995; Schreier, 1994).

Mountain farming systems depend on symbiotic fixation of N plus animal manure, but substantial increase in levels can only be maintained through balanced used of fertilizers (Brady, 1992).

A system analysis of soil fertility in relation to mandarin orchard in the mid-hills of Western Region (MHWR), Nepal indicated that bearing trees are better cared than young seedling. There has been no consistent manuring practice in mandarin orchards (Joshi *et al*., 1995; Gupta *et al*., 1989) reported the deficiency of B, Mo, Cu, Ca, and Zn in potential mandarin growing pockets of Dhankuta District. Lohar (1985) observed poor fertility as one of the major constraints for low citrus productivity at Lohi (550m amsl), Bachegaon (7500 m amsl), and Bandipur (1000 m amsl) areas of Nepal.

Most of citrus growing soils are acidic in nature, which covers 49% of the total geographical area. In addition to soil pH, available Al, Fe, and Mn present in soil affect the crop yield at the toxic levels. Concerns over soil acidification have featured prominently (Shah *et al*., 1991). One of the major contributing factors to declined in soil fertility is the increasing menace of soil acidification (Tripathi and Shah, 1984; Turton *et al*., 1996), resulting in overall decline in productivity of citrus orchard adapting citrus based farming systems.

Soil Ca, and Mg experience a depleting pattern with citrus crop, the menace of which becomes increasingly more acute under no use of agriculture lime or dolomite. Uplands soils, mainly slopping terraces with rainfed citrus crop (**Bari),** losses in soil fertility are attributed to depletion of soil organic matter (Maskey *et al*., 2001). Various soil properties showed higher fertility of **Bari** than low land plain terraces with irrigation system, (Khet) land. The physicochemical properties at various land use patterns and physiographic position indicated most favorable physico –chemical properties under alley furit tree cropping.

Red soils are prevalent in the river basin, lower hills of eastern and western parts of Nepal. In the western hills red soils are dominant in **tars**, which comprise 2.3 percent of the total agricultural land in the research command area having 11 hill districts of ARS Lumle Research Command Area (Gurung, 1994). Vaidya *et al*. (1995) reported that red and black soils were the common soil types in western hills. Black soils are regarded as fertile soils, since they contain high organic matter, available P, and moisture content compared to red soils.

Shah *et al*. (1991) pointed out a problem of P fixation with Fe and Al oxides in red soils in Jikhu Khola watershed. Tripathi and Harding (2001) reported occurrence of large scale B deficiency in mandarin growing Bhorletar, Shishaghat, Dhimire, and Syaut areas of mid hill Lamjung and Bakrang, Ashrang, Ghairung, Tanglichok, Manakamana, and Gaikhur of Gorkha district.

The inherent nutrient holding capacity of the soils is poor, with low nitrogen and cation exchange capacity in the Eastern hills (Goldsmith, 1981). Soils are also generally, poor in available phosphorus; however, the amount is very often site specific and can vary from low to very high. At higher altitudes, available phosphorus is very low because of the strongly acidic soils which have pH values ranging from 4.7 to 5.9. Since the major minerals are feldspar and mica, the available potassium is medium to very high. Potassium, which is adequately available, is not fully utilized for increasing crop productivity because of the low nitrogen content of the soils. The acidic nature of the soil also hinders the availability of certain macro and micro nutrients. Organic matter content increases with increasing altitude and in general varies from 2.20 to 4.75%. The higher organic matter content at higher altitude may due to farmers applying higher doses of compost and FYM and lower temperatures which results in lower oxidation rates (Sherchan, 1987).

Information on the micronutrient status of the soils in the hills is limited. Gupta *et al.*, (1989) reported that boron, magnesium, copper, calcium and zinc are deficient in soils of the mandarin growing areas of Dhankuta district. Cabbage and cauliflower crops are already showing signs of boron and molybdenum deficiencies in areas where off-season vegetables and seed crops are being produced.

2.1.5 Effects of soil to leaf nutrient relation on citrus cultivation

The relationship between leaf nutrient content and soil fertility status helps to find out the expected response on the nutrition level of citrus tree as a result of change in fertility due to fertilizer application (Ko and Kim, 1987). A number of studies (Plessis, 1977; Koo, 1982) have shown significant correlation between soil Mg versus leaf Mg and soil Ca/Mg versus leaf Mg. With the type of relationship occurring between soil available nutrients and leaf nutrients, the expected response on leaf nutrient status can be easily simulated with change in availability of nutrients in soil due to fertilization. Dhillon and Dhatt (1988) observed that foliar K exhibited positive correlation with soil N and negative with foliar P. They further observed that foliar N, P, and K content were directly related with their respective nutrient content in soil in Ferozpur district of Punjab.Murthy *et al.* (1986) reported positive relationship (r=0.454) between P content of soil and leaf in Coorg mandarin (y=0.328 + 6.36x). Similarly, Mazuelos Vela and Gonazalez Garcia (1993) observed positive correlation between soil and leaf P in Seville region of Spain. Soil P had negative relationship (r=0.33) with leaf K. Plessis (1971) observed no correlation between leaf and soil P contents at 0.15 and 15.30 cm depth in Valencia orange orchards. Malewar *et al.*, (1978) depicted positive correlation between soil available Zn and plant Zn concentration. A synergistic relation between P and K has been observed in a 10 year old mandarin orchard having alluvial calcareous soil with pH 7.3 and fertilized with $N:P_2O_5K_2O$ at 250:250:120 g $tree^{-1}$, respectively. While, these nutrients interacted negatively on an acid podzolic soil with pH 5.8 fertilized with $N:P_2O_5:K_2O$ at 250:200:100 g tree-^{1}, respectively (Magnitskii and Takidze, 1972).

Anderson and Albrigo (1971; 1972) carried out two nutritional surveys to study the soil-plant relationship in dolomitic citrus orchards in central Florida and observed that none of the procedures provided soil Mg values that could be significantly related by themselves to leaf Mg. Plessis *et. al.* (1984) observed no correlation between leaf and soil Ca content in citrus orchard soils of South Africa, but good correlation existed between soil and root Cu content.

On the other hand, leaf Mg related negatively to the ratio of soil Ca/Mg. Kazak and Khalidy (1974) investigating the possible causes of nutritional disorders prevailing in Cenabose citrus orchards reported that leaf K was not related to the soil exchangeable K, but negatively correlated with leaf Ca. Leaf Mg correlated negatively with the K/Mg ratio in the soil, but showed no relation to leaf K, leaf Ca or NH_4OAC extractable Mg in the soil. Close association between leaf Mg and the K/Mg ratio in the soil indicated a probable antagonistic effect of high accumulation of K in the soil on the absorption of Mg. The high accumulation of K in the soil coupled with the low K content in the leaves was attributed to the antagonism of excess Ca on K absorption. Therefore, an attempt to correct the low status of K in the leaves by soil application without considering the level of available Mg in the soil aggravated Mg deficiency without necessarily improving the status of K in the leaves. Martin and Page (1965) suggested that the citrus leaf Ca and Mg percentages were much more closely related to the actual exchangeable soil Ca and Mg, respectively, than Ca-Mg or Mg-Ca antagonism effects.

Anderson and Albrigo (1977) later observed significant correlation between soil and leaf K in deep sandy soils of Florida. A similar observation had earlier been reported by many workers (Harding, 1954, Pratt *et al*., 1957; McColloch *et al*., 1957). The increase in N and K contents in plants with increase in soil available N and K has been shown by Hume *et al*. (1985a; 1985b) with positive correlation between soil and leaf Mg level in clay loam soils of Cook Islands. High leaf K level was observed to be associated with low soil Ca level in acidic soils of Florida and vice versa in alkaline soils of California (Chapman, 1949). Several researchers Bester 1969; Khalidy and Kazak 1970 and Braga 1970) reported that excess soil Ca and constant water shortage resulted in reduced in K and Mg level in tree tissue. Murthy *et al*. (1986) obtained a positive relationship (r=0.401) between K contents in soil and leaf of Coorg mandarin (y=1.16 + 2.82x). Leaf K and leaf Mn (r=0.561) also followed a positive relationship (y=11.2 + 66.9x). Leaf K correlated negatively with available N and P in soil, probably due to the presence of Ca. The dose of fertilizer can be streamlined based on soil fertility status in a given soil type and climate. Li *et al*. (1998) observed a significant correlation with total N/available K and hydroxydizable N/available K in citrus orchards of Fujian province of China. Beridze (1986a) observed that increasing exchangeable Ca and K in the soil intensified N re-utilization. The Ca blocked the K uptake by the plant, whereas Mg intensified K absorption in Western Georgian soils.

In citrus orchards survey, Shome and Singh (1965) observed a negative correlation of leaf Ca + Mg with leaf K content (r=0.62), irrespective of healthy and declining citrus orchards. Spencer and Wander (1960) observed a close relationship between leaf Mg and exchangeable Mg (r=0.85) in soil under Valencia and Pineapple orange on rough lemon rootstock. Symptoms of Mg deficiency in lemon appeared at leaf Mg level of less than 0.35 percent and soil exchangeable Mg less than 0.6 me 100 cm^{-3}. Later, other workers (Koto and Takeshita, 1959; Anderson 1971a; 1973; Caetano *et al*., 1984; Quaggio *et al*., 1992b; Dey and Singha, 1998) reported a close relationship between leaf and soil Mg content.

Anderson and Albrigo (1971) conducted multiple linear regression analysis to determine soil characteristics more related to leaf Mg and found that the ratio of soil Ca/Mg was the strongest independent covariable (r=0.51). Similar correlations had been obtained by Ibrikci (1994) between soil available N, P, K, Ca and Mg and their concentrations in leaf in mandarin orchards of coastal region of Tukey. Zhuang *et al*. (1984) on the other hand, observed no correlation between soil and leaf element content in mandarin orchards of Fujian, China, Oseni (1988) reported only 12 correlations significant out of 48 with regard to N, P, and K content in leaf versus soil relationship. Study further advocated that analysis of single nutrient status of tree might not reveal the true relationship, since it was affected by many other soil factors. Positive correlation between soil and leaf Zn, Mo, and Cu had been observed in citrus orchards of China (Quyang, 1993). Konli *et al*. (1993) observed that application of increasing levels of soil applied N/K ratio from 0.0 to 8.0 increased leaf N content from 2.10 to 2.92 percent and reduced the leaf K from 1.90 to as low as 0.90 percent (r=0.88). Srivastava *et al*. (1995) observed that significant correlation of soil available K and leaf K content in mandarin orchards of Kalmeshwar (r=0.85) and Katol (r=0.61) tehsils of Nagpur district, with negative correlation between N and K. Considering inverse N/K ratio as a better indice than monitoring leaf N and K individually, the leaf N/K ratio of 2.42 is suggested as an appropriate value for optimum productivity of Nagpur mandarin. The leaf micronutrient concentration showed a positive correlation with soil DTPA extractable micronutrients in mandarin orchards of Saoner and Hingna teshils of Nagpur district (Kohli *et al*., 1994). They further observed increase in leaf Fe by 8.2 mg kg^{-1}, Mn by 1.4 mg kg^{-1}, Zn by 13.3 mg kg^{-1} and Cu by 2.8 mg kg^{-1} with 1 mg kg^{-1} increase in DTPA extractable nutrient in Nagpur mandarin orchard soils in central India.

Better correlation of leaf B content has been obtained with saturation extract B (r=0.821) than with hot water extractable B (r=0.779). Saturation extract and hot water extractable B further correlated positively (r=0.736) with a linear regression equation, Y=0.38 + 1.47x, where Y stands for hot water extractable B and X saturation extract B (Elseewi and Elmalky, 1977). Plessis (1977) obtained higher probability of response with combined use of leaf and soil analysis norms compared to either leaf or soil analysis alone for P and K fertility evaluation. In a study on citrus response to salinity, Shalhevet *et al*., (1974) showed a 4.3 percent yield reduction per mel^{-1} increase in irrigation water chloride concentration for Shamouti orange on sweet lime. Positive correlation between leaf and soil B in sweet orange cultivar Pera on Rangpur lime rootstock in a red sandy acidic Latosol at Bebedouro, Brazil (Viti *et al*., 1993b).

2.1.6 Soil tests and soil fertility

The deteriorating condition of citrus orchards in India and abroad has been attributed mainly to soil related nutritional factors. Chapman (1961) suggested that no new orchard should be established without a thorough consideration of climate and soil characteristics.

Soil quality is a concept, which describes soil in terms of its capacity to perform three major functions, those of enhanced productivity, environmental protection, and health (Parr *et al*., 1992).

The soil singled out as the best or ideal in terms of productivity and represents the standard by which the other soils are judged (Connor, 1954; Ollier *et al*., 1971; Kotur *et al*., 1982; Dvorak, 1988; Osunade, 1988; Srivstava *et al*., 1999), provides a dress rehearsal for developing soil suitability guidelines for citrus. An appraisal of soil suitability criteria may, therefore, help to identify suitable soils, and scientifically expand the acreage under citrus, so that big existing gap between the present and potentially possible productivity level may be abridged by avoiding the risk of crop failure, due to soil related constraints.

Optimization of soil properties and condition has recently emerged as a promising field of study. It represents a new stage in managing soil fertility, in which the transition is made from simple improvement of soil properties to regulation of these properties aimed to bringing them into agreement with plant needs in order to achieve maximum yield. The central element of this new concept is the optimum value, best regarded not as a constant, but as having a range of values within the highest crop yield may be obtained, consistent with the potential crop varieties, climatic condition, and field management. The idea has become firmly established that the optimum value is a rather variable quantity, current models of soil fertility take little or no notice of this fact (Medvedev, 1990).

Use of soil testing, specifically for citrus as a guide for fertilizer recommendations has been restricted due to the lack of calibration for P and K in soils and crop response (Obreza, 1990); Hanlon *et al*., 1995). Shishov and Kapshuk (1984) suggested that reddish brown soils of the Tripolitanian costal plain of USSR were considered suitable for Citriculture, if the several soil properties criteria were met. Ko and Kim (1987) observed that high yielding orchards had high mineral content, but low in available P. Available N and P levels were high in orchard soils in which an early cultivar was grown, while Ca and Mg are high in those orchards soils in which an early cultivar was grown, while Ca and Mg were high in those orchards practicing cultivation of mid season cultivars in Cheju country of Korea with average values of soils as pH 5, 7, organic matter 8.9 percent, and exchangeable K, Ca, Mg, and N levels of 1.4, 6.7, 2.3 and 0.2 me 100 g^{-1} soil, respectively. Evaluation of various citrus growing soil series for citrus production in central Taiwan revealed the suitability of 27 soil series and 5 great groups. Orchards established on dark grey colluvial soils registered the highest fruit yield of 28.1 tons ha^{-1} and the lowest yield of 16.1 tons ha^{-1} on yellow earth soils. In terms of soil series, the soils in grey yellow colluvial soils registered the highest fruit yield of 39.6 tons ha^{-1} and 16.1 tons ha^{-1} in soils of Y and K in the yellow earth colluvial soils (Lay and Wang, 1997). Beridze (1987) observed the highest fruit yield of Satsuma mandarin (10-12 tons ha^{-1}) in soil having 31-49 mg 100 g^{-1} exchangeable K, 52-54 mg 100 g^{-1} Mg, and 197-223 mg 100 g^{-1} Ca with Ca: Mg 2.5:3.0 Mg : K_2O_3.0-4.0, and Ca : K_2O8.0-10.0 in Western Georgia. Soils maintained above 50-65 percent of exchangeable Ca and Mg under Valencia orange on rough lemon showed no response of Ca or Mg application (Aso and Dantur, 1971).

Growth of Satsuma mandarin trees is seriously depressed in the presence of 30 mg kg^{-1} Al (ionic concentration about 9 mg kg^{-1}) and 30 mg kg^{-1} Mn. Plants supplied with 30 mg kg^{-1} Mn contained 4000 ppm and 3600 ppm Mn in spring and summer leaves, respectively, compared to 500 and 580 ppm in control leaves (Otsuka and Morizaki, 1969). In Brazil, class limits of soil testing for citrus has been adapted from annual crops (Grupo Paulista, 1988). Earlier, Jorgensen (1978) suggested the soil fertility norms for Valencia to be grown in Queensland, Australia. Comparatively, recent works by Cantarella *et al*. (1992) and Quaggio *et al*. (1996) have established the specific calibration for P and K in soils, N content in leaves, and citrus responses to added fertilizer, based on a network of long term field trials. The results of these works and other previously published in Brazil and summarized by Malavolta (1992) helped to reevaluate the guidelines for citrus fertilization in Brazil, based on soil testing, leaf analysis, and yield goals (Grupo Paulista, 1994). Koo (1971) obtained high yield and quality of grapefruit and sweet orange at soil exchangeable Mg between 0.4-0.6 me Mg 100 cm^{-3}. Aso and Bustos (1981) working in several citrus regions of Argentina reported the appearance of hidden signs of Mg on soils having exchangeable Mg^{2+} less than 0.8 me 100 g^{-1}. Hidden hunger signs have been also induced due to high K content (K/Mg>0.4) or Ca (Ca/Mg>7). Maximum yield of Valencia oranges on Rangpur lime rootstock has been obtained when the exchangeable Mg in soil constituted more than 10 percent of total cation exchange capacity (Quaggio *et al*., 1992b).

Influence of various soil fertility levels on yield of Nagpur mandarin orchards in central India revealed that fruit yield increased from 4.4 tons ha^{-1} at 82.4 mg kg^{-1} available N 7.6 mg kg^{-1} available P, and 0.58 mg kg^{-1} available Zn to 38.2 tons ha^{-1} at 132.8 mg kg^{-1} available N, 17.4 mg kg^{-1} available P and 1.10 mg kg^{-1} available Zn considering 0.15 cm depth. Fertility variation at 15-30 cm depth had comparatively less magnitude of effect on yield.

Soil test values emerged from various citrus growing corners of the world, which could be used to great effect in evaluating soil fertility constraints of citrus orchards. Soil fertility evaluation rating for citrus growing soils was developed by Chapman (1961) showing the soil conditions responsible for development of nutrient deficiency could further prove very helpful in this direction. Smith (1975) suggested that citrus trees did not had a narrow optimal Ca requirement. Sys *et al*. (1993) suggested soil suitability criteria taking into account the characteristics like topography, wetness, physical properties, fertility, salinity, and alkalinity. Using similar parametric approach, Pati *et al*., (1999b) suggested soil and climatic norms for Nagpur mandarin grown under central Indian conditions. Comprehensive efforts made over the 10 years or so to develop soil suitability criteria in relation to productivity levels using multivariate quadratic response equation (Srivastava and Singh, 2000a; 2000b; 2000c) which provided useful information with regard to soil fertility evaluation of Nagpur mandarin orchard soils.

In the absence of soil suitability criteria, citrus growing soils are often misdiagnosed with the result the productivity potential of soils is under exploited. A number of recommendations for various soil properties have emerged which can be suitably utilized. A thorough soil suitability criteria in relation to productivity have been developed for Nagpur mandarin (Srivastava, and Singh, 1999a, 1999b and 2000).

2.1.7 Leaf analysis and soil fertility

Leaf analysis is generally preferred to soil analysis for most nutrients. The leaves integrate uptake of nutrients over an extended period and the tree is the most accurate soil extraction system to indicate adequacy of each nutrient. A yearly program of leaf analysis may be useful to citrus growers in assessing the overall nutritional health and fertilizer requirement of an orchard. As with soil analysis, proper leaf sampling is important (Koo *et al*., 1984). Fertilizer and cultural practices should be consistent over the sampled area.

Several extensive studies have been done on effects of leaf age, location on the shoot and fruit load on nutrient levels (Smith, 1966b). Generally, N.P. and K levels decrease from 1 to 4 months of age, while Mg and Ca levels increase. Levels plateau for leaves between 4 and 7 months, with values decreasing for all elements as leaves age and nutrients are tranlocated to newer developing tissues. Similarly, leaf N and K levels increase with leaf age within a shoot, with newly developing leaves having lower levels than older ones. Conversely, levels of P, Mg and Ca remain fairly constant along the shoot. Leaf nutrient concentration are also higher for non-growing compared with growing shoots, with the exception of P concentration which is relatively constant.

The presence of fruit on a shoot significantly decreases leaf nutrient concentrations of N, P, K, Mg and Ca in most instances (Smith, 1966b: Embleton *et al*., 1963). This is expected since leaves compete for nutrients with developing fruits. This is evidenced by leaf N and K levels being inversely related to cropland (Smith and Rasmussen, 1961). For example, leaf N ranged from 1.97 to 2.31% in heavy crop years to 2.55 to 2.75% in years with light crops, with differences in K varying nearly twofold between heavy and light croploads.

Therefore, leaf samples are usually collected from non-fruiting, fully expanded, 4-7 month-old leaves in most citrus regions, with the exception of South Africa where samples are taken from fruiting shoots. If micronutrient of fungicidal Cu sprays have been applied it is very difficult to remove contamination, even with acid washing, and analysis will be inaccurate. Leaf samples should be washed three or four times with deionized water before airdrying and shipped in paper or plastic bags to an appropriate laboratory for analysis. Typical ranges of leaf analysis for sweet oranges in several citrus producing areas are given. Values may differ slightly for grapefruit, lemons and other commercial cultivars (Embleton *et al*., 1978). Leaf nutrient classifications include deficient, low, optimum, high and excess. These ranges refer to yield and fruit quality responses.

Leaf analysis is a practical tool in determining fertilizer needs for citrus by developing leaf nutrient indices (critical level) for different elements responsible for growth and productivity. (Embleton *et al*., 1973; Kohli and Srivastava, 1997; Oppenhiemer, 1954; Srivastava and Singh, 1998; Srivastava *et al*., 1993).

The leaf sampling technique is a pre-requisite for development of leaf nutrient standards. Under hot sub-humid tropical climate of central India for Nagpur mandarin cultivar,6 to 8 month old leaves for **Ambia** flush and 5 to7 month old leaves for **Mrig** flush from any leaf position out of 2nd, 3rd or 4th leaf on a shoot at an height of 1.5 to 1.8 m from the ground and number of leaves as low as 30 covering 2% trees in an orchard will be sufficient to represent the nutrient status. While in acid lime 3 to 5 month old leaves were found suitable for leaf sampling (Srivastava and Singh, 1998; Srivastava *et al*., 1995; Srivastava *et al*., 1997; Srivastava *et al*., 1994). The use of spring flush leaves in Kinnow mandarin under Terai conditions has been recommended for collection of leaf sample to diagnose the nutrient status. The citrus growing countries depending upon soil, climate and crop variety utilize various leaf sampling periods. The leaf nutrient guide developed in

China for Satsuma mandarin and Valencia orange in Australia are also widely used. Little efforts have been made in the direction of developing such as leaf nutrient guide having wide acceptability.

The biggest practical utility of leaf nutrient standards is the perfect correlation of leaf nutrient levels with varying productivity. The leaf nutrient standards developed for Sweet orange cultivar, Washington Navel and Valencia are widely used for working out the nutritional status of citrus orchards (Embleton *et al*., 1973).

Optimum N levels for vegetative growth and yields are usually determined based on previous yields or through leaf analysis. Nitrogen – deficient leaves are distinctly light green to yellow in colour. The entire leaf becomes pale compared with the interveinal chlorosis which occurs with other nutrient deficiencies. Optimum levels of leaf N generally range from 2.5 to 2.7% for most cultivars. Ranges for leaf N for mature sweet oranges from several citrus regions are given. These ranges are intended as general guidelines and may not apply to every situation and cultivar (Smith, 1966b). Leaf N concentration is often much higher for young, nonbearing trees than for mature trees, particularly just after transplanting from the nursery.

2.2 Nitrogen management studies

Nitrogen plays a key role on the nutrition of plants. A large amount of N required by the plants is of special significance in fruit culture. Nitrogen status of soil depends on soil types temperature and rainfall. The top layer of cultivated soil usually contains less percent of nitrogen. The Nepalese soils are commonly deficient in nitrogen. Among the nutrients required for plant growth, N is usually required most often, due to high rate of depletion by plant use, leaching, volatilization, denitrification and N losses and assimilation by micro-organisms (Brradbent and Carlton, 1978; Volk, 1961). The climate, cropping patterns and soil management practices further aggravate the situation.

Continuous cropping with non-legumenous crops, clean cultivation which stimulates nitrification and burning of organic matter impoverish the soils of these elements.

2.2.1 Deficiency symptoms of N

Citrus requires large quantity of nitrogen for normal growth and productivity compared to phosphorus and potassium. The problem of low leaf N is common in Nepal (Sharma and Mahajan, 1990) as well as in many of the frontline citrus growing countries like Brazil (Rodriguez *et al*., 1977), Japan (Yuda, 1977), USA (Embleton *et al*., 1973) and upto some extent in Australia (Gollasch *et al*., 1984).

The Nepalese soils being low in N, the fruit trees grown under such conditions usually show signs of N deficiency.

The new leaves of citrus trees suffering from moderate or acute N deficiency tend to be thin and fragile when young and the angle between stem and leaf may be narrower than when N is adequate. The N-deficient leaves are smaller, uniformally dull green or yellowish. There is dieback of twigs and a gradual defoliation which results in thin, brushy appearance of tops. The trees suffering from chronic N deficiency are stunted, unsymmetrical in shape and twig growth. Such trees seldom die. There is great reduction in fruit production but quality is not seriously lowered. The juiciness may slightly increase and total solids are not much affected. The fruit rind is smooth, somewhat pale. The fruit size may be reduced (Chapman, 1968)

Smith (1969) observed stunted growth and light green to yellow foliage in citrus only under severe N deficiency. On the other hand, a different behaviors pattern consisting of premature defoliation and the consequential sparsity of foliage occurred under a moderate stress for N or where repeated additions of N were made. There was striking difference in tree appearance due to N level. On low N, the canopy of foliage was very thin and one could readily see through the trees. With higher rates, the canopy was very dense.

2.2.2 Correction of N deficiency

Under optimum soil conditions, weak and old trees can be reinvigorated and their production can be increased by supplying sufficient amount of N. It may take two, three or even four times more than the recommended rate of N application.

Considerable work has been done on the effect of N fertilization on the cropping and quality of different fruit crops. Various aspects of this problem which have been investigated include the amount and sources of N, and the time and method of application of nitrogenous fertilizers alone and in combination with other nutrients notably P and K.

Parkeer and Jones (1951) reported the results of a fertilizer experiment on Navel oranges during a period of 22 years. Several concentrated materials were found to be of equal value as sources of N during 1928-29 when applied at rates supplying 454 g. of N per tree annually.

Smith (1970) compared N sources and rates on old, high yielding ‘Valencia’ orange trees in Florida.

2.2.2.1 Effect of non vegetative growth

The adequate N supply essential for proper growth is accepted by all researchers. Smith *et al*. (1953) conducted an outdoor, sand culture experiment on ‘Valencia’ orange of tree levels each of N, K and Mg. Of the three elements, N exerted by far the greatest effect on tree growth. The highest rate of N application resulted in a doubling of tree dry weight and an increase in the dry matter percentage of all tissues. Smith (1970) working with old, high-yielding ‘Valencia’ orange trees in Florida found that thinness of foliage from premature leaf abscission was the most prominent symptom of inadequate N. There was a reduction in leaf size also due to low N. Reuther and Smith (1950, 1952) found that the tree growth as indicated by the percentage increase in the trunk cross-sectional area was increased slightly by heavy N fertilization. Reese and Koo (1974) applied four rates of N to sweet orange trees and found that the low rate of N produced less tree growth than the other three rates. On the other hand, Sites and his co-workers (1961) reported a reduction in tree vigor with more than 257.6 kg of N per hectare in grapefruit.

In young orange trees, 454g the first year, 908 g the second and two kg the third year of an inorganic 8-2-8 mixed fertilizers were sufficient for good tree growth. Timing of application of fertilizer was also not critical for young ‘Valencia’ or Hamlin’ orange trees (Rasmussen and Smith, 1961).

Smith (1965, 1985) studied the distribution of ‘Valencia’ orange rootlets in the top 1.52 meters of soil following several years of differential N applications. With N rates of 168 to 336 kg per hectare, a tendency existed for more roots at the lower rates but the differences were not significant, Smith et.al. (1968) found a distinct effect on N placement on root development in ‘Pineapple’ orange. At the end of ten years, there were 50 percent more roots in the bands receiving N than there were in the areas that did not receive N application.

2.2.2.2 Effects of N on young and non-bearing trees

A number of studies have been conducted on fertilization practices for young trees (Rasmussen and Smith, 1961; Marler *et al*., 1987; Willis *et al*., 1990, 1991; Swietlik, 1992). In general, young trees (nonbearing trees less than three years old) are fertilized more frequently than maturec trees, 4-6 times per year vs 2-3 times, using smaller amounts of material for each application. This is due to the relatively limited root zone, particularly of a newly planted tree. Fertilizer rates are based on tree age or size, soil type and growing conditions and may vary considerably among citrus regions.

Nitrogen is the most important element regulating growth of young citrus trees as during this time trees are growing very rapidly. It is not uncommon for tree trunk diameter to increase by 100 to 200% or more during the first and second growing seasons (Jackson and Davies, 1984) and canopy volume to increase tenfold in the humid subtropics. Other macro-elements, particularly P and K, are usually added to the fertilizer mix but have less impact on tree growth than N. In fact, studies from Florida indicate that leaf macronutrient levels from the nursery often are in the high to excess range. Similarly, leaf micronutrient levels are usually relatively high when the tree leaves the nursery and thus supplemental sprays or soil applications are not needed unless indicated by leaf analyses or nutrient deficiency symptoms (Smith, 1966).

2.2.3 Effects of N on yield and fruit quality

Considerable work on citrus fertilization has been done in Florida and California. Results of survey of the mineral nutrition status of 'Valencia' oranges in Florida (Koo *et al*., 1958) showed that N is the only element directly related to fruit production. Increase in the quantity of N applied was accompanied by an increase in fruit production, but the relation was not linear. Increase in yield became proportionately smaller as more N was added. Similarly, Parker and Jones (1951) also obtained marked yield responses from the application of nitrogenous fertilizers. In a long-term experiment, they found that 1.36 kg of N annually (half from a concentrated fertilizer, half from manure) with winter cover crops resulted in the highest yields and fruit sizes.

Nitrogen seems to be of special importance for citrus trees at flowering time. Generally, the number of flowers formed is dependent on the level to N in the tree as this element migrates from leaves to flowers at this time (Smith, 1966).

The highest rate of N application resulted in a nine-fold increase in yield, reduced fruit size, increased juiciness, increased total soluble solids and decreased ascorbic acid content as compared with the lowest rate (Smith *et al*. ,1953). Fruit-rind thickness and juice acidity were not appreciably different. In another experiment on young, bearing

‘Valencia’ orange trees growing on acid, deep sandy soil in Florida, Reuther and Smith (1950) recorded a sharp increase in yield as the rate of N fertilization increased.

This was highlighted by Smith (1970) whose work on 40-year old, high-yielding ‘Valencia’ orange trees in Florida showed that high N-fertilization need not be detrimental to citrus trees. He obtained appreciable increase in both quantity of fruit and soluble solids per unit area upto 400 kg of N per hectare.

Fruit size decreased in ‘Valencia’ orange when the leaf-N increased from 2.35 to 2.95 percent. When the leaf-N dropped below 23 percent, the yield was reduced in one out of six years. As the amount of N was increased, the peel of the fruit became rough and thick and there was a reduction in the percentage of juice. Jones and Embleton (1961 and 1967). Accordingly, N application should be so adjusted as to get high yields and yet have the least possible detrimental effect on fruit size and quality. Embleton *et al*. (1975) suggest that leaf-N level should be maintained in the lower part of the range for maximum production of good quality fruit.

An increase in N fertilization resulted in thick fruit rind, increased yield and sugar content and slightly reduced mean fruit weight (Ishihara et.al. 1965). Koo and McCormack (1965), Koo and Reese (1977) and Reese and Koo (1977) working in Florida found that high N rate (448 kg N/ha) in ‘Dancy’ tangerine and 266 kg N/ha/year in ‘Temple’ orange increased yield and acid content and reduced TSS/acid ratio, thus delayed fruit maturity. It also produced fruit with more traces of green than did the low N rate, although the difference was small. Aiyappa et.al. (1965) analysed leaves of seedling mandarin trees at Coorg and found 2.39 percent N in the fruiting terminals of healthy, high performing trees.

Regreening of peel especially in late cvs such as ‘Valencia’ orange increases with increasing N. As N is increased, the intensity of orange in the orange-coloured portion of the peel increases; but the total surface area showing orange is decreased.

Characteristically, a low-N furit is more uniformly pale orange as contrasted to a non-uniform intense orange and green of a high-N fruit due to more regreening on a portion of the surface of the fruit (Jones et.al.1968).

The young leaves are undersized, thin and fragile and develop a very light green colour, which may ultimately become yellow. If nitrogen is deficient when growth begins, its deficiency reduces growth rate and fruit production (Randhawa *et al*., 1967). Soils containing 110 kg/acre of easily oxdisable nitrogen are rated low in available nitrogen and are expected to respond to supplemental applications. Matured leaves of citrus well supplied with nitrogen usually show values above 2.4% total nitrogen in the dry matter of the leaf (Chapman, 1961; Embleton and Jones, 1963). There is considerable evidence to show that increasing applications of nitrogen significantly reduce the concentrations of PK at low but at high soil K levels both in leaves and roots. Nitrogen deficiency in declined citrus tree is widely reported (Awasthi *et al*., 1984; Goelho *et al*., 1984; Dhillon and Dhatt, 1988; Kohli *et al*., 1997). However, Dey and Singha (1998) observed no significant differences in leaf nitrogen contents of healthy and declined trees of mandarin in Assam. On the contrary, Wutscher *et al*. (Wutscher *et al*., 1980) reported higher leaf nitrogen concentrations in declining than in healthy grapefruit trees in South Texas.

As stated previously, fertilization of matured, bearing orange trees is necessary to replenish nutrients lost during harvest and leaching or volatilization, to maintain tree vigor and to obtain optimum yields (Smith, 1966a). Nitrogen has the greatest effect on tree growth and yields of all elements. For example, increasing the N rate for matured grapefruit trees in Florida initially produced a linear and significant increase in yields; however, at rates of above 200-250 kg ha-1 increasing N had a far smaller effect on yields. This law of the minimum, or the Mitscherlich effect, suggests that while N is necessary to obtain optimum yields, excessive N cannot be justified economically (Smith, 1966a).

Nitrogen increases yields primarily by increasing fruit number rather than fruit size. Moreover, trees receiving optimum N are more densely foliated and produce more flowers than N-deficient trees.

Several studies have been conducted worldwide to determine optimum rates and timing of fertilizer application, with as expected, variable results depending on location, cultivar and intended use of the fruit (fresh or processed). Long-term studies by Smith (1969) in Florida suggest that about 900 g N tree^{-1} annually is necessary to achieve optimum yields for matured grapefruit, and that multiple compared with single applications has little effect on yields or fruit quality. Similarly, Mungomery *et al*. (1978) found that 900 g N tree^{-1} was the annual optimum for matured Navel orange trees growing in Australia. They also observed that increasing N rates from 900 to 1350 g tree^{-1} did not increase yields, supporting Smith's previous findings. Twenty years of research from Brazil suggested that yields of matured 'Bahianinha' navel orange increased as N rates increased from 0 to 250 g of N tree^{-1} but no further increase was observed at 500 g tree^{-1} (Rodriquez and Moreira, 1969). These results were for non-irrigated trees, which may explain the lower optimum than in previous studies. They also observed that application of optimum levels of N and P together gave better results than either individually. DeVillers (1969) conducted a 6 year study on 'Washington' navel orange in South Africa found that about 1300 g N tree^{-1} annually produced optimum yields. Leaf mineral composition, growth and yields were compared over 9 years for 'Valencia' oranges in Arizona (Sharples and Hilgeman, 1969). Ammonium nitrate (granular) at nine annual rates from 0 to 3630 g of N tree^{-1} was compared with foliar urea sprays (230 g tree^{-1}). Little effect was observed on trunk growth related to rate or source; however, optimum yield occurred at about 600 g N tree^{-1}. Studies from Spain on 'Navelagte' oranges again suggested optimum N rates in the 1000 g tree^{-1} range (Legaz *et al*., 1981). Fruit weight tended to decrease with increasing

N rate probably due to increased cropload. In this study, split application of fertilizer and fertigation were superior to single or granular applications. Studies from Israel also support that view point, yet research from California (Jones and Embleton, 1967) and Florida (Smith, 1966a) suggest no yield advantage to split applications or use of fertigation for mature trees. Undoubtedly, climatic and edaphic differences between regions account for these conflicting results, although certainly optimum levels of N are minimized.

In most soils suitable for citrus, however, primarily N and K, which are readily leachable, are supplementally needed. Growing region also affects the amount of supplemental nutrition required. Regions with high rainfall and temperatures are more likely to lose nutrients from the soil due to leaching or volatilization. Cropload is also closely tied to fertilization program for mature trees since many nutrients are removed by harvesting the fruit. For example, a tonne of 'Valencia' oranges contains 1.31 kg N, 0.19 kg P and 1.8 kg K (Smith and Reuther, 1953). Therefore, an orchard producing 50 tonnes ha^{-1} would require 66, 9.5 and 90 kg ha^{-1} of N, P, and K to replenish nutrients lost during harvest alone. This does not account for losses due to leaching or volatilization or utilization of nutrients for vegetative growth.

2.2.4 Effects of N and its interaction with P and K on fruit quality

Nutrition and fertilization practices also influence fruit quality. Thus, varying fertilizer rates and the ratio of elements is used commercially to change fruit quality depending on market demands. Nitrogen, P and K have the greatest influence on fruit quality, provided that other elements are not severely limiting (Embleton *et al*., 1978). The general influence of N, P, and K on fruit quality also varies with species, with sweet oranges showing more response to N and P than lemons. Nevertheless, the general effects of changing leaf N levels from 2.0 to 3.0% dry weight for 'Valencia' a Navel sweet orange are given in (Embleton *et al*., 1978). As leaf N levels increase fruit size, juice content and ascorbic acid levels decrease. Effects on TSS and TA are inconsistent. Increased N levels in addition increase peel thickness and coarseness of peel texture and decrease peel colour. Therefore, leaf N levels in the excessive range adversely affect fresh fruit quality. These same trends also occur for navel oranges. Increasing leaf P levels from 0.10 to 0.21% dry weight generally slightly decreases fruit size, TSS, TA, ascorbic acid, and peel thickness and coarseness. However, P levels have less effect on fruit quality than N or K .Potassium levels in the leaf have a pronounced effect on fruit quality as they increase from 0.3 to 1.9% K on dry weight.basis Fruit size and peel thickness and coarseness increase with increasing K levels and juice content decreases slightly. Increased K levels also reduce the amount of fruit creasing.

Total Soluble Solids (TSS) and sugars showed significant positive correlation with available N content of soil. Reducing sugar of fruit juice correlates significantly with soil N and P contents (Reddy *et al*., 1992).

2.2.5 Nitrogen-interaction/correlation

There are several noteworthy interactions among the various nutrient elements. Nitrogen levels influence those of most other elements (Smith, 1966a). Nitrogen and P leaf levels are inversely related with N levels having a pronounced effect on P levels. The N interaction with K has been widely studied and most often these are inversely related. However, the ratio between N and K has a significant effect on yield and fruit size (DuPlessis and Koen, 1988). Maximum yield for ‘Valencia’ orange trees in South Africa was obtained at a N:K ratio between 2.4 and 3.0 on dry weight basis. Both N and K had to be at levels greater than 2.1 and 0.8% dry weight, respectively. In contrast, optimum fruit size was attained at a ratio between 1.6 and 2.2 with N greater than 1.8% and K greater than 0.9%. Most importantly, the greatest income was achieved at relatively low N levels. This situation occurs only for areas producing fresh fruit such as South Africa where fruit size and quality are directly related to income. Where citrus processing is more important than fresh production, N levels should be in the moderate range to attain maximum yields. The ratios used in this study may differ from those in other citrus areas of the world due to climatic factors and since leaf nutrient levels in South Africa are determined for fruiting rather than non-fruiting shoots. Nitrogen and Mg levels in the leaf are positively correlated and synergistic, while conditions which produce high Ca leaf levels generally depress N levels. Potassium interacts with other elements besides N, Potassium and Ca displace one another in the soil and thus are mutually antagonistic. 'Thus concentrations in the leaf are inversely correlated. Similarly, NH_4^+ and K^+ compete for sites in the soil lattice structure. Potassium in addition is a strong antagonist of Mg, although Mg has only a moderate effect on K levels. There are several other interactions among elements but these have less effect than the those mentioned above. Detail nutrient element intractions are reviewed by Smith (1966a).

Application of fertilizers and manures increased the plant growth and fruit yields tremendously in citrus. This has been demonstrated in Dhankuta and Lumle through research findings. A combination of fertilizer and compost used annually on mandarin orange increased fruit yield by 77% over the farmer's practices. Use of 20 kg FYM and green manure (of soybean) to one to two years old mandarin trees increased plant height by 53% over the farmer's practice (Subedi *et al*., 1995). These findings indicate that fruit trees respond to nutrient supplements in Nepal. It is suggested to use the recommended doses of manure and fertilizers for mandarins so as to get maximum fruit production. A similar recommendation is also available for citrus fruit crops (Shrestha and Upadhyaya, 1985).

Management studies in citrus orchards of Horticulture Farms of Government of Nepal have come up with some recommendation for managing trees in farmers' fields. Two to 3-year-old trees supplied with 65-130 g. nitrogen, 140 g phosphorus and 40-80 g potash have good growth. Tree below 12 years are recommended to supply nitrogen 0.4-0.5, phosphorus 0.3-0.4 and potash 0.4-1.0 kg. Half of the amounts should be supplied in May-June and rest in September-October to get higher yield (Ghale, 1996). Another study made at Lumle indicated that a combined application of compost (25-30 kg/tree) and fertilizer (0.700: 0.500: 0.600 NPK kg/tree) used to 8 to 12 year-old bearing trees annually increased fruit yield by 76.6% over the farmers' practice. This indicates that fertilizer requirements for small young non-bearing trees are lower than that for bearing mandarin trees.

The addition of N fertilizer in Nepal is not as high as in the developed countries; the increasing use of acid producing fertilizer such as ammonium sulphate and even urea slowly increases soil acidity (Sehreier *et al*., 1995). However, in the hills, farmyard manure still being major sources of plant nutrients. Although, in the accessible areas and intensively cultivated areas the use of chemical fertilizer is increasing due to reduced availability of organic manures (Tripathi, 1996).

Chemical fertilizers are the only easy and ready materials which can be efficiently used to replenish the deficit. The use of chemical fertilizers has increased steadily over the years (Pandey, 1993). The Agriculture Perspective Plan (1995) gives emphasis on the use of inorganic fertilizer research with indigenous technique and also relies heavily on the use of inorganic fertilizers.

The N, P and K requirements of different citrus species in various agro-ecological zone of India were standardized as 400:200-400 g/tree for Kinnow mandarin, 300:250:300 g/tree for Khasi mandarin, 600-800:200:100-400 g/tree for Nagpur mandarin, 400:200:200 g/tree for acid lime grown in Perryakulam (Singh and Nagvi, 2001).

In a review on N fertilization in citrus orchards, it was concluded that based on observation from several citrus growing areas in the world, that an annual application of

200 kg N/ha is sufficient to sustain good citrus yield and tree development. (Dasberg, 1983).

Assessment of nutritional requirement for mandarin, sweet orange and acid lime under different agro-climatic conditions indicates that citrus require 600-800 g. N 300-400 g P_2O_5 and 600-800 g K_2O /plant/year for bearing trees (Anon, 1991).

3 MATERIALS AND METHODS

This research was carried out in two phases. In the first phase of the project, it was directed to find out the soils and plant nutritional dynamisms and appraisal of nutrient constraints in the farmer’s mandarin orchards in the Mid-hills of Western Region of Nepal based on altitudes and orchards performances as reflected by overall trees healthiness and age. The relationship between plants and soil analyses were also established for recommendation of fertilizer practices in mandarins.

In the second phase, nitrogen fertilization was found to be the most problematic nutrient based on literatures reviews and findings of the first phase of the study for mandarin cultivation. Considering of the gaps, efficacy of N-fertilization practices were studied. With this in mind, four experiments were initiated to elucidate the roles of various levels of soil applied nitrogen, methods of N-application, and NPK - interaction on growth, yield and quality characteristics of mandarin.

3.1 Part I: Survey of soil and foliar (tissue) of mandarin orange under farmer’s field conditions at different altitude, age and health of orchards in Tanahun, Lamjung and Gorkha District

Duration: Fiscal Year 2002/03 or 2003/04

3.1.1 General description of the study areas

The map of Nepal depicting general location of studied areas are presented in Figure 1.

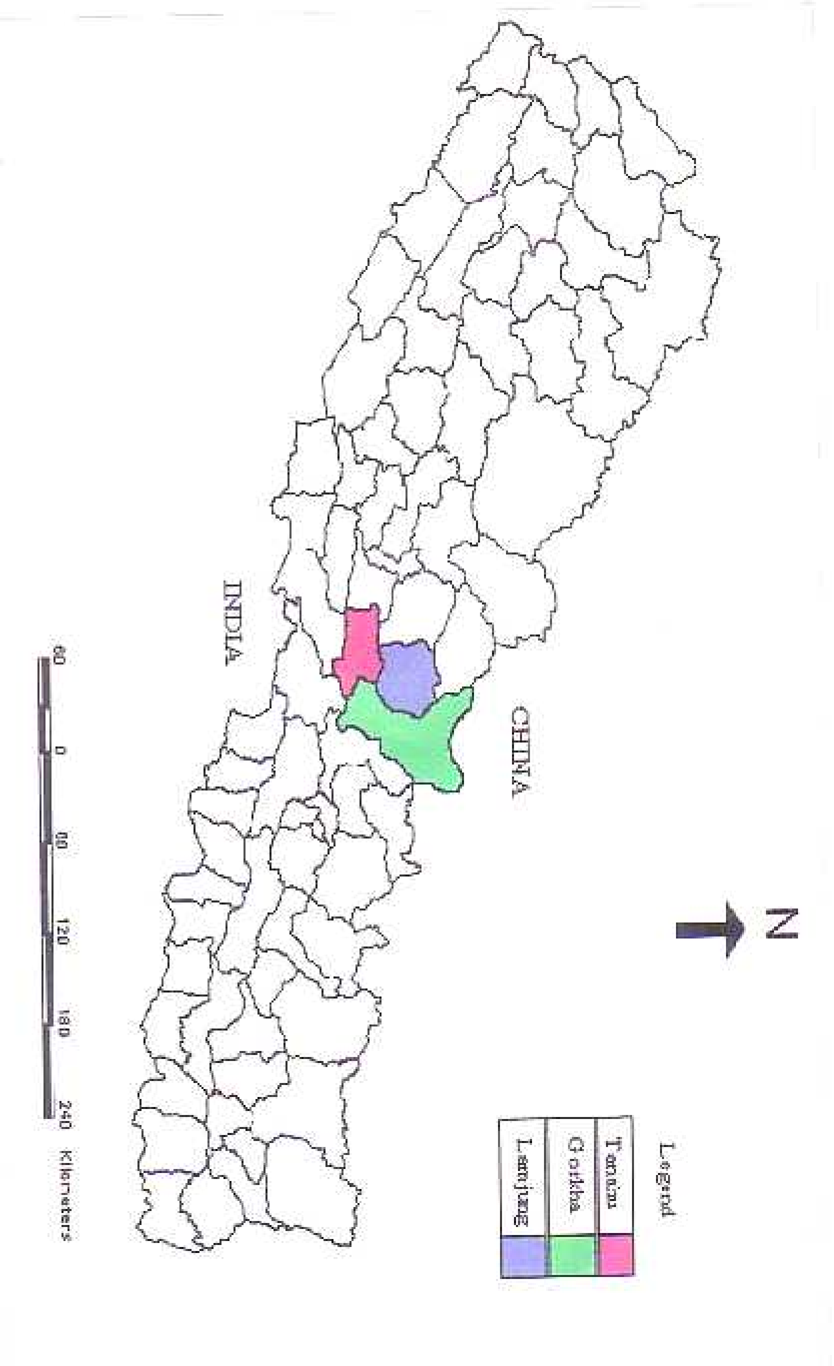


Figure 1. Map of Nepal showing the study sites

Tanahun District

Tanahu District is located in the Western Development Region of Nepal. Geographically, it lies at 27°36’ and 28°5’ North latitude and 83°57’ and 84°34’ East longitude with altitude ranging from 187 to 2134 msl and occupies an area 156877 ha. This district comprises 46 VDC and one municipality called “Byas Municipality”.

There are three different climates with respect to its geographic location namely tropical upto 1000 masl, sub-tropical between 1000 to 2000 masl and temperate over 2000 masl. The mean monthly temperature is about 2-3 ^{o}C. in January and about 38 ^{o}C in June (DADO, 2000). Heavy monsoon rain begins in May and ends in October. This monsoon comprises about 85 percent. Average annual rainfall ranges from 1500 to 3000 mm. District Agricultural Development Office (DADO) has given emphasis on horticultural development in this district. At present, fruit trees (citrus, temperate fruits and evergreen fruits) cover 1532.5 ha land on which citrus covers 808.5 ha. Mandarin is cultivated in 554 ha.

General site description

Lohi: The altitude of this site facing northern slope ranges from 550 to 700 m amsl. The brownish silty clay soil was acidic in reaction with low in total N and available P but high in K.

Aabukhairieni (500-650 m asl) and **Ghasikuwa** (altitude <700 m amsl) along the Marsyandi River were two specific sites selected in Tanahun.

Lamjung District

Lamjung District is located in the Western Development Region of Nepal. It is boarded by Gorkha in the east, Manang and Gorkha in the north, Kaski and Manang in the west and Palpa, Tanahun, Kaski and Gorkha in the south. Geographically, it lies at 28^{o} 3’ and 28^{o}33’ north latitude and 84^{o}41’ and 84^{o}85’ east longitude with altitude ranging from 793 to 8155 masl and occupies an area 1934 sq. km. This district comprises 37 VDC.

Similar to Tanahu, there are also different climates with respect to its geographic location namely subtropical, temperate, cool temperate, alpine and tundra. The mean annual minimum temperature is about 15 ^{o}C and maximum temperature is about 26 ^{o}C (Aryal *et al*., 1982). Heavy monsoon rain begins in July and ends towards October, this monsoon comprises about 80 percent of total rainfall. Average annual rainfall ranges from 2000 to 2500 mm.

Lamjung District has a total area of 2.61, 140 ha. Though it has a total cultivable area of 45.045 ha, only 33.470 ha is under cultivation. Government has given emphasis on horticultural development in Lamjung District. At present, fruit trees (citrus, temperate and tropical fruits) cover 1.096 ha land on which citrus covers 636 ha. Mandarin orange is cultivated in 542 ha.

Site description

Naruwal Village: It is located in 800 – 1000 m amsl. The soils was dark, silt loam, medium light and granulated structured. The pH were in acidic reaction. The soils were generally poor in nutrient status especially N. The slopes were faced to northern side.

Subedi Gaun: This site falls in medium altitudes (> 700-900 m amsl. Soils were generally lateritic on slopes, well drained, sily loam, good structure with pH of acidic side. The aspect faces to northern side.

Botechaur: It is located in medium altitude ranging from 800 to 900 m amsl. The soils are dark, granulated, medium to heavy texture with pH moderately acidic. The slopes were faced northern side.

Gorkha District

This district is also located in the Western Development Region of Nepal. Geographically, it lies at 27^{o}15’ and 28^{o}45’ North latitude and 84^{o}27’ and 85^{o}58’ East longitude with altitude ranging from 370 to 7177 masl and occupies an area 3610 sq. km. This district comprises 66 VDC and one municipality by “Prithivi Narayan Municipality”.

There are three different climates with respect to its geographic location namely tropical up to 1000 masl, sub-tropical between 1000 to 2000 masl and temperate over 2000 masl. Heavy monsoon rain begins in May and ends in October, this monsoon comprises about 85 percent. Average annual rainfall ranges from 1500 to 2000 mm.

With a total area of 361,000 ha. it had cultivable area of 55,656 ha., only 46,172 ha was cultivated. Government has given emphasis on horticultural development in Gorkha District. At present, fruit trees (citrus, temperate and tropical fruits) cover 1,096 ha of which citrus covers 636 ha. Mandarin orange was cultivated in 542 ha.

Site description

Nareshwor Village: The altitude of this village ranges from 1100 to 1300 m amsl. The soils were brownish silty loam, medium light texture, sloppy, upland and rainfeds. The slopes are oriented to northern aspects.

Bhogeteni Village: It is located at high altitude ranging from 1200 to 1300 m amsl. The soils were dark, red, fairly well drained, good structure, medium to heavy texture with moderate to high acidic. The slopes are faced to northern direction.

Manakamana Village: It is located at from 1000 to 1100 m amsl altitude. The soil of this areas were dark, red, deep, good structure, medium to heavy texture with moderately acidic. The slopes are also faced towards northern side.

3.1.2 Nutritional survey procedures

A nutritional survey of Local Mandarin orchards at Gorkha, Lamjung and Tanahun located in 9 sites (VDC’s), 3 from each district at high altitude (>1100 m msl), mid altitude (>700 m msl) and low altitude (<700 m msl), respectively were carried out across these districts. A total of 9 citrus pockets were utilized in the region representing three different altitudes. Matured and young healthy pockets and poorly managed unhealthy both matured and young orchards were taken for study to asses the nutritional status of the trees through the foliar and soil analyses.

Leaf sampling: The mandarin orchards were surveyed once in a year during the year 2002/2003 and 2003/2004 in December-January (Autumn flushed). Leaf samples were taken during these periods. Physiologically matured 6 to 8 months old 40-50 middle leaf samples from 2nd, 3rd, or 4th leaf from non-fruiting terminals (Figure 2) facing all four directions of the trees were collected. Plant samples were composited from five trees for each of the treatment/orchard as mentioned below.

Figure 2. Metyhods of leaf sampling taken from 4-7 months old leaves.

Leaf samples were collected in perforated paper bags which were taken to the laboratory for the sample preparation and the analyses. There were 12 plants samples from each district. Thus, a total number of the samples were 36 for 2002/2003 fiscal year. The same plant sampling procedures and sample number were also repeated for the second year 2003/2004 also.

Soil sampling: The soil samples were collected from the zones of maximum feeder root concentration at a depth 0-30 cm and at 1 m distance from the main trunk. Soil samples collected in cloth bags were taken to the laboratory for the sample preparation and the analyses. There were 12 soils samples from each district. Thus, a total number of soil samples were 36 for 2002/2003 fiscal year. The same sampling procedures and sample number were also repeated for the second year 2003/2004.

The soil samples were dried at an ambient temperature, ground and sieved through 2 mm sieve.

Treatments: The detail of the treatments were as followed:

A. **High altitude** (> 1100 m) Three mandarin pockets of Gorkha district were Nareshor, Bhogeteni and Manakamana

B. **Medium altitude** (>700m msl) Three mandarin pockets of Lamjung district were Naruwal, Subedi Gaun and Botechour

C. **Low altitude** (<700 m msl). Three mandarin pockets of Tanahun district were Ghasikuwa, Aabu Khaireni and Lohi

Leaf and soil samples from the 9 sites (VDC's) of the districts were sampled as given below:

T1 : Healthy fruit bearing and matured trees/orchards of more than 15 years old.

T2 : Healthy non-bearing and young trees/orchards of less than 5 years old.

T3 : Unhealthy bearing and matured trees/orchards of more than 15 years old.

T4 : Unhealthy non-bearing and young trees/orchards of less than 5 years old.

These treatments reflected the orchard performance at each altitude (district).

Each treatment was replicated 3 times for each district.

T1: Healthy fruit bearing and matured trees/orchards of more than 15 years old.

T2: Healthy non-bearing and young trees/orchards of less than 5 years old.

T3: Unhealthy bearing and matured trees/orchards of more than 15 years old.

T4: Unhealthy non-bearing and young trees/orchards of less than 5 years old.

3.1.3 Sample preparation and analyses

Plant analysis

The plant samples were prepared and analysed for major and micro-nutrients (Chapman, 1968, Jackson, 1978; Issac and Kesber, 1971). Drying of plant samples was done in an oven at 70 ^{o}C for 72 hours. Grinding of samples was done using grinder. The ground samples were stored in plastic bags. The ground plant samples were passed through 20-mesh sieve and 1 g sample was weighed for analysis. The nutrient deficiency symptoms in trees were photographed and were presented in the Appendix Figures.

Wet acid digestion: The prepared leaf samples were digested in di-acid mixture of 2 parts of H_2SO_4, plus one part perchloric acid ($HClO_4$). In addition, 30% hydrogen peroxide (H_2O_2) was combined to sulfuric acid (H_2SO_4) to hasten the digestion. The use of hot sulfuric acid (H_2SO_4) with repeated additions of 30% hydrogen peroxide increased the digestion to complete. This digestion procedure was worked best with small sample aliquots (0.10-025 g) and was used to prepare samples for the analysis of total nitrogen (N) and the other essential major elements and micronutrients (Wolf, 1982).

Total nitrogen (organic and ammonium forms minus nitrate). Modified macro Kjeldahl (HACH Kjeldahl digestion system, HACH Company) method: The basic principle of Kjeldahl procedure had remained much the same to day as described by Bradstreet (1965) and Morries (1983). The modified Kjeldahl method was used to determine the total nitrogen consisting of organic and ammonium forms. It was wet oxidiation procedure which utilizes sulfuric acid to digest organic matter in the plant sample. The digestion mixture consisted of sulfuric acid plus potassium sulfate 0.5 g/ml of acid. The addition of digestion mixture raised the boiling point of and speeded the digestion time. The amount of sulfuric acid consumed during digestion was determined for this total N estimation. Frequent rotation of the resting Kjedahl flask on the heating mantle was done during the digestion step to avoid ammonia loss. Copper sulfate had used as a catalyst in the digestion mixture with selenium. The time period required to clear the digestion mixture was extended by an additional equal length of time in order to obtain complete nitrogen conversion to ammonium. The sample size was 1.0 g. in order to have sample homogeneity. In this way, the organic nitrogen was converted to ammonium sulfate by the sulfuric acid during digestion. For the distillation of ammonium, the solution was made alkaline. The distilled ammonium was received in boric acid and was titrated with a standard acid.

Total phosphorus by vanadomolybdate-phoshoric acid yellow colour method: Acid-peroxide wet digested sample aliquots was used (Wolf, 1982). In an acid solution, 0.4 N acidity, orthophosphate combined vandomolybdate which formed a yellow colored solution complex. Molybdate – vanadate solution was made dissolving 25 g ammonium molybdate in 500 ml of distilled water with 1.25 g ammonium vanadate. 2 N nitric was used to make an acid solution. Standard phosphorus solution was prepared by dissolving 0.11 g monobasic potassium phosphate in distilled water having 25 ppm. Phosphorus solution. The total P was assayed with measuring percent transmittance at 420 nm and compared with that of the phosphorous standards using Spectrophotometer – 20.

Total K: Acid-peroxide wet digested sample aliquots of the above (Wolf, 1982) was used for the total K determination using Atomic Absorption Spectrophotography (Issac and Kerber, 1971).

Total Ca and Mg: Acid peroxide digested sample aliquots was used for determination of total Ca and Mg by Atomic Absorption Spectrophotography (Issac and Kerber, 1971).

Boron: In dry ashing, which was carried out in a muffle furnace, at 500 ^{o}C for not less than 4 hours. The ashing vessel was porcelain crucibles. The concentrated nitric acid was used as an ashing aid. The tissue in the ashing vessel was wetted with the reagent, the vessel was placed on a hot plate to bring the wetted contents to dryness, and the vessel was placed in the muffle furnace. The tissue was ashed in muffle at 500 ^{o}C for at least four hours. Then the ashing vessel was removed and cooled, and the ash was dissolved in 20% nitric acid in order to bring the ash into solution (Westerman, (eds.), 1990 and spectrophotometric analysis was used for B determination.

Fe, Mn, Cu and Zn : Acid-peroxide wet digested sample aliquot (Wolf, 1982) was used for total Fe, Mn, Cu and Zn determination by Atomic Absorption Spectrophotography (Issac and Kerber, 1971).

Soil Analysis: The soil samples were dried at an ambient temperature, ground and sieved through 2 mm sieve.

Soil reaction (pH): Soil extraction was prepared as soil: water ratio of 1:1 and the potentiometric method of pH determination with a pH meter was used (Jackson, 1973).

Organic carbon: Organic carbon was determined by Walkley – Black dichromate method (1934). Three basic steps were involved in the determination of the quantity of oxidizable soil organic matter: (1) treatment of soil samples with an excess of $K_2Cr_2O_7$, (2) the addition of a large amount of concentrated H_2SO_2 to the soil $K_2Cr_2O_7$, and (3) determination of the $K_2Cr_2O_7$ which was not reduced by the organic matter in the soil sample.

Total nitrogen: The modified Kjeldahl method was used to determine total N (Bradstreet, 1965; Morries, 1983). Digested samples were distilled and ammonium – N determined by titration with 0.05 N standard acid.

Available phosphorus: Bray and Kurt method (Jackson, 1973). Ammonium floride (0.03 NH_4F) in acid solution (0.1NHCl) as extractant in acid was followed for available phosphorus determination for the soil whose pH was less than 7.3 (Bray No.2 Method) while for soils whose pH were more than 7.3 the modified Olsen method (Dewis and Freitas, 1970) 0.5 M $NaHCO_3$ extractant followed by spectrophotometric determination.

Exchangeable potassium: The soil was extracted with neutral 1N ammonium acetate. Exchangeable potassium in the soil was replaced by ammonium ion and the K released into solution was estimated by flame photometric determination (Jackson, 1973).

Exchangeable Ca and Mg: The exchangeable cations were extrated with N ammonium acetate. The ammonium acetate extract containing the exchangeable cations was evaporated to dryness. The organic matter and the ammonium salts were destroyed by digestion with nitric and hydrochloric acid, followed by ignition at 390 ^{o}C. After evaporation with hydrochloric acid, the residue was dissolved in 0.1 N nitric acid. The exchangeable cations were then determined directly in separate aliquots (Black, 1965) using spectrophotometer.

Available boron: Hot water extraction method (Berger and Truog, 1939; Naftel, 1939) was followed for the determination of available boron. Spectronic – 20 was utilized for B estimation.

Available micro-nutrients: (Zn, Fe, Mn, and Cu). Ten g soil was taken and mixed with 100 ml of acid ammonium acetate. DTPA extraction solution was prepared according to the method described by Sillampaa 1982 and Mortvedt *et al*., 1990. and then it was shaken in horizontal mechanical shaker for about 2 hours. The sample solution was subjected to centrifuge for about 10 minutes to obtain a clear supernatant liquid. Zinc, Fe, Mn, and Cu were determined using Atomic Absorption Spectrophotometer (AAS) with background correction (Issack and Kerber, 1971).

3.1.4 Statistical design and evaluation

The years were arranged in a main plot and the different altitudes were organized in the sub-main plots and the productivity of the trees treatments in the sub-plot resulting into the split-split plot factorial design. Data were compiled from all sites and analyzed using GENSTAT 5.4 version and EXCEL software packages. The analysis of variance were performed using GENSTAT 5.4 version software. Plant and soil analysed data were undertaken looking at effects of altitude and orchard performances as reflected by the tree's health and age. Also, leaf was used as a primary indicator of nutrient status of orchards and while the soil analysis was used as an indicator of the nutrient sources available to the plants (Jorgensen and Price, 1978). The leaf and soil analyses were used as diagnostic tools for identification of nutritional problems of mandarin orchards.

3.2 Part II: Nitrogen nutrient management experiments

Description of site

The field experiment at the farmer's field was carried out from December - April in 2004/05 fiscal year at Dudhe Khuna, mandarin growing pocket of Tanahun district which was located in the Western Region of Nepal. This area falls in subtropical region with 600 to 700 m msl (low altitude), minimum monthly temperature is about 2-3 ^{o}C in January and about 38 ^{o}C in June. Heavy monsoon rain begins in May and ends in October; average annual rainfall ranges from 1500 to 2000 mm. monsoon rain comprises about 85%.

According to soil tests, the soil was classified as sandy loam in texture, pH ranged from 4.3 to 5.1 having N as low (0.06% N), available P as moderate (22 kg P_2O_5/ha), available K as high (505 K_2O kg/ha) and organic matter as low rating (1.2%), rainfed and upland soils. Soils were lateritic on slopes, red loam, fairly deep, well drained, and good structure. In general, soil fertility was poor in nutrient content.

History and management of tree

The mandarin orchard was consisted of one block with over 100 trees (Figure 3a, b, c, d). The seedling of ***Local Mandarin*** (Suntola) were planted about 3 m spacing between rows and plants in the rainy season of 1998/1999 year (Figure 4). The trees were planted in previously dug-filled pits and received 10 to 20 kg of FYM per tree annually during December-January. Besides, an optimal orchard management practices as recommended were given. Similar to other orchards, this mandarin orchard also did not receive any chemical fertilizers.

Experiment 1. Effects of different fertilizer package on growth, yield and quality of mandarin.

1	3	2	4	6	5	R_1	N
5	6	2	3	4	1	R_2	
1	3	2	4	6	5	R_3	
5	6	2	1	4	3	R_4	
1	3	4	6	5	2	R_5	
5	2	4	1	3	6	R_6	

Treatments:

1. FP Control
2. NPK + MN + L
3. NPK + MN (-L)
4. NPK + L (-MN)
5. NPK only
6. FP + L

Figure 3a. The layout showing the different N-fertilization management experiments.

Experiment 2. Interaction effects of major nutrients on growth and production of mandarin.

N

1	3	5	7	6	2	4	R_1
2	7	4	6	5	1	3	R_2
3	5	7	4	2	6	1	R_3
6	4	2	7	1	3	5	R_4

Treatments:

1. N = 200 g/plant/year (-PK)
2. P = 100 g/plant/year (-NK)
3. K = 200 g/plant year (-NP)
4. NP (-K)
5. NK (-P)
6. PK (-N)
7. NPK (all)

Figure 3b. The layout showing the different N-fertilization management experiments.

Experiment 3. Effects of soil-applied nitrogen on growth, yield and quality of mandarin.

N ↑

N_0	N_3	N_2	N_5	N_6	N_1	N_4	R_1
N_4	N_3	N_5	N_6	N_1	N_0	N_2	R_2
N_6	N_0	N_5	N_1	N_4	N_2	N_3	R_3
N_5	N_1	N_4	N_2	N_0	N_3	N_6	R_4
N_5	N_3	N_1	N_0	N_2	N_4	N_6	R_5
N_4	N_2	N_0	N_6	N_5	N_1	N_3	R_6
N_1	N_5	N_6	N_4	N_2	N_0	N_3	R_7

Treatments:

1. N_0 = 0 g N/plant/year
2. N_1 = 100 g N/plant/year
3. N_2 = 200 g N/plant/year
4. N_3 = 300 g N/plant/year
5. N_4 = 400 g N/plant/year
6. N_5 = 500 g N/plant/year
7. N_6 = 120 g N/plant/year

Figure 3c. The layout showing the different N-fertilization management experiments.

Experiment 4. Effects of methods of N-application on growth, yield and quality of mandarin.

N

N_1	N_3	N_4	N_2	R_1
N_3	N_4	N_2	N_1	R_2
N_2	N_1	N_3	N_4	R_3
N_4	N_3	N_1	N_2	R_4

Treatments:

1. N_1 = 2 splits (2 soils + 0 folio) - control
2. N_2 = 2 splits (1 soil + 1 folio)
3. N_3 = 3 splits (2 soils + 1 folio)
4. N_4 = 3 splits (1 soil + 2 folio)

Figure 3d. The layout showing the different N-fertilization management experiments.

Figure 4. Farmer's orchard hosting nitrogen management experiments.

Four experiments were undertaken to elucidate the role of various levels of soil applied nitrogen, methods of N application and nitrogen interaction with P and K on growth and quality parameters of locally grown most popular variety ***'Local Mandarin'*** (*Citrus reticulata*. Blanco). Therefore, overall, these experiments suggest efficient N-application through the complete package with N-K combination fertilizers, amount and method of N application was expected to produce optimal fruit yield and quality.

Local mandarin (Suntola)

It is commercially grown throughout the Mid-Hills of Nepal known by different names locally. Its tree is medium to large with erect habit, dense foliage, both thorny and thornless; fruit depressed, globose-ovate, orange – yellow to bright orange, surface smooth, base even, short-necked, segments 8-10, abundantly juicy, juicy orange color; seed 9-25, loose skin and flowering in March – April and fruiting May – June.

Experiment No. 1: Effects of fertilizer package on growth, yields and quality of mandarin under farmer's conditions in MHWR of Nepal

The experiment was designed to determine the roles of different yield components and to identify yield constraints fertilizer package for the successful production of mandarin orange.

Description of the treatments

Fertilization: The plants were fertilized with inorganic fertilizers @ 200-100-200 g NPK/plant/year. Full dose of P_2O_5 and K_2O and half dose of nitrogen were applied to each randomly designated trees on February 1st, 2004. These N, P_2O_5 and K_2O nutrients were supplied through urea (46% N), α-Di-ammonium phosphate (18% N + 48% P_2O_5) and muriate of potash (60% K_2O), respectively. Fertilizers were placed in a 30 cm wide circular band, 10 cm deep trench, between 100 to 125 cm radial distances. Remaining nitrogen was applied during first week of June. In the same year, 2 kg agri-lime per tree was broadcast around the canopy of the tree according to the treatments applied to reclaim the soil as per recommendation made after the pH of the soils assessment.

Treatments

1= Farmer's practices @ 30 kg FYM/plant/year (FP - control)[1]

2=200: 100: 200g-NPK/plant/year (NPK[2]) + Spray of Micro-nutrient (MN[3]) + (L[4]) Liming (complete package)

3=NPK+MN (-L)

4=NPK+L (-MN)

5=NPK only

6=FP+L

1 = Farmer's practices; 2 =200: 100: 200g-N, P_2O_5, K_2O/plant/year; 3 = Commercial formulated containing all micro nutrients; 4 =Agri.- lime @ 2 m tons per hectare (2 kg/tree).

Micro-nutrients (MN) sprays: Micro-nutrients were applied through foliar spray of Plantoplex (0.05%, W/V in water) in March at early – flushed stage and June when the flush of leaves fully expanded of 2004.

Farmer's practices (FP): 30 kg per plant of FYM was applied in the month of January/February every year.

Irrigation: The trees were kept as rain-fed conditions.

Mulching: All the trees were mulched uniformly with locally available materials (grass, straw and dried leaves) after February's fertilization.

Training and Pruning: All the dead, dried, diseased and broken branches were removed, water shoots and suckers crossed and crowded branches were thinned-out and headed-back as per requirement.

Insect pests/diseases control: Red and brown scale were major insects appeared as problematic. For the problem, it was managed using Metasystox and Rogors available in the market during Mid-March, early May and early August as per requirement. Bordeaux mixture/paint was applied as foliar spray (1%) or painted around the tree in January, May and September to control root rots, citrus cancker and pink diseses.

Application of treatments: All the above treatments were applied randomly to the trees in a randomized – complete – block- design (RCBD). The trees were blocked based on uniformity i.e. vigor, soils conditions and slopes. The treatments were replicated six times and one tree per treatment was utilized for imposing the treatments.

Experiment No. 2: N–interaction effects of major nutrients on growth and production of mandarin

This experiment was aimed to assess N fertilization interaction with P and K nutrients on growth, yield and quality parameters of mandarin.

Treatments

1=Nitrogen @ 200 g/plant/year.

2=Phosphorus @ 100 g/plant/year (–NK).

3=Potash @ 200 g/plant/year (-NP)

4=NP(-K)

5=NK(-P)

6=PK(-N)

7=NPK[1]

1 =200: 100: 200g-N, P_2O_5, K_2O/plant/year.

All the aforementioned treatments were arranged in randomized complete block design with four replications. One tree per treatment was utilized.

The detailed of the management of this experiment was the same as the Experiments No. 1 as above and when it was needed.

Experiment No. 3: Effects of soil applied nitrogen on growth, yield and quality of mandarin

The experiment was undertaken to relate different levels of nitrogen to various growth, yield and quality parameter in farmers field conditions for optimal mandarin production.

Treatments

1 = 0 g. N*/plant/year + PK** + MN***

2 = 100 " " "

3 = 200 " " "

4 = 300 " " "

5 = 400 " " "

6 = 500 " " "

7 = 120- 86 – 36 g. N, P_2O_5 and K_2O /plant/year (GO's recommendation).

** 100 : 200 g. P and K/plant/year ; *** Spray of commercial micro-nutrient formulation

Government's recommendation (GO's): Three parts of di-ammonium phosphate (18 percent N + 48 percent P_2O_5), one part of urea (46 percent N) and one part of muriate of potash (60 percent K_2O) at the rate of 300 g/plant/year i.e. 60:86:36 g N, P_2O_5, K_2O, respectively were applied to each randomly designated tree in first week of February, 2004. The second split of N application @ 60 g /plant was applied in first week of June of the same year.

All the aforementioned treatments were arranged in randomized complete block design with seven replications. One tree per treatment was utilized.

The detailed of the management of this experiment was the same as the Experiments No. 1 as above and when it was needed.

Experiment No. 4: Effects of methods of N application on growth, yield and quality of mandarin

This experiment was conducted to observe the effects of various N-methods of application on growth, yield and quality of mandarin oranges.

Treatments

1. N_1 = 200 g./plant/year : 2 spilts: (2 soils + 0 foliar) = control
2. N_2 = 200 g./plant/year : 2 spilts: (1 soils + 1 foliar) + PK* + MN**
3. N_3 = 200 g./plant/year : 3 splits: (2 soils + 1 foliar) + “ “
4. N_4 = 200 g./plant/year : 3 splits: (1 soils + 2 foliar) + “ “

*100 : 200 g. P and K/plant/year ;

**Spray of commercial micro- nutrient formulation

All the aforementioned treatments were arranged in randomized complete block design with four replications. One tree taken as treatment unit per treatment was utilized.

The detailed of the management of this experiment was the same as the Experiments No. 1 above as and when it was needed.

One tree per treatment was utilized for the administering the dose of N fertilizer. Two percent foliar spray of urea was done during second week of March, 2004. The second foliar spray was performed. When the flush of leaves fully expanded in second week of June.

General growth measurements

Number of new developing leaves, length of new vegetative shoot, number of flowers, immature fruits and matured fruits were obtained from four middle branches taken from the four sides of corner.

Observation on number of flushing month, length of newly grown vegetative shoots (dry matter accumulation) and number of leaves per branch before and after treatment application were recorded. Seasonal cumulative shoot elongation in two major flushes or almost continuously were measured and cumulated for 2 seasons i.e. spring and autumn flashes. Number of leaves per branch were recorded twice after 4-6 weeks of full bloom. Flower and fruit set number per branch after the treatment application were recorded. Flower and fruit set number per branch at initial time were also recorded. Mixed shoot blooms were utilized for the flower counting.

Harvesting procedures

Yield on the whole tree basis was recorded at each harvesting during first week of December, 2004 and accumulated in order to obtain a total production. In addition samples of 20 fruit were taken for recording weight, size, and quality to determine treatment effects.

Twenty fruit samples from each treatment were taken to the laboratory during the first to second week of December, 2004 to assess quality parameters. Weight of 20 fruits diameter (D), and length of the fruits (L) using Vernier Caliper and fruit texture by Fruit Pressure Tester (Magness Corp. Ltd.) were measured. Length (L) and Diameter (D) ratio was calculated in order to have the idea of the shape of the fruits. After, the sample was peeled off, the peel diameter was recorded by Vernier Caliper. The number of segments were counted and peel weight was also taken. Then, the fruits samples were crushed to record the juiciness (%) and number of seeds and weight. A-10 ml sample of the juice pipetted into a beaker. The total titratable acidity was determined (Hortwitz, 1960). The acidity was expressed as percent of anhydrous citric acid. For calculating sugar and acid ratio, the percent of total sugar was divided by percent acidity. The details were as follows:

Total soluble solids brix

Total soluble solids brix were determined by hand held Refractometer (Model: Erma, Japan). Correction factor was added on refractometer reading because the room temperature was above 30^{o}C. Before recording the observation, calibration was done by adjusting the knob on Refractometer.

Titratable acidity (%)

Titratable acidity was determined by titrating pulp juice against 0.1 N NaOH using phenolphthalein as an indicater, Titratable acidity was calculated (as critic acid being dominant acid by using the following fomula (Saini *et al*., 2001).

$$\text{Titratable Acidity}\,\% = \frac{\text{Na x Va x Milliequivalent wt. of predominant acid x 100 x d.f.}}{\text{Volume of the sample}}$$

Where, Na = Normality of base (NaOH)

Va = Volume of the base

d.f. = Dilution facto

Milliequivalent wt. of predominant acid i.e. citric acid = 0.067.

Juice percentage

Amount of juice was measured by squeezing the pulp and Juice percent was calculated by using following formula:

$$\text{Juice percent} = \frac{\text{Amount of juice (vol.) x 100}}{\text{Total weight of pulp}}$$

TSS/TA ratio

The TSS/TA ratio was calculated by dividing the percentage of TSS with the percentage of titratable acidity.

Statistical design and analysis

All the treatments from each experiment were arranged in RCBD. Data were compiled from each experiment and analysed using GEN STAT5.4 version and EXCEL software packages. Analysis of variances and DMRT were undertaken to determine the treatments effects validity on vegetative, yield and quality parameters of mandarin.

4 RESULTS

4.1 Part I: Survey of foliar (tissue) and soil of mandarin orange under farmer's fieldconditions at different altitudes, age, and health of orchards in Tanahun, Lamjung and Gorkha districts

4.1.1. Foliar analysis

Foliar analysis of mandarin orchards was done to assess the performance of healthy/non-healthy, bearing /non-bearing orchards and citrus growing belts located at different altitudes. The findings of the analysis are given below:

4.1.1.1 Foliar nutrient levels as affected by altitudes and orchard performances nitrogen (N)

Foliar levels of nutrients in citrus orchards located at high (Gorkha), mid (Lamjung) and low (Tanahun) altitudes indicated that N was affected by the attitudinal variation in 2003 and 2004 (Table 1) with a gradual decrease in leaf N from higher altitudes to the lower ones; but the differences were not statistically significant.

The effects of plant's health and age had highly significant on foliar N content of manadarin (Table 1). Significantly, higher leaf N content of healthy non-bearing trees was recorded compared to healthy bearing trees at all the altitudes. Similarly, unhealthy trees between bearing and non-bearing had the similar trends with respect to N content of the leaves as that healthy bearing and non-bearing trees. Irrespective of bearing and non-bearing conditions, the healthy trees contained higher N in their leaves than those of unhealthy trees.

Table 1. Plant nitrogen content (%) of 4-7 months old bearing, non-bearing, healthy and unhealthy mandarin leaves at different altitudes of the districts in Mid-hills of Western Region, Nepal.

	Year 1 ^{NS}					Year 2			
Treatments/Altitudes	H ^{NS}	M	L	Means		H	M	L	Means
Healthy bearing **	2.69	2.52	2.28	2.50		2.56	2.38	2.38	2.44
Healthy non-bearing	2.48	5.59	2.82	2.63		2.71	2.76	2.82	2.76
Unhealthy bearing	2.62	2.49	2.18	2.43		2.49	2.56	2.28	2.45
Unhealthy non-bearing	2.95	2.49	2.24	2.56		2.59	2.66	2.22	2.49
Means	2.68	2.52	2.38	2.53		2.59	2.59	2.43	2.53

NS = Non-Significant

* & ** =Significant at 5 & 1% level of significance

LSD.trt.=0.14 at 5% level.

LSD.dist.trt.** = 0.33 at 5% level.

H, M and L = High, Mid and Low altitudes correspondingly represented by Gorkha, Lamjung and Tahanun districts respectively.

Phosphorous (P)

Commercial mandarin growing orchards located at different altitudes had significant effect on the P-foliar content (Table 2). The highest mean (0.25% P) at the highest altitude (Gorkha) was found as compared to the 0.19% P and 0.22% P at the mid and the lower altitudes, respectively for the first year. However, for the second year, the foliar P composition was not varied significantly amongst the altitudes.

Orchards performances as represented by plant's health and age of trees affected highly significant (P=0.01) on the foliar P content (Table 2). The foliar phosphorous content was higher (0.22%) in healthy non-bearing trees than bearing trees (0.19%).

Similar results were also found from the unhealthy groups bearing and non-bearings. This trend was valid for the both the year of study. The healthy trees group had lower P levels (0.19-0.22%) compared to unhealthy trees (0.22 – 0.24%P) for the first year and similar trends of P content were also observed for the second year.

Table 2. Plant phosphorus content (ppm) of 4-7 months old bearing, non-bearing, healthy and unhealthy mandarin leaves at different altitudes of the districts in Mid-hills of Western Region, Nepal

	Year 1^{NS}					Year 2			
Treatments/Altitudes → ↓	H *	M	L	Means		H	M	L	Means
Healthy bearing **	0.21	0.18	0.18	0.19		0.17	0.15	0.28	0.20
Healthy non-bearing	0.22	0.20	0.25	0.22		0.35	0.21	0.27	0.28
Unhealthy bearing	0.24	0.20	0.21	0.22		0.28	0.25	0.23	0.25
Unhealthy non-bearing	0.31	0.19	0.22	0.24		0.23	0.28	0.27	0.26
Means	0.25	0.19	0.22	0.22		0.26	0.22	0.26	0.25

NS = Non-Significant

* & ** =Significant at 5 & 1% level of significance

LSD.trt. = 0.03 at 5% level

LSD.dist. = 0.04 at 5% level

LSD.year.dist.trt.** = 0.10 at 5% level.

H, M and L = High, Mid and Low altitudes correspondingly represented by Gorkha, Lamjung and Tahanun districts respectively.

Potash (K)

The leaf levels of K varied significantly with the different altitudes (Table 3). The highest leaf K content (1.71%) at higher altitude was analyzed compared to mid (1.63%)

and lower altitude (1.06%) for the first year. The variation of foliar K in second year was similar to that of the first year i.e. year to year variation was not significant.

The tree's health and age had no significant effects on K foliar levels (Table 3). However, the higher K content was obtained from both healthy and unhealthy groups of young trees compared to bearing tree's of healthy and unhealthy groups. Overall, healthiness of trees did not affect leaves K levels.

Table 3. Plant potassium content (%) of 4-7 months old bearing, non-bearing, healthy and unhealthy mandarin leaves at different altitudes of the districts in Mid-hills of Western Region, Nepal

	Year 1[NS]					Year 2			
Treatments/Altitudes	H [*]	M	L	Means		H	M	L	Means
Healthy bearing [NS]	1.51	1.61	0.96	1.36		1.59	1.49	1.44	1.51
Healthy non-bearing	1.69	1.64	1.29	1.54		1.68	1.37	1.63	1.56
Unhealthy bearing	1.80	1.65	0.93	1.46		1.73	1.45	1.18	1.45
Unhealthy non-bearing	1.82	1.62	1.06	1.50		1.64	1.68	1.21	1.51
Means	1.71	1.63	1.06	1.46		1.66	1.50	1.37	1.51

NS = Non-Significant

* & ** =Significant at 5 & 1% level of significance

LSD.dist..= 0.41 at 5% level

H, M and L = High, Mid and Low altitudes correspondingly represented by Gorkha, Lamjung and Tahanun districts respectively.

Calcium (Ca)

The effect of citrus growing altitudes on foliar Ca content was found non-significant (Table 4). The leaf Ca content also showed variable trends. There was no variation of leaf Ca content between first and second year.

Orchard performances of trees as represented by overall plant health and age had highly significant effects on foliar Ca levels (Table 4), which was higher in healthy bearing (3.45% Ca) as compared to unhealthy bearing (2.64%) for the first year. Similar effects were also found for the second year. The young non-bearing healthy treeswas also analyzed for Ca contents, which were higher compared to unhealthy non-bearing for both the years. Higher amount of Ca in bearing groups of both healthy and unhealthy trees had found as compared to non-bearing groups except for the first year where unhealthy groups did show differences between young and matured trees.

Table 4. Plant calcium content (%) of 4-7 months old bearing, non-bearing, healthy and unhealthy mandarin leaves at different altitudes of the districts in Mid-hills of Western Region, Nepal

	Year 1^{NS}					Year 2			
Treatments/Altitudes	H^{NS}	M	L	Means		H	M	L	Means
Healthy bearing *	3.66	3.40	3.30	3.45		3.71	3.56	4.94	4.07
Healthy non-bearing	3.35	3.24	2.89	3.16		3.23	3.56	3.43	3.41
Unhealthy bearing	2.81	2.36	2.76	26.4		3.99	2.51	3.40	3.30
Unhealthy non-bearing	2.62	2.75	3.08	2.82		2.64	2.94	2.67	8.75
Means	3.11	2.94	3.01	3.02		3.39	3.14	3.61	3.38

NS = Non-Significant

* & ** =Significant at 5 & 1% level of significance

LSDtrt. = 0.51 at 5% level.

H, M and L = High, Mid and Low altitudes correspondingly represented by Gorkha, Lamjung and Tahanun districts respectively.

Magnesium (Mg)

The similar trend of leaf Mg as of Ca was noticed (Table 5) with respect to altitudes and year variation. However, the Mg content of leaves seemed to be more at lower altitudes than located at the mid or higher altitudes of mandarin orchards.

Orchard's performances did not impact on leaf Mg levels (Table 5). However, healthy groups had higher Mg content compared with those in non-healthy groups of both ages. However, age of the trees had no effects on Mg levels.

Table 5. Plant magnesium content (%) of 4-7 months old bearing, non-bearing, healthy and unhealthy mandarin leaves at different altitudes of the districts in Mid-hills of Western Region, Nepal

	Year 1^NS					Year 2			
Treatments/Altitudes → ↓	H ^NS	M	L	Means		H	M	L	Means
Healthy bearing ^NS	0.42	0.40	0.40	0.41		0.37	0.42	0.48	0.42
Healthy non-bearing	0.45	0.42	0.37	0.41		0.32	0.39	0.41	0.37
Unhealthy bearing	0.38	0.30	0.46	0.38		0.38	0.37	0.42	0.39
Unhealthy non-bearing	0.32	0.41	0.46	0.40		0.35	0.25	0.42	0.34
Means	0.39	0.38	0.42	0.40		0.35	0.36	0.43	0.38

NS = Non-Significant

* & ** =Significant at 5 & 1% level of significance

LSD.year.dist.trt.** = 0.12 at 5% level

H, M and L = High, Mid and Low altitudes correspondingly represented by Gorkha, Lamjung and Tahanun districts respectively.

Boron (B)

Altitudes and year had no significant effects on the leaf B. (Table 6) for two years of study. But the trend was seen to be lower B plant content at the lower altitude than at the higher altitude.

Boron content in leaves of mandarin oranges was not affected at all by orchard's performances (Table 6). No systematic trends was also obtained from the effects of tree's health and age on B levels for the first year. However, for the second year, the healthy trees had higher leaf B level than non-healthy trees in general.

Table 6. Plant boron content (ppm) of 4-7 months old bearing, non-bearing, healthy and unhealthy mandarin leaves at different altitudes of the districts in Mid-hills of Western Region, Nepal

	Year 1 [N]					Year 2			
Treatments/Altitudes → ↓	H [NS]	M	L	Means		H	M	L	Means
Healthy bearing [NS]	65.5	24.8	4.2	31.5		49.1	22.9	53.0	41.1
Healthy non-bearing	33.0	29.0	17.0	26.3		71.3	43.3	38.6	51.1
Unhealthy bearing	55.8	23.4	19.0	32.7		35.4	21.4	46.5	34.4
Unhealthy non-bearing	60.0	36.3	18.9	38.4		44.2	47.5	50.7	47.5
Means	53.6	28.4	14.8	32.2		50.0	33.8	47.2	43.7

NS = Non-Significant

* & ** =Significant at 5 & 1% level of significance

H, M and L = High, Mid and Low altitudes correspondingly represented by Gorkha, Lamjung and Tahanun districts respectively.

Iron (Fe)

Foliar iron content of mandarin tree was highly significantly affected by the location of mandarin orchards namely: high (H), medium (M) and low (L) altitudes as represented by Gorkha, Lamjung and Tanahun, respectively (Table 7). The foliar Fe amount was higher at the higher altitudes (137.6 ppm) compared to lower altitudes in both the years except for the first year where in the mid-altitudes had higher Fe-content than at the high altitudes.

The Fe-content of mandarin was affected tremendously by trees health and age of the trees. The healthy matured trees had higher Fe content (155.8 ppm) than unhealthy adult trees (138.7 ppm) (Table 7). Similarly, healthy young trees analyzed higher Fe (158.4 ppm) compared to unhealthy young non-bearing trees (139.7 ppm). Age of the trees with respect to bearing and non-bearing had no significant effects on leaf Fe content in the first year. Similarly, for the second year also, health's of the trees and age had the same effects as that of the first year.

Table 7. Plant iron content (ppm) of 4-7 months old bearing, non-bearing, healthy and unhealthy mandarin leaves at different altitudes of the districts in Mid-hills of Western Region, Nepal

	Year 1^NS					Year 2			
Treatments/Altitudes→ ↓	H *	M	L	Means		H	M	L	Means
Healthy bearing **	154.6	173.1	138.8	155.5		197.0	197.4	155.0	183.1
Healthy non-bearing	140.5	187.2	147.5	158.4		177.4	188.3	161.0	175.7
Unhealthy bearing	124.4	163.3	128.6	138.7		164.4	160.4	110.7	145.2
Unhealthy non-bearing	130.7	173.0	115.3	139.7		171.1	112.9	132.7	148.9
Means	137.6	174.1	132.5	148.1		177.4	172.3	139.9	163.2

NS = Non-Significant

* & ** =Significant at 5 & 1% level of significance

LSDtrt. = 20.41 at 5% level

LSD.dist.18.27 at 5% level

LSD.year.dist.* = 26.09 at 5% level

H, M and L = High, Mid and Low altitudes correspondingly represented by Gorkha, Lamjung and Tahanun districts respectively.

Manganese (Mn)

The foliar Mn content was not affected by the mandarin located at different altitudes (Table 8). Similarly, year to year variation was also found non-significant with respect to Mn content of leaves.

The data from Table 8 revealed that high Mn content (25.00 ppm) was found from healthy bearing tree as compared to unhealthy matured trees (21.28 ppm) for the first year. Similar results were also shown in the second year. Among the treatments the Mn content in the healthy non-bearing trees was significantly higher (32.91 and 40.67 ppm) for the first and second year, respectively as compared to bearing trees (25.03 and 28.41 ppm). Similarly, in unhealthy trees groups between bearing and non-bearing had similar trends as that of healthy groups.

Table 8. Plant manganese content (ppm) 4-7 months old bearing, non-bearing, healthy and unhealthy mandarin leaves at different altitudes of the districts in Mid-hills of Western Region, Nepal

	Year 1 NS					Year 2			
Treatments/Altitudes → ↓	H NS	M	L	Means		H	M	L	Means
Healthy bearing**	27.78	25.78	24.5	25.03		28.52	26.02	30.67	28.41
Healthy non-bearing	32.94	32.91	33.91	33.25		46.73	35.04	40.25	40.67
Unhealthy bearing	16.84	21.82	21.82	21.28		18.67	20.86	24.65	21.39
Unhealthy non-bearing	23.77	25.91	29.96	26.55		24.75	20.03	29.95	24.91
Means	24.58	26.60	28.39	26.53		29.67	25.49	31.38	28.85

NS = Non-Significant

* & ** =Significant at 5 & 1% level of significance

LSD.trt. = 4.8 at 5% level

H, M and L = High, Mid and Low altitudes correspondingly represented by Gorkha, Lamjung and Tahanun districts respectively.

Copper (Cu)

Because of highly erratic data obtained, there were no significant effects of altitudes on Cu content of mandarin leaves (Table 9). Some contamination of the mandarin leaves with spraying chemicals such as Bordeaux – paint/mixture suspected for this highly inconsistency data.

There were no effects of healthiness and age of mandarins trees on Cu leaf content (Table 9). Highly erratic results were found from the treatments effects.

Table 9. Plant copper content (ppm) of 4-7 months old bearing, non-bearing, healthy and unhealthy mandarin leaves at different altitudes of the districts in Mid-hills of Western Region, Nepal

	Year 1 NS					Year 2			
Treatments/Altitudes→ ↓	H NS	M	L	Means		H	M	L	Means
Healthy bearing NS	11.2	4.9	121.4	45.8		5.8	7.3	14.2	9.1
Healthy non-bearing	14.5	7.1	120.2	47.3		91.3	8.1	11.2	36.9
Unhealthy bearing	12.4	11.1	148.9	57.4		18.9	13.3	9.5	13.9
Unhealthy non-bearing	12.4	10.6	20.7	14.6		17.2	16.4	124.8	52.8
Means	12.6	8.4	102.8	41.3		33.3	11.3	39.9	28.2

NS = Non-Significant

* & ** =Significant at 5 & 1% level of significance

H, M and L = High, Mid and Low altitudes correspondingly represented by Gorkha, Lamjung and Tahanun districts respectively.

Zinc (Zn)

There was no year to year variation with respect to Zn-content of the mandarin leaves (Table 10). But the altitudes of mandarin growing orchards had highly significant effects on the foliar Zn content. Higher amount of leaf Zn was obtained at higher altitudes than at the lower mandarin growing orchards.

In both the years of study (Table 10), the healthy bearing trees had higher Zn (14.54 and 14.97 ppm) contents as compared to unhealthy bearing (12.18 and 10.68 ppm) respectively. There were similar trends for unhealthy groups. The non-bearing trees of both healthy and unhealthy groups had higher Zn content in both the years compared to bearing trees of both healthy and unhealthy trees.

Table 10. Plant zinc content (ppm) of 4-7 months old bearing, non-bearing, healthy and unhealthy mandarin leaves at different altitudes of the districts in Mid-hills of Western Region, Nepal

	Year 1^{NS}					Year 2			
Treatments/Altitudes → ↓	High altitude**	Mid altitude	Low altitude	Means		High altitude	Mid altitude	Low altitude	Means
Healthy bearing**	17.11	13.39	13.13	14.54		13.73	16.58	14.59	14.97
Healthy non-bearing	22.10	14.79	16.18	17.69		18.88	18.80	14.47	17.38
Unhealthy bearing	13.71	12.91	9.91	12.18		11.12	12.87	8.06	10.68
Unhealthy non-bearing	16.58	12.39	15.13	14.70		17.57	20.42	10.73	26.24
Means	17.38	13.37	13.59	14.78		15.33	17.17	11.96	14.82

NS = Non-Significant

* & ** =Significant at 5 & 1% level of significance

LSD.trt. = 2.1 at 5% level

LSD.dist.= 1.85 at 5% level

LSD.year.dist.** = 2.62 at 5% level

H, M and L = High, Mid and Low altitudes correspondingly represented by Gorkha, Lamjung and Tahanun districts respectively.

4.1.1.2 Appraisal of nutrient constraints through foliar composition

The nutrients constraints of mandarin orchards were identified according to the leaf nutrient standard developed for sweet orange cultivars (Embletion *et al*., 1973). This leaf nutrient standards are widely used for working out the nutritional status of citrus growing belts worldwide.

Nitrogen (N)

The leaf N content (Table 11) of orchards varied from 1.87 to 3.25% with the mean of 2.53%. According to (Embletion *et al.*, 1973) above standards, the N was found deficient in 50%, 25%, 12.5% orchards of low, mid and high altitudes, respectively (Figure 5). Just in the reverse order, the N was found to be excess in 54.2, 41.7 and 29.2% orchards respectively in high, mid and low altitudes.

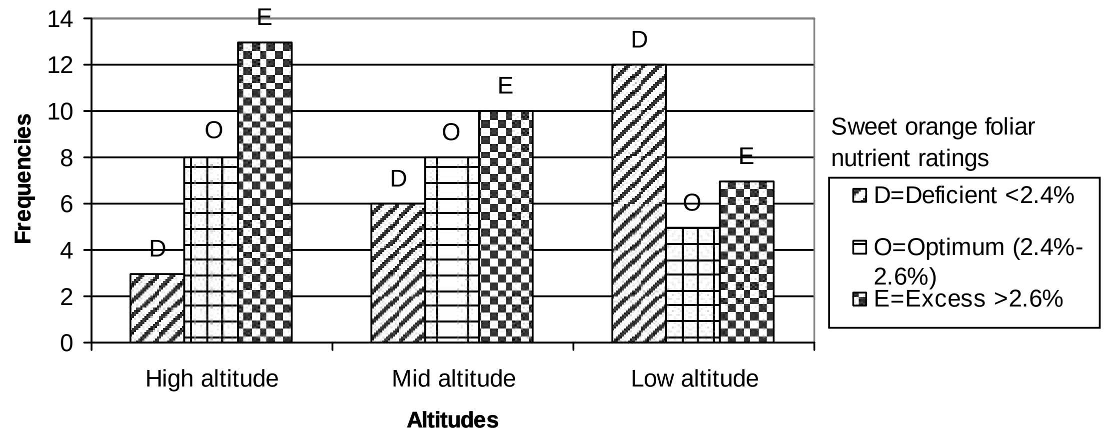


Figure 5 : Foliar Nitrogen Status of Mandarin Orchards

Table 11. Leaf nutrient contents of mandarin

Nutrients*	Range	Mean
N (%) N=72	1.87 – 3.25	2.53
P (%) “	0.13 – 0.46	0.23
K (%) “	0.47 – 2.7	1.49
MK (%) “	1.81 – 7.6	3.2
Mg (%) “	0.02 – 0.56	0.39
B (ppm)	0.01 – 143.5	37.95
Fe “	85.1 – 2.831	155.6
Mn “	16.12 – 62.15	27.69
Cu “	1.52 – 424.6	34.73
Zn “	1.43 – 25.37	14.8.0

* Number of samples 72.

Phosphorus (P)

Majority of the mandarin orchards at all the three altitudes i.e. high, mid and low had 'excess' categories i.e.: 91.7, 79.2, 95.8% with respect to foliar P levels, respectively (Figure 6). The foliar P contents of the orchards were ranged from 0.13 to 0.44% with the grand mean value of 0.23% P (Table 11). Virtually, no P deficient orchards were found in all 3 altitudes except at low altitude where only 17.7% of the orchards were in deficient ranges.

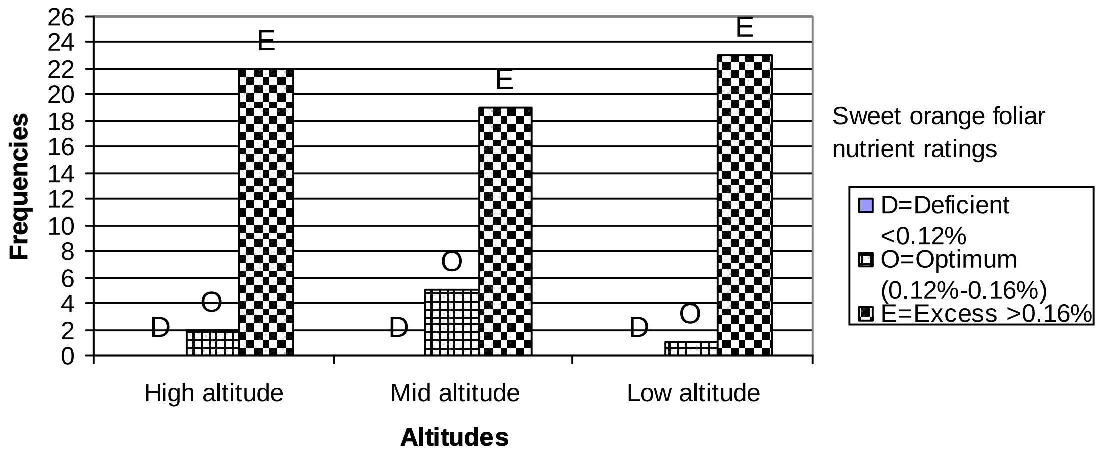


Figure 6 : Foliar Phosphorous Status in Mandarin Orchards

Potassium (K)

The leaf K content varied from 0.47 to 2.7% (mean 1.49%) in the study site (Table 11). The leaf K level of orchard (Figure 7) was in excess ranges particularly at high and mid altitudes in the order of: 93.8% and 95.8%, respectively. However, at low altitude, only 58.3% samples were categorized as excess standards. About 26.6% of the samples were rated as deficient in K content at low altitude.

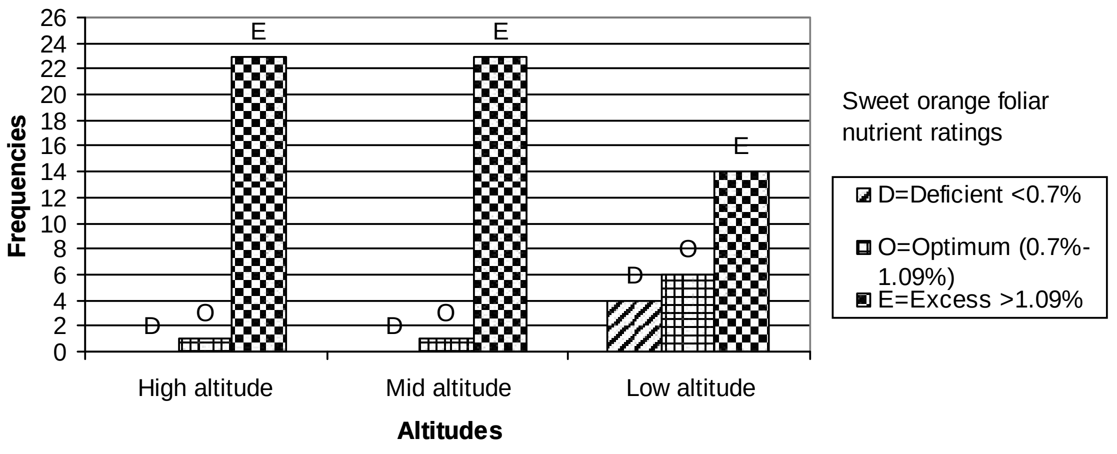


Figure 7 : Foliar Potassium Status in Mandarin Orchards

Calcium (Ca)

Leaf Ca (Table 11) showed a variation between 1.81 and 7.6% (mean 3.2 %) On the basis of above standards, a 33.3, 54.2 and 50.00 % of orchards were observed to have deficient of Ca at high, mid and low altitudes, respectively (Figure 8). Majority of the sampled orchards were in optimum range of leaf Ca content i.e. 62.5%, 45.8 and 45.8% at high, mid and low altitudes, respectively.

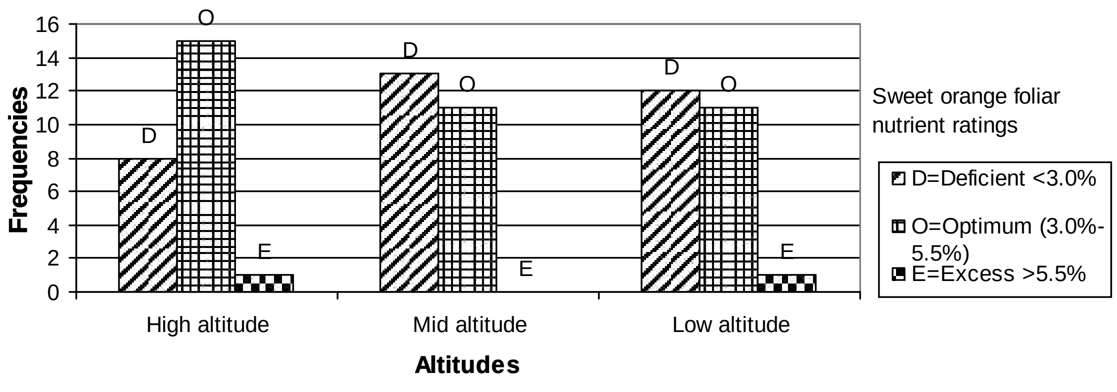


Figure 8: Foliar Calcium Status in Mandarin Orchards

Magnesium (Mg)

Leaf Mg (Table 11) varied from 0.02 to 0.56% (mean 0.39%). As shown in the Figure 9, 91.6%, 91.6 and 100% samples were found to be in the optimum ranges of Mg levels at high, mid and low altitudes, respectively.

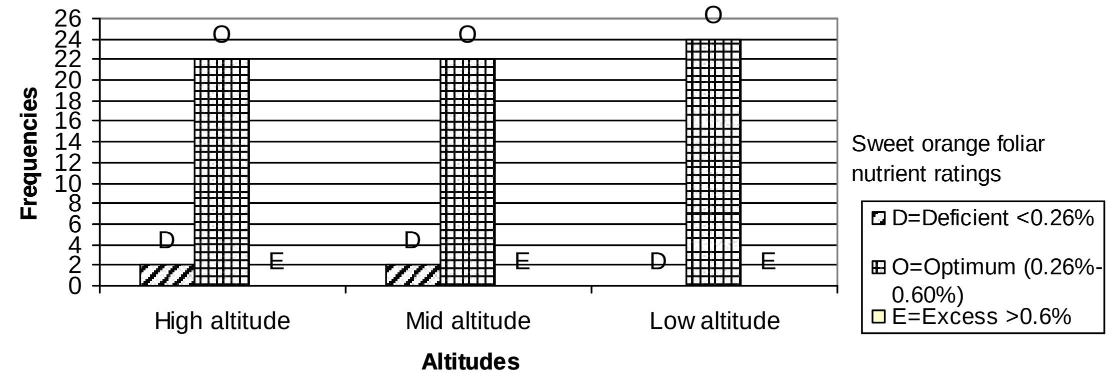


Figure 9: Foliar Magnesium Status in Mandarin Orchards

Boron (B)

The leaf B (Table 11) status ranged from 0.01 to 143.5 ppm (mean 37.95 ppm). The orchards recorded to possess optimum level of leaf B contents 79.2, 54.2 and 58.3% (Figure 10) at high, mid and low altitude, respectively on the basis of suggested optimum levels of B 31-140 ppm. Deficient percentage of orchard had increased as altitudes decreased from mid to low (41.6 to 45.8%) compared to 16.7% samples only deficient in B at high altitude.

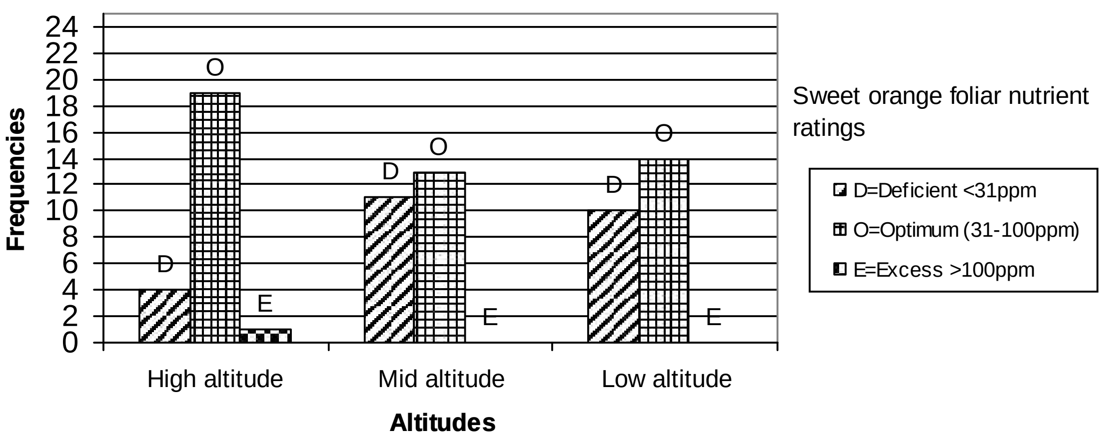


Figure 10 : Foliar Boron Status in Mandarin Orchards

Iron (Fe)

The leaf Fe content range was from 85.1 to 283.1 ppm with the mean value of 155.6 ppm (Table 11). The 95.8, 100 and 70.8% (Figure 11) samples were rated as excess at high, mid and low altitudes, respectively. And only 29.2% and 4.2% orchards had optimum range correspondingly in low and but mid altitudes and high altitudes did not show any Fe deficiency in leaf.

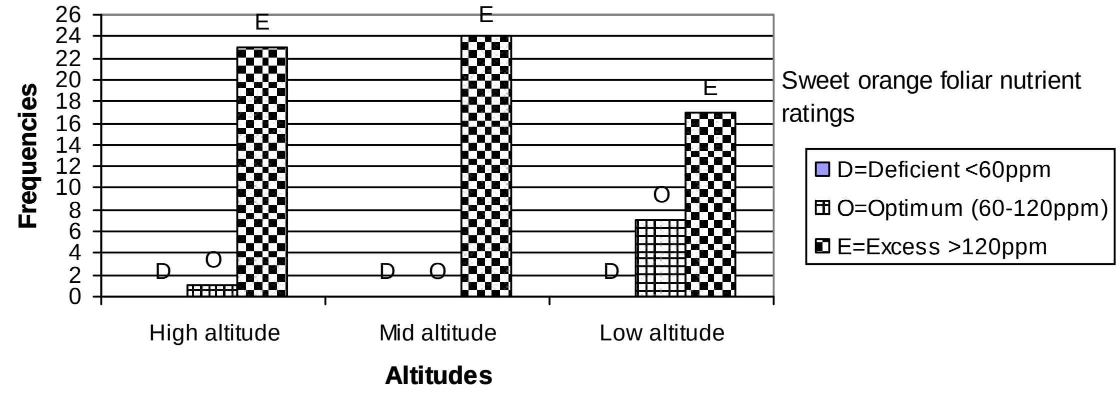


Figure 11 : Foliar Iron Status in Mandarin Orchards

Manganese (Mn)

The Mn leaf levels (Table 11) were ranged from 16.12 to 62.15 ppm (mean 27.69 ppm) High, mid and low altitudes (Figure 12) showed deficiency of leaf Mn content of 62.5, 54.2, and 8.3% of orchards, respectively. Samples were found no excess range of leaf Mn content. The maximum samples (91.6%) were in 'excess' rating at low altitude followed by 45% and 37.5% samples, respectively at mid and high altitudes.

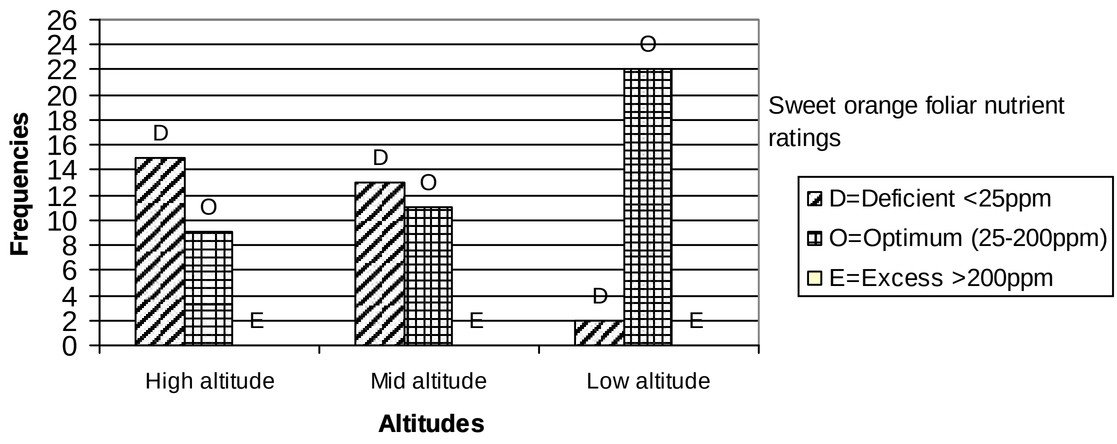


Figure 12 : Foliar Manganese Status in Mandarin Orchards

Copper (Cu)

The leaf Cu ranged from 15.2 to 42.4% with the mean value 37.73 in the studied sites (Table 11). Majority of the samples were in optimum to excess range of leaf Cu at all three locations representing different altitudes (Figure 13). Non-existence of deficient rating of leaf Cu at all the three altitudes. Highly erratic results were recorded for leaf Cu with respect to altitudes.

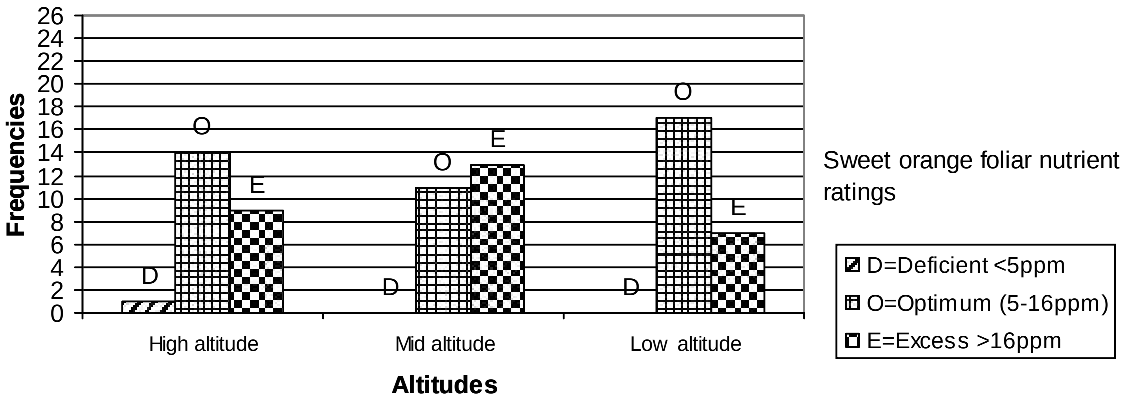


Figure 13: Foliar Copper Status in Mandarin Orchards

Zinc (Zn)

The leaf Zn levels (Table 11) ranged from 1.43 to 25.37 ppm (mean 1.4.80 ppm) Almost all the orchards were in the Zn deficiency ratings namely 95.8, 100, and 95.8% of samples at high, mid and low altitudes, respectively (Figure 14). Virtually, there were no optimum and excess ranges of Zn rating orchards at all the three locations.

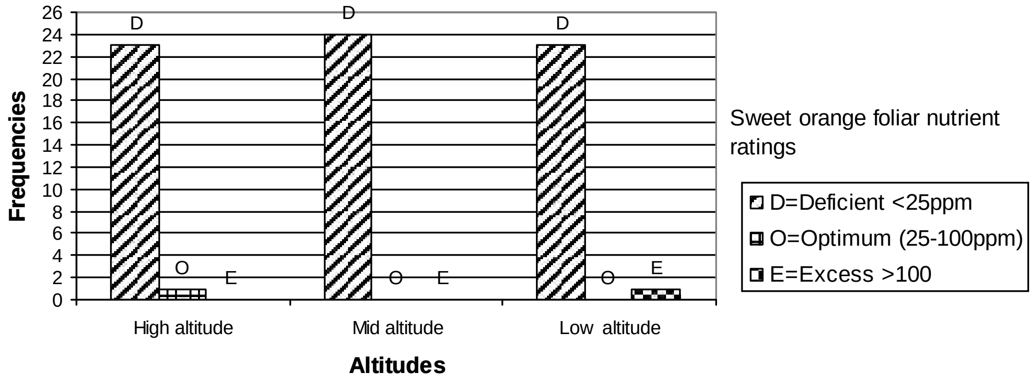


Figure 14: Foliar Zinc Status in Mandarin Orchards

4.1.2 Soils analysis

4.1.2.1 Soil nutrient levels as affected by altitudes, age and health of mandarin orchards

Soil analysis of mandarin orchards are also expected to affect by altitudes, healthy/unhealthy and bearing/non-bearing factors. The effects of these factors on soil analysis are presented below.

Soil pH

Different citrus growing altitude ranges had highly significant effects on soil pH (Table 12). The significantly lower pH at the highest altitude were 5.5 and 5.7 for the year 1 and Year 2, respectively compared to pH 7.3 and 6.6 at the lowest altitude ranges. The intermediate pH ranges were recorded for the medium altitude for both the years.

The soil pH of mandarin orchards located at different altitudes was not affected by overall orchard's health and age of trees (Table 12).

Table 12. Soils pH of mandarin orchards at various altitudes, age and health in Mid-hills of Western Region of Nepal

	Year 1 NS					Year 2			
Treatments/Altitudes	H**	M	L	Means		H	M	L	Means
Healthy bearing NS	6.2	5.8	7.1	6.4		6.1	6.3	6.7	6.4
Healthy non-bearing	5.3	5.6	6.9	5.9		5.5	5.5	6.0	5.7
Unhealthy bearing	5.4	5.4	7.2	6.0		5.8	5.9	6.7	6.1
Unhealthy non-bearing	5.2	5.8	7.8	6.3		5.3	6.2	7.1	6.2
Means	5.5	5.6	7.3	6.1		5.7	6.0	6.6	6.1

NS = Non-Significant

& ** =Significant at 5 & 1% level of significance

LSD.dist.= 0.54 at 5% level

H, M and L = High, Mid and Low altitudes correspondingly represented by Gorkha, Lamjung and Tahanun districts respectively.

Soil organic matter (OM)

Soil organic matter (OM) was influenced significantly by the citrus growing altitudes (Table 13). The higher amount of OM accumulation (5.16%) was found at the highest altitude whereas the low accumulation was observed at (3.55%) the lowest range. However, there was no significant difference in the amount of OM accumulation between the highest and mid-altitude ranges. This trend was true for the second year also.

The effects of orchard's healthiness and age of mandarin trees on organic matter content of soils was found significant (Table 13). The higher amount of soil organic matter content of healthy groups both bearing and non-bearing trees was recorded as compared to lower amount in unhealthy group trees. This was true for the second year also. However, the age of the trees did not record the differences in the amount of soil organic matter for both the years.

Table 13. Soils organic matter of mandarin orchards at various altitudes, age and health in Mid- hills of Western Region of Nepal

	Year 1 [NS]					Year 2			
Treatments/Altitudes → ↓	H*	M	L	Means		H	M	L	Means
Healthy bearing *	5.59	5.40	4.16	5.05		5.74	5.45	4.05	5.08
Healthy non-bearing	5.32	6.20	3.31	4.94		4.84	4.23	5.36	4.81
Unhealthy bearing	5.00	4.54	3.51	4.35		4.34	5.41	3.96	4.57
Unhealthy non-bearing	4.74	4.60	3.24	4.19		5.28	4.94	3.53	4.58
Means	5.16	5.18	3.55	4.63		5.05	5.01	4.23	4.76

NS = Non-Significant

* & ** =Significant at 5 & 1% level of significance

LSD.trt.= 0.55 at 5% level

LSD.dist.= 0.73 at 5% level

LSD.yr.dis.trt. = 1.44 at 5% level

H, M and L = High, Mid and Low altitudes correspondingly represented by Gorkha, Lamjung and Tahanun districts respectively.

Nitrogen (N)

Altitudes had the influence on total soil N (Table 14). It was observed that higher total soil N (0.16%) was found at the highest altitude compared to the lowest (0.13%) altitude in the first year. In the second year also, there was a gradual decrease in soil N content with decrease in altitude from 0.22% to 0.17%. There was a little change in soil N with change in time (year).

The mandarin tree's health and maturity were not affected by the amount of N present in the soil (Table 14). However, there was a clear-cut trend that total soil N was higher in healthy both matured and young trees as compared to lower totals of N in unhealthy trees groups. This trend was recorded for both the years. Similarly, younger trees groups of healthy and unhealthy trees tended to be lower in soil N than in matured bearing trees groups.

Table 14. Soils nitrogen of mandarin orchards at various altitudes, age and health in Mid-hills of Western Region of Nepal

	Year 1 NS					Year 2			
Treatments/Altitudes → ↓	H*	M	L	Means		H	M	L	Means
Healthy bearing NS	0.23	0.19	0.13	0.18		0.25	0.24	0.15	0.21
Healthy non-bearing	0.16	0.21	0.14	0.17		0.22	0.19	0.19	0.20
Unhealthy bearing	0.15	0.17	0.14	0.15		0.20	0.22	0.17	0.20
Unhealthy non-bearing	0.11	0.14	0.14	?		0.23	0.18	0.16	0.19
Means	0.16	0.18	0.13	0.66		0.22	0.21	0.17	0.20

NS = Non-Significant

* & ** =Significant at 5 & 1% level of significance

LSD.trt.= at 5% level

LSD.dist.= at 5% level

LSD.yr.dist.trt. = at 5% level

H, M and L = High, Mid and Low altitudes correspondingly represented by Gorkha, Lamjung and Tahanun districts respectively.

Phosphorus (P)

The available soil P was found to be higher at the lower altitudes than at the higher altitudes (Table 15).

The effects of different orchard performances as indicated by the age and health of the trees on soil P nutrient content was found to be significant (Table 15). Healthy bearing trees groups (bearing and non-bearing) had high soil available P than unhealthy bearing trees groups in both the years. Age of the trees had no definite trends on soil P content.

Table 15. Soils P of mandarin orchards at various altitudes, age and health in Mid- hills of Western Region of Nepal

	Year 1 *					Year 2			
Treatments/Altitudes → ↓	H**	M	L	Means		H	M	L	Means
Healthy bearing *	0.005	0.004	0.006	0.005		0.008	0.021?	0.003	0.010
Healthy non-bearing	0.005	0.002	0.004	0.004		0.002	0.031?	0.004	0.012
Unhealthy bearing	0.001	0.004	0.005	0.003		0.001	0.007	0.002	0.003
Unhealthy non-bearing	0.001	0.002	0.003	0.002		0.002	0.013	0.002	0.005
Means	0.003	0.003	0.004	0.004		0.003	0.018	0.003	0.008

NS = Non-Significant

* & ** =Significant at 5 & 1% level of significance

LSD.trt.= 0.004 at 5% level

LSD.dist.= 0.002 at 5% level

LSD.yr. = 0.006 at 5% level

LSD.yr.dist.= ?

LSD.yr.trt. = 0.006

H, M and L = High, Mid and Low altitudes correspondingly represented by Gorkha, Lamjung

Potassium (K)

Soil K was not affected by citrus growing orchards located at different altitudes (Table 16).

The available soil K was not affected by the orchards healthiness and age of trees (Table 16).

Table 16. Soils potassium of mandarin orchards at various altitudes, age and health in Mid- hills of Western Region of Nepal

	Year 1 NS					Year 2			
Treatments/Altitudes→ ↓	H NS	M	L	Means		H	M	L	Means
Healthy bearing NS	0.05	0.03	0.02	0.03		0.03	0.02	0.01	0.02
Healthy non-bearing	0.02	0.02	0.02	0.02		0.01	0.02	0.01	0.01
Unhealthy bearing	0.02	0.02	0.03	0.02		0.01	0.02	0.01	0.01
Unhealthy non-bearing	0.01	0.02	0.02	0.02		0.04	0.02	0.01	0.03
Means	0.03	0.02	0.02	0.02		0.02	0.02	0.01	0.02

NS = Non-Significant

* & ** =Significant at 5 & 1% level of significance

H, M and L = High, Mid and Low altitudes correspondingly represented by Gorkha, Lamjung and Tahanun districts respectively.

Calcium (Ca)

The available soil Ca was higher (0.17%) at the lower citrus growing belts than at the higher altitudes (0.07%) (Table 17) for the first year of study. However, in the second year, the soil Ca was not affected much by the difference in altitudes of citrus growing orchards.

As evidence from Table 17, no systematic effects of maturity of trees and overall health of orchards on soil available Ca were noticed.

Table 17. Soils calcium of mandarin orchards at various altitudes, age and health in Mid-hills of Western Region of Nepal

	Year 1 NS					Year 2			
Treatments/Altitudes → ↓	H **	M	L	Means		H	M	L	Means
Healthy bearing NS	0.12	0.09	0.23	0.15		0.23	0.19	0.14	0.19
Healthy non-bearing	0.06	0.08	0.16	0.10		0.07	0.16	0.10	0.11
Unhealthy bearing	0.05	0.05	0.18	0.09		0.14	0.10	0.18	0.14
Unhealthy non-bearing	0.06	0.06	0.10	0.08		0.16	0.13	0.19	0.16
Means	0.07	0.07	0.17	0.01		0.15	0.14	0.15	0.15

NS = Non-Significant

* & ** = Significant at 5 & 1% level of significance

LSD.dist. = 0.04 at 5% level

H, M and L = High, Mid and Low altitudes correspondingly represented by Gorkha, Lamjung and Tahanun districts respectively.

Boron (B)

There was no effect of altitudes on soil B in citrus orchards (Table 19). There was a significant variation in soil B content from year to year. Higher soil B (1.06 ppm) was recorded for the first year as compared to second year (0.53 ppm).

Age and health of the orchard's trees had no significant effects on soil B nutrient composition (Table 19). However, there was a certain trend of the treatments applied on soil B. Healthy matured trees showed a lower amount of soil B than unhealthy bearing trees soils, unlike, healthy non-bearing orchard had lower for soil B than unhealthy non-bearing. Similarly, so far as the age effects on soil B are concerned, healthy bearing recorded higher than healthy non-bearing whereas unhealthy matured had lower B compared to unhealthy non-bearing trees in both the years.

Table 19. Soils boron of mandarin orchards at various altitudes, age and health in Mid-hills of Western Region of Nepal

	Year 1 *					Year 2			
Treatments/Altitudes → ↓	H NS	M	L	Means		H	M	L	Means
Healthy bearing NS	1.39	0.62	1.13	1.05		1.07	0.05	0.55	0.56
Healthy non-bearing	1.04	0.37	0.86	0.76		0.73	0.05	0.49	0.42
Unhealthy bearing	0.91	1.24	1.29	1.15		0.25	0.23	0.72	0.40
Unhealthy non-bearing	0.72	1.97	1.97	1.29		0.82	1.03	0.32	0.73
Means	1.02	1.05	1.12	1.06		0.72	0.34	0.52	0.53

NS = Non-Significant

* & ** =Significant at 5 & 1% level of significance

LSD.yr.= 0.67 at 5% level

H, M and L = High, Mid and Low altitudes correspondingly represented by Gorkha, Lamjung and Tahanun districts respectively.

Iron (Fe)

Erratic soil Fe composition of mandarin orchards at various altitudes was recorded (Table 20). There was higher grand mean of Fe (40.5 ppm) at the first year compared to second year (32.1 ppm)of Fe content.

There was a non-significant effects of orchards health and maturity on soil Fe nutrient (Table 20). However, the healthy matured trees tended to be higher in soil Fe than healthy young one and unlike in unhealthy groups, young trees had the trends higher soil Fe than the matured one. No systematic trend was noticed in the effects of healthiness of trees on soil Fe amount.

Table 20. Soils iron of mandarin orchards at various altitudes, age and health in Mid-hills of Western Region of Nepal

	Year 1 NS					Year 2			
Treatments/Altitudes → ↓	H NS	M	L	Means		H	M	L	Means
Healthy bearing NS	53.2	54.6	21.8	43.2		50.8	27.5	39.8	39.4
Healthy non-bearing	48.8	50.6	17.6	39.0		33.1	10.2	54.1	32.5
Unhealthy bearing	42.3	40.4	22.5	35.1		20.2	18.1	42.6	27.0
Unhealthy non-bearing	64.1	51.7	18.4	44.7		41.8	26.1	20.4	29.4
Means	52.1	49.3	20.0	40.5		36.5	20.5	39.2	32.1

NS = Non-Significant

* & ** =Significant at 5 & 1% level of significance

LSD.yr.dist. = at 5% level

H, M and L = High, Mid and Low altitudes correspondingly represented by Gorkha, Lamjung and Tahanun districts respectively.

Manganese (Mn)

The soil Mn content was also not affected by the variation in citrus growing pockets located at different altitudes (Table 21). Stable grand means of 33.4 and 35.1 ppm of Mn were recorded for the first and second year, respectively.

Non-significant effects were obsered in soil available Mn (Table 21) under different age and health categories. However, age of the trees had shown the trends that in healthy matured trees had higher soil Mn than the young one and reverse was true for unhealthy trees groups. Erratic results had recorded for the effects of age on soil Mn.

Table 21. Soils manganese of mandarin orchards at various altitudes, age and health in Mid- hills of Western Region of Nepal

	Year 1 NS					Year 2			
Treatments/Altitudes → ↓	H NS	M	L	Means		H	M	L	Means
Healthy bearing NS	43.8	20.8	71.4	45.3		37.6	50.6	25.7	37.9
Healthy non-bearing	33.7	14.6	28.1	25.5		37.3	25.9	38.8	34.0
Unhealthy bearing	38.5	18.5	36.6	31.2		29.2	23.0	33.1	28.4
Unhealthy non-bearing	25.4	20.9	48.7	31.7		37.3	41.2	41.6	40.0
Means	35.3	18.7	46.2	33.4		35.4	35.2	34.8	35.1

NS = Non-Significant

* & ** =Significant at 5 & 1% level of significance

H, M and L = High, Mid and Low altitudes correspondingly represented by Gorkha, Lamjung and Tahanun districts respectively.

Copper (Cu)

Highly inconsistent results of Cu content of mandarin orchards at different altitudes were found (Table 22). However, there was a trend of higher amount of Cu content in the first year (15.6) and in the second year (14.7 ppm) at the lowest altitudes compared to the highest altitude as 1.8 and 2.9 ppm of Cu in the first year and second year, respectively.

There was no effects of age and health of the orchard on soil available Cu content (Table 22). Highly unsystematic results of Cu content were produced by the age and healthiness of the trees.

Table 22. Soils copper of mandarin orchards at various altitudes, age and health in Mid-hills of Western Region of Nepal

Treatments ↓ Altitudes →	Year 1 NS H NS	M	L	Means		Year 2 H	M	L	Means
Healthy bearing NS	2.9	1.8	13.0	5.9		6.7	7.8	18.7	11.1
Healthy non-bearing	1.5	1.6	16.2	6.4		2.3	1.5	28.2	10.7
Unhealthy bearing	1.6	1.4	30.9	11.3		1.4	1.3	7.5	3.4
Unhealthy non-bearing	1.1	0.8	2.3	1.4		1.3	2.0	4.3	2.5
Means	1.8	1.4	15.6	6.3		2.9	3.2	14.7	6.9

NS = Non-Significant

* & ** =Significant at 5 & 1% level of significance

H, M and L = High, Mid and Low altitudes correspondingly represented by Gorkha, Lamjung and Tahanun districts respectively.

Zinc (Zn)

The effects of altitudes on soil Zn composition were found to be non-significant (Table 23). However, the Zn content of the soils tended to decrease as the altitude lowered down from higher to lower ranges. This was true for both the years.

Available soil Zn was highly and significantly affected by the health and age of the trees (Table 23). Healthy matured trees had higher soil Zn content viz. 4.54 in the first year and 5.95 ppm in the second year while 2.37 ppm in the first year and 1.43 ppm of Zn with second year for unhealthy matured trees. Similarly, young trees had also the similar effects on soil Zn as that of matured trees between healthy and unhealthy trees. Matured trees had higher soil Zn content than young trees in both healthy and unhealthy groups except in the second year where unhealthy non-bearing had recorded higher Zn content.

Table 23. Soils zinc of mandarin orchards at various altitudes, age and health in Mid-hills of Western Region of Nepal

	Year 1 NS					Year 2			
Treatments/Altitudes	H NS	M	L	Means		H	M	L	Means
Healthy bearing **	4.89	6.33	2.40	4.54		11.30	4.06	2.49	5.95
Healthy non-bearing	1.53	3.16	1.55	2.08		1.12	2.02	2.29	1.81
Unhealthy bearing	3.58	0.98	2.53	2.37		0.86	1.71	1.73	1.43
Unhealthy non-bearing	0.72	2.38	1.21	1.44		1.26	3.10	1.11	1.82
Means	2.68	3.21	1.92	2.6		3.64	2.72	1.90	2.75

NS = Non-Significant

* & ** =Significant at 5 & 1% level of significance

LSD.trt.=2.56 at 5% level

LSD.dist.trt.= 2.56 at 5% level

LSD.yr.dist.trt.07p = 4.34 at 5% level

H, M and L = High, Mid and Low altitudes correspondingly represented by Gorkha, Lamjung and Tahanun districts respectively.

4.1.2.2 Soil fertility evaluation through soil test

No well established standard for available nutrients in soil having a wide adaptability are available for evaluating the soil fertility status of citrus orchards. The interpretation were made available on the basis of suggested optimum levels for the soil nutrients (Tripathi, 2001).

pH

The pH of the orchards under the study varied from 4.6 to 10.00 (mean 6.11) (Table 24). The majority of pH in the orchards located at high (95.81) and mid (87.5%) altitudes were classified as low. The percentage of soil samples for pH were 29.2, 37.5 and

33.3 which were rated under low, medium and high, respectively (Figure 15). The interpretation were made available on the basis of suggested ranges of pH as low (acidic) <6.5, medium (neutral) 6.6-7.0, and high (alkaline) >7.0 pH (Tripathi, 2001).

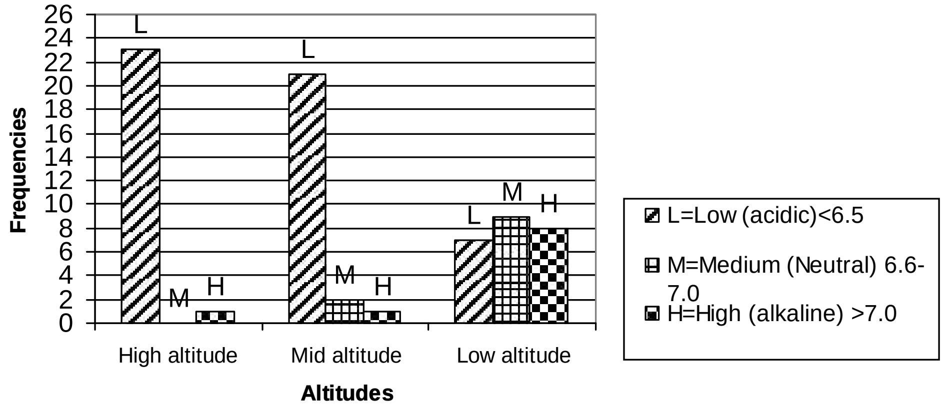


Figure 15 : Rating of pH from the Mandarin Orchards

Organic matter (OM)

The organic matter contents of the soils were ranged from 2.58 to 7.35% with mean 4.70% (Table 24). The higher percentage number of samples (54.2%) rated as high amount of OM (Figure 16) at the highest altitude and it was gradually decreased to 41.7% and 12.5% samples at mid and low altitudes range, respectively. The maximum number of samples classified as medium OM rating (87.5%) at the lowest belts followed by 58.3 and 45.8% at the mid and high altitudes, respectively. None of the samples was rated as low OM content at all the three altitudes.

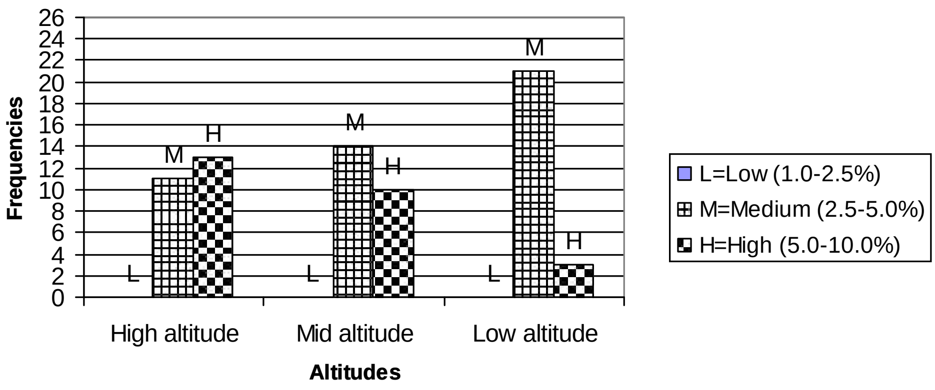


Figure 16 : Rating of Soil Organic Matters from the Orchards

Soil total nitrogen

The soil N status ranged from 0.011 to 0.18% with mean of 0.13% (Table 24). The available soil N in the orchards located at the low, mid and high altitudes were found in medium ranges ratings as: 95.8, 37.5 and 41.7% samples, respectively (Figure 17) and the high ratings of N as 54.2, 58.3 and 0% of the total samples, were analyzed at high, mid and low altitudes, respectively.

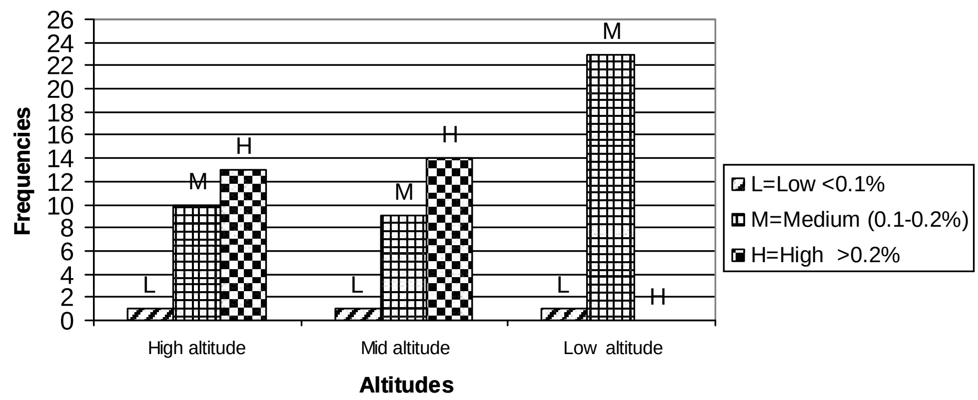


Figure 17: Rating of Soil Total Nitrogen from the Mandarin Orchards

Soil available phosphorus

The available P content of the soils varied from 0.1 to 0.3% (Table 24). The available P was found at high ranges as 83.3, 70.8 and 66.7% of the samples at low, mid and high altitudes ranges, respectively (Figure 18). The remaining samples were in medium availability ranges at all altitudes.

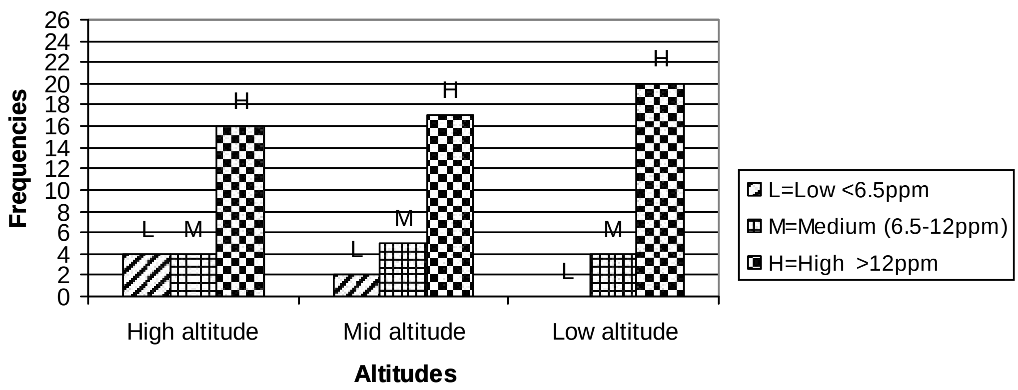


Figure 18: Rating of Soil Available Phosphorous from the Mandarin Orchards

Soil available potassium

The available K contents varied from 0.003 to 0.12% with mean 0.02% (Table 24). Most of the orchards located at all the three altitudes ranges possessed high to medium ranges of available K contents (Figure 19). Altitudes had no influences on available soil K ratings.

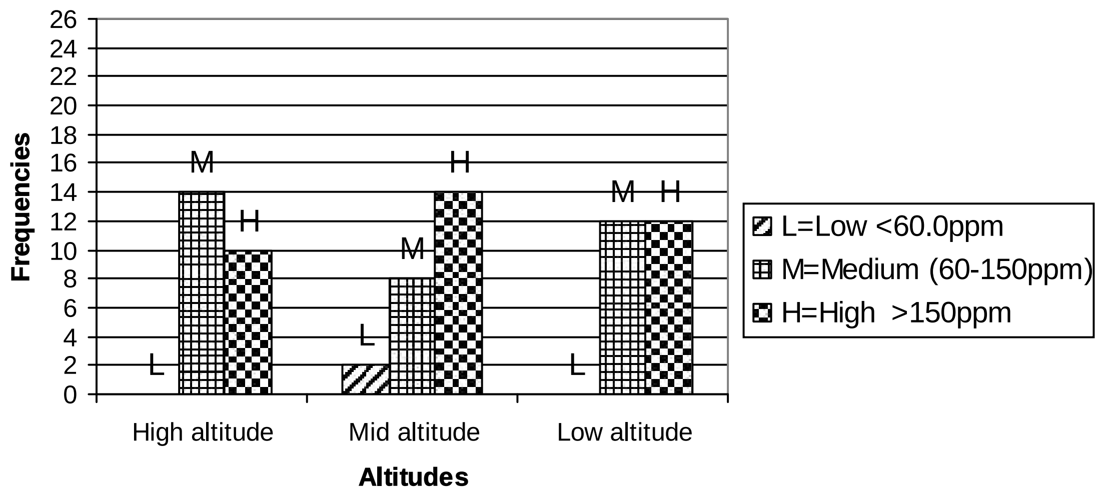


Figure 19: Rating of Soil Available Potassium from the Mandarin Orchards

Soil available calcium

The soil available Ca ranged from 0.01 to 0.41% with the mean 0.13% (Table 24). Majority of the orchards possessed low rating of available Ca as 70.8, 66.7 and 46.8% of samples at high, mid and low altitude ranges, respectively (Figure 20). The medium ratings of Ca were 29.2, 33.3 and 41% of total soil samples at high, mid and low altitudes respectively and they were increased as the altitudes decreased. Less than 7 percent samples were rated high in the area of study.

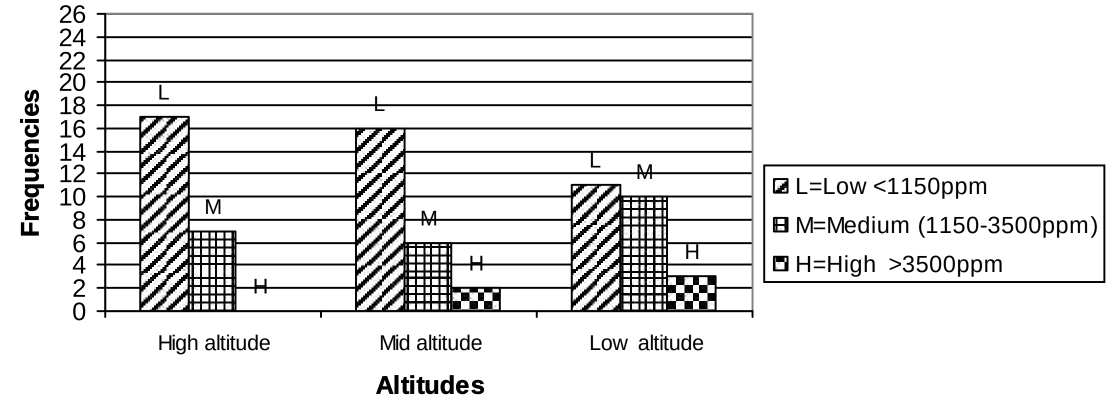


Figure 20: Rating of Soil Available Calcium from the Mandarin Orchards

Soil available magnesium

Majority of the orchards located at high altitudes had low (41.7%) and medium (58.3%) Mg status(Figure 21). No systematic effects of altitudes on Mg contents were produced for mid and low citrus growing belts.

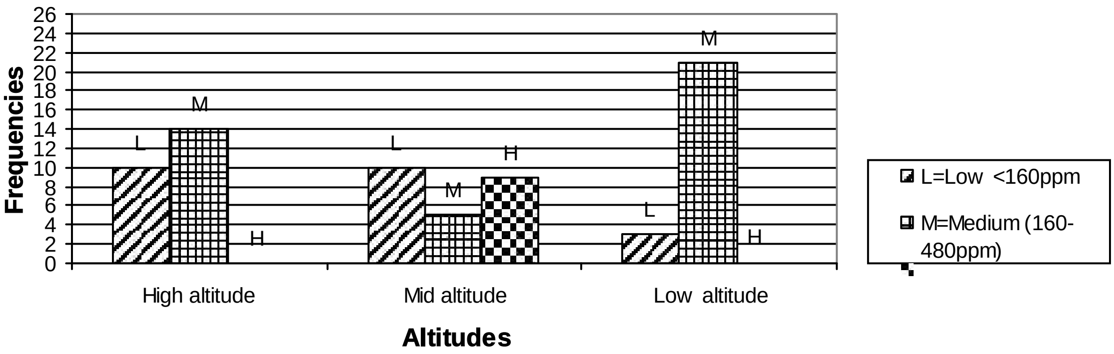
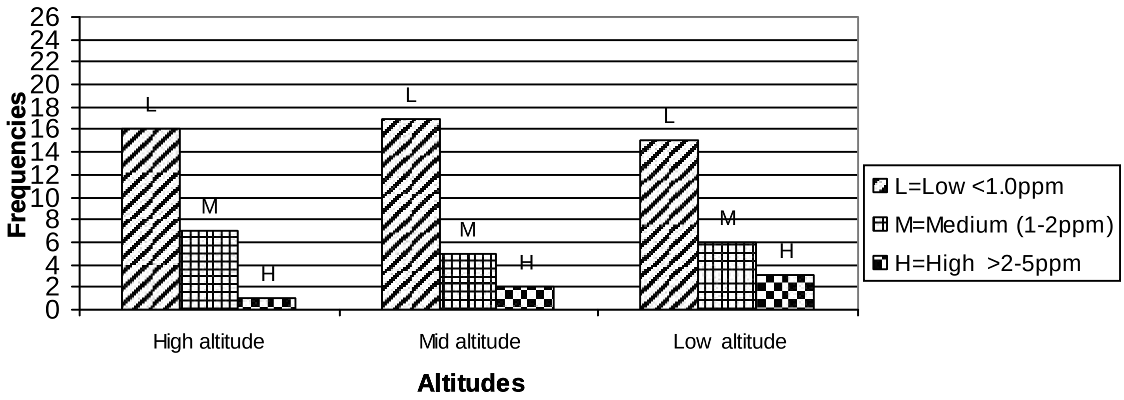


Figure 21: Rating of Soil Available Magnesium from the Mandarin Orchards

Soil available boron

The available soil B varied from 0.03 to 3.0 ppm with the mean value 0.79 ppm (Table 24). The percentage of samples 66.7, 70.8 and 62.5% were rated as low B contents at high, mid and low altitudes, respectively (Figure 22). Few orchards samples had medium and low ranges of B rating.



Figures 22 : Rating of Soil Available Boron from the Mandarin Orchards

Soil available iron

The available Fe content ranged from 0.006 to 113.9 ppm with the mean value 36.28 ppm (Table 24). The soil sample 95.8, 100, and 100% from orchards at high, mid and low altitudes were rated as high status of Fe contents (Figure 23).

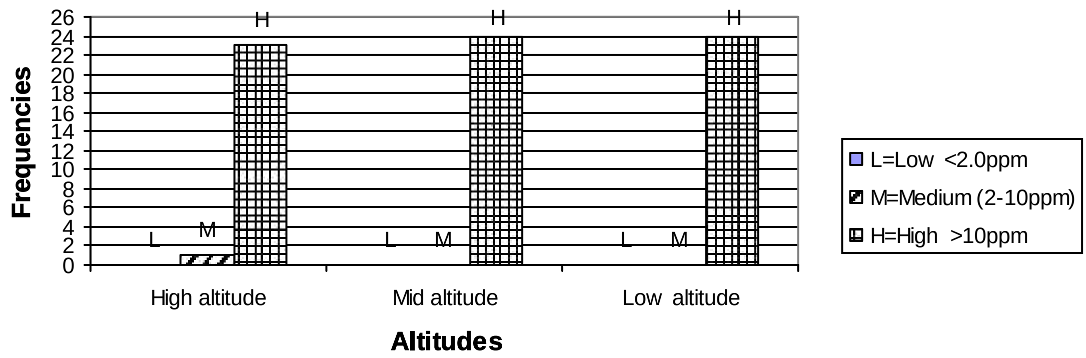


Figure 23 : Rating of Soil Available Iron from the Mandarin Orchards

Soil available manganese

The available Mn content ranged from 0.88 to 99.58 ppm with mean 34.26 ppm (Table 24). Soil samples of 91.7, 70.8 and 87.5% of total were categorized as high Mn status at high, mid and low altitudes, respectively (Figure 24).

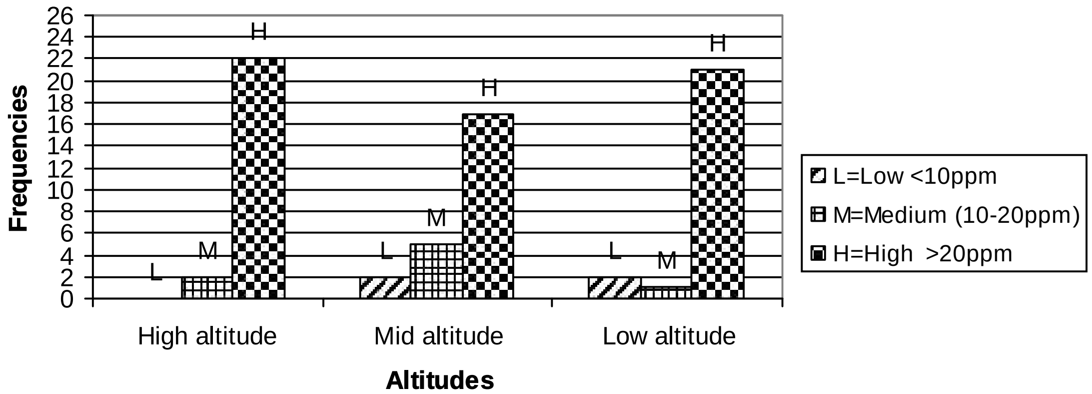


Figure 24 : Rating of Soil Available Manganese from the Mandarin Orchards

Soil available copper

All soils samples were rated as high with respect to Cu contents (Figure 25). The available soil copper ranged from 0.56 to 9.2 ppm with mean 6.58 ppm, (Table 24).

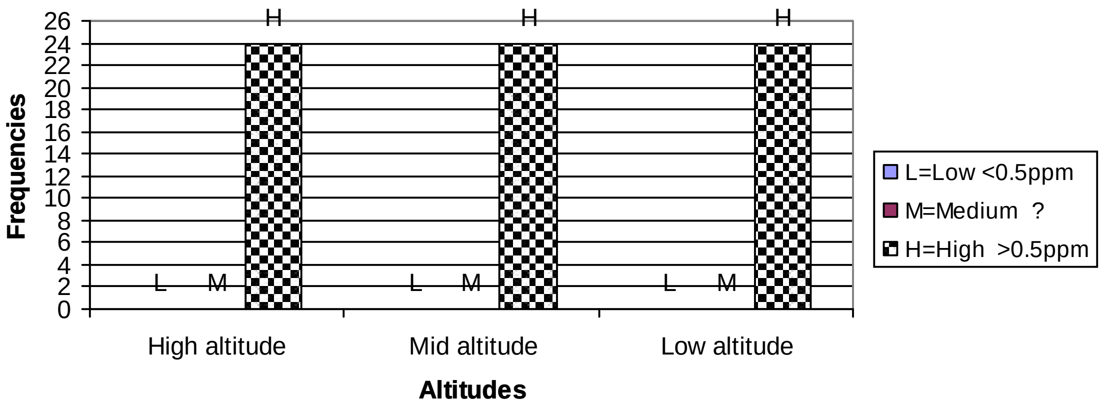


Figure 25: Rating of Soil Available Copper from the Mandarin Orchards

Soil available zinc

The Zn contents of the orchards ranged from 6.16 to 15.92 ppm with mena 2.68 ppm (Table 24). Majority of the soils in all the 3 mandarins pockets located at different altitudes ranges rated as high amount of soil available Zn contents (Figure 26).

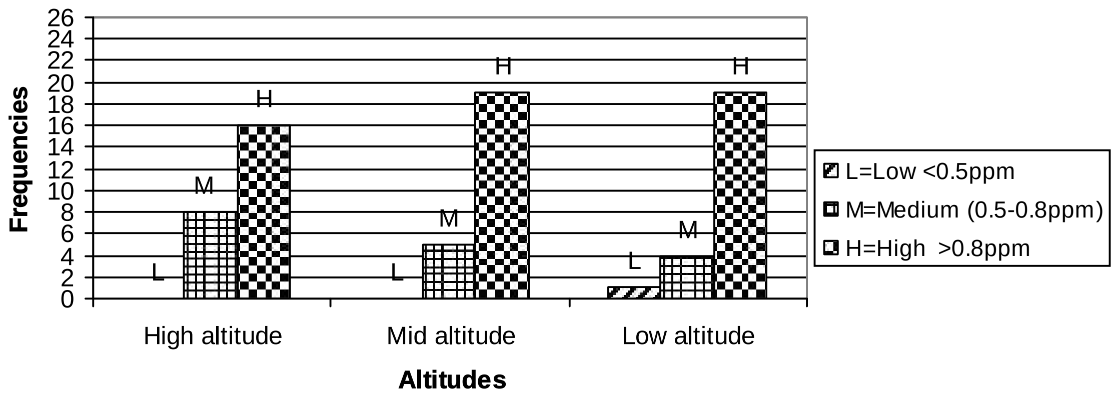


Figure 26 : Rating of Soil Available Zinc from the Mandarin Orchards

Table 24. Soil pH, organic matter and available nutrients of orchards.

Sample*	Range	Mean
pH	4.6 – 10.00	6.12
Organic matter	2.58 – 7.35	4.696
N	0.011 – 0.18	0.1281
P	0.1-0.3 – 0.048	0.005
K	0.063 – 0.12	0.02
Ca	0.01 – 0.41	0.13
Mg	0.001- 0	1.47
B	0.03-3.0	0.79
Fe	0.006 – 113.9	36.28
Mn	0.88 – 99.58	34.26
Cu	0.56 – 90.2	6.581
Zn	6.16 – 15.92	2.679

* Number of samples 72.

4.1.3 Correlation among and between plant and soil nutrients

4.1.3.1 Among the leaf nutrient relationships

The relationship among the leaf nutrients contents is given in Table 25. It is evident from the table that the leaf N (N=72) was positively and significantly related to Fe (r=0.24) and Zn (r=0.433). The leaf P and K had also the significant positive association with each other and K was significantly positively related to B (r = 0.273) whereas the leaf K was negatively and significantly related to Cu (r = -0.365) and Mg (r=0.461). It was also evident from the table that leaf Ca content had the significant positive correlation with leaf B (r = +0.276) and Mg (r=+0.370). Likewise, the leaf Mn had the relation with Fe positively (r=0.274), and Zn had the positive relation to Fe (r=0.262) and negative to Mg (r =-0.254) and Mn (r=–0.344).

4.1.3.2 Among the soil nutrient relationships

The relationship among the soil nutrient of the surveyed orchards is presented in the Table 26. The soil available Fe had negative and significant relationship with the available Ca (r = -0.258); K had positive with B (r = 0.261); the organic matter was related positively with Fe (r=0.364); P was negatively related to Fe (r = 0.247) and positively with Mg (r = 0.357); the pH was related negatively and significantly with Fe and organic matter (r = -0.297 and –0.448 respectively) but positive with Ca (0.511). Likewise, soil available Zn had strong positive relationships with Fe, K and organic matter (r = 0.256, 0.296 and 0.424, respectively).

4.1.3.3 Soil and leaf nutrient relationships

The availability of soil nutrients relationships with total leaf nutrient contents are presented in Table 27. Among the nutrients the leaf Ca and N only had significantly and positively related to soil available Ca and total nitrogen (r = 0.184 and 0.233 respectively) whereas leaf P was negatively related to soil available P (r -= -0.209). The availability of soil nutrients did not bear any significant relationship with leaf nutrient content for the rest of the nutrients.

Table 25. Correlation coefficients (r values) among the leaf nutrient contents of mandarin.

B	1.000									
Ca	0.276 *	1.000								
Cu	- 0.123	0.003	1.000							
Fe	- 0.094	0.024	- 0.041	1.000						
K	0.273*	- 0.197	- 0.365 **	0.118	1.000					
Mg	0.039	0.370 **	0.058	- 0.051	- 0.461**	1.000				
Mn	0.120	0.132	0.105	0.274*	- 0.033	0.146	1.000			
N	0.128	- 0.183	- 0.030	0.240	0.009	- 0.138	0.151	1.000		
P	0.070	- 0.172	- 0.023	- 0.078	0.427**	- 0.340 **	0.054	0.004	1.000	
Zn	0.088	0.075	- 0.016	0.262 *	- 0.009	- 0.254	-0.344**	0.433 **	-0.001	1.000
	B	Ca	Cu	Fe	K	Mg	Mn	N	P	Zn

N = 72 plant samples and *, ** = r values are significant at 5 and 1% levels.

Table 26. Correlation coefficients (r values) among the soil nutrient contents of mandarin.

B	1.000											
Ca	-0.085	1.000										
Cu	0.100	0.064	1.000									
Fe	0.185	-0.258*	-0.078	1.000								
K	0.261*	0.004	0.072	0.142	1.000							
Mg	-0.112	-0.139	-0.042	-0.031	0.186	1.000						
Mn	0.176	-0.012	-0.058	-0.115	0.026	-0.190	1.000					
N	-0.055	-0.106	-0.043	-0.009	-0.031	-0.015	-0.002	1.000				
OM	-0.055	-0.001	-0.087	0.364**	0.117	-0.078	-0.112	-0.011	1.000			
P	-0.182	0.002	0.037	-0.247*	0.090	0.357**	0.121	-0.064	0.129	1.000		
PH	0.042	0.511**	0.185	-0.297*	0.035	-0.066	0.002	-0.121	-0.448**	-0.045	1.000	
Zn	0.132	0.220	0.080	0.256*	0.296*	-0.049	0.195	-0.055	0.474**	0.121	0.014	1.000
	B	Ca	Cu	Fe	K	Mg	Mn	N	OM	P	PH	Zn

N = 72 plant samples and *, ** = r values are significant at 5 and 1% levels.

Table 27. Correlation coefficients (r values) between plant and soil nutrient contents of mandarin.

6	1.000																			
B-S	-0.083	1.000																		
Ca-P	0.289**	-0.080	1.000																	
Ca-S	-0.090	-0.085	0.184*	1.000																
Cu-P	-0.120	0.051	0.002	0.139	1.000															
Cu-S	-0.170*	0.100	-0.097	0.064	-0.083	1.000														
Fe-P	-0.079	-0.117	0.020	0.046	-0.043	-0.132	1.000													
Fe-S	0.275**	0.185*	-0.057	-0.258**	-0.203**	-0.078	0.069	1.000												
K-P	0.248**	-0.263 **	-0.192*	-0.291**	-0.367**	-0.177*	0.138	0.212**	1.000											
K-S	0.119	0.261**	-0.055	0.004	-0.087	0.072	0.151*	0.142	-0.131	1.000										
Mg-P	0.077	0.156*	0.368**	0.228**	0.054	0.178*	-0.071	0.039	-0.441**	-0.030	1.000									
Mg-S	0.064	-0.112	-0.051	-0.139	-0.036	-0.042	0.053	-0.031	0.073	0.186*	-0.113	1.000								
Mn-P	0.129	-0.131	0.130	0.126	0.104	-0.033	0.271**	-0.077	-0.026	-0.095	0.141	-0.063	1.000							
Mn-S	0.117	0.176*	-0.091	-0.012	0.169*	-0.058	0.067	-0.115	-0.299**	0.026	-0.029	-0.190*	-0.112	1.000						
N-P	0.133	0.075	-0.184*	-0.176*	-0.030	0.010	0.239**	0.248**	-0.006	0.138	-0.144	0.107	0.150*	-0.019	1.000					
N-S	0.072	-0.055	-0.067	-0.106	-0.035	-0.043	-0.034	-0.009	0.040	-0.031	-0.117	-0.015	-0.055	-0.002	0.233**	1.000				
P-P	0.023	-0.189*	-0.166*	-0.128	-0.016	0.168*	-0.056	-0.096	0.399**	-0.145	-0.304**	0.075	0.067	-0.107	0.009	0.116	1.000			
P-S	0.038	-0.182*	0.170*	0.002	-0.143	0.037	0.256**	-0.247**	-0.086	0.090	-0.041	0.357**	-0.010	0.121	0.022	-0.064	-0.209*	1.000		
Zn-P	0.078	0.031	0.079	-0.059	-0.014	-0.120	0.269**	0.011	-0.021	0.308**	-0.247**	0.057	0.348**	0.026	0.435**	0.104	-0.019	0.240**	1.000	
Zn-S	0.161*	0.132	0.178*	0.220	-0.159	0.080	0.177*	0.256**	-0.074	0.296**	0.134	-0.049	-0.118	0.195*	0.039	-0.055	-0.325**	0.121	0.016	1.000
	B-P	B-S	Ca-P	Ca-S	Cu-P	Cu-S	Fe-P	Fe-Sl	K-P	K-S	Mg-P	Mg-S	Mn-P	Mn-S	N-Pt	N-Sl	P-P	P-S	Zn-P	Zn-S

N = 144 plant samples and *, ** = r values are significant at 5 and 1% levels.

4.2 Part II: Nitrogen management experiments

The foliar and soil analyses across the orchards located at different citrus growing altitudes evidenced that the orchards were deficit in N particularly in low altitudes citrus belts (500-700 msl). Unhealthy trees irrespective of bearing or non-bearing and age above or below 5 years old, showed sub-optimal for the most of the nutrients. Among them, N was the most acute across the orchards located from low to high altitudes. With this in mind, four experiments were initiated to elucidate the role of various levels of soil applied nitrogen, methods of N-application, and N - interaction trials on growth, yield and quality characteristics of mandarin. The results are given as under.

4.2.1 Experiment # 1: Effects of fertilizer package on growth, yields and quality of mandarin under farmers conditions in MHWR of Nepal

4.2.1.1 Effects of soil applied major nutrients and other recommended package on growth, yield and quality relationships

One-year of experimentation showed the relative importance of the fertilization of different components to recommend package for the successful production of mandarin orange under farmers' conditions in the MHWR of Nepal.

Number of new leaves: There was a significant production of first new leaves flush over control by the applied treatments. The number of new leaves per branch ranged from 65.3 in the control trees to 106.5 in the treated trees that received complete recommended package i.e. NPK + All micro-nutrients (MN) + liming (L) (Table 28). The major nutrients NPK produced only 85 leaves per branch on an average. The number of new leaves decreased significantly in the order of minus micro nutrients > minus liming > (FP + liming) > control treated trees. There was a significant difference between control and FP + liming treatments. Farmer's practices with liming addition produced more leaves number than the control.

Table 28. Effects of fertilization of major nutrients micro-nutrients and liming on growth and yield of mandarin orange production in farmer's field conditions Mid-hills Western Region of Nepal, 2004-2005.

Treatments	New leaves/ Branch (No.)	Length of new shoots (cms.)	Flowers/branch (No.)	Immature fruits/branch (No)	Mature fruits/tree (No.)	Final fruit yield (kg/tree)
1. FP(control)[1]	65.3f [z]	18.5d	73.5a	23.0c	61.00d	4.4e
2. NPK[2]+MN[3]+L[4]	106.5a	43.7a	38.0d	42.3a	103.00a	11.6a
3. NPK+MN(-L)	92.0c	30.7c	43.7c	29.7b	88.7b	8.6c
4. NPK+L(-MN)	99.2b	33.7b	54.7b	40.8a	97.7a	9.8b
5. NPK only	85.0d	26.8c	57.8b	22.2c	74.2c	5.9d
6. FP+L	74.0e	19.7d	71.5a	28.5b	74.0c	5.6d
F-Test	**	**	**	**	**	**

*, ** Non-significant (N.S.), significant at 5% (*), and at 1% (**) level,
Z = Mean values followed by the same letter in a column are not significantly different at 5% level as determined by Duncon's Multiple Range Test (DMRT).
1 = Farmer's practices; 2 =200-100-200g-NPK/plant/year ; 3 spray of Commercial formulation of all micro nutrients; 4 = Liming @ 2 mt/ha

Table 29. Effects of fertilization of major nutrients, micro-nutrients and liming to mandarin on quality parameters of mandarin orange in farmer's field conditions of Mid-hills Western Region of Nepal, 2004-2005.

Treatments	Fruit Size (gms)	Fruit Diameter (mm)		Fruit shape (L/D ratio)	Fruit firmness (kg/sq. cm)	Peel thick-ness (mm)	TSS (%)	TA (%)	TSS/ TA ratio	Juiciness (%)	No.of seeds/ fruit	Seed weight /fruit (gms)	No. of seg-ments/ fruit
		D	H (L)										
1=FP(control)[1]	71.7d[z]	51.3d	45.5d	0.89b	1.46a	23.2d	9.4b	0.85a	11.1c	43.2d	12.8	3.2e	9.3
2=NPK[2]+MN[3]+L[4]	112.0a	68.7a	62.7a	0.91a	1.25c	38.2a	10.9a	0.68bc	16.3a	51.7ab	13.8	7.0a	10.5
3=NPK+MN(-L)	96.5b	60.2c	54.7c	0.91a	1.26c	26.2cd	10.3a	0.73b	14.1b	48.3c	13.5	5.0b	10.2
4=NPK+L(-MN)	100.5b	62.8bc	57.0bc	0.91a	1.29bc	29.7c	10.9a	0.67c	16.4a	53.8ab	12.3	5.4b	9.7
5=NPK only	79.0c	65.7ab	60.0ab	0.91a	1.33b	33.7b	11.0a	0.70bc	15.8a	49.0bc	12.5	4.4c	10.3
6=FP+L	76.2c	54.5d	49.0d	0.90ab	1.45a	24.8d	11.2a	0.80a	14.0b	47.3c	14.0	3.8d	10.0
F Test	**	**	**	* (0.04)	**	**	**	**	**	**	N.S.	**	N.S.

N.S., *, ** Non-significant (N.S.), significant at 5% (*), and at 1% (**) level,
Z = Mean values followed by the same letter in a column are not significantly different at 5% level as determined by Duncon's Multiple Range Test (DMRT).
1 = Farmer's practices; 2 =200-100-200g-NPK/plant/year; 3 = Spray of commercial formulation of all micro nutrients; 4 = Liming @ 2 mt/ha.

Length of new shoots: A significant increase in the length of new shoots from the complete package of nutrients applied to trees and the maximum growth was 43.7 cm followed by 33.7, 30.7, 26.8, 19.7 and 18.5 cm from the minus MN, minus liming, NPK only FP + liming and control plots, respectively (Table 28). There were no significant differences in new branches production between NPK only and -liming treated trees and between control and FP + liming trees.

Number of flowers: Table 28 showed that the number of flowers recorded per branch was the highest from the control and FP + L treated trees. The NPK only and minus MN plots showed similar effects with respect to the number of flower production. However, the lowest number of flowers were found from the complete package applied trees followed by minus liming treatments.

Number of immature fruits: The complete package and MN minus treatments produced maximum number of immature fruits per branch and ranging from 40.8 to 42.3 among the treatments (Table 28). The minimum number of fruits from 22.0 to 23.0 was found from the control and NPK only treatments. The fruit number from minus liming was similar to the FP+ liming treatments.

Fruit yields: The relative importance of the different component to recommended package for the successful production of mandarin was found highly significant (P=0.01) on number of fruits, average fruit weight and final overall fruit yield (Table 28 and 29). The highest fruit number (103 fruit/tree), average fruit weight (112.g/fruit) and final fruit yield (11.6 kg per tree) were observed from the complete package treated trees followed by all but minus MN treated trees which produced 97.7 fruits/trees, 100.5 g/ fruit weight, and 9.8 kg fruit/tree. The lowest number of fruit, fruit size and final fruit yield were recorded from the control, followed by FP + liming, NPK only treated trees.

Fruit diameter, (D) length (L) and Shape (L/D ratio): The effects of different fertilization components to recommended package on fruit diameter, length and fruit shape (L/D ratio) are presented in the Table 29. Differential fertilizer packages had highly significant influence (P=0.01) on fruit diameter. The largest fruit diameter (68.7 mm) was obtained from the complete fertilizer recommended package. The smallest fruit diameter (54.5 mm) was found from the FP + liming treated trees and it was not significant different from the FP practices (51.3 mm). Intermediate fruit diameters between the highest and the lowest were recorded from the rest of the packages of different fertilizing components. The individual components package had similar response as that of the fruit diameter. However, the fruit shape (L/D ratio) was not influenced significantly by the treatments. The fruit shapes remained unaffected by the majority of the treatments except for the control and FP + liming treated trees.

Fruit firmness: The FP's practices (1.46 kg/cm^2) and FP's + liming (1.45 kg/cm^2) treated trees produced the hardest fruit firmness as it was measured by Pressure Tester (Table 29). All the fertilizer components package, did not differentiate each other with respect to fruit firmness but had fruits with firmness ranging from 1.25 to 1.33 kg/cm^2.

Peel thickness: The treatments had highly significant effects (P=0.04) on fruit peel thickness (Table 29). The maximum thickness (38.2 mm) was observed in the complete fertilizer applied trees but the control had 23.2 mm. The NPK only trees had 33.7 mm peel thickness which was thicker than minus liming (26.2 mm) and minus MN (29.7 mm) treatments.

Total soluble solids (TSS): The TSS had significantly affected by the treatments packages (Table 29). But only FP practices (control) trees recorded a significantly lower TSS (9.4%) than the rest of others treatments, which however were not found differentiated from each others.

Titratable acidity (TA): The fertilizer treatments packages had tremendous influence (P=0.01) on TA of the mandarin orange (Table 29). The TA content was significantly higher than the control (0.85 percent) and FP + liming trees (0.80 percent) than the remaining treatments on the trees. The complete package did not show difference from the remaining treatments except MN treated trees which had significantly lower TA (0.70%) than control.

TSS/Acidity ratio: TSS/TA ratio reflects the proper blending of sugar and acid in the fruits. This is one of the major criteria standardizing fruits for the consumer's acceptance. The TSS/acid was highly and significantly affected by the treatments packages of different fertilizers (Table 29). The complete fertilizers treated trees performed (16.3 ratio) significantly higher as compared to control trees (11.1 TSS/acidity ratio). However, this complete package of nutrients applied to trees did not find different from the minus MN and NPK only treated trees. The FP's + liming and minus liming treated trees produced similar TSS/acidity ratio of the fruit.

Juiciness: The applied treatments had highly significant effects on juiciness of the fruits (Table 29). The highest (51.7%) juice content of fruit among the treatments were from the complete package treatments trees and minus MN treatments (53.8%) than from the remaining treatments. The control treatments produced the lowest juiciness (43.2%) of the fruits.

Number of seeds, seed weight and number of segments of fruits: The number of seeds in a fruit was not affected by the treatments applied (Table 29). A total of 12 – 14 seeds per fruit were recorded. However, the seed weight of a fruits was significantly (P=0.01) affected by the applied treatment packages. Maximum total seed weight (7.09) was obtained from the balanced package treatments. Absence of the one component from each of the complete package significantly reduced the seed weight. The number of segments in a fruit remained unaffected by the application of treatments.

4.2.2 Experiment # 2: Nitrogen interaction effects of major nutrients on growth and production of mandarin

4.2.2.1 Major nutrients interaction, vegetative, yield and quality parameters relationship

Number of new leaves: Number of new leaves as shown in the Table 30 were significantly increased with N either in NPK, a complete combination, or singly N only without PK or NP (-K) or NK (-P) combinations. The higher number of new leaves per branch (89.3 - 95.80) was produced by the N included fertilizer combinations with PK as compared to the other N – minus combinations.

Length of new shoots: The maximum length of new shoots (36,0 cm) was obtained from the NPK combined treated trees whereas the minimum length was from P – applied trees (Table 30). Besides, N, the K fertilizer combination produced 34.8 cm length shoots per season followed by NP combination. The single major nutrient K applied trees produced 19.3 cm shoot length which was superior to the only P – treated trees.

Number of flowers: Profused flowering were recorded from N-released fertilizer combinations without N (65.3) although it was at par with that of single N and P (Table 30). Wherever, N-fertilizer added to the combination of the treatments, there was less number of flowers per branch (44.0 – 47.5 ranges) as compared to N minus treatments combinations (54.5 to 65.3).

Number of immature fruits: As shown in the Table 30, number of immature fruits per branch was significantly affected by the different combinations of NPK – fertilizers package imposed to the mandarin trees. The maximum number of immature fruits were obtained from P(-NK), K (-NP), NK (-P) and NPK treatments combinations followed by PK (- N). The lowest number of immature fruits were found from only N (-PK) and NP (-K) treatments.

Number of mature fruits: Similar number of matured fruits in the trees were recorded as with the number of immature fruits by the imposition of various NPK-combination packages (Table 30). However, the lowest number of fruit 37.7 per branch was found from P(-NK) treatments just opposite to immature fruits where maximum number was recorded. The maximum number of matured fruits 86.2 per branch was from only N (-PK) applied treatments.

Final fruit yield: The treatment combinations showed highly significant (P=0.01) effects on the fruit yield per tree (Table 30) in mandarin. The highest tree fruit yield (10.4 kg/tree) was obtained from the complete NPK recommended package. The NK (-P) combination recorded 8.7 kg/trees next to the NPK treatment. The lowest fruit yield 1.6 kg/tree was found from only P (-NK) treated trees.

Fruit size: Different combinations of NPK – fertilization had highly significant effects on mandarin fruit size (Table 31). The maximum weight per fruit was obtained from NPK – balanced treatments (111.8 g) followed by NK (99.59 g) treated package. The minimum weight per fruit (41.3 g) was found from only P (-NK) fertilizer combination. Absence of K and N treatments in NPK combination had similar effects and singly applied nutrients P and K recorded the smallest fruits size.

Fruit diameter, fruit length and fruit shape: With respect to fruit diameter, the NPK, NK (-P), and K (-NP) treatments had the largest effects but they were similar to each other (Table 31). The smallest fruit diameter (53 mm) was recorded from P (-NK) treated trees and the fruits were in medium diameter range (58.8 – 62.0) for the rest of the treatments. Similarly, the length of the fruit was also affected significantly by the treatments as in the fruit diameter. However, the treatments showed non-significant effect on fruit shape.

Fruit firmness: The fruit firmness was significantly affected by the different fertilizers treatment combinations (Table 31). All the treatment combinations effects were similar to each other except NK (-P) combination which was lower (6.97 kg/cm^2) than the rest of the treatments combinations (1.34 – 1.51 kg/cm^2).

Peel thickness: The NPK – treatment combinations had highly significant effects on peel thickness of the mandarins orange fruits (Table 31). The P only treated trees had the thinnest peel (16.00 mm) while the thickest from NK (-P) treated trees (41.00 mm). Single nutrient element either N or K applied trees had thinner peel ranges than from either NP (-K) or PK (-N) or NPK combinations.

Total – soluble solids (TSS): Different major nutrient packages for successful production of mandarins orange showed highly significant effects on TSS (Table 31). The maximum TSS of the fruit juice was produced from the complete package (11.2%) and NK (-P), (11.3%) added trees. Singly K (-NP) and PK (-N) applied trees had in the intermediate TSS ranges and all the rest K-released plots showed the lowest TSS ranges.

Titratable Acidity (TA): The effects of different combination of major fertilizer elements on TA were highly significant (Table 31). The NP (-K) and PK (-N), fertilizers added treatments had the higher TA of 0.74 and 0.71%, respectively and it was lower than the N (-PK), P (-NK), K (-NP) and NK (-P) treated trees. The intermediate TA ranges were obtained from the NPK, PK (-N), NK (-P), P (-NK), and N (-PK) which were not significantly different from each other.

Table 30. Roles of NPK fertilizers and micro-nutrient spray on vegetative and yield parameters of farmer's managed mandarin orchards of Mid-hills Western Region of Nepal, 2004-2005.

Treatments	New leaves /branch (No.)	Length of new shoots (cm)	Flowers/ branch (No.)	Immature fruits/branch (No.)	Mature fruits/tree (No.)	Final fruit yield (kg/tree)
1=N-(PK)+MN[2]	91.5a [z]	29.0c	63.0a	15.3c	86.2a	6.7c
2=P(-NK)+MN	65.3b	14.8e	61.5a	29.5a	37.7c	1.6f
3=K(-NP)+MN	68.5b	19.3d	54.5b	32.8a	85.5a	4.7d
4=NP(-K)+MN	89.3a	32.0b	47.0c	15.5c	54.7b	3.6e
5=NK(-P)+MN	95.80a	34.8ab	44.0c	28.3a	87.0a	8.7b
6=PK(-N)+MN	62.5b	16.5de	65.3a	21.3b	48.3b	3.5e
7=NPK[1]+MN	93.5a	36.0a	47.5c	28.8a	93.0a	10.4a
	**	**	**	**	**	**

*, ** Non-significant (N.S.), significant at 5% (*), and at 1% (**) level,
Z = Mean values followed by the same letter in a column are not significantly different at 5% level as determined by Duncon's Multiple Range Test (DMRT).
1= 200 – 100 – 200g. N, P_2O_5 and K_2O per plant per year; 2 = Spray of commercial micro nutrient formulation.

Table 31. Roles of major nutrients (NPK) and micro-nutrient orange on quality parameters of mandarin grown in farmer's field conditions of Mid-hills Western Region of Nepal, 2004-2005.

Treatments	Fruit Size (gms)	Fruit Diameter (mm)		Fruit shape (L/D ratio)	Fruit firmness (Kg/sq. cm)	Peel thick-ness (mm)	TSS (%)	TA (%)	TSS/ TA ratio	Juiciness (%)	No.of seeds/ fruit	Seed weight /fruit (gms)	No. of seg-ments/fruit
		D	H (L)										
1=N(-PK)+MN	76.3e[z]	59.0b	53.0de	0.90	1.36a	21.3c	9.2d	0.68bc	13.5c	42.0d	14.8	6.4c	10.0
2=P(-NK)+MN	41.3f	53.0c	49.0e	0.92	1.38a	16.0d	8.7e	0.68bc	12.8c	44.3bc	13.8	4.5d	9.5
3=K(-NP)+MN	55.0c	67.3a	62.0b	0.92	1.47a	24.0c	10.7b	0.65c	16.5a	41.8d	15.3	6.3c	10.0
4=NP(-K)+MN	66.0d	62.0b	57.3d	0.92	1.51a	37.0b	9.6c	0.74a	12.9c	45.0b	18.5	5.6c	10.0
5=NK(-P)+MN	99.5b	69.0a	65.8a	0.95	0.97b	41.0a	11.3a	0.68bc	16.8a	51.3a	14.8	7.6b	9.0
6=PK(-N)+MN	72.8cd	58.8b	54.8d	0.93	1.40a	32.0b	10.6b	0.71ab	14.9b	42.5cd	14.8	4.5d	11.0
7=NPK[1] + MN[2]	111.8a	67.3a	61.0bc	0.91	1.34a	30.5b	11.2a	0.69b	16.3a	49.3a	15.3	8.6a	10.0
F Test	**	**	**	N.S.	**	**	**	**	**	**	N.S.	**	N.S.

N.S., *, ** Non-significant (N.S.), significant at 5% (*), and at 1% (**) level,
Z = Mean values followed by the same letter in a column are not significantly different at 5% level as determined by Duncon's Multiple Range Test (DMRT).
1= 200 – 100 – 200g. N, P_2O_5 and K_2O per plant per year; 2 = Spray of commercial micro nutrient formulation.

TSS/acidity ratio (TSS/TA ratio): The suitable TSS/TA ratios were obtained from NPK (16.3), NK, (16.8) and K (16.5) treated trees whereas the rest of the treatments produced less than 16.00 TSS/TA ratios. This ratio is not considered favorable for consumption (Table 31).

Juiciness (%): Juiciness of the mandarin fruits was affected significantly by the treatments (Table 31). The higher juicy fruit was found from NPK (49.3%), and NK (51.3%) treated trees followed by NP (-K) and P (-NK) treatments. The remaining treatment combinations produced the juice content below standard.

Seed weight and seed number: Seed weight was affected by the treatments but seed number remained unaffected (Table 31). The highest seed weight per fruit (8.69) was recorded from NPK treatments and followed by NK (7.6 g). The lowest seed weight per fruit was from NPK (5.6 g) and the rests were between the above ranges.

Number of segments: Number of segments of fruit remained consistent by the by the application of fertilizer treatment combinations (Table 31).

4.2.3 Experiment # 3: Effect of soil applied nitrogen on growth, yield and quality of mandarin

4.2.3.1 Soil applied N, growth, and yield relationships

Number of new leaves: A significant increase in number of new leaves per branch occurred as soil applied N increased from 0 to 500 g per tree per year (Table 32). The leaf number gradually increased and reached the highest number of leaves per branch (109.0) with the maximum rate of N-applied (500 g). The minimum leaf number was recorded from the Farmer’s Practices (FP) control (75.79 g). The official recommended package of N (60 g N per plant per year) for mandarin also counted the lowest number of leaves after the FP’s control.

Table 32. Effects of Nitrogen fertilizations on vegetative and yield parameters of mandarin orange at farmers field of Mid-hills Western Region of Nepal, 2004-2005.

Treatments	New leaves/ Branch (No.)	Length of new shoots (cms)	Flowers/ branch (No.)	Immature fruits/ branch (No.)	Mature fruits/tree (No.)	Final fruit yield (kg/tree)
1=0g.N[1]+PK[2]+MN[3]	75.7f [z]	19.4e	75.9a	10.6e	53.7f	3.3e
2=100g.N " "	82.4e	22.0e	66.6b	14.9d	73.4de	5.3d
3=200g.N " "	85.4d	27.0d	54.4c	21.9c	85.4bc	6.9c
4=300g.N " "	92.9c	33.9c	47.1d	30.1b	94.0b	8.7b
5=400g.N " "	98.9b	42.3b	42.9e	35.1a	128.6a	15.5a
6=500g.N " "	109.a	52.6a	29.00f	17.9d	81.7cd	8.1bc
7=GO's recommend.[4]	84.9d	43.6b	67.6b	22.4c	67.4e	4.9d
F-Test	**	**	**	**	**	**

*, ** Non-significant (N.S.), significant at 5% (*), and at 1% (**) level,
Z = Mean values followed by the same letter in a column are not significantly different at 5% level as determined by Duncon's Multiple Range Test (DMRT).
1=Nitrogen per plant per year; 2=100-200 g.P_2O_5 and K_2O per plant per year; 3 = Spray of commercial formulation of all micronutrient; 4 = 300 g.DAP : Urea : MOP : : 3:1:1 per plant per year

Table 33. Effects of Nitrogen fertilization on quality standards of farmer's managed mandarin trees of Mid-hills Western Region of Nepal, 2004-2005.

Treatments	Fruit Size	Fruit Diameter (mm)		Fruit shape (L/D ratio)	Fruit firmness (kg/sq. cm)	Peel thickness (mm)	TSS (%)	TA (%)	TSS/ TA ratio	Juiciness (%)	No. of seeds/ fruit	Seed weight/fruit (gms)	No. of Segments /fruit
		D	H (L)										
1=0g.N[1]+PK[2]+MN[3]	60.6e[z]	53.6d	49.0d	0.91	1.69a	19.1e	9.1e	0.81a	11.3e	40.9f	14.6	3.4e	9.7
2=100N+ " + "	72.7d	58.0cd	53.6e	0.92	1.45b	21.6e	9.8d	0.76b	12.9d	44.1e	15.0	5.2d	10.1
3=200N+ " + "	81.9c	61.4bc	56.3bc	0.92	1.33c	27.9d	10.6c	0.72c	14.7c	47.7d	16.9	7.1c	9.7
4=300N+ " + "	92.9b	65.6b	60.7b	0.93	1.19d	31.9c	11.1b	0.66e	16.8b	53.3b	14.4	8.3b	10.3
5=400N+ " + "	119.6a	73.0a	67.9a	0.93	1.13d	40.0b	11.7a	0.58f	20.4a	57.3a	13.9	9.4a	9.7
6=500N+ " + "	98.3b	75.3a	70.1a	0.93	0.95e	45.7a	10.3c	0.71cd	14.5c	57.6a	14.0	9.6a	9.9
7=GO's[4] recomm.	73.1d	59.9c	54.bc	0.91	1.40bc	30.3cd	10.3c	0.68de	15.1c	50.3c	12.4	6.7c	9.7
F Test	**	**	**	NS	**	**	**	**	**	**	NS	**	NS

N.S., *, ** Non-significant (N.S.), significant at 5% (*), and at 1% (**) level,
Z = Mean values followed by the same letter in a column are not significantly different at 5% level as determined by Duncon's Multiple Range Test (DMRT).
1=Nitrogen per plant per year; 2=100-200 g. P_2O_5 and K_2O per plant per year; 3 = Spray of commercial formulation of all micronutrient;
4 = 300 g. DAP : Urea : MOP : : 3:1:1 per plant per year

Length of new shoots: Differential N-rates had significant effects on length of new shoots (Table 32). The gradual increase in N amount increased the length of new shoots gradually and reached 52.6 cm per season at 500 g N per plant per year and it was the highest growth.

Number of flowers: The effects of N-application rates on number of flowers per branch were highly significant (Table 32). As the dose of soil applied N increased, the number of flowers per branch decreased and counted the minimum number of 29.0 per branch at the highest rate of 500 g N per plant per year. The highest flower number 75.9 per branch was recorded from the control followed by Government recommended package and N @ 100 g N per plant per year.

Number of immature fruits: An increase in the application rates of N, there was a significant increase in number of immature fruits per branch (Table 32). The maximum number of immature fruits 35.1 per branch was observed from the @ N=400 g/plant/year as from control treatment it was 10.6 fruits/branch. The highest N rate 500 g N/pl./yr. declined the number of immature fruits production as compared to preceding N-rates.

Number of matured fruits: Total number of harvestable matured fruits was significantly increased by increasing N application rates (Table 32) up to 400 g N/pl/yr (128.6/tree). Farmer’s Practices trees recorded the lowest count (53.7/tree) followed by GO’s fertilizer’s package (67.4/tree). The declined number of fruits were observed from the highest N rate @ 500 g/pl/yr.

Total fruit yield and fruit size: Final fruit yield per tree and average fruit size were highly and significantly affected by the graded doses of N-application (Tables 32 and 33). As the dose of N-application increased, total yield of fruit/tree and size were reached maximum of 15.5 kg and 11 9.6 g/fruit respectively at the 400 g N/tree/yr whereas control treatments produced only 3.3 kg/tree and 60.6 g/fruit, respectively. There was a reduction of total yield and the fruit size at N @ 500 g/tree/yr.

Fruit diameter (D) fruit length (L) and fruit shape (L/D ratio): Fruit diameter (D) was highly significant from the increasing the N application rates (Table 33). The highest N @ 500 g/pl/yr produced the largest fruit diameter (75.3 mm) which was not significantly different from the N application rate of 400 g/tree/year. The FP's and 100 g N/tree/year treated trees showed similar response in terms of fruit diameter. Similarly, official recommendations (120 g N) and 100 g N application rates were similar in fruit diameter. Fruit length also showed similar response as that of fruit diameter. Fruit shape as represented by the L and D ratio was not affected by the treatments applied. However, there was an increasing trend of L and D ratio with the increasing N-application rates.

Fruit firmness: Differential doses of N application had highly significant effects on fruit firmness (Table 33) As the N application rates increased, the fruit firmness decreased and reached the lowest 0.95 kg/cm^2 with the highest N-rate @ 500 g/tree/year where the hardest fruit was obtained from control (1.69 kg/cm^2). The recommendation of GO's and 100 g N/pl/yr had no significant effects on fruit firmness.

Peel thickness: The treatments effects on peel thickness of mandarin orange were highly significantly (Table 33). Gradual increase in peel thickness was obtained from the graded increase in the N-application rates. The thickest peel was (45.7 mm) observed from the highest N – applied (500 g N/pl/yr) trees.

Total soluble solids (TSS): With an increase in the nitrogen application rates from 0 to 500 g N/pl/yr there was a significant increase in the TSS (Table 33). The N rate of 400 g N/pl/yr produced the maximum TSS (11.7%). The TSS was reduced to 10.3% at N-rate of 500 g /pl/yr. TSS content increased with increased in N rate up to 400 g beyond which it was declined.

Titratable acidity (TA): Titratable acidity (TA) was decreased by increasing application rates of N (Table 33). As the N-rates were increased from 0 to 400 g/pl/yr, the TA reached the lowest (0.58%) at N @ 400 g/pl/yr. However, 0.71% TA was found at the highest N-rate (500 g/pl/yr).

TSS/TA ratio: The most favourable and tasty sugar and acid blending mandarin fruit (20.4 TSS/TA) was attended at 400 g/pl/yr N-rate (Table 33). The higher or lower than this N application rate produced, TSS/TA ratio below 16.0 which was unfavorable and not tasty.

Juiciness (%): The highest juice % (57.6%) in fruit was obtained from 500 g N/pl/yrs. followed by 57.3% on volume basis from 400 g N/pl/yr (Table 33). Lower than the above N-application rates, there was less juicy fruit.

Seed numbers and seed weight: Seed number was not affected by the N-application rates (Table 33). However, seed weight was highly significant by the various N-application rates. The seed weight was gradually increased as the N dose was increased and it reached the highest seed weight (9.4 – 9.6 g/fruit) at 400-500 g N/pl/yr rates. On an average 9-11 seeds/fruit were recorded.

Number of segments: Number of segments were not affected by the graded dose of N-application rates (Table 33).

4.2.4 Experiment # 4: Effects of methods of N application on growth, yield and quality of mandarin

4.2.4.1 Methods of N-application, growth, yield and quality relationships

Number of new leaves: Split basally soil applied and foliarly applied N affected the number of new leaves of mandarin in the season (Table 34). Two split doses of soil applied plus one foliar N applied produced the highest number of new leaves per branch (106.5) in the spring flush. Two split (1S + 1F) and Three-split (1S + 2F) doses of N produced consistent number of new leaves per branch (83.0-86.0).

Length of new shoots: Similarly, length of new shoots was highly significant from the application of various methods of N-application (Table 34). The faster growth (35.8 cm) from 2S + 1F applied trees was obtained as compared to control (21.8 cm) trees. Moderate growth of branches were received from the (1S+1F), and (1S + 2F) applied trees.

Number of flowers: Table 34 indicates that the lowest number of flowers per branch was produced from the 2S+1F trees (44.5). The higher number of flowers per branch was found from 2 split doses (2S+0F), and (1S+1F) than split (1S+2F) treatments (60.5).

Number of immature fruits: The trees treated with 2S + 1F nitrogen resulted in higher number of immature fruit/branch compared to 2 split N (2S+0F) as control (Table 34). The treatments 1S+1F and 1S+2F were similar with respect to the production of immature fruits.

Total tree yield: Frequency and methods of N-application had strong influence on total tree yields of mandarin (Table 34). The higher fruit yield (14.8 kg/tree) was produced from 2S + 1F method of N application compared to control (5.5 kg/tree). Three split (1S+2F) and 2 split (1S+1F) methods of N applications were found non-significant in terms of fruit yield.

Number of mature fruit and fruit weight: Number of harvestable mandarin fruits and fruit size as shown in the Table 35 were significantly higher from 2S + 1F trees compared to control 2S+0F treated trees (Table 35). Intermediate fruit number and sizes were obtained from the 1S+1F and 1S+2F – applied trees.

Fruit diameter (D), fruit length (L), fruit shape (L/D ratio): Fruit diameter, fruit length and fruit-shape were significantly affected by the methods of N-application. The maximum fruit diameter (72.5 mm) and the maximum fruit length (67.5 m) were produced from the three split N application methods namely two basally and one foliar applied trees which 60.8 mm and 5.48 mm, respectively produced from two basally applied treatments.

Table 34. Effects of methods of N-applications on growth and yield of local mandarins in Mid-hills Western Region of Nepal, 2004-2005.

Treatments	New leaves/ Branch (No.)	Length of new shoots (cms.)	Flowers/ branch (No.)	Immature fruits/branch (No.)	Mature fruits/tree (No.)	Final fruit yield (kg/tree)
1=2 Splits(2S[1]+0F[2])	64.0c [z]	21.80c	65.3ab	21.3b	68.0c	5.5c
2=2 Splits (1S+!F)	83.5b	26.80b	67.5a	26.8b	85.0b	7.8b
3=3 Splits (2S+1F)	106.5a	35.80a	44.5c	89.0a?	117.2a	14.8a
4=3 Splits (1S+2F)	86.0b	28.5b	60.5b	28.5b	88.2b	8.11b
F-Test	**	**	**	**	**	**

*, ** Non-significant (N.S.), significant at 5% (*), and at 1% (**) level,
Z = Mean values followed by the same letter in a column are not significantly different at 5% level as determined by Duncon's Multiple Range Test (DMRT).
1= Soils or basal applications of 200-100-200 g. N, P_2O_5 and K_2O per plant per year with spray of commercial formulation of micro nutrients;

Table 35. Effects of methods of N-application on post harvest parameters of mandarin grown at farmer's field conditions of Mid-hills Western Region of Nepal, 2004-2005.

Treatments	Fruit Size	Fruit Diameter (mm)		Fruit shape (L/D ratio)	Fruit firmness (Kg/sq. cm)	Peel thick-ness (mm)	TSS (%)	TA (%)	TSS/ TA ratio	Juiciness (%)	No.of seeds/ fruit	Seed weight /fruit (gms)	No. of seg-ments/ fruit
		D	H (L)										
1=2 splits=2S[1]+0F[2]	81.0b[z]	60.8c	54.8bc	0.90ab	1.35b	31.0c	10.7b	0.73a	14.8c	45.5b	19.3	6.3b	9.0
2=2splits=1S+1F	90.7b	66.5b	59.3b	0.89b	1.29b	36.5b	11.2ab	0.68b	16.4b	52.3a	17.5	5.8bc	10.3
3=3splits=2S+1F	126.2a	72.5a	67.5a	0.93a	1.14c	43.5a	11.6a	0.60c	19.4a	55.0a	16.5	8.0a	9.5
4=3splits=1S+2F	92.b	55.8d	52.0c	0.93a	1.46a	25.8d	9.4c	0.75a	12.5d	44.8b	19.0	4.7c	10.8
F Test	**	**	**	*	**	**	**	**	**	**	N.S	**	N.S

N.S., *, ** Non-significant (N.S.), significant at 5% (*), and at 1% (**) level,
Z = Mean values followed by the same letter in a column are not significantly different at 5% level as determined by Duncon's Multiple Range Test (DMRT).
1= Soils or basal applications of 200-100-200 g. N, P_2O_5 and K_2O per plant per year with spray of commercial formulation of micro nutrients;
2 = 2 percent

Fruit firmness: The softer texture fruits (Table 35) were produced from the two basally and one foliar sprayed trees (1.14 kg/cm^2) compared to control i.e.2 basally applied only (1.35 kg/cm^2).

Peel thickness: The effect of mode of N – application on peel thickness was found significant (Table 35) with three splits (2S+1F) had thicker (43.5mm) peel than two split (control). The minimum peel thickness was recorded from 1S+2F applied trees.

Total soluble–solids (TSS): Table 35 shows that the methods of N-application had resulted significant effects on TSS of mandarin fruits. The maximum TSS (11.6%) was attended from the two soil applied N with 1 foliar spray N followed by 1S+1F applied treatment.

Titratable acidity (%): Titratable acidity (TA) was affected by the treatments applied (Table 35). Two-split basally applied N + one foliar N application produced the lower acidity (0.6%) compared to two basally applied control trees (0.73%).

TSS/TA ratio: The most favorable TSS/TA ratio (19.4) was achieved from the 2S+1F N applied trees (Table 35).

Juiciness (%): Higher juicy fruits (55.0%) was found from the 2S+1F treatments as compared to 2S + 0F (45.5%) trees (Table 35). With respect to juiciness of the fruits other methods of N-application were not different from each other.

Seed weight and number: The seed number were not affected by the methods of N-application whereas the seed weight was affected (Table 35). Heavier seeds (8.09/fruit) were recorded from 2S+1F trees compared to 6.3 g/fruit seeds from the 1S+2F treated trees.

Number of segment of fruits: This remains unaffected by the N-methods of application (Table 35).

5 DISCUSSION

5.1 Part I: Survey of soil and foliar (tissue) of mandarin orange under farmer's field conditions at different altitude and management levels in Tanahun, Lamjung and Gorkha Districts

Citrus culture for commercial purposes is being practiced at an altitude ranging from 500 to as high as 1500 m msl stretching from east to west covering about 50 mid-hills districts of Nepal. The agro-ecological conditions of these mid-hills regions characteristically very much complex, rainfed, uplands, marginal fertility and steep topography, are very much favorable for the cultivation of citrus. The agro-ecological zones are synonymous with the altitudes and the sites are classified as high (>1100 m), mid (>700m) and low latitude (>500m) in the citrus growing ranges. The climatic parameters such as temperature, rainfall and light are directly or indirectly influenced by the altitudes. Several micro-climatic regions exist within these altitudes and the citrus production are influenced by these diverse agro-ecological factors directly or indirectly including soil fertility i.e. both soil and plant nutrient composition. These agro-ecological changes are influenced by the variation in altitude and orchard performances which in turn also affect the appraisal of fertility constraints in different altitudes. They occur, because the latitudinal gradients determine environmental gradients.

In the following discussing sections based on evidences provided by these studies, soil and plant nutrients composition and the appraisal of nutrient constraints (status) as moderated by altitudes variation in MHWR of Nepal and the effects of orchards performances as represented by the age and overall healthiness of the trees on soils and plant nutrients composition and their interaction are discussed.

5.1.1 Foliar analysis

5.1.1.1 Plant (foliar) nutrients composition and altitudes relationship

In the present study also, the leaf P, K, Fe and Zn were strongly affected by the variation in altitudes (Tables 2, 3, 7 and 10). At higher altitudes, the total leaf P, K, Fe and Zn contents were higher as compared to lower altitudes. Since the major minerals are feldspar and mica at high altitudes, the availability of the K also becomes high (Shah, 1995; Schreier *et al*., 1995; Goldsmith, 1981). Potassium was adequately available, was not fully utilized for increasing productivity because of the low N content of the soils. Low soil pH at high altitude (Table 12) increased the availability of Fe, Zn, Cu, Mn, B and Al. Increase of soluble Al and Fe in the soil was usually associated with a reduced availability of P as the pH falls below 6.5. The concentration of these micro-nutrients in plants were negatively correlated with soil pH (Jones, Jr. and *et al*., 1991). Low soil temperature had often been associated with lower concentration of P, Fe and Zn in a number of plants. (Appendix Table). The effects on these plant nutrient concentrations appeared to be related to the amount of already available nutrients in the soils due to low pH.

However, there was a trend to increase the leaf N and B at high altitude (Table 1 and 6). Organic matter content increases with increasing altitude (Singh *et al*., 1989; Subedi *et al*., 1998). The high amount of organic matter content at higher altitudes might be due to farmers applying higher doses of composts and prevailing lower temperature which results in lower oxidation rates (Sherchan, 1987). Elemental concentrations in the plant may actually be less at higher than at a lower temperature, because of the higher temperature may increase dry matter production to a greater extent than does the element uptake (Jones *et al*., 1991). There was no systematic trend at all and widely varied for Mn and Cu content of citrus leaves with the variation of altitudes, rather highly erratic results were obtained. Similar trends were also reported by previous workers (Embleton *et al*.,

1978) who found indiscriminate use of Bordeaux mixtures/paint and other commercial micro-nutrient formulation accessible to growers in the local markets are suspected for the variables results of these micro-nutrients.

Leaf analysis is emerging in modern agriculture as a practical tool widely as a diagnostic technique to asses the nutritional status of citrus plants and their response to fertilizer application. Foliar content of the plant not only depends on available nutrient in the soil, but it is also affected by various environmental factors such as temperature, light, moisture as well as several other cultural management factors. Of these, climatic variation (the agro-ecological zones) which are synonymous with altitudes variation, had strong influence on the mineral composition of leaves and consequently the interpretation of foliar analysis. These associations of foliar nutrient composition with location, agro-ecological zones mainly soil and climatic variation and year variation were studied by the various workers (Smith, 1962; Chapman, 1966; 1961, Parr *et al*., 1992).

5.1.1.2 Foliar composition and orchard performance relationships (bearing/non-bearing and healthy/unhealthy trees)

The effects of orchards performances as reflected by overall health and age of the mandarin orchards had impact on foliar nutrient levels of N, P, Ca, Fe, Mn and Zn as evidenced by the Tables 1, 2, 4, 7 and 8. Healthy trees of both young and matured trees out-performed the unhealthy trees with respect to all these plant nutrients content except P which was lower for both healthy bearing and non-bearing trees compared to unhealthy bearing ones. This is implicated that the leaf analysis is preferred to soil analysis particularly for N, Ca, Fe, Mn and Zn and for P, foliar analysis may not be suitable. This is consistent with many previous workers especially Wutscher and Obreza (1987). The leaves integrate uptake of nutrients over an extended period and the tree is the most accurate soil extraction system to indicate adequacy of each of the above nutrient which have high mobility rate in soils than P which is more or less fixed and localized. A yearly program of leaf analysis is useful for these nutrients to citrus growers in assessing the overall nutritional health and fertilizer requirement of an orchard. However, for P assessment whether P application is needed or not because of its high immobility in soil, only leaf analysis may not be very useful. Phosphorus is highly immobile in soils during winter season or in cold climates or at low temperature. At high altitudes temperature is low so, the uptake of P by the plant is low. Both soils and leaf analyses may be needed for P fertilizer need assessment. For the most of the micro-nutrients and highly mobile N and K, soil analyses are usually not representative of the levels in the tree because of the mobile nature of these ions.

Bearing and Non-bearing

As evidenced by the Tables 1, 2, 3, 8 and 10, the young non-bearing orchards of less than 5 years old of both healthy and unhealthy orchards had high amounts of leaf N, P, K, Mn and Zn at all the altitudes. The presence of fruits on a shoot significantly decreases leaf nutrient concentrations of N, P, K, Mg and Ca in most instances (Smith, 1966b; Embleton *et al*., 1963, 1973). This is expected since leaves compete for nutrients with developing fruits. This is evidenced by leaf N and N levels being inversely related to crop load (Smith and Rasmussen, 1961). Nitrogen, P, K, Mg, B, Cu, Fe and Zn move readily from leaves to fruit, resulting in lower concentrations of these elements in leaves of fruiting trees than of non-fruiting terminals. (Jones *et al*., 1991; Childers, 1966) Additional growth had modifying effects on mineral nutrient contents. Rapid changes in nutrients compositions are seen, when the plant is young and non-bearing and as the plant matures, changes related to time occur more slowly. The continued growth of new parts on a plant may appreciably alter the mineral composition of old leaves (Jones *et al*., 1991). New growth was supplied largely from the shifting of contained minerals, replacements by absorption occurred subsequent to the growth period.

However, the leaf Ca, Mg, B, Fe and Cu are not affected by the age of the trees in this study (Tables 4, 5, 6, 7 and 9). These elements may enter the leaves at rates that prevent dilution (Smith, 1966b). Generally, the concentrations of Ca, Mg, Al, B, Fe, and Mn tend to increase or become stable with the age of tissue/plant (Smith, 1966b; Embleton et.al. 1978).

Leaf analysis is a practical tool for developing fertilizer needs for citrus by developing leaf nutrient indices for different elements responsible for growth and productivity (Embleton, *et al*., 1973; Kohli and Srivastava, 1997; Oppenhiemer, 1954; Srivastava and Singh, 1998; Srivastava *et al*., 1993; Srivastava *et al*., 1994, 1997, 1995).

The biggest practical utility of leaf nutrient standards is the perfect correlation of leaf nutrient levels with varying productivity. Foliar content of the plant not only depends on nutrient availability in the soil, but it is also affected by various environmental factors such as light, temperature and moisture as well as several other cultural and management factors. The interpretation of the foliar level is largely dependent on an understanding of plant factors such as the overall healthiness and age of the trees whether trees are bearing/mature or non-bearing/young keeping the other factors under similar conditions. Understanding the interactions among health's, age and foliar nutrient composition of the mandarin trees help to modify the leaf nutrient standards developed and are widely used for working out (Smith, 1966a and 1966b; Embleton *et al*., 1973; Ko and Kim, 1987) nutritional status of citrus orchards under Nepalese situation.

5.1.1.3 Appraisal of nutrient constraints based on foliar analysis

Foliar levels of N and Zn in majority and B, Ca, and Mg in more than fifty percent of the mandarin growing studied pockets located at less than 700 m altitude (low altitude) representing Tananhun district, were deficient. (Figures 1, 4, 5, 6 and 10). Leaf Zn in all the orchards and B and Mn in about 50% of the pockets located at 700-1100m altitudes of Lamjung district were in deficient ranges (Figures 6, 8 and 10). At high citrus growing altitudes as represented by Gorkha district, only Zn and Mn leaf levels were deficient in most of the orchards (Figures 8 and 10). Similar appraisal of nutrient constraints based on soils and plant analyses in citrus growing pockets from east to west mid-hills of Nepal were reported by various workers (Tripathi, 2001; Tripathi *et al*., 1998; Gupta *et al*., 1989; Joshi *et al*., 1995; Tripathi and Harding 2001; Tripathi and Shah, 1986). However, there were some disagreement in the present findings particularly in the diagnosis of mirco-nutrient problems because the nutrient varied significantly depending on the different altitudes, age and health conditions of trees.

The trees across the orchards were deficit in N but P and K sufficient at all the three mandarin growing altitudes. Deficiency of N was the most acute problem in lower citrus growing altitudes. Most of the orchards were sub-optimal for Zn and B in all the locations. These results suggested that the nutritional status of the mandarin orchards could be improved through application of N as well as Zn and B across the orchards.

This study indicated that prior to leaf sampling for the appraisal of nutrients constraints and suggestion for the fertilizer requirements, leaf sampling must be taken from uniform, representative of the general orchard’s conditions of similar altitudes besides consideration of several other factors primarily age and health conditions of trees.

Foliar analysis is emerging in modern agriculture as a guide both for evaluating the nutritional status of citrus and for also working fertilizer requirements and remedial measures in case of deficiencies or toxicities (Rajput and Haribabu, 1995; Embleton *et al*., 1973; Srivstava and Singh, 1988). The nutrients constraints of mandarin orchards of MHWR of Nepal were identified according to the leaf nutrients standards developed for sweet orange cultivars (Embleton *et al*., 1973).

5.1.2 Soil analysis

5.1.2.1 Soil nutrients composition and altitudes relationships

Table 12, 13, 14, 15 and 17 showed that soil organic matter and total N and P were higher at high altitudes compared to soils of lower altitudes whereas soil pH and exchangeable P and Ca were lower at high altitudes. The available B, Fe, Mn, Cu and Zn contents of the surface soils varied widely (Tables 19, 20, 21, 22 and 23) and there were no systematic effects by citrus growing altitudes on the soil nutrient composition. Soils of high altitudes are developed mostly on granite and gneiss parent materials and are by large, acidic in nature (Wyatt Smith, 1982; LRMP, 1986). Intensive leaching of bases under high rainfall (Appendix Weather Table) have contributed towards the development of acidity in the soils of high altitudes. The high amount of organic matter and N in the mandarin orchards at the high altitudes is the results of the recycling of nutrients through organic manure. The earlier scientists (Lyngdoh and Shukla, 1993; Singh *et el*., 1989, 1997) reported that higher organic matter content, total soil N and low exchangeable P were found at higher altitudes compared to lower altitudes. Singh and Datta, (1989) observed a decrease in pH with increasing altitude in acidic hill soils of Mizoram, Inida. Avasthe and Avasthe (1995) showed higher organic matter and CEC and lower pH, exchangeable Ca and Mg were in soils at high altitude than at low latitude in acidic soils of Sikkim, India. Losses of Ca and Mg due to excess rain are high in the hills of Nepal, high leaching rates of basic cations (Ca, Mg and K) have been also reported (Shah, 1985; Shah *et al*., 1991). At high altitudes of Nepal, soils are darker with high organic matter content. They are usually more acidic due to high rainfall, with removal of bases from the soil. With the oxidation of organic matter, acidity becomes a stronger limiting factor. Pine and pine litters have a tendency to acidify the soil (Shah, 1995; Sehreier *et al*., 1995).

The high altitudes soils are developed under cold, humid mild temperate with mixed deciduous forests. While, low altitude soils are developed under warm, humid, sub-tropical with mixed semi-evergreen and evergreen forests (Appendix Table). There have been contrasting features which may account for differences in available P content at high and low altitudes (Singh and Datta, 1983 and 1987).

5.1.2.2 Soil anaysis and orchard performances relationships (age and health of trees)

Orchard performances as reflected by healthiness and age of the mandarin trees had affected the soil composition mainly organic matter, total soil N, available P and Zn (Tables 13, 14, 15 and 23). Overall, healthy mandarin trees both bearing and non-bearing had higher amount of these nutrients as compared to unhealthy bearing and non-bearing. However, the effect of age of the trees on the nutrients were not consistant.

The soil analysis method was developed on the assumption that it would be a simple and direct relationship between the extractable concentration of ions in the soil and their uptake by plants. But various physical and chemical factors as well as quality parameters of soils influenced the uptake of nutrient by plants, which were not measured by soil analysis. It is difficult to obtain samples which adequately reflect the explored nutrients by the root system. This is especially true with orchard tree crops like citrus, which have extensive and deep root systems (Bould, 1963). This is the reason most of the soil nutrients based on soil tests did not impact by orchard performance i.e. healthy/unhealthyness of trees and young and matured bearings.

5.1.2.3 Diagnosis through soil analysis

No well established standards for available soil nutrients having wide adoptability are available for evaluating soil fertility status of citrus orchards in Nepal, particularly for Mid-hills Western Regions. The interpretations were available on the basis of suggested optimum levels (Tripathi, 2001).

Soil pH of majority of mandarin orchards located at high altitude representing Gorkha district was found low followed by mid (Lamjung) and low altitudes (Tanahun) as evidenced by the Figure 12. The concerns over soil acidification have featured prominently (Shah, *et al*., 1991); Shah, 1995; Schreier *et al*., 1995; Tripathi, 1996). Major causes of development of soil acidity in Nepal have been identified: acidic nature of parent material of soil, aluminums toxicity, less of Ca, Mg due to excess rain, continuous use of acidic fertilizers, crop removal of Ca, Mg and presence of large scale pine plantation. One of the major contributing factors to decline in soil fertility is the increasing menace of soil acidification (Tripathi and Shah, 1986; Turton *et al*., 1996), resulting in decline in productivity of citrus orchard adapting citrus based farming systems. The organic matter, total soil N, available P and K were no problems in high and mid altitudes representing Gorkha and Lamjung, rather majority of the orchards were rated as medium to high ranges of these nutrients availability (Figures 13, 14,15 and 16). However, availability of N and B were found to be low to medium ranges in low altitudes representing Tanahun (Figures 14 and 19). The Ca and Mg availability were problems comparatively at higher than lower altitudes and most were in the low- to medium ranges of availability. The available Fe, Mn and Cu contents of the majority of the orchards were found having exceedingly high supply (Figures 20, 21 and 22) and the soil Zn content were fallen in high to medium ranges (Figure 23). There has been no consistent manuring practice in mandarin orchards and reported the deficiency of B, Mg, Cu, Ca and Zn in potential mandarin growing pockets of Dhankuta district (Joshi, *et al*., 1995; Gupta *et al*., 1989). Available Al, Fe and Mn present in soil affect the crop yield at their toxic levels (Brady, 1992).

It is well known that pH per se has no direct effect on plant growth. In such a low pH soils, may create Al, Fe and Mn at the toxic levels hamper plant growth.

5.1.3 Among and between leaf and soil nutrients relationships

5.1.3.1 Leaf nutrients relationships

The positive association of leaf nutrients were: Ca and B; K and B; Mg and Ca; Mn and Fe; N and Fe/Mn; P with K; Zn with Fe and N; and negative associations were: K with Cu, Mg, Ca; P with Mg; Zn with Mg and Mn (Table 25). The relationship among the leaf nutrient contents just described was not consistent with many previous works and some interactions were contrast of the previous works.

'Ion interactions' may be defined as the enhancing or depressing influence of one ion in a tissue on other ions of different species. It is important to know whether low or high leaf value of that element is an indication of soil supplies for that element or an interacting influence of some other element. Generally, as N increases in the foliage, P and K decreases (Bould, 1968 and 1966; Smith, 1966) and Mg is increased. The general effects of an applied element on mineral composition of citrus leaves was reported (Smith, 1962) and indicated that how extensively and in what direction, the mineral pattern of leaves may be modified by increasing the supply of one element. Chapman (1971) indicated that P interferes with Zn and Cu and frequently with other nutrients in plant when present in excess amount. Murthy *et al*. (1986) also found negative correlation between leaf N and K and positive with the Ca and Zn. Calcium showed a positive relationship with Zn and negative with Fe, whereas Mg had the reverse trend with Zn. The nutrient elements Cu, Zn and Mn were well associated with each other and former two had negative relationship with Fe while later had the positive relation.

From the above discussion, it is clear that understanding of ion interactions is valuable in interpreting foliar analysis results. Emmert (1959) suggested that the cause of interactions may be physiological as well as environmental. Shear *et al*. (1946, 1948) reported that concepts of intensity and balance must be satisfied before drawing any conclusion from leaf analysis study. Shear *et al*. (1946) mentioned that plant growth is a function of two variables intensity and balance. Both can have a direct influence on the composition of leaves of the plant during its growth and development. At any level of nutritional intensity several ratios may exist between these elements. When the concentration of the elements is substantially different from this optimum intensity, the supply of the other nutrient would not produce satisfactory growth and yield. All the nutrient elements must be brought into balance at a new level of intensity to obtain maximum growth and yield of crops. If balance is not corrected, the crop will first show a decrease in growth and later a reduction in yield, or visual deficiency symptoms, or all three may occur simultaneously.

5.1.3.2 Soil nutrients relationships

As evidenced from the results (Table 26) the soil pH, organic matter, available Fe, Zn, Ca, Mg, P and K were related. The soil pH had negative influence on available Ca, Fe and organic matter and organic matter had positive relationship with Fe and Zn availability. The available Zn influenced positively with Fe, K, and organic matter.

The pH of soil influences primarily by affecting the availability of nutrient elements. Low soil pH, will increase the availability of most of the micro-nutrients except Mo. Micro-nutrients availability was mostly influenced by each other in the soils.

5.1.3.3 Leaf Vs soil relationships

The availability of soil nutrient did not show any significant relationship with leaf nutrient content for the most of the nutrient (Table 27). A number of studies have been done by several workers to show the relationship between leaf nutrient contents and soil fertility status helps to find out the expected response on nutrition level of citrus tree as a result of change in fertility due to fertilizer application. Ko and Kim, (1987) found that the availability of soil nutrients did not affect the leaf nutrient contents for most of the nutrients except N, and Ca which had significantly and positively related and P was rather negatively related. Use of soil test specifically for citrus as a guide for fertilizer recommendations has been restricted due to the lack of relation between the availability of soil nutrient and leaf nutrient contents (Pleissis, 1977; Zhuang *et al*., 1984; Patiram and Upadhyaya, 1994; Obreza, 1990; Hanlon *et al*., 1995; Shishov and Kapshuk, 1984). The roots of a tree as compared to crops, absorbs nutrients from the larger volume of soil and also difficult to obtain soil sample which can adequately represent the total environment of the roots (Jones and Embleton, 1973). A better elucidation can be obtained when leaf to soil relation based on fertilizer schedule is adopted.

5.2 Part II: Nitrogen management experiments

The discussion of the results of four nitrogen fertilizers management experiments with Local Mandarin variety grown in farmer's managed orchards in Tanahun districts was divided into two parts. The first part deal with the effects of soil applied major nutrients and other packages of major nutrients fertilization interaction amongst themselves, role of graded dose of N – application and methods of N – application on vegetative and yield related parameters as revealed by the experiments. The second part was concerned with the effects of the above mentioned various N – management studies on quality and post-harvest related variables.

As previously presented in the results, the total yield was increased by the efficient N – fertilization managements. So, we are more concern with the source of yield increase.

Yield components of mandarin yield included were: a) Number of new leaves b) length of shoots c) number of flowers d) number of immature and mature fruits e) fruit size in the present investigations. All yield components were increased significantly except number of flowers per branch by various efficient nitrogen management activities such as average complete package (NPK + MN + Liming), N – interaction with major nutrients, amount and methods of N – application.

All factors directly or indirectly contributed to enhance mandarin fruit yields. In the following sections, the effects of above nitrogen management treatments on these factors, their role in increasing yield and the related literature were discussed.

5.2.1 Nitrogen nutrient managements, vegetative and yield parameters relationships

Number of new leaves: As evidenced by Table 28, number of new leaves per branch from the complete recommended package (200-100-200 g NPK per tree + MN sprays + Liming) was increased by 62.9% over FP's control. The deduction of any one of these components from the complete package produced lower number of new leaf flush than the complete package. In another experiment, as shown by Table 29, there were positive effects of N (-PK), NP (-K), NK (-P) and NPK treatments on number of new leaf flushes per branch. The total increase in new leaf number after fertilization increased by 44.0% with 500 g. N treatment compared to zero N level (Table 30). With the same amount of N fertilization, the increase in number of leaves production with 3 splits i.e. 2 soil and 1 foliar spray produced superior to other split N – fertilization combinations (Table 31). Similar relationships between N application and vegetative growth had been shown by many previous investigators working with Valencies Orange and Nagpur and

Khasi mandarins in different part of the world (Smith *et al*., 1953; Smith, 1970; Rauther and Smith 1950, 1951; Reece and Koo, 1974; Sites and Co-workers, 1961).

Length of new shoots: Length of new shoots increment of mandarin was attributed to the complete recommended package of nutrients (Table 28). In an interaction experiment, the release or remains of N nutrient element from any of the combination had produced tremendous reduction in length of new shoots (Table 29). The combinations of NPK, NK, NP and N had a positive effects on shoot's growth. Length of new shoots growth was not stable even at an increase of N levels to the highest rate i.e. 500 g. N/Pl/yr (Table 30). A several studies by earlier workers showed the similar effects of N on vegetative growth parameters in citrus mainly in sweet and mandarin oranges (Rasmussen and Smith, 1961; Marler *et al*., 1987; Willis *et al*., 1990, and 1991; Sweitlik, 1992; Jackson and Davies, 1984). The official N-fertilizer recommendation by the Government of Nepal on mandarin produced shoots similar to the 400 g. N pl/yr rate. Three split doses of N-fertilizer namely (2 basal plus one foliar spray) gave better results than other methods of N-application. This indicated that with the spilt N application along with foliar urea spray on plants was efficient in N-utilization which was consistent with previous workers (Jones and Embletion, 1967; Smith 1966a). Application of urea sprays may increase the number of leafy blooms. Generally, shoots with a high leaf: flower ratio, i.e. mixed shoots having a few flowers and many leaves, produced the greatest percentage of fruit to maturity. There has been interest in finding practical methods of producing a higher percent of leafy blooms, thus increasing fruit set and potentially yield (Jahn, 1973). It is unclear whether the greater fruit set of leafy blooms is due to increased net CO_2 assimilation and carbohydrate levels produced by the newly developed leaves or to improved vascular connections to the developing fruit mediated by harmones from the newly developed leaves or a greater sink capacity of mixed shoots/buds. However, newly developed leaves after anthesis, may decrease fruit abscission rather than increase fruit set (Erner and Bravdo, 1983).

Nitrogen is the most important element regulating vegetative growth. As discussed above, N had tremendous increment in vegetative parameters in mandarin. Other macro-elements, particularly P and K had lower impact on tree growth than N. Abundant supply of N is needed as indicated by vigorous growth of shoots and leaves. It imparts dark color and rich glossiness to leaves. Productivity is highly correlated to canopy bearing volume. Nitrogen deficiency reduces total tree growth and finally yield. Proper N supply is essential for proper growth particularly young tree of mandarin.

Number of flowers: As evidenced by the Tables 28, 29, 30 and 31, removal of N-fertilization either from the package or NPK –combinations or lower amount of N-applied in the graded dose or inefficient method of N application produced trees with excessively flower which were largely without fruits and highly erratic to lead yield decline with less number of immature and mature fruits in final (Tables 28 and 29). Since N-less tree produces poor vegetative growth, there is less sink capacity of mixed shoots having several flowers and a few leaves (Jahn, 1973). This means that there may be increased flower abscission due to poor vegetative growth rather than increase fruit set to maturity. Nitrogen is required more particularly at the time of flowering and the number flowers produced is directly related to the level of N in the tree (Smith, 1966). During this time, N migrates from leaves to flowers. This is in contrast with our present findings. However, low levels of N in leaves promotes extensive flowering, without although fruit set having yield poor (Davenport, 1990). Nitrogen as ammonia may directly affect flowering via. regulation of ammonia and polyamine levels in the bud (Lovatt et.al., 1988). However, severely N deficient trees produce few flowers.

As earlier stated, many researchers have mentioned that the intensity of flowering is directly proportional to rate of N assimilation.

Plant nutrition is directly and indirectly associated with flowering of citrus trees. High nitrogen levels for young citrus trees may induce excess vigor and produce a vegetative growth rather than mature trees. Since N less trees produce poor vegetative growth, there is less sink capacity of mixed shoots having several flowers and a few leaves. Therefore, maintaining N fertilization in the balanced and efficient level produce a moderate number of flowers but the greatest fruit set and yield.

The regulation of flower initiation by the balance of carbohydrate to nitrogen is recognized internationally as Kraus – Kraybill hypothesis (Davies, 1979).

Two hypothesis proposed for induction of flowering are : the accumulation of ammonia under stress results in increased biosynthesis of arginine, polyamines and subsequently an increased rate of cell division following the release of citrus plants from stress; (Lovatt *et al*., 1988); and these physiological changes and the subsequent rapid increase in cell division are pre-requisites to flower initiation in citrus.

Carbohydrate levels have been suggested as a limiting factor for flower formation in citrus. It was provided that the floral intensity is dependent on both starch and ammonia content. Threshhold values for starch and ammonia, critical to flowering in the system studied are reported besides many other factors such as hormones, temperature and water relations (Davenport, 1990).

Carbohydrate have been assumed to play a dominant regulatory role in the nutrient diversion hypothesis of flowering. Levels of stored, non-structural carbohydrates in the form of starch have been suggested to be a limiting factors in flower formation in mandarins. Carbohydrate availability to roots may play a significant role in the ability of mandarin to flower (Davenport, 1990).

The primary response is not only a lack of flowering but also lack of new shoots production during normal flowering period. The substantial loss of feeder roots due to carbohydrate starvation during these period has also been blamed for the onset of severe nutritional symptoms observed in foliage. In extreme cases during heavy fruit load, trees decline to bear mortality. Other root associated factors involved with new shoot initiation could affect floral expressions through control of new shoot production. The availability of root-produced cytokinins known to stimulate bud break would likely to decrease with the decline of the functional roots, possibly resulting in reduction of the number and frequency of shoot formation.

It is obvious from the above sections that the physiological basis of flowering in citrus is not clearly understood although many pieces of the puzzle have been assembled. From the discussion, one of the most likely control factor associated with flowering is N-nutrition besides may other factors.

Number of immature and mature fruits: Both mature and immature fruit number were increased with the complete fertilizer package i.e. NPK + MN + L or any treatment combination with N, NK or NPK (Tables 28 and 29). Application of 400 g.N/pl./yr. recorded (231% and 139%) increase in number of immature and mature fruits, respectively (Table 30). Both parameters leveled off and there was no sign of further increase or decrease at the higher N rate. As shown by the Table 31, two times basally applied with one foliar spray of N had maximum number of fruits. These results are consistent with many earlier investigators (Smith, 1966; Smith 1969; Montgomerry *et al.*, 1978; Dev Villers, 1969; Sharples and Hilgeman, 1969; Jones and Embleton, 1967; Embleton *et al.*, 1978). Therefore, maintaining efficient N-application through the complete package with N-K combination fertilizers and 400 g/pl./yr. for 5-6 years old trees with split doses with basal and foliar N-application as a supplemental, produced high number of immature and mature fruit and ultimately highest final fruit yield. Spit application of urea may increase the number of leafy blooms which encourages mixed shoots having a few large leaves. This is in turn, may decrease fruit abscission and maintain more fruits to maturity (Erner and Bravdo, 1983).

Fruit size and total fruit yield: In this study fruit size and total fruit yield were affected by various N-management treatments namely the recommended package (Tables 28 and 32), and the treatment combination containing N and K (Tables 29 and 33). In another experiment, fruit size and total final fruit size and total fruit yield were highly significant by the application of 400 g N/pl/yr. (Tables 30, and 34). However, with further increment of N (500 g/pl/yr) reduced fruit size and fruit yield due to N induced vegetative growth resulting in fewer fruits (Davenport, 1990). Mandarin trees with respect to optimal fruit size and total fruit yield responded to N application when the N application rate was split into three namely two split as basal application and the remaining one by foliar application (Tables 31 and 35). This indicated that with splits of N application, the trees were more efficient in N utilization (Impey and Jones, 1960a, and 1960b; Lovatt *et al*., 1984; Lovatt and Hake, 1988) for maximum yields and greater fruit size. Good response of low biuret urea sprayed increased flowering and yield of 'Shamouti' orange trees (Rabe and van der Walt, 1992).

Considerable work has been done on various aspects of N fertilization management which have been investigated are the amount and sources N and the time and methods of application of nitrogenous fertilization and in combination with other nutrients notably P and K (Smith 1966; 1967, 1961, 1953, 1970); Reuter and Smith, 1950; Jones and Embleton, 1961, 1967; Montgomery *et al*., 1978; Rodriquez and Moreira, 1969; Devillers, 1969; Sharples and Higeman, 1969; Legaz *et al*., 1981). These investigators worked on the various aspects of N-fertilization management on the cropping and the quality of citrus mainly sweet orange and mandarins. Fruit size and fruit yield of citrus were increased by the balanced management of N fertilization under different agro-ecological conditions.

It is possible that mandarin may need a more frequent and abundant supply of N and other nutrients during flowering for the early fruit initiation which possibly not be met by only a winter and spring basal N-application. So, the splits basal applications of N along with foliar spray appear to be superior; however, additional studies need to verify this relationship.

The N requirement for ‘Local Mandarin’ in MHWR of Nepal, doest not seem to be that much different from other similar agro-climatic zones of especially North-East Regions of India namely Sikkim, Assam and Meghalaya (Singh and Nagvi, 2001).

However, N application (400 g. N per plant per year) was the optimum dose under MHWR conditions of Nepal for optimal fruit size and yield. A similar recommendation under varied soils and climatic conditions was made by Ghale, (1996). Subedi *et al*. (1995) recommended 700 g/pl/yr for 8-12 years old similar variety of mandarin for MHWR regions of Nepal.

Nitrogen generally is believed to increase quality losses of fruits if applied at high or excessive dose whereas K extends shelf – life. Deficient or excessive K levels limit fruit sizes.

These studies have shown that increased dose of N up to 400 g N/pl/yr with frequent split with foliar application have favorable effects on quality of fruits.

5.2.2 Nitrogen management studies and quality relationships

External and internal quality of fruits

Nutrition practices influence fruit quality under varying fertilizer rates and the ratio of elements is used commercially to change fruit quality depending on market demands whether fresh fruit or juice purpose. Fertilization objectives for fresh differ from the processing fruit. In this study, we are interested in fresh mandarin fruits. Fresh mandarin fruit must meet internal quality standards such TSS, TA, TSS : TA ratio and juiciness as well as fruit size, shape, and external peel color, thickness and fruit texture as an external quality.

External Quality appearance and N-fertilization management

In the present study, with complete fertilizer package containing N, P and K had pronounced effects on fruit size, fruit diameter, fruit shape, firmness and peel thickness (Table 32). All these external quality standards, were found increased except peel firmness which was decreased by balanced N, P and K fertilization. Among the treatments combination of major nutrient elements namely NPK, NK, PK and K increased all these external quality characteristics of mandarin fruit (Table 33). This suggested the more importance of N and K than P on maintenance of external quality standards of mandarin. Phosphorus had lower effects than N and K on fruit quality which was consistent with other findings. Nitrogen, P and K have the greatest influence on fruit, provided others elements are not severely limiting (Embleton *et al*., 1978). The general effects of changing leaf N levels for 2.0-3.0% dry weight for sweet oranges, increase N levels, increase peel thickness, coarseness of peel texture and decrease peel color. Nitrogen levels in excess adversely affect fresh fruit quality. Deficient N also limits fruit size. Potasium has significant effect on fruit quality. Low K results in small fruit size and reduces peel thickness which predisposes the fruit to splitting, plugging and creasing. The similar effects of N and K on external fruit quality standards of citrus working under different conditions were reported by several previous investigators (Smith, 1953; Jones and Embleton, 1961 and 1967).

Carbohydrates account to 75-80 percent of the TSS in the fruit. As a consequence, regulation of carbohydrate loading into the citrus fruit has a great impact on internal fruit quality. Fruit growth is a function of tree water status and carbohydrate partitioning as well as temperature. Erickson (1968) reported that the major groups of carbohydrate in citrus fruits were mono-saccharides (glucose, fructose), oligosaccharides (sucrose) and polysaccharides (cellulose, starch, hemi-cellulose, pectin)

Potassium is an activator of many enzymes that are essential for photosynthesis and respiration, and it also activates enzymes needed to form starch and protein (Bhandal and Mallik, 1988).

Fruit size, fruit diameter and length, fruit firmness and peel thickness were found to increase rapidly with each increment dose of N upto 400 g/pl/yr (Table 34). These external fruit parameters either leveled off or there was no sign of further increase or decrease at the higher rates of N. This was consistent with the findings of Smith 1966a, Ishihara *et al*., 1965; and Embleton *et al*., 1975. All these fruit parameters were important external quality appearance standards. Under very vigorous growing conditions due to excessively high N fertilization levels produced a puffy peel, thick skins, incidence of blemishes and susceptibility of disease incidence.

Two splits of basal application of nitrogen with one foliar spray of urea just after blossoming were effective in increasing fruit size, fruit length and diameter and peel thickness and decreasing the fruit firmness (Table 35). For quick N build – up in the foliage in the early spring or following blossoms, use of foliar spray of urea was useful and part of the N need of a citrus tree was supplied by foliage spray and urea spray was an effective source of N fertilization (Impey and Jones, 1960a, and 1960b).

Internal quality standards and n-fertilization management relationships

The relative importance of the fertilization of different components to recommend package for the successful production of mandarin orange under farmer's conditions had shown the effects on internal quality standards of fruit (Table 32). The internal parameters such as TSS, TA, TSS/TA ratio, juiciness, numbers and weight of seeds were improved by the complete fertilizer package compared to other treatment combinations. Similarly, in another study the treatment combinations having either NPK or NK or PK or K only had positive effects on all the internal quality standards (Table 33). As the graded dose of N increased from 0 to 400 g per plant per year, TSS, TSS : TA, juiciness and seed weight were increased. The titratable acidity (TA) was decreased while the number of seeds and segments remained unaffected by the application of N dose. Most of the factors were leveled off and there was no sign of further increase or decrease at the higher rates of N (Table 34). The effects of the split application of N as 2 splits as basal and one split as supplemental of urea spray on internal fruits characters had positive and favorable (Table 35) effects.

The general effects of changing N – management for citrus particularly oranges and mandarin on internal fruit quality standards in the different parts of the world were homonymous with the present results just described (Embleton *et al*., 1978; Smith, 1953; Smith, 1970; Smith and Rasmussen, 1961; Smith, 1961a; Koo and Reese, 1977; Reese and Koo, 1977).

Fruit quality standards determine minimum levels of palatability and commercial acceptability. Total soluble solids (TSS) to titratable acidity (TA) ratio determines whether fruits are harvestable and is more reliable indicator than rind color. It is a good indicator of palatability. The juiciness and toughness of the pulp vesicles affect the palatability of fresh citrus. The TSS: TA ratio and in particular the attainment of a certain minimum ratio is a reliable and practical means of assessing fruit quality (Harding and Fisher, 1945). Total acidity of citrus juices is an important factor in overall juice quality and in determining time of fruit harvest (Harding *et al*., 1940). The TSS level increases as fruit size increased. Organic acids contribute significantly to overall juice acidity. Citric acid is the primary organic acid (70 – 90 percent of total) followed by malic and oxalic acids with lesser amount of other organic acids (Erickson, 1968). In general, commercially seedless fruits (< 9 seeds/fruit) are more desirable than seedy fruits (Hensz, 1971) in mandarin.

6 GENERAL SUMMARY AND CONCLUSION

6.1 Part I: Survey of soil and foliar (tissue) of mandarin orange under farmer's field conditions at different altitudes and management levels in Tanahun, Lamjung and Gorkha districts

This study was directed to find out association of foliar and soil analyses trends with altitudes and orchard performance representing healthiness and age of the mandarin trees. This relationship was also utilized to assess the nutrient constraints for guiding fertilizer practices in mandarin orchards. The following evidences support the soil fertility trends of moderation of orchards by the altitudinal differences and orchard performances which in turn modified the appraisal of nutrient constraints in the region.

1. As this study indicated the soil fertility trends of mandarin orchards as reflected by foliar and soil analyses had strongly affected by the altitudinal differences of mandarin growing locations. It was particularly true for the leaf P, K, Fe, and Cu nutrients based on foliar analysis which were higher at high altitudes as compared to lower altitudes. Based on soil tests, it showed that soil organic matter, total N and available P were high at high altitude citrus cultivation. However, the soil pH and exchangeable Ca and Mg were low at high altitudes. The rest of the nutrients either had shown no effect by the altitudes or shown no systematic patterns by the altitudes differences. This was implicated that while taking samples for leaf and soil analyses of mandarin orchards for close interpretation of the test results, the samples needed to be taken attitudinally also besides consideration of several other cultural and management factors.
2. The high performing orchards as reflected by the overall health and age of the trees affected the foliar nutrients of N, P, Ca, Fe, Mn and Zn. Generally, healthy trees of both matured and young out-performed the unhealthy trees groups with respect to the

contents of these nutrients. Similarly, young and non-bearing trees of both healthy and unhealthy trees had high amount of leaf N, P, K, Mn and Zn at all the altitudes. However, based on soil analysis, only organic matter, total N, and available P and Zn contents were influenced by the orchard performances. These evidences suggested that for accurate interpretation of foliar and soil tests results collected foliar and soil samples must be from uniform, representative of the general orchard conditions similar to orchard performances particularly similar in overall healthiness and age of the trees, besides the consideration of several other factors including fertilizers and cultural practices over the sampled area. It is emphasized that the factors such as bearing/non-bearing and healthy/unhealthy trees which affect nutrient composition of leave should be taken into account while interpreting leaf tests data. This suggests that the relationship between leaf composition, growth and yields is very completed.

3. Majority leaf samples of the orchards located at high altitudes of Gorkha district were deficient in Zn, Ca, Mg and Mn; leaf Zn, B and Mn in about 50-100% orchards at mid altitude (Lamjung) were in deficient ranges; and foliar N, K and Zn were deficient in majority of the samples at low citrus growing belts (Tanahun). However, based on soil test, low soil pH was the problem at high altitude citrus growing which resulted in toxic levels of Fe and Mn while Ca and Mg were at low availability levels. Besides, at low citrus growing ranges (Tanahun), N and B were found to be low to medium in most of the orchards and Fe and Cu were toxic ranges which hampered tree growth. This indicated that a different foliar and soil tests rating for the appraisal of nutrient constraints were to be developed for altitudewise. In other words, a different rating is required for each altitude for both foliar as well as soil test applications.

4. A better elucidation can be obtained from if leaf to soil relation based fertilizer schedule is adopted and calibrated in a long term well-designed field experiments under each agro-ecological zones.
5. It was shown that the interactions among the leaf nutrients had very strong whether they were positive or negative. Hence, it is essential to know the principal nutrient interactions, the comparable nutrient levels that should be present during this period, and knowledge of the intensity and balance of the nutrients.

6.2 Part II: Nitrogen management experiment

This work was initiated to elucidate the efficient role of N fertilization and its interaction with the major nutrients packages, amount and methods of N-application to assess tree growth, yield and quality parameters of local mandarin grown at mid-hills of western regions of Nepal. The following evidences support the efficient use and maintenance of N and other plant nutrients levels by regular 'optimal' fertilizer applications.

1. Among the various components to recommend packages for the successful mandarin production under farmer's field conditions, application of the complete package that includes 200-100-200 g NPK/plant/year with two sprays of Plantoplex (0.05%, w/v in water) and 2 kg of lime per tree out-performed with respect to all growths, yield and quality parameters. This is the most important package followed by only NPK package minus in the complete package of which the trees suffer the most compare to other packages.
2. Among the three major fertilizer elements interactions, N had tremendous impact, particularly on vegetative growth i.e. if there was no nitrogen added trees suffered the most in terms of the vegetative and yield components. However, for the maintenance of

both external and internal quality standards of fruits application of N and K was more important than P fertilization.

3. The optimal N-application rate of 400 g/plant/year in winter and again in early spring in two equal split before flowering was appropriate dose under western mid-hills conditions to keep trees more productive, both in quantity and quality. Excessive or deficient N-fertilization not only affects the fruit yield in quantity but also affected fruit quality standards. So, judicious use of N-fertilizer with respect to its amount is recommended.
4. Because of high N losses due to leaching, volatilization, and denitrification, a split application of N viz. two basal applications in winter and early spring and one foliar spray of urea as supplemental in May after fruit set (following blossoms) produced even greater yields and quality improvements. However, this aspects need to be confirmed by further study.

In summary, efficient N fertilization management strongly affected vegetative growth, yield and quality components. The presence of balanced nutrition package, optimum and judicious N-fertilization create a nutritionally healthy trees, which have the ability to produce a good commercial crops of ‘local mandarin’ variety in mid-hill western region of Nepal.

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APPENDICES

Appendix 19. Statistical analysis – ANOVA tables

***** Analysis of variance *****

Variate: B

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	5387.0	2693.5	4.58	
Rep.Y_e_ar stratum					
Y_e_ar	1	2345.1	2345.1	3.99	0.184
Residual	2	1175.5	587.8	0.38	
Rep.Y_e_ar.dist stratum					
dist	2	6883.1	3441.5	2.21	0.173
Y_e_ar.dist	2	4212.0	2106.0	1.35	0.313
Residual	8	12482.0	1560.3	4.39	
Rep.Y_e_ar.dist.Trt stratum					
Trt	3	838.1	279.4	0.79	0.509
Y_e_ar.Trt	3	1256.5	418.8	1.18	0.331
dist.Trt	6	1397.8	233.0	0.66	0.685
Y_e_ar.dist.Trt	6	3214.8	535.8	1.51	0.203
Residual	36	12781.6	355.0		
Total	71	51973.6			

***** Analysis of variance *****

Variate: Ca

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	1.2086	0.6043	0.89	
Rep.Y_e_ar stratum					
Y_e_ar	1	2.3991	2.3991	3.54	0.201
Residual	2	1.3556	0.6778	0.43	
Rep.Y_e_ar.dist stratum					
dist	2	0.9698	0.4849	0.31	0.743
Y_e_ar.dist	2	0.5366	0.2683	0.17	0.846
Residual	8	12.5672	1.5709	2.72	
Rep.Y_e_ar.dist.Trt stratum					
Trt	3	9.8681	3.2894	5.69	0.003
Y_e_ar.Trt	3	1.5767	0.5256	0.91	0.447
dist.Trt	6	3.5548	0.5925	1.02	0.426
Y_e_ar.dist.Trt	6	3.2515	0.5419	0.94	0.481
Residual	36	20.8279	0.5786		
Total	71	58.1159			

***** Analysis of variance *****

Variate: Cu

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	27812.	13906.	0.50	
Rep.Y_e_ar stratum					
Y_e_ar	1	3095.	3095.	0.11	0.770
Residual	2	55187.	27594.	1.60	
Rep.Y_e_ar.dist stratum					
dist	2	50396.	25198.	1.46	0.288
Y_e_ar.dist	2	23216.	11608.	0.67	0.537
Residual	8	138113.	17264.	4.62	
Rep.Y_e_ar.dist.Trt stratum					
Trt	3	1959.	653.	0.17	0.913
Y_e_ar.Trt	3	18557.	6186.	1.65	0.194
dist.Trt	6	6280.	1047.	0.28	0.943
Y_e_ar.dist.Trt	6	44647.	7441.	1.99	0.093
Residual	36	134571.	3738.		
Total	71	503833.			

***** Analysis of variance *****

Variate: Fe

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	1994.0	997.0	1.17	
Rep.Y_e_ar stratum					
Y_e_ar	1	4116.9	4116.9	4.82	0.159
Residual	2	1708.4	854.2	1.13	
Rep.Y_e_ar.dist stratum					
dist	2	16547.0	8273.5	10.98	0.005
Y_e_ar.dist	2	5768.5	2884.2	3.83	0.068
Residual	8	6025.5	753.2	0.83	
Rep.Y_e_ar.dist.Trt stratum					
Trt	3	11396.8	3798.9	4.17	0.012
Y_e_ar.Trt	3	1220.8	406.9	0.45	0.721
dist.Trt	6	1438.7	239.8	0.26	0.951
Y_e_ar.dist.Trt	6	2326.2	387.7	0.43	0.857
Residual	36	32822.7	911.7		
Total	71	85365.3			

***** Analysis of variance *****

Variate: K

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	3.0773	1.5387	68.30	
Rep.Y_e_ar stratum					
Y_e_ar	1	0.0343	0.0343	1.52	0.343
Residual	2	0.0451	0.0225	0.06	
Rep.Y_e_ar.dist stratum					
dist	2	2.8628	1.4314	3.82	0.068
Y_e_ar.dist	2	0.6469	0.3234	0.86	0.457
Residual	8	2.9947	0.3743	3.37	
Rep.Y_e_ar.dist.Trt stratum					
Trt	3	0.1458	0.0486	0.44	0.728
Y_e_ar.Trt	3	0.0702	0.0234	0.21	0.888
dist.Trt	6	0.6525	0.1088	0.98	0.454
Y_e_ar.dist.Trt	6	0.1622	0.0270	0.24	0.959
Residual	36	4.0007	0.1111		
Total	71	14.6924			

***** Analysis of variance *****

Variate: Mg

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.045585	0.022793	3.17	
Rep.Y_e_ar stratum					
Y_e_ar	1	0.004608	0.004608	0.64	0.507
Residual	2	0.014378	0.007189	0.63	
Rep.Y_e_ar.dist stratum					
dist	2	0.052973	0.026486	2.31	0.161
Y_e_ar.dist	2	0.007077	0.003538	0.31	0.742
Residual	8	0.091541	0.011443	3.29	
Rep.Y_e_ar.dist.Trt stratum					
Trt	3	0.021243	0.007081	2.04	0.126
Y_e_ar.Trt	3	0.018957	0.006319	1.82	0.161
dist.Trt	6	0.033044	0.005507	1.59	0.180
Y_e_ar.dist.Trt	6	0.065166	0.010861	3.13	0.014
Residual	36	0.125042	0.003473		
Total	71	0.479613			

***** Analysis of variance *****

Variate: K

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	3.0773	1.5387	68.30	
Rep.Y_e_ar stratum					
Y_e_ar	1	0.0343	0.0343	1.52	0.343
Residual	2	0.0451	0.0225	0.06	
Rep.Y_e_ar.dist stratum					
dist	2	2.8628	1.4314	3.82	0.068
Y_e_ar.dist	2	0.6469	0.3234	0.86	0.457
Residual	8	2.9947	0.3743	3.37	
Rep.Y_e_ar.dist.Trt stratum					
Trt	3	0.1458	0.0486	0.44	0.728
Y_e_ar.Trt	3	0.0702	0.0234	0.21	0.888
dist.Trt	6	0.6525	0.1088	0.98	0.454
Y_e_ar.dist.Trt	6	0.1622	0.0270	0.24	0.959
Residual	36	4.0007	0.1111		
Total	71	14.6924			

***** Analysis of variance *****

Variate: Mg

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.045585	0.022793	3.17	
Rep.Y_e_ar stratum					
Y_e_ar	1	0.004608	0.004608	0.64	0.507
Residual	2	0.014378	0.007189	0.63	
Rep.Y_e_ar.dist stratum					
dist	2	0.052973	0.026486	2.31	0.161
Y_e_ar.dist	2	0.007077	0.003538	0.31	0.742
Residual	8	0.091541	0.011443	3.29	
Rep.Y_e_ar.dist.Trt stratum					
Trt	3	0.021243	0.007081	2.04	0.126
Y_e_ar.Trt	3	0.018957	0.006319	1.82	0.161
dist.Trt	6	0.033044	0.005507	1.59	0.180
Y_e_ar.dist.Trt	6	0.065166	0.010861	3.13	0.014
Residual	36	0.125042	0.003473		
Total	71	0.479613			

***** Analysis of variance *****

Variate: Mg

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.045585	0.022793	3.17	
Rep.Y_e_ar stratum					
Y_e_ar	1	0.004608	0.004608	0.64	0.507
Residual	2	0.014378	0.007189	0.63	
Rep.Y_e_ar.dist stratum					
dist	2	0.052973	0.026486	2.31	0.161
Y_e_ar.dist	2	0.007077	0.003538	0.31	0.742
Residual	8	0.091541	0.011443	3.29	
Rep.Y_e_ar.dist.Trt stratum					
Trt	3	0.021243	0.007081	2.04	0.126
Y_e_ar.Trt	3	0.018957	0.006319	1.82	0.161
dist.Trt	6	0.033044	0.005507	1.59	0.180
Y_e_ar.dist.Trt	6	0.065166	0.010861	3.13	0.014
Residual	36	0.125042	0.003473		
Total	71	0.479613			

***** Analysis of variance *****

Variate: N

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.39056	0.19528	3.95	
Rep.Y_e_ar stratum					
Y_e_ar	1	0.00050	0.00050	0.01	0.929
Residual	2	0.09875	0.04938	0.29	
Rep.Y_e_ar.dist stratum					
dist	2	0.67743	0.33871	1.97	0.201
Y_e_ar.dist	2	0.09484	0.04742	0.28	0.766
Residual	8	1.37389	0.17174	3.74	
Rep.Y_e_ar.dist.Trt stratum					
Trt	3	0.70814	0.23605	5.14	0.005
Y_e_ar.Trt	3	0.12122	0.04041	0.88	0.461
dist.Trt	6	1.03258	0.17210	3.75	0.005
Y_e_ar.dist.Trt	6	0.26616	0.04436	0.97	0.462
Residual	36	1.65273	0.04591		
Total	71	6.41679			

***** Analysis of variance *****

Variate: P

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.054041	0.027021	2.02	
Rep.Y_e_ar stratum					
Y_e_ar	1	0.016230	0.016230	1.21	0.386
Residual	2	0.026803	0.013402	3.57	
Rep.Y_e_ar.dist stratum					
dist	2	0.026106	0.013053	3.48	0.082
Y_e_ar.dist	2	0.003746	0.001873	0.50	0.625
Residual	8	0.030016	0.003752	1.77	
Rep.Y_e_ar.dist.Trt stratum					
Trt	3	0.038324	0.012775	6.03	0.002
Y_e_ar.Trt	3	0.005004	0.001668	0.79	0.509
dist.Trt	6	0.017132	0.002855	1.35	0.262
Y_e_ar.dist.Trt	6	0.052215	0.008702	4.11	0.003
Residual	36	0.076219	0.002117		
Total	71	0.345836			

***** Analysis of variance *****

Variate: P

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.054041	0.027021	2.02	
Rep.Y_e_ar stratum					
Y_e_ar	1	0.016230	0.016230	1.21	0.386
Residual	2	0.026803	0.013402	3.57	
Rep.Y_e_ar.dist stratum					
dist	2	0.026106	0.013053	3.48	0.082
Y_e_ar.dist	2	0.003746	0.001873	0.50	0.625
Residual	8	0.030016	0.003752	1.77	
Rep.Y_e_ar.dist.Trt stratum					
Trt	3	0.038324	0.012775	6.03	0.002
Y_e_ar.Trt	3	0.005004	0.001668	0.79	0.509
dist.Trt	6	0.017132	0.002855	1.35	0.262
Y_e_ar.dist.Trt	6	0.052215	0.008702	4.11	0.003
Residual	36	0.076219	0.002117		
Total	71	0.345836			

***** Analysis of variance *****

Variate: B

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	2.1418	1.0709	2.45	
Rep.Year stratum					
Year	1	5.1200	5.1200	11.70	0.076
Residual	2	0.8754	0.4377	0.43	
Rep.Year.Locatn stratum					
Locatn	2	0.3776	0.1888	0.19	0.834
Year.Locatn	2	0.5385	0.2693	0.26	0.774
Residual	8	8.1504	1.0188	1.77	
Rep.Year.Locatn.Trt stratum					
Trt	3	1.5750	0.5250	0.91	0.445
Year.Trt	3	0.3939	0.1313	0.23	0.876
Locatn.Trt	6	6.2499	1.0417	1.81	0.125
Year.Locatn.Trt	6	0.6883	0.1147	0.20	0.975
Residual	36	20.7322	0.5759		
Total	71	46.8431			

***** Analysis of variance *****

Variate: Ca

Source of variation	d.f.(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.050293	0.025147	0.71	
Rep.Year stratum					
Year	1	0.037169	0.037169	1.05	0.413
Residual	2	0.070865	0.035433	8.11	
Rep.Year.Locatn stratum					
Locatn	2	0.044772	0.022386	5.12	0.037
Year.Locatn	2	0.032151	0.016075	3.68	0.074
Residual	8	0.034960	0.004370	0.47	
Rep.Year.Locatn.Trt stratum					
Trt	3	0.042155	0.014052	1.52	0.226
Year.Trt	3	0.012649	0.004216	0.46	0.715
Locatn.Trt	6	0.024815	0.004136	0.45	0.842
Year.Locatn.Trt	6	0.027365	0.004561	0.49	0.809
Residual	35(1)	0.323391	0.009240		
Total	70(1)	0.694343			

***** Analysis of variance *****

Variate: Cu

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	927.5	463.7	0.43	
Rep.Year stratum					
Year	1	7.8	7.8	0.01	0.940
Residual	2	2181.7	1090.9	1.65	
Rep.Year.Locatn stratum					
Locatn	2	2630.8	1315.4	1.99	0.199
Year.Locatn	2	24.4	12.2	0.02	0.982
Residual	8	5282.5	660.3	5.24	
Rep.Year.Locatn.Trt stratum					
Trt	3	529.8	176.6	1.40	0.258
Year.Trt	3	482.6	160.9	1.28	0.297
Locatn.Trt	6	810.7	135.1	1.07	0.397
Year.Locatn.Trt	6	659.6	109.9	0.87	0.524
Residual	36	4532.4	125.9		
Total	71	18069.9			

***** Analysis of variance *****

Variate: Fe

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	3439.8	1719.9	12.47	
Rep.Year stratum					
Year	1	1279.3	1279.3	9.28	0.093
Residual	2	275.8	137.9	0.18	
Rep.Year.Locatn stratum					
Locatn	2	2643.0	1321.5	1.74	0.236
Year.Locatn	2	7371.1	3685.6	4.86	0.042
Residual	8	6069.7	758.7	2.86	
Rep.Year.Locatn.Trt stratum					
Trt	3	964.2	321.4	1.21	0.320
Year.Trt	3	325.9	108.6	0.41	0.747
Locatn.Trt	6	2482.4	413.7	1.56	0.187
Year.Locatn.Trt	6	1251.0	208.5	0.79	0.587
Residual	36	9551.8	265.3		
Total	71	35654.1			

***** Analysis of variance *****

Variate: K

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.0015133	0.0007566	5.34	
Rep.Year stratum					
Year	1	0.0006778	0.0006778	4.78	0.160
Residual	2	0.0002834	0.0001417	0.30	
Rep.Year.Locatn stratum					
Locatn	2	0.0007480	0.0003740	0.78	0.491
Year.Locatn	2	0.0004132	0.0002066	0.43	0.664
Residual	8	0.0038400	0.0004800	1.87	
Rep.Year.Locatn.Trt stratum					
Trt	3	0.0010960	0.0003653	1.42	0.252
Year.Trt	3	0.0014897	0.0004966	1.94	0.141
Locatn.Trt	6	0.0029891	0.0004982	1.94	0.101
Year.Locatn.Trt	6	0.0012678	0.0002113	0.82	0.559
Residual	36	0.0092381	0.0002566		
Total	71	0.0235562			

***** Analysis of variance *****

Variate: Mg

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	296.1	148.0	1.01	
Rep.Year stratum					
Year	1	150.6	150.6	1.03	0.417
Residual	2	293.2	146.6	1.00	
Rep.Year.Locatn stratum					
Locatn	2	300.3	150.1	1.02	0.403
Year.Locatn	2	303.4	151.7	1.03	0.400
Residual	8	1177.6	147.2	1.00	
Rep.Year.Locatn.Trt stratum					
Trt	3	443.9	148.0	1.00	0.402
Year.Trt	3	445.5	148.5	1.01	0.400
Locatn.Trt	6	892.0	148.7	1.01	0.435
Year.Locatn.Trt	6	890.1	148.4	1.01	0.436
Residual	36	5301.8	147.3		
Total	71	10494.6			

***** Analysis of variance *****

Variate: Mn

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	3852.9	1926.4	19.25	
Rep.Year stratum					
Year	1	52.3	52.3	0.52	0.545
Residual	2	200.1	100.1	0.24	
Rep.Year.Locatn stratum					
Locatn	2	2247.6	1123.8	2.68	0.129
Year.Locatn	2	2353.2	1176.6	2.81	0.119
Residual	8	3355.3	419.4	1.11	
Rep.Year.Locatn.Trt stratum					
Trt	3	1746.7	582.2	1.54	0.220
Year.Trt	3	875.0	291.7	0.77	0.517
Locatn.Trt	6	597.1	99.5	0.26	0.950
Year.Locatn.Trt	6	2703.3	450.5	1.19	0.332
Residual	36	13596.6	377.7		
Total	71	31580.1			

***** Analysis of variance *****

Variate: N

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	8.845	4.422	1.00	
Rep.Year stratum					
Year	1	3.805	3.805	0.86	0.452
Residual	2	8.884	4.442	1.02	
Rep.Year.Locatn stratum					
Locatn	2	9.518	4.759	1.10	0.379
Year.Locatn	2	8.633	4.316	1.00	0.411
Residual	8	34.686	4.336	0.98	
Rep.Year.Locatn.Trt stratum					
Trt	3	12.747	4.249	0.96	0.424
Year.Trt	3	13.151	4.384	0.99	0.410
Locatn.Trt	6	26.840	4.473	1.01	0.436
Year.Locatn.Trt	6	26.280	4.380	0.99	0.449
Residual	36	159.907	4.442		
Total	71	313.296			

***** Analysis of variance *****

Variate: OM

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	2.6456	1.3228	1.48	
Rep.Year stratum					
Year	1	0.3042	0.3042	0.34	0.618
Residual	2	1.7841	0.8920	0.74	
Rep.Year.Locatn stratum					
Locatn	2	23.4992	11.7496	9.73	0.007
Year.Locatn	2	2.6774	1.3387	1.11	0.376
Residual	8	9.6641	1.2080	1.84	
Rep.Year.Locatn.Trt stratum					
Trt	3	5.7868	1.9289	2.95	0.046
Year.Trt	3	0.6996	0.2332	0.36	0.785
Locatn.Trt	6	1.9068	0.3178	0.49	0.815
Year.Locatn.Trt	6	11.8075	1.9679	3.01	0.017
Residual	36	23.5717	0.6548		
Total	71	84.3471			

***** Analysis of variance *****

Variate: P

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.00008337	0.00004169	1.34	
Rep.Year stratum					
Year	1	0.00031836	0.00031836	10.21	0.086
Residual	2	0.00006234	0.00003117	4.50	
Rep.Year.Locatn stratum					
Locatn	2	0.00080789	0.00040395	58.34	<.001
Year.Locatn	2	0.00094987	0.00047494	68.60	<.001
Residual	8	0.00005539	0.00000692	0.18	
Rep.Year.Locatn.Trt stratum					
Trt	3	0.00031465	0.00010488	2.76	0.056
Year.Trt	3	0.00015668	0.00005223	1.37	0.266
Locatn.Trt	6	0.00024390	0.00004065	1.07	0.399
Year.Locatn.Trt	6	0.00040848	0.00006808	1.79	0.129
Residual	36	0.00136887	0.00003802		
Total	71	0.00476980			

***** Analysis of variance *****

Variate: PH

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	2.5686	1.2843	1.31	
Rep.Year stratum					
Year	1	0.0501	0.0501	0.05	0.842
Residual	2	1.9553	0.9776	1.51	
Rep.Year.Locatn stratum					
Locatn	2	25.3969	12.6985	19.56	<.001
Year.Locatn	2	3.2619	1.6310	2.51	0.142
Residual	8	5.1928	0.6491	1.04	
Rep.Year.Locatn.Trt stratum					
Trt	3	3.1182	1.0394	1.66	0.192
Year.Trt	3	0.3849	0.1283	0.21	0.892
Locatn.Trt	6	3.6497	0.6083	0.97	0.458
Year.Locatn.Trt	6	0.3647	0.0608	0.10	0.996
Residual	36	22.5100	0.6253		
Total	71	68.4532			

***** Analysis of variance *****

Variate: Zn

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	118.974	59.487	2.49	
Rep.Year stratum					
Year	1	0.402	0.402	0.02	0.909
Residual	2	47.832	23.916	5.93	
Rep.Year.Locatn stratum					
Locatn	2	21.499	10.750	2.67	0.130
Year.Locatn	2	6.527	3.264	0.81	0.478
Residual	8	32.256	4.032	0.79	
Rep.Year.Locatn.Trt stratum					
Trt	3	159.152	53.051	10.40	<.001
Year.Trt	3	13.509	4.503	0.88	0.459
Locatn.Trt	6	93.037	15.506	3.04	0.016
Year.Locatn.Trt	6	66.047	11.008	2.16	0.070
Residual	36	183.593	5.100		
Total	71	742.827			

***** Analysis of variance *****

Variate: %_flower

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	5	19.14	3.83	0.37	
Reps.*Units* stratum					
Treatment	5	6156.47	1231.29	118.69	<.001
Residual	25	259.36	10.37		
Total	35	6434.97			

***** Analysis of variance *****

Variate: %_imm_frt_

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	5	39.583	7.917	1.02	
Reps.*Units* stratum					
Treatment	5	2250.917	450.183	57.94	<.001
Residual	25	194.250	7.770		
Total	35	2484.750			

***** Analysis of variance *****

Variate: %_mat_frt_

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	5	110.58	22.12	1.02	
Reps.*Units* stratum					
Treatment	5	7741.25	1548.25	71.56	<.001
Residual	25	540.92	21.64		
Total	35	8392.75			

***** Analysis of variance *****

Variate: %_new_lea

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	5	271.67	54.33	4.85	
Reps.*Units* stratum					
Treatment	5	7174.33	1434.87	128.11	<.001
Residual	25	280.00	11.20		
Total	35	7726.00			

***** Analysis of variance *****

Variate: Fi_frt_yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	5	1.3573	0.2715	0.34	
Reps.*Units* stratum					
Treatment	5	232.6374	46.5275	58.56	<.001
Residual	25	19.8631	0.7945		
Total	35	253.8578			

***** Analysis of variance *****

Variate: Length_ns

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	5	20.00	4.00	0.30	
Reps.*Units* stratum					
Treatment	5	2649.33	529.87	39.46	<.001
Residual	25	335.67	13.43		
Total	35	3005.00			

***** Analysis of variance *****

Variate: Sin_frt_wt_gm

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	5	45.47	9.09	0.18	
Reps.*Units* stratum					
Treatment	5	7692.47	1538.49	30.06	<.001
Residual	25	1279.69	51.19		
Total	35	9017.64			

***** Analysis of variance *****

Variate: Sin_frt_wt_kg

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	5	0.00004547	0.00000909	0.18	
Reps.*Units* stratum					
Treatment	5	0.00769247	0.00153849	30.06	<.001
Residual	25	0.00127969	0.00005119		
Total	35	0.00901764			

***** Analysis of variance *****

Variate: Sin_frt_wt_kg

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	5	0.00004547	0.00000909	0.18	
Reps.*Units* stratum					
Treatment	5	0.00769247	0.00153849	30.06	<.001
Residual	25	0.00127969	0.00005119		
Total	35	0.00901764			

***** Analysis of variance *****

Variate: %_flower

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	6	25.96	4.33	0.42	
Reps.*Units* stratum					
Treatment	6	11361.39	1893.56	185.36	<.001
Residual	36	367.76	10.22		
Total	48	11755.10			

***** Analysis of variance *****

Variate: %_imm_frt_

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	6	116.980	19.497	2.73	
Reps.*Units* stratum					
Treatment	6	3064.980	510.830	71.63	<.001
Residual	36	256.735	7.132		
Total	48	3438.694			

***** Analysis of variance *****

Variate: %_mat_frt_

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	6	725.06	120.84	1.77	
Reps.*Units* stratum					
Treatment	6	23768.49	3961.41	58.00	<.001
Residual	36	2458.65	68.30		
Total	48	26952.20			

***** Analysis of variance *****

Variate: %_new_lea

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	6	226.69	37.78	1.66	
Reps.*Units* stratum					
Treatment	6	5293.84	882.31	38.80	<.001
Residual	36	818.73	22.74		
Total	48	6339.27			

***** Analysis of variance *****

Variate: Fi_frt_yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	6	22.024	3.671	2.12	
Reps.*Units* stratum					
Treatment	6	669.757	111.626	64.40	<.001
Residual	36	62.401	1.733		
Total	48	754.183			

***** Analysis of variance *****

Variate: Length_ns

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	6	202.49	33.75	3.03	
Reps.*Units* stratum					
Treatment	6	6366.20	1061.03	95.27	<.001
Residual	36	400.94	11.14		
Total	48	6969.63			

***** Analysis of variance *****

Variate: Sin_frt_wt

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	6	444.29	74.05	1.58	
Reps.*Units* stratum					
Treatment	6	16305.14	2717.52	57.94	<.001
Residual	36	1688.57	46.90		
Total	48	18438.00			

***** Analysis of variance *****

Variate: Sin_frt_wt

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	6	444.29	74.05	1.58	
Reps.*Units* stratum					
Treatment	6	16305.14	2717.52	57.94	<.001
Residual	36	1688.57	46.90		
Total	48	18438.00			

***** Analysis of variance *****

Variate: %_flower

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	6	25.96	4.33	0.42	
Reps.*Units* stratum					
Treatment	6	11361.39	1893.56	185.36	<.001
Residual	36	367.76	10.22		
Total	48	11755.10			

***** Analysis of variance *****

Variate: %_imm_frt_

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	6	116.980	19.497	2.73	
Reps.*Units* stratum					
Treatment	6	3064.980	510.830	71.63	<.001
Residual	36	256.735	7.132		
Total	48	3438.694			

***** Analysis of variance *****

Variate: %_mat_frt_

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	6	725.06	120.84	1.77	
Reps.*Units* stratum					
Treatment	6	23768.49	3961.41	58.00	<.001
Residual	36	2458.65	68.30		
Total	48	26952.20			

***** Analysis of variance *****

Variate: %_new_lea

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	6	226.69	37.78	1.66	
Reps.*Units* stratum					
Treatment	6	5293.84	882.31	38.80	<.001
Residual	36	818.73	22.74		
Total	48	6339.27			

***** Analysis of variance *****

Variate: Fi_frt_yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	6	22.024	3.671	2.12	
Reps.*Units* stratum					
Treatment	6	669.757	111.626	64.40	<.001
Residual	36	62.401	1.733		
Total	48	754.183			

***** Analysis of variance *****

Variate: Length_ns

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	6	202.49	33.75	3.03	
Reps.*Units* stratum					
Treatment	6	6366.20	1061.03	95.27	<.001
Residual	36	400.94	11.14		
Total	48	6969.63			

***** Analysis of variance *****

Variate: Sin_frt_wt

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	6	444.29	74.05	1.58	
Reps.*Units* stratum					
Treatment	6	16305.14	2717.52	57.94	<.001
Residual	36	1688.57	46.90		
Total	48	18438.00			

***** Analysis of variance *****

Variate: Sin_frt_wt

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	6	444.29	74.05	1.58	
Reps.*Units* stratum					
Treatment	6	16305.14	2717.52	57.94	<.001
Residual	36	1688.57	46.90		
Total	48	18438.00			

***** Analysis of variance *****

Variate: %_flower

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	104.19	34.73	3.02	
Reps.*Units* stratum					
Treatment	3	1292.19	430.73	37.43	<.001
Residual	9	103.56	11.51		
Total	15	1499.94			

***** Analysis of variance *****

Variate: %_imm_frt_

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	50.25	16.75	0.66	
Reps.*Units* stratum					
Treatment	3	12211.25	4070.42	160.50	<.001
Residual	9	228.25	25.36		
Total	15	12489.75			

***** Analysis of variance *****

Variate: %_mat_frt_

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	293.19	97.73	1.20	
Reps.*Units* stratum					
Treatment	3	4990.19	1663.40	20.48	<.001
Residual	9	731.06	81.23		
Total	15	6014.44			

***** Analysis of variance *****

Variate: %_new_lea

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	147.50	49.17	1.94	
Reps.*Units* stratum					
Treatment	3	3626.00	1208.67	47.61	<.001
Residual	9	228.50	25.39		
Total	15	4002.00			

***** Analysis of variance *****

Variate: Fi_frt_yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	6.056	2.019	1.19	
Reps.*Units* stratum					
Treatment	3	191.749	63.916	37.67	<.001
Residual	9	15.269	1.697		
Total	15	213.074			

***** Analysis of variance *****

Variate: Length_ns

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	47.188	15.729	5.04	
Reps.*Units* stratum					
Treatment	3	403.187	134.396	43.10	<.001
Residual	9	28.062	3.118		
Total	15	478.437			

***** Analysis of variance *****

Variate: Sin_frt_wt

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	50.19	16.73	0.26	
Reps.*Units* stratum					
Treatment	3	4687.69	1562.56	24.41	<.001
Residual	9	576.06	64.01		
Total	15	5313.94			

***** Analysis of variance *****

Variate: %_flower

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	6.96	2.32	0.23	
Reps.*Units* stratum					
Treatment	6	1808.36	301.39	30.01	<.001
Residual	18	180.79	10.04		
Total	27	1996.11			

***** Analysis of variance *****

Variate: %_flower

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	6.96	2.32	0.23	
Reps.*Units* stratum					
Treatment	6	1808.36	301.39	30.01	<.001
Residual	18	180.79	10.04		
Total	27	1996.11			

***** Analysis of variance *****

Variate: %_mat_frt_

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	45.86	15.29	0.50	
Reps.*Units* stratum					
Treatment	6	12268.43	2044.74	66.66	<.001
Residual	18	552.14	30.67		
Total	27	12866.43			

***** Analysis of variance *****

Variate: %_new_lea

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	130.68	43.56	2.53	
Reps.*Units* stratum					
Treatment	6	5194.43	865.74	50.34	<.001
Residual	18	309.57	17.20		
Total	27	5634.68			

***** Analysis of variance *****

Variate: %_new_lea

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	130.68	43.56	2.53	
Reps.*Units* stratum					
Treatment	6	5194.43	865.74	50.34	<.001
Residual	18	309.57	17.20		
Total	27	5634.68			

***** Analysis of variance *****

Variate: Fi_frt_yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	0.2399	0.0800	0.30	
Reps.*Units* stratum					
Treatment	6	235.0394	39.1732	147.84	<.001
Residual	18	4.7694	0.2650		
Total	27	240.0487			

***** Analysis of variance *****

Variate: Length_ns

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	71.821	23.940	5.87	
Reps.*Units* stratum					
Treatment	6	1935.714	322.619	79.09	<.001
Residual	18	73.429	4.079		
Total	27	2080.964			

***** Analysis of variance *****

Variate: Sin_frt_wt

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	52.14	17.38	0.76	
Reps.*Units* stratum					
Treatment	6	14306.43	2384.40	104.72	<.001
Residual	18	409.86	22.77		
Total	27	14768.43			

***** Analysis of variance *****

Variate: Acidity

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	0.0047188	0.0015729	2.13	
Reps.*Units* stratum					
Trts	3	0.0538688	0.0179563	24.28	<.001
Residual	9	0.0066563	0.0007396		
Total	15	0.0652438			

***** Analysis of variance *****

Variate: Firmness_Kg_cm

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	0.003750	0.001250	0.56	
Reps.*Units* stratum					
Trts	3	0.222350	0.074117	33.35	<.001
Residual	9	0.020000	0.002222		
Total	15	0.246100			

***** Analysis of variance *****

Variate: Fruit_diam_mm_D

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	42.250	14.083	1.60	
Reps.*Units* stratum					
Trts	3	628.250	209.417	23.78	<.001
Residual	9	79.250	8.806		
Total	15	749.750			

***** Analysis of variance *****

Variate: H_L

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	87.250	29.083	3.22	
Reps.*Units* stratum					
Trts	3	551.250	183.750	20.35	<.001
Residual	9	81.250	9.028		
Total	15	719.750			

***** Analysis of variance *****

Variate: Juicyness_%

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	21.500	7.167	2.30	
Reps.*Units* stratum					
Trts	3	328.500	109.500	35.20	<.001
Residual	9	28.000	3.111		
Total	15	378.000			

***** Analysis of variance *****

Variate: Shape_ratio_L_D

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	0.0051322	0.0017107	3.75	
Reps.*Units* stratum					
Trts	3	0.0052159	0.0017386	3.82	0.051
Residual	9	0.0041009	0.0004557		
Total	15	0.0144491			

***** Analysis of variance *****

Variate: TSS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	0.2500	0.0833	0.59	
Reps.*Units* stratum					
Trts	3	10.8950	3.6317	25.64	<.001
Residual	9	1.2750	0.1417		
Total	15	12.4200			

***** Analysis of variance *****

Variate: TSS_Acidity_ratio

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	2.6556	0.8852	1.15	
Reps.*Units* stratum					
Trts	3	101.0702	33.6901	43.67	<.001
Residual	9	6.9434	0.7715		
Total	15	110.6693			

***** Analysis of variance *****

Variate: %_seeds

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	6	24.69	4.12	0.30	
Reps.*Units* stratum					
Trts	6	75.27	12.54	0.93	0.489
Residual	36	488.16	13.56		
Total	48	588.12			

***** Analysis of variance *****

Variate: %_Segment

Source of variation	d.f.(m.v.)	s.s.	m.s.	v.r.	F pr.
Reps stratum	6	12.690	2.115	1.93	
Reps.*Units* stratum					
Trts	6	2.548	0.425	0.39	0.883
Residual	35(1)	38.429	1.098		
Total	47(1)	51.979			

***** Analysis of variance *****

Variate: Acidity

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	6	0.010167	0.001695	1.46	
Reps.*Units* stratum					
Trts	6	0.225824	0.037637	32.46	<.001
Residual	36	0.041747	0.001160		
Total	48	0.277739			

***** Analysis of variance *****

Variate: Firmness_Kg_cm

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	6	0.042710	0.007118	0.74	
Reps.*Units* stratum					
Trts	6	2.454853	0.409142	42.49	<.001
Residual	36	0.346661	0.009629		
Total	48	2.844224			

***** Analysis of variance *****

Variate: H_L

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	6	103.84	17.31	0.97	
Reps.*Units* stratum					
Trts	6	2533.27	422.21	23.67	<.001
Residual	36	642.16	17.84		
Total	48	3279.27			

***** Analysis of variance *****

Variate: Juicyness_%

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	6	28.408	4.735	0.88	
Reps.*Units* stratum					
Trts	6	1709.551	284.925	52.67	<.001
Residual	36	194.735	5.409		
Total	48	1932.694			

***** Analysis of variance *****

Variate: Peel_thickness_mm

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	6	200.245	33.374	5.11	
Reps.*Units* stratum					
Trts	6	3766.531	627.755	96.21	<.001
Residual	36	234.898	6.525		
Total	48	4201.673			

***** Analysis of variance *****

Variate: Seed_Wt

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	6	2.1678	0.3613	0.56	
Reps.*Units* stratum					
Trts	6	214.8919	35.8153	55.93	<.001
Residual	36	23.0528	0.6404		
Total	48	240.1124			

***** Analysis of variance *****

Variate: Shape_ratio_L_D

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	6	0.0025509	0.0004251	1.20	
Reps.*Units* stratum					
Trts	6	0.0028007	0.0004668	1.32	0.274
Residual	36	0.0127505	0.0003542		
Total	48	0.0181020			

***** Analysis of variance *****

Variate: TSS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	6	0.7220	0.1203	1.00	
Reps.*Units* stratum					
Trts	6	29.7392	4.9565	41.13	<.001
Residual	36	4.3380	0.1205		
Total	48	34.7992			

***** Analysis of variance *****

Variate: TSS_Acidity_ratio

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	6	13.2747	2.2124	2.36	
Reps.*Units* stratum					
Trts	6	352.0646	58.6774	62.60	<.001
Residual	36	33.7454	0.9374		
Total	48	399.0846			

***** Analysis of variance *****

Variate: %_seeds

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	5	15.00	3.00	0.20	
Reps.*Units* stratum					
Trts	5	15.00	3.00	0.20	0.961
Residual	25	383.00	15.32		
Total	35	413.00			

***** Analysis of variance *****

Variate: Acidity

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	5	0.010892	0.002178	1.22	
Reps.*Units* stratum					
Trts	5	0.161525	0.032305	18.17	<.001
Residual	25	0.044458	0.001778		
Total	35	0.216875			

***** Analysis of variance *****

Variate: Fruit_diameter_D

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	5	92.47	18.49	1.51	
Reps.*Units* stratum					
Trts	5	1313.81	262.76	21.42	<.001
Residual	25	306.69	12.27		
Total	35	1712.97			

***** Analysis of variance *****

Variate: Fruit_firmness_Kg_cm

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	5	0.019458	0.003892	1.49	
Reps.*Units* stratum					
Trts	5	0.247958	0.049592	18.94	<.001
Residual	25	0.065458	0.002618		
Total	35	0.332875			

```
***** Analysis of variance *****

Variate: Fruit_Shape_L_D

Source of variation     d.f.        s.s.        m.s.    v.r.  F pr.

Reps stratum               5  0.0008193   0.0001639    0.73

Reps.*Units* stratum
Trts                       5  0.0030653   0.0006131    2.72  0.043
Residual                  25  0.0056393   0.0002256

Total                     35  0.0095240
```

```
***** Analysis of variance *****

Variate: H_L

Source of variation     d.f.        s.s.        m.s.    v.r.  F pr.

Reps stratum               5      69.14       13.83    1.24

Reps.*Units* stratum
Trts                       5    1283.47      256.69   23.00  <.001
Residual                  25     279.03       11.16

Total                     35    1631.64
```


```
***** Analysis of variance *****

Variate: H_L

Source of variation     d.f.        s.s.        m.s.    v.r.  F pr.

Reps stratum               5      69.14       13.83    1.24

Reps.*Units* stratum
Trts                       5    1283.47      256.69   23.00  <.001
Residual                  25     279.03       11.16

Total                     35    1631.64
```

```
***** Analysis of variance *****

Variate: H_L

Source of variation     d.f.        s.s.        m.s.    v.r.  F pr.

Reps stratum               5      69.14       13.83    1.24

Reps.*Units* stratum
Trts                       5    1283.47      256.69   23.00  <.001
Residual                  25     279.03       11.16

Total                     35    1631.64
```

***** Analysis of variance *****

Variate: H_L

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	5	69.14	13.83	1.24	
Reps.*Units* stratum					
Trts	5	1283.47	256.69	23.00	<.001
Residual	25	279.03	11.16		
Total	35	1631.64			

***** Analysis of variance *****

Variate: Juicyness_%

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	5	14.222	2.844	0.44	
Reps.*Units* stratum					
Trts	5	405.889	81.178	12.42	<.001
Residual	25	163.444	6.538		
Total	35	583.556			

***** Analysis of variance *****

Variate: Peel_thickness_mm

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	5	62.222	12.444	1.26	
Reps.*Units* stratum					
Trts	5	991.222	198.244	20.00	<.001
Residual	25	247.778	9.911		
Total	35	1301.222			

***** Analysis of variance *****

Variate: Seed_weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	5	1.6448	0.3290	2.12	
Reps.*Units* stratum					
Trts	5	54.0786	10.8157	69.86	<.001
Residual	25	3.8703	0.1548		
Total	35	59.5937			

***** Analysis of variance *****

Variate: Segments

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	5	6.333	1.267	1.13	
Reps.*Units* stratum					
Trts	5	5.667	1.133	1.01	0.431
Residual	25	28.000	1.120		
Total	35	40.000			

***** Analysis of variance *****

Variate: TSS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	5	1.0158	0.2032	1.58	
Reps.*Units* stratum					
Trts	5	13.8525	2.7705	21.52	<.001
Residual	25	3.2192	0.1288		
Total	35	18.0875			

***** Analysis of variance *****

Variate: TSS_acid_ratio

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	5	8.1090	1.6218	1.66	
Reps.*Units* stratum					
Trts	5	122.7255	24.5451	25.08	<.001
Residual	25	24.4684	0.9787		
Total	35	155.3029			

***** Analysis of variance *****

Variate: %_Segments

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	4.1429	1.3810	1.47	
Reps.*Units* stratum					
Trts	6	8.8571	1.4762	1.58	0.211
Residual	18	16.8571	0.9365		
Total	27	29.8571			

***** Analysis of variance *****

Variate: Acidity

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	0.0012857	0.0004286	0.87	
Reps.*Units* stratum					
Trts	6	0.0210000	0.0035000	7.07	<.001
Residual	18	0.0089143	0.0004952		
Total	27	0.0312000			

***** Analysis of variance *****

Variate: C14

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	38.00	12.67	0.79	
Reps.*Units* stratum					
Trts	6	54.21	9.04	0.57	0.752
Residual	18	287.50	15.97		
Total	27	379.71			

***** Analysis of variance *****

Variate: Firmness_Kg_cm

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	0.11883	0.03961	1.06	
Reps.*Units* stratum					
Trts	6	0.73964	0.12327	3.29	0.023
Residual	18	0.67362	0.03742		
Total	27	1.53209			

***** Analysis of variance *****

Variate: Fruit_diam_mm_D

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	11.25	3.75	0.33	
Reps.*Units* stratum					
Trts	6	815.86	135.98	12.06	<.001
Residual	18	203.00	11.28		
Total	27	1030.11			

```
***** Analysis of variance *****

Variate: H_L

Source of variation     d.f.        s.s.        m.s.     v.r.  F pr.

Reps stratum               3      11.536       3.845     0.44

Reps.*Units* stratum
Trts                       6     802.714     133.786    15.37  <.001
Residual                  18     156.714       8.706

Total                     27     970.964


***** Analysis of variance *****

Variate: Juicyness_%

Source of variation     d.f.        s.s.        m.s.     v.r.  F pr.

Reps stratum               3      20.000       6.667     3.53

Reps.*Units* stratum
Trts                       6     333.429      55.571    29.42  <.001
Residual                  18      34.000       1.889

Total                     27     387.429


***** Analysis of variance *****

Variate: Peel_thickness_mm

Source of variation     d.f.        s.s.        m.s.     v.r.  F pr.

Reps stratum               3      11.821       3.940     1.11

Reps.*Units* stratum
Trts                       6    1892.357     315.393    88.80  <.001
Residual                  18      63.929       3.552

Total                     27    1968.107

***** Analysis of variance *****

Variate: Seed_wt

Source of variation     d.f.        s.s.        m.s.     v.r.  F pr.

Reps stratum               3      2.7064      0.9021     3.07

Reps.*Units* stratum
Trts                       6     53.9304      8.9884    30.63  <.001
Residual                  18      5.2822      0.2935

Total                     27     61.9190
```

***** Analysis of variance *****

Variate: TSS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	0.41536	0.13845	2.56	
Reps.*Units* stratum					
Trts	6	25.03357	4.17226	77.25	<.001
Residual	18	0.97214	0.05401		
Total	27	26.42107			

***** Analysis of variance *****

Variate: TSS_Acidity_ratio

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	0.9102	0.3034	0.76	
Reps.*Units* stratum					
Trts	6	72.7164	12.1194	30.41	<.001
Residual	18	7.1731	0.3985		
Total	27	80.7996			

***** Analysis of variance *****

Variate: %_seeds

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	5	15.00	3.00	0.20	
Reps.*Units* stratum					
Trts	5	15.00	3.00	0.20	0.961
Residual	25	383.00	15.32		
Total	35	413.00			

***** Analysis of variance *****

Variate: Acidity

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	5	0.010892	0.002178	1.22	
Reps.*Units* stratum					
Trts	5	0.161525	0.032305	18.17	<.001
Residual	25	0.044458	0.001778		
Total	35	0.216875			

***** Analysis of variance *****

Variate: Fruit_firmness_Kg_cm

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	5	0.019458	0.003892	1.49	
Reps.*Units* stratum					
Trts	5	0.247958	0.049592	18.94	<.001
Residual	25	0.065458	0.002618		
Total	35	0.332875			

***** Analysis of variance *****

Variate: Fruit_Shape_L_D

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	5	0.0008193	0.0001639	0.73	
Reps.*Units* stratum					
Trts	5	0.0030653	0.0006131	2.72	0.043
Residual	25	0.0056393	0.0002256		
Total	35	0.0095240			

***** Analysis of variance *****

Variate: H_L

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	5	69.14	13.83	1.24	
Reps.*Units* stratum					
Trts	5	1283.47	256.69	23.00	<.001
Residual	25	279.03	11.16		
Total	35	1631.64			

***** Analysis of variance *****

Variate: Juicyness_%

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	5	14.222	2.844	0.44	
Reps.*Units* stratum					
Trts	5	405.889	81.178	12.42	<.001
Residual	25	163.444	6.538		
Total	35	583.556			

***** Analysis of variance *****

Variate: Peel_thickness_mm

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	5	62.222	12.444	1.26	
Reps.*Units* stratum					
Trts	5	991.222	198.244	20.00	<.001
Residual	25	247.778	9.911		
Total	35	1301.222			

***** Analysis of variance *****

Variate: Seed_weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	5	1.6448	0.3290	2.12	
Reps.*Units* stratum					
Trts	5	54.0786	10.8157	69.86	<.001
Residual	25	3.8703	0.1548		
Total	35	59.5937			

***** Analysis of variance *****

Variate: Segments

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	5	6.333	1.267	1.13	
Reps.*Units* stratum					
Trts	5	5.667	1.133	1.01	0.431
Residual	25	28.000	1.120		
Total	35	40.000			

***** Analysis of variance *****

Variate: TSS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	5	1.0158	0.2032	1.58	
Reps.*Units* stratum					
Trts	5	13.8525	2.7705	21.52	<.001
Residual	25	3.2192	0.1288		
Total	35	18.0875			

***** Analysis of variance *****

Variate: TSS_acid_ratio

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	5	8.1090	1.6218	1.66	
Reps.*Units* stratum					
Trts	5	122.7255	24.5451	25.08	<.001
Residual	25	24.4684	0.9787		
Total	35	155.3029			

***** Analysis of variance *****

Variate: %_seeds

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	6	24.69	4.12	0.30	
Reps.*Units* stratum					
Trts	6	75.27	12.54	0.93	0.489
Residual	36	488.16	13.56		
Total	48	588.12			

***** Analysis of variance *****

Variate: %_Segment

Source of variation	d.f.(m.v.)	s.s.	m.s.	v.r.	F pr.
Reps stratum	6	12.690	2.115	1.93	
Reps.*Units* stratum					
Trts	6	2.548	0.425	0.39	0.883
Residual	35(1)	38.429	1.098		
Total	47(1)	51.979			

***** Analysis of variance *****

Variate: Acidity

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	6	0.010167	0.001695	1.46	
Reps.*Units* stratum					
Trts	6	0.225824	0.037637	32.46	<.001
Residual	36	0.041747	0.001160		
Total	48	0.277739			

***** Analysis of variance *****

Variate: Firmness_Kg_cm

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	6	0.042710	0.007118	0.74	
Reps.*Units* stratum					
Trts	6	2.454853	0.409142	42.49	<.001
Residual	36	0.346661	0.009629		
Total	48	2.844224			

***** Analysis of variance *****

Variate: Fruit_diam_mm_D

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	6	107.92	17.99	1.06	
Reps.*Units* stratum					
Trts	6	2653.92	442.32	26.13	<.001
Residual	36	609.51	16.93		
Total	48	3371.35			

***** Analysis of variance *****

Variate: H_L

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	6	103.84	17.31	0.97	
Reps.*Units* stratum					
Trts	6	2533.27	422.21	23.67	<.001
Residual	36	642.16	17.84		
Total	48	3279.27			

***** Analysis of variance *****

Variate: Juicyness_%

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	6	28.408	4.735	0.88	
Reps.*Units* stratum					
Trts	6	1709.551	284.925	52.67	<.001
Residual	36	194.735	5.409		
Total	48	1932.694			

***** Analysis of variance *****

Variate: Peel_thickness_mm

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	6	200.245	33.374	5.11	
Reps.*Units* stratum					
Trts	6	3766.531	627.755	96.21	<.001
Residual	36	234.898	6.525		
Total	48	4201.673			

***** Analysis of variance *****

Variate: Seed_Wt

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	6	2.1678	0.3613	0.56	
Reps.*Units* stratum					
Trts	6	214.8919	35.8153	55.93	<.001
Residual	36	23.0528	0.6404		
Total	48	240.1124			

***** Analysis of variance *****

Variate: Shape_ratio_L_D

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	6	0.0025509	0.0004251	1.20	
Reps.*Units* stratum					
Trts	6	0.0028007	0.0004668	1.32	0.274
Residual	36	0.0127505	0.0003542		
Total	48	0.0181020			

***** Analysis of variance *****

Variate: TSS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	6	0.7220	0.1203	1.00	
Reps.*Units* stratum					
Trts	6	29.7392	4.9565	41.13	<.001
Residual	36	4.3380	0.1205		
Total	48	34.7992			

***** Analysis of variance *****

Variate: TSS_Acidity_ratio

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	6	13.2747	2.2124	2.36	
Reps.*Units* stratum					
Trts	6	352.0646	58.6774	62.60	<.001
Residual	36	33.7454	0.9374		
Total	48	399.0846			

BIOGRAPHICAL SKETCH

The author was born on 17 July, 1954 at Jitpur VDC, Ilam, Nepal as the eldest son of Shree Surya Prasad and Damanta Devi Baral. He started his schooling from Shree Shanischare Secondary School, Sanischare, Jhapa where he completed his S.L.C. in 1971. He completed I. Sc. from Tri-chandra College, TU, Kathmandu in 1974. Likewise, He obtained his B. Sc. Ag. (Hons) in 1977 from the Punjab Agric. Univ., Ludhiana India. He got his M. S. in Horticulture from The Ohio State University, Columbus, USA in 1984. He has the rich experience of teaching in the Institute of Agriculture and Animal Science, Rampur Campus, Department of Horticulture at different capacities of over 30 years. Presently, he is a Professor of Horticulture. Besides, he has conducted several researches in horticultural related areas and published several articles in journals, reports as well as books and manuals for students, farmers and researchers. He has worked as a subject matter specialist in several horticultural related trainings to the farmers, extension and research workers. He has also affiliated voluntarily in several private institution intended for agricultural and rural development.

He is happily married with Laxmi Baral and has bestowed with the dearest son and daughter Pranaya and Pranita.