ANNUAL REPORT

2060/061 (2003/004)

NEPAL AGRICULTURAL RESEARCH COUNCIL
NATIONAL CITRUS RESEARCH PROGRAM
PARIPATLE DHANKUTA

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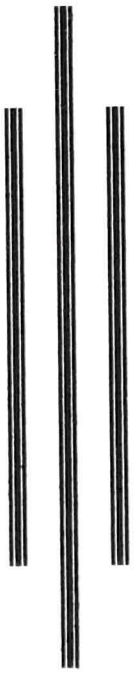

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Correct citation: NCRP. 2004. Annual Report 2060/061 (2003/2004)

FOREWORD

Citrus fruit crops occupy top position in area and production among fruit crops in Nepal. The agro-climatic condition of mid-hills of Nepal is very suitable for high quality citrus production especially for mandarin and sweet orange. Because of production potential, government has regarded citrus as high value prioritized commodity for mid-hill regions of Nepal. Improved production and post-production technology is very vital input for improving quality, productivity and production period of these crops. National Citrus Research Program (NCRP), established in July 2000, is the only public organization of the country fully involved in technology generation on citrus fruit crops. This is the 4th annual report of NCRP. This report highlights the research activities and major findings of the past with especial emphasis on FY 2006/061 (2003/04).

I gratefully acknowledge the valuable works and efforts of all Scientists, Technical Officers and other technical and administrative staffs of NCRP for their contributions to accomplish the researches and help in bringing out this annual report.

I believe that this report will be useful to all concerned with citrus research and production in Nepal. Constructive comments and suggestions on this publication will be highly appreciated and will be used as guidelines in future.

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Coordinator
NCRP, Dhankuta.

ACRONYMS AND ABBREVIATION

C	=	Citrus
CGD	=	Citrus Greening Disease
cm	=	Centimeter
CTV	=	Citrus Tristeza Virus
FY	=	Fiscal year
GA	=	Giberellic acid
gm	=	Gram
Ha	=	Hectare
HMG/N	=	His Majesty' Government of Nepal.
Hort.	=	Horticulture
IAA	=	Indole Acetic Acid
IAAS	=	Institute of Agriculture and Animal Sciences
ICIMOD	=	International Centre for Integrated Mountain Development
IPGRI	=	International Plant Genetic Resource Institute
Kg.	=	Kilogram
Km	=	Kilometer
LSD	=	Least Significant Difference
M	=	Meter
MS	=	Murashige and Skoog
N	=	North
NAA	=	α-Naphthalene Acetic Acid
NARC	=	Nepal Agricultural Research Council
NCRP	=	National Citrus Research Program
^{0}C	=	Degree Celsius
PCR	=	Polymerase Chain Reaction
Rs	=	Rupees (Nepali)
T	=	Ton
TA	=	Total Acidity
TSS	=	Total soluble solids
VDC	=	Village Development Committee
W.	=	Washington
@	=	At the rate of

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1. INTRODUCTION

1.1 Background and History

National Citrus Research Programme (NCRP), is one of the commodity based research institutions of Nepal Agricultural Research Council (NARC). Firstly, it was established in the name of **"Citrus Research Station"** in 1961 with the objectives to generate the technologies on *Citrus species* and to promote commercial citrus cultivation in mid-hills of Nepal. In 1966, the name of this station was changed to **"Horticulture Research Station"** and mandate was given to work on other horticultural commodities too although major emphasis was on citrus fruits. Chungbang farm, established in 1967, as an independent farm to conduct research on cereal crops was also later annexed to Paripatle farm and consequently programs on cereal crops were abandoned and horticultural activities mainly on citrus fruits were initiated. This satellite farm is situated at a distance of 10 km from Paripatle farm. After the establishment of NARC, HMG/N handed over both Chungbang and Paripatle stations to Nepal Agricultural Research Council and named as Agriculture Research Station (Hort.), Dhankuta.

Although the functions of the station were primarily focused on citrus fruit crops since it's establishment, officially it was recognized as **National Citrus Research Program** (NCRP) from July 2000 (Shrawan 2057) and national mandate was given for technologies generation on citrus fruit crops.

1.2 Location

The main research station, commonly known Paripatle farm of this Program is located at Belahara VDC ward No-1, Paripatle village of Dhankuta district. Geographically it is situated at 27^0 1' North latitude and 87^0 18' East longitude. The altitude of station ranges from 1250 to 1390 meter. It is situated 3.85 km west of Kagate (a point at Dharan-Dhankuta-Hile highway) and is connected by a graveled road. The satellite station, Chungbang farm is located at Chungbang VDC at a distance of 10 km from Paripatle farm.

1.3 Soil and Climate

The soil texture of Paripatle research farm varies from sandy to sandy loam along with gravel in different terraces. The pH of soil is acidic ranging from 4.5 to 6.2 with low (0.044%) to medium (3.33%) organic matter. Phosphorus and potash content of the soil vary from 15 to 50 kg/ha and 2.14 to 3.50 kg/ha respectively. The land of Paripatle farm is east faced of the hill whereas Chungbang farm is north faced with sub-tropical type of climate. Paripatle farm receives average annual minimum and maximum temperature of 12.4^0 C and 26.78^0 C respectively. Monthly average meteorological data are presented in Appendix 5.

1.4 Land Utilization

National Citrus Research Program has a total of 26 hectare of land. Out of this, Paripatle farm has 20.0 hectares and rest is in Chungbang farm. Land utilization pattern of both the stations has been presented in Table 1. Most of the farm area has been covered by citrus fruit crops namely mandarin, sweet orange and lime. Old plantations are mostly dominated by single variety of Khoku mandarin and Dhankuta selection sweet orange. It is due to the reason that at the time when station was established major emphasis was to demonstrate commercial citrus production to farmers. In recent years more emphasis has been given on collection, evaluation, maintenance and utilization of citrus diversities in terms of genus, species, varieties and land races. Number of collections and recommended genotypes (indigenous and exotic) are increasing every year. Nearly 30% of the land is still covered by forest or is fallow, which can be utilized for cardamom, coffee or for other non-timber forest product.

Table 1: Land utilization pattern of National Citrus Research Program

S.N.	Utilization pattern	Area (ha)		
		Paripatle Farm	Chungbang Farm	Total
1.	Orchard	8.0	3.0	11.0
2.	Fruit nursery	1.0	0.50	1.5
3.	Vegetable seed production	2.0	0.50	3.5
4.	Building, canal and road	2.3	0.50	2.8
5.	Forest and fallow	6.7	1.50	7.2
	Total	20.0	6.0	26.0

1.5 Goal of NCRP

The goal of NCRP is to contribute in increasing productivity and quality of citrus fruit crops in Nepal with especial emphasis in mid-hill region of the country.

1.6 Objectives of NCRP

The short-term goal or objective of this programme is to develop technologies on citrus fruit crops needed for all types of clients.

1.7 Functions of NCRP

To achieve above mentioned goal and objective NCRP performs the following activities on citrus fruit crops:

- Identify production and postproduction problems faced by immediate clients such as citrus growers, traders and processing industries.
- Develop appropriate technologies to solve the problems faced by these clients.
- Disseminate proven technologies to the clients (farmers, traders and processing industries) through out-reach research, extension and publication of research findings.
- Coordinate with other national and international organizations in order to develop and disseminate citrus technologies efficiently.
- Compilation and publication of research findings and other information related to citrus fruit crops from national and international sources and made available to target groups.
- Serve as the repository for technical know how and genetic resources of citrus species.
- Production and supply of healthy mother plants to nursery owner and farmers.

1.8 Working Strategy

- Identification of researchable problems faced by extension agents, farmers, traders and processing industries through formal and informal discussion, survey, meetings, reports etc.
- Prioritization of problems based on their severity and formulation of research projects proposals on priority projects.
- Presentation of research proposals to Nepal Agricultural Council and other potential donors.
- Implementation of approved research projects in research stations and farmers' fields.
- Verification of newly developed technology in farmers' fields through outreach research.
- Transfer of the technologies that are accepted by farmers to extension agents for scaling-up.

Present Status of Citrus Production in Nepal

Citrus fruits are cultivated all over the world in tropical and sub-tropical region where there are suitable soil and climatic condition. In Nepal, the climatic condition of mid-hill regions having altitude range of 900 to 1300 m from east to far west of the country are considered very favorable for all types of citrus fruit cultivation. Pummelo, lime and lemon can also be cultivated in Terai regions (< 500 m). Citrus is the number one fruit crop of Nepal covering about 25% of total area under fruit cultivation. The three most important species on which Nepal's citrus industry is based are mandarin (*Citrus reticulata*), sweet orange (*Citrus sinensis*) and lime (*Citrus aurantifolia*). These species are also potential exportable commodity particularly to India and Bangladesh.

The history of citrus fruit cultivation in Nepal is not well documented, but the description of fruits in old scriptures about their importance in religious ceremonies and medicinal values indicates that citrus farming must have been a traditional practice since ancient period. But commercial cultivation of citrus fruits in Nepal started only after seventies. Table 2 presents changes in area, production and productivity of citrus fruit crops in Nepal. At present, major citrus producing districts are Ilam, Panchthar, Terathum, Dhankuta, Bhojpur, Sindhuli, Ramechhap, Kabre, Dhanding, Gorkha, Lamjung, Tanahu, Kaski, Syanja, Gulmi, Argakhachhi, Dailekh. Dadeldhura, Baitadi and Darchula.

Table 2. Area and production of citrus fruit crops in Nepal from 1975 to 2002.

Year	Total area (Ha)	Productive area (Ha)	Production (T)	Productivity (T/Ha)
1974/75 (2031/32)	2,600	1,690	15,000	8.9
1979/80 (2036/37)	5,200	3,300	30,000	9.1
1984/85 (2041/42)	8,448	5,000	45,000	9.0
1989/90 (2046/47)	13,515	7,136	78,639	11.0
1993/94 (2050/51)	13,544	7,899	76471	9.68
1994/95 (2051/52)	14,628	8,448	83,375	9.82
1995/96 (2052/52)	15,243	8,977	88,635	9.87
1996/97 (2053/54)	15,924	9,330	92,994	9.97
1997/98 (2054/55)	17026	10034	100,352	10.00
1998/99 (2055/56)	18,007	10,592	107,250	10.13
1999/00 (2056/57)	19,017	11,277	115,062	10.20
2000/01 (2057/58	20,672	11,892	121,665	10.23
2001/02 (2058/59)	22,423	12,615	130,928	10.38
2002/03 (2059/60)	23,663	13,312	139,110	10.45

Source: Annual Reports of Citrus Development Section, Department of Agriculture.

Since last 25 years area and production has been increased by more than eight folds whereas productivity has been remained stagnant at about 8-10 tons per hectare level. The productivity of citrus fruits in Nepal is very low (10 t/ha) as compared to 20 - 50 t/ha in most citrus growing countries of the world. Thus, increase in production level in Nepal is primarily attributed to the

increase in area under citrus cultivation. So, there is enormous scope of increasing productivity of citrus fruit crops in Nepal which can be achieved by utilizing better varieties along with improved orchard management system. Production statistics of citrus fruit crops of Nepal for the year 2002/03 has been presented in Table 3.

Table 3. Area and production of citrus fruit crops in Nepal in the year 2002/2003 (2059/60)

Region	Mandarin		Sweet orange		Lime		Lemon		Other		Total	
	Area (Ha)	Prod. (Mt)	Area (Ha)	Prod. (Mt)	Area (Ha)	Prod. (Mt)	Area (Ha)	Prod. (Mt)	Area (Ha)	Prod. (Mt)	Area (Ha)	Prod. (Mt)
Eastern	34,70.49 (2022)	23,114	755.08 (497)	5561	1404.27 (849)	6798	17,4.53 (147)	1363	25,.86 (18)	156	54,830 (3533)	36,991
Mid	26,42.41 (1440)	16,152	2789.29 (1615)	20311	731.37 (458)	3673	90.47 (74)	587	3,3.81 (25)	215	62,85.4 (3612)	40,938
Western	50,77.4 (2747)	30,692	586.28 (220)	2170	811.38 (493)	3638	187.47 (138)	577	5,7.87 (43)	317	67,20.4 (3641)	37,395
M. W.	21,09.4 (1048)	10,428	277.29 (126)	1242	399.34 (233)	1782	76.35 (62)	460	3,3.41 (27)	200	28,95.8 (1496)	14,111
F. W	10,99.52 (519)	5,310	477.58 (272)	2624	261.72 (169)	1236	70.03 (53)	383	2,2.55 (17)	121	19,31.4 (1031)	9,674
Nepal	14,399.2 (7777)	85,696	4883.5 (2730)	31907	3608.1 (2202)	17127	598.7 (473)	3,371	17,3.5 (129)	1008	23,663 (13312)	139,110

Source: Ministry of Agriculture.

** Figure inside parenthesis are production area i.e. area under fruit bearing trees.

2. TECHNOLOGIES DEVELOPED

Since its establishment NCRP has been involved in technology generation, testing, dissemination, farmers' training and production of foundation mother trees of citrus species. Some of the major achievements (technologies) of the past are given below:

2.1 Germplasm collection and evaluation

NCRP has collected various varieties and land-races of citrus germplasm. These germplasm are being established in the field gene bank of Paripatle farm for evaluation. Collected germplasm include local mandarins (land races from 10 different districts of Nepal), Kamala, introduced mandarin varieties (Unshiu, Murkott, Kinnow and Fruetrel early, Kalamondin, Yoshida Ponkan, Ponkan Mandarin), sweet orange (22 varieties) lime (28 accessions), grapefruit (one variety), pummelo (4 accessiond), hill lemon, (24 accessions) and citrus rootstocks (rough lemon, trifoliate orange, citrange, Rangpur lime). A farmers' participatory survey was carried out in Terai and mid-hills of Nepal and 132 pummelo trees grown in farmers' field were also evaluated *in situ*. The study revealed very high level of diversity in pummelo population with respect to fruit quality. Terai area has been found more suitable for quality pummelo production. From 132 pummelo trees evaluated, five trees (4 from Terai and one from mid hill) are identified as elite types.

2.2 Variety Selection

A number of varieties have been recommended to the farmers as a result of germplasm evaluation works carried out in last three years. Recommended varieties are presented in Table 4.

Table 4 Recommended varieties of mandarin, sweet orange and lime in Nepal.

Crop	Variety	Harvesting season
1. Mandarin	1. Okitsuwase (Unshu mandarin)	Early (Aswin - Kartik)
	2. Khoku (Common mandarin)	Mid-season (Mangsir - Magh)
	3. Murkott (Mandarin x Sweet orange)	Late (Falgun - Chaitra)
2. Sweet orange	1. Washington Navel	Early (Kartik - Mangsir)
	2. Pineapple	Mid season (Poush – Falgun)
	3. Valencia late	Late season (Chaitra-Baisakh)
3. Lime	1. Eureka	Early (Bhadra- Aswin)
	2. Terathum	Mid (Kartik - Poush)

2.3 Standardization of nursery system

Studies were carried out to standardize the vegetative propagation of mandarin and sweet orange. It was recommended that veneer method of grafting should be performed in the months of November and December in mid-hill climate. Maintenance of grafted plants under plastic tunnel for three months produces up to 95 percent success. Trifoliate orange is suitable rootstocks for mandarin and sweet orange. Grafted saplings packed in moistened moss and jute sheet can survive up to 12 days during transportation.

Hunglungbin (greening) and Citrus tristeza virus (CTV) are major graft transmissible diseases causing citrus decline worldwide. These diseases have been found present in many citrus orchards of Nepal including in government farms. Collection and use of scions from unprotected mother plants could serve the source of such diseases resulting in introduction and spread such diseases to disease-

free areas with planting materials. So, a new approach of foundation mother plants establishment and maintenance has been adopted in NCRP, Dhankuta. Under this approach mother plants of selected varieties are indexed for Hunglungbin by PCR technique and for CTV using lime as indicator plants. The disease free mother plants are maintained inside insect proof screen houses. Scions are obtained from these protected mother plants for sapling production. Mother plants are indexed in every two years and will be replaced in every 7 years. Low cost screen house suitable for Nepal has been designed.

2.4 Control of fruit fly

Fruit fly is most serious insect pest of sweet orange and lemon in the eastern hills of Nepal. Its population dynamics has been studied using Feromin traps in Dhankuta area since five years. Study showed that population of citrus fruit flies starts increasing from Baisakh (April), reaches in its peak point in Sawan and Bhadra (September) and becomes almost nil in Aswin (October). Therefore, protein bait spray for fruit fly control should be carried out during Shrawan and Bhadra when sweet orange fruits start to attain physiological maturity. On the basis of past research findings recommendations for the control of citrus fruit flies are (i) collection and destruction (burying into soil or boiling in water) of infected fruits within half an hour of their drop from the tree (iii) spraying (one sq. meter per tree) with sugar + hydrolysed protein + malathion solution during July - August (iv) use of Pheromone trap from March to September (5 ml malathion + 5 ml methyl eugenal per trap; one trap per 10 trees).

2.5 Control of scale insects

Various types of scale insects such as red scale, arrowhead scale, soft scale, cottony-cushion scale damage citrus fruits. It has been found that spray of mineral oil - ATSO @ 5 ml + 1 ml Rogor/liter of water just after the harvest of fruit (February - March) and June-July is very effective for controlling most scale insects.

2.6 Control of green sting bug

For the effective control of green sting bugs spraying of insecticide when bugs are at nymph stage (yellow color) is more effective than at adult stage because adults may fly away and escape from insecticide treatment.

2.7 Rejuvenation of declining trees due to root-rot

Exposure of affected roots during dry season and drenching with Bordeaux mixture in February and May and approach grafting with trifoliate rootstocks during May - June can improve the health of the declining trees. Proper drainage system in the basin area of the tree is also very important.

2.8 Storage of mandarin in cellar store

Matured mandarin fruits with fruit stalk can be stored for two months and sweet orange for three months at room temperature of 10^0 C. and nearly 95% relative humidity inside cellar store.

2.9 Control of Powdery Mildew

Powdery mildew is one of the serious diseases of citrus species. It affects young twigs developed from second flush (May-June). Affected twigs die and fruits drop pre-maturely or quality deteriorates. Spraying of Karathion @ 1 ml/liter of water was recommended previously. However, farmers were found reluctant to use this fungicide, as this is an expensive chemical (Rs 250 per 100-ml bottle). A study carried out at NCRP showed that another fungicide- ' Insuf ' is five times cheaper and as effective as Karathion.

3. RESEARCH REPORTS (2060/61)

All the research projects implemented in FY 2060/61 were continuation of previous years. These projects were in mid-way of implementation and therefore, all the envisaged activities have not been completed. Thus the results and the conclusion drawn in the following sections are based on the activities that have been completed or at final stage of completion. Following research projects were carried out during this year:

1. Variety Improvement in Citrus
2. Use of Tissue Culture for Standardization of Bud-wood Sanitation Program in Nepal.
3. Participatory Technology Generation on Mandarin.
4. Germplasm Maintenance and Production of Horticultural Commodities.

Implementation status of each of these projects is presented in the following sections.

3.1 VARIETY IMPROVEMENT IN CITRUS

Citrus fruit crops mainly mandarin, sweet orange and lime are important commodities for mid-hill farmers as a source of income and family nutrition. However, there is only seasonal production mainly from November to January resulting in glut during this period in the market. Moreover, quality of fruit in the market is very heterogeneous due to the use of unselected genotypes and seed propagated planting materials. Increasing the diversity of varieties by screening local gene pool and new introductions can help to solve this problem. Therefore, this project was initiated in 2001 and will be completed in 2010. The project intends to carry out three main activities namely (i) identification and collection of different citrus varieties from local and exotic sources (ii) multi-location evaluation of elite genotypes and (iii) problem identification of citrus cultivation.

3.2.1 Germplasm Collection

During reporting period (first and second year of the project) several varieties/genotypes of mandarin, sweet orange, lime, lemon and grape fruit were collected. The collections were made from indigenous (farmers' fields and Horticulture Stations) and exotic sources. Planting materials of elite genotypes that were collected during first year of the project were multiplied in second year. Multi-location evaluation of these materials will be started from next year. The new collections made during reporting period are presented in Table 5. A total of 11new accessions of mandarin, 8 accessions of sweet orange, one accession of grapefruit, 30 accessions of lime and 24 accessions of hill lemon have been collected. Presently, new collections are established at variety evaluation plot of Citrus Research Program, Dhankuta. Efforts are also being made for further introduction of new varieties from France especially early and/or late maturing and seedless types.

3.2.2 Variety evaluation

Sweet Orange (Citrus sinensis

Sweet orange (*Citrus sinensis* (L.) Osbeck) occupies first position among citrus fruit crops in area coverage and contributes nearly 60% of the total citrus production of the world. This crop has been grown in most citrus growing countries but Brazil, Mexico, Unites States of America and China are the leading sweet orange producers of the world. About 30 thousands tons of sweet orange fruits was produced in Nepal in 2002 from 4690 hectare of orchards. It is the second important citrus species of Nepal after mandarin sharing about 20 and 23 % of total citrus area and production respectively. The two districts: Ramechhap and Sindhuli account nearly 56 percent of total sweet orange production of Nepal. Genetic base of sweet orange cultivation in Nepal is very narrow since almost all plantations are composed of single variety: 'Junar' which is the selection from local land races. Junar is a mid-

season variety having harvesting season during January-February, a normal season for sweet orange production in Nepal. In the other months, sweet orange fruits are imported from India to meet market demands. Limited studies carried out in the past were mainly focused on evaluation of 'Junar' trees for mother plant selection, rootstock selection and propagation techniques. Most citrus growing countries have developed several varieties suitable for different harvesting season and production environment. However, varieties for different harvesting seasons are completely lacking in the citriculture industry of Nepal, which has resulted to a very narrow harvesting season. Therefore, a variety evaluation study was carried out to select superior sweet orange varieties especially early and late maturing type for mid-hill region of Nepal.

Table 5: Citrus germplasm collected during 2058/59 - 2060/61 (2001/02 - 2003/04)

Species	Variety /accession #	Type of collection	Source	Origin
Mandarin	1. Yoshida Ponkan	Graftling	Hort. Kirtipur	Japanese
	2. Otsu-4	Graftling	Hort. Centre, Kirtiput	Japanese
	3. Hayamura	Graftling	Hort. Centre, Kirtiput	Japanese
	4. Miyagawawase	Graftling	Hort. Centre, Kirtiput	Japanese
	5. Okitsuwase	Graftling	Hort. Centre, Kirtiput	Japanese
	6. Murkott	Graftling	Hort. Centre, Kirtiput	American
	7. Nagpur	Nucellar	Nagpur, India	Indian
	8. Khoku	Graftling	Khoku, Dhankuta	Nepal
	9. Pongan	Scion	ICIMOD	China
	10. Kamala	Scion	Farmer's field	Dhankuta Nepal
	11. Baskharka local	Scion	ARS, Lumle	Nepal.
	12. Sikkime	Layer	Farmer of Terathum	Sikkim, India
Sweet orange	1. Yoshida Navel	Graftling	Hort. Centre, Kirtipur	Japanese
	2. Taraco Nucellar	Graftling	Hort. Centre, Kirtipur	Japanese
	3. Delicious seedless	Scion	ICIMOD	Chinese
	4. Skage Binanza	Scion	ICIMOD	Chinese
	5. Blood Red	Scion	ICIMOD	Chinese
	6. Newhall Navel	Scion	ICIMOD	Chinese
	7. Succari	Scion	ICIMOD	Pakistan
	8. Meisheu-9	Scion	ICIMOD	Chinese
Grapefruit	1. Shamber	Scion	ICIMOD	Pakistan
Lime	1. Udayapur	Seedling	Farmer's field	Udayapur, Nepal
	2. Nagpur	Seedling	Farmer's field	India, Nagpur
	3. Tenali	Seedling	Farmer's field	India, Tenali
	4. Madrasi	Layer	Private nursery	India
	5. Banarasi	Layer	Private nursery	India
	6. Variegated	Layer	Private nursery	India
	7. Various 24 accessions	Seedlings	Different districts of Nepal	Nepal.

A total of 14 sweet orange varieties (Table 6) established at research orchard of National Citrus Research Programme, Dhankuta (1350 m altitude) were evaluated for horticultural characters in 2002 and 2003. Of the 14 varieties evaluated Junar was a local selection whereas rest of the 13 were exotic varieties introduced from India. All varieties were grafted on rough lemon (*Citrus jambhiri*) rootstocks and age ranged from 20 to 30 years. The fruit characters which are important for market acceptance and least affected by external environment like fruit, apex and base shape, rind texture, skin colour, fruit weight, seed number, rind, pulp and juice percent, total soluble solids (TSS), total acids (TA) and TSS/TA ratio were recorded. Most of the quantitative characters vary depending on maturity period. It is important to compare the fruit quality of varieties at similar maturity stage. So, first of all initiation of maturity period was determined. For this, in the first year of evaluation, fruits of selected trees of each variety were observed for color development from mid October (beginning

of Kartik). When most fruits started to turn yellow color, fruit samples (two fruits/tree) were evaluated for TSS, TA and their ratio in weekly interval. Same fruit samples were also used for organoleptic test. The fruits were found sweet enough for fresh consumption when ratio of TSS and TA crossed 7:1 level. So, the time at which this ratio was recorded was considered as initiation of maturity period for that variety. Fifteen days after the date when TSS/TA ratio crossed 7 all fruit characters as mentioned above were evaluated in detailed. Therefore, unless otherwise mentioned all data presented are those recorded at this time. For detailed evaluation, fruit samples (10 fruits/tree) were randomly collected from all directions of the tree. Fruit shape, apex shape, base shape and rind texture were determined following the Citrus Descriptors (IPGRI, 1999). TSS was recorded by hand refractometer. Two ml fruit juice was titrated with 0.1 N sodium hydroxide (NaOH) solution to Phenophthalein end point and percentage of TA was calculated using formula of Rangana (1995). Rind, pulp and juice percent was calculated based on fruit weight. Means of two years data with standard deviations within variety were used for comparison.

Table 6 presents the quantitative fruit characteristics, which are important on horticultural point of view and were evaluated 15 days after TSS/TA ratio crossed 7 (initiation of maturity). Average fruit size ranged from 101.8 to 157.7 gm among varieties. Shamauti produced biggest fruits (157.7 ± 22.1 gm) whereas Dhankuta Junar (101.8±8.6 gm), Lue Gim Gong (104.4 ± 14.9 gm) had smallest fruits. Navelencia (30.2%), Hamlin (31.1%), Lue Gim Gong (31.7%) and W. Navel (32.6%) recorded the lowest rind percentage. On the other hand the percentage of pulp in the fruit was highest in these varieties. The varieties with highest rind percentage (thick rind) such as Mosambi and Malta Blood Red had lowest pulp content in the fruits.

Washington Navel and Nevelencia were seedless (Fig. 2); Pineapple, Shamauti, Sevelle Common, Vanelle, Lue Gim Gong and Hamling had very less seeds (3-5 seeds per fruit). Valencia, Rubi and White Taker were medium seeded (5-9 seeds/fruit). Dhankuta Junar and Malta Blood Red had 7-14 seeds in a fruit whereas Mosambi was very seeded (20.3 ± 4.2 seeds/fruit). Juice content in fruit was lowest in Mosambi (26.2%) and in Malta Blood Red (28.5%). But fruits of Gue Gims Gung (39.6%), Hamblin (38.6%) and Nevelencia (35.7 %) were more juicy. Evaluation of varieties at similar stage of maturity (but at different time could have resulted to relatively less variation on TSS and TA.

External fruit characters such as fruit shape and texture are important factors for market acceptance. Table 7 shows the variation on such qualitative traits among the varieties. Fruits with three types of shape namely spheroid (height and diameter nearly equal) oblate (height less than diameter) and ellipsoid (height greater than diameter) were recorded. Fruits of W. Navel were oblate; Shamauti and Vanelle had ellipsoid fruits while other 11 varieties produced spheroid fruits. Citrus traders were found to prefer spheroid and oblate type of fruits as such fruits are easy in packaging (personnel communication with local traders). Varieties with two types (truncate or convex) of fruit bases and apices were found. Rind surface in all the varieties except in Mosambi was smooth. Fruit rind in Mosambi was grooved which was very prominent at basal end. On horticultural point of view sweet oranges are classified into four groups namely navel, common, pigmented and acidless. Except acidless, other three types of sweet oranges were identified in this study. W. Navel and Nevelencia were navel type with small secondary fruit embedded in the apex of the main fruit. Malta Blood Red was pigmented or blood type since at full maturity fruit pulp of this variety was pink in color due to the development of anthocynin in the juice. All other varieties were common or blond oranges. Acidless or sugar oranges have very less acid in the fruit juice generally less than 0.2%. Fruit juice analysis (Table 6) showed that all the 14 varieties had more than 1% acid confirming that none of these varieties were acidless type.

Table 6. Quantitative fruit characters of 14 sweet orange varieties

Variety	Fruit Weight (gm)	Rind (%)	Pulp (%)	Seed No.	Juice (%)	TSS (^{0} Brix)	TA (%)	TSS/TA
Pineapple	136.2 (±13.6)	39.6 (±2.7)	62.0 (±1.6)	2.6 (±1.5)	36.7 (±2.7)	10.3 (±0.3)	1.3 (±0.1)	8.2 (±0.6)
W. Navel	144.1 (±28.7)	32.6 (±1.4)	67.2 (1.4)	0.8 (±0.8)	35.3 (±1.6)	11.4 (±0.6)	1.4 (±0.1)	8.4 (±0.8)
Malta Blood Red	130.0 (±25.9)	44.4 (±6.2)	53.9 (±6.0)	10.5 (±4.0)	28.5 (±7.5)	10.3 (±1.0)	1.6 (± 0.3)	7.5 (±0.9)
Shamauti	157.7 (±22.1)	35.6 (±3.2)	64.0 (±3.3)	3.7 (±2.1)	30.6 (±3.0)	10.8 (±0.6)	1.4 (±0.1)	7.9 (±1.0)
Mosambi	120.8 (±16.4)	46.0 (±5.4)	51.1 (±5.1)	20.3 (±4.2)	26.2 (±5.6)	9.0 (±0.7)	1.2 (±0.2)	7.6 (±1.3)
Sevelle Common	111.0 (±10.1)	34.0 (±5.1)	65.0 (±5.0)	4.8 (±2.3)	34.6 (±4.7)	9.9 (±0.6)	1.3 (±0.2)	7.5 (±1.1)
Valencia	124.5 (±20.7)	34.2 (±2.1)	64.7 (±2.2)	5.3 (±1.9)	35.3 (±2.6)	10.0 (±0.8)	1.2 (±0.2)	8.4 (±0.9)
Nevelencia	148.0 (±40.7)	30.2 (±3.7)	69.7 (±3.6)	0.6 (±0.9)	38.4 (±3.6)	10.2 (±0.5)	1.1 (±0.2)	9.1 (±1.3)
Vanelle	124.5 (±20.7)	34.3 (±8.4)	65.0 (±8.4)	4.5 (±2.0)	36.3 (±8.1)	10.6 (±1.0)	1.3 (±0.1)	8.7 (±0.7)
Dhankuta Junar	101.8 (±8.6)	37.2 (±4.0)	60.1 (±3.9)	10.2 (±3.4)	34.0 (±3.2)	9.9 (±1.2)	1.2 (±0.6)	8.2 (±2.2)
Rubi	113.9 (±24.6)	36.8 (±8.1)	62.0 (±7.7)	7.7 (±4.1)	32.8 (±11.1)	11.1 (±2.0)	1.4 (±0.2)	8.3 (±1.8)
Lue Gim Gong	104.4 (±14.9)	31.7 (±2.6)	67.2 (±2.7)	4.8 (±1.4)	39.6 (±3.3)	9.6 (±1.0)	1.3 (±0.2)	7.5 (±1.3)
White Taker	132.9 (±18.2)	34.1 (±6.0)	64.7 (±6.4)	8.5 (±3.0)	37.5 (±4.4)	9.0 (±0.8)	1.2 (±0.3)	7.9 (±1.8)
Hamlin	151.5 (±21.2)	31.1 (±4.6)	68.3 (±4.7)	4.4 (±2.5)	38.6 (±4.5)	9.1 (±0.2)	1.3 (±0.1)	7.2 (±0.8)

As mentioned above, fruit samples (when rind stated to develop yellow color) were used for organoleptic taste and same samples were also used for TSS and TA analysis. It was found that when TSS/TA ratio crossed 7:1, sweet orange fruits were sweet enough in organoleptic taste. So, TSS/TA ratio of 7 has been considered as indicator of initiation of maturity and harvesting time in sweet orange in mid-hill condition of Nepal. Table 2 presents the maturity periods of all 14 varieties evaluated. Based on maturity period the varieties were classified into three groups: early (maturing from November), mid-season (maturing from January) and late (maturing from March). Washington Navel and Nevelecia were early varieties; Valencia, Sevelle Common and Lue Gim Gong were late maturing varieties and rests of the varieties were found mid-season maturing type. The TSS/TA ratio in mid and late season varieties was less than 5 and fruits were sour in taste even after one month of full yellow color development on rind surface. On the other hand, in early maturing varieties like W. Navel fruits were sweet and TSS/TA ratio crossed 7 even when only about 50% of the fruit rind had

turned to yellow color. Differences in maturation between early and late cultivars are believed to reflect differences in heat unit requirements- late cultivars require a larger sum of heat units. In California, Valencia orange matures in 12 months after bloom and harvesting can be continued about three months. which is very close to the results obtained in this study.

Table 7. Qualitative fruit characteristics of sweet orange varieties

Variety	Fruit Shape	Base shape	Apex shape	Stylar end	Maturity period
Pineapple	sheroid	tuncate	convex	closed	Jan.-Feb.
W. Navel	obate	convex	truncate	open-navel	Nov.-Dec.
Malta Blood Red	sheroid	tuncate	truncate	closed	Jan.- Feb.
Shamauti	elipsoid	tuncate	convex	closed	Jan.- Feb.
Mosambi	sheroid	convex	convex	closed	Jan.- Feb.
Sevelle common	sheroid	truncate	convex	closed	Mar.-Apr.
Valencia	sheroid	truncate	convex	closed	Mar.–Apr.
Nevelencia	sheroid	convex	truncate	open- navel	Nov.– Dec.
Vanelle	elipsoid	tuncate	convex	closed	Jan.- Feb.
Dhankuta Junar	sheroid	convex	truncate	closed	Jan.- Feb.
Ruby	sheroid	convex	truncate	closed	Jan.- Feb.
Lue Gim Gong	sheroid	tuncate	convex	Slightly open	Mar.–Apr.
White taker	sheroid	convex	convex	closed	Jan.- Feb.
Hamlin	sheroid	truncate	convex	closed	Jan.- Feb.

Citrus fruits are non-climacteric in nature meaning that changes in fruit texture and composition during maturation takes place in a slow and gradual manner. Maturation of citrus fruit is characterized by gradual changes in juice content and some of its constituents. On one hand there is a decline in total acidity (TA) brought about by decomposition of citric acid, a principal organic acid of citrus juice. On the other hand, there is an increase in sugars, usually expressed as total soluble solids (TSS). With acidity declining and sugars increasing towards maturation, the TSS/TA ratio starts to increase and is commonly used as 'maturity index' in most countries. But in Nepal, development of yellow color in rind surface is a commonly used indicator of maturity in sweet orange. The results of present study also revealed that color development might not be the true indicator of maturity since it may depend on several factors like variety, climate and season. TSS/TA ratio of 8 has been used as maturity and harvesting index of sweet orange in USA but considering the production climate of Nepal and taste preferences of consumers TSS/TA ratio of 7 has been suggested as the indicator of harvesting time of sweet orange for Nepal.

As mentioned earlier, there was diversity (from November to April) among varieties on maturity period and these varieties were broadly grouped into early, mid and late maturing types. So, an attempt was also made to select superior varieties for each maturity group. For selection, varieties within each maturity group were compared on fruit size, rind, pulp and juice percent, seed number, TSS, TA, TSS/TA ratio and other observation made during evaluation.

W. Navel and Nevelencia were early maturing varieties. Both varieties were very similar in most fruit characters but in Nevelencia very high rate of post bloom fruit drop was observed in comparison to W. Navel. So, W. Navel was selected for early season production. On first week of November (second week of Kartik) TSS/TA ratio in W. Navel was 7.37:1 (Fig. 1) and taste was adequately sweet for fresh consumption. It confirms that this variety started to mature from the beginning of November at 1350 elevation. It is likely that this variety may mature 1-2 weeks earlier at lower (1000-1200 m) altitude because higher amount of heat unit and sunshine are received at lower altitude.

Fig. 1 Change in TSS, TA and TSS/TA ratio over time in early variety: W. Navel

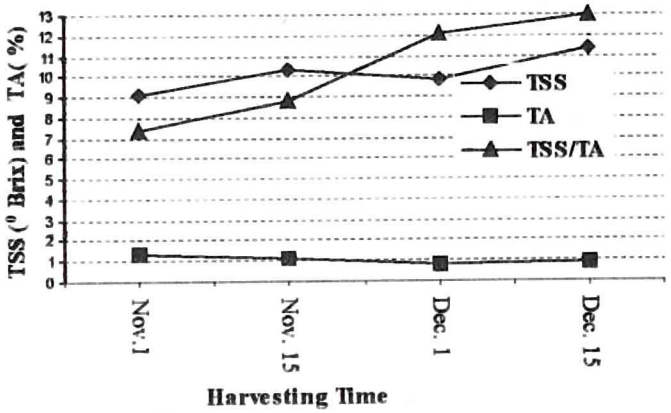
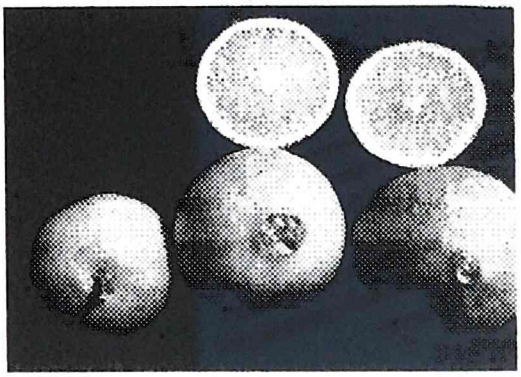


Fig. 2 Seedless fruits of W. Navel sweet orange



Of the 14 varieties evaluated 9 were found maturing during January – February, which is considered as mid or normal season in Nepal. The TSS/TA ratio of these varieties crossed 7 in the beginning of January (mid Paush). Junar, a predominantly cultivated local variety of Nepal, was a mid-season variety. However, present study showed (Table 6) that Hamlin and Pineapple are superior to Junar in most of the fruit characters such as high pulp and juice and low rind and seed content. So, in addition to Junar, Hamlin and Pineapple were also recommended for mid-season production. Dissemination of these varieties to farmers' fields will be helpful for improving fruit quality of sweet orange in Nepal. The fruit quality of Mosambi, a popular commercial variety of India was found very poor (low pulp and juice percent, highly seeded and thick rind) in mid-hill condition of Nepal. It suggests the need of location specific varieties for quality fruit production. .

Three late maturing varieties: Valencia, Sevelle Common and Lue Gim Gong were very similar in all characters except that fruits of Valencia were biggest possibly due to better tree health of this variety. It is likely that these varieties could have been originated as clonal progenies of same variety but given different names in different countries. According to Hodson (1967) Lue Gim Gong is a nucellar selection of Valencia. The acid content was high (>2.8%) and taste was sour in late varieties until mid-February. After this, acid content started to decrease with slightly increase in TSS which resulted to sharp increase in TSS/TA ratio. The fruits of Valencia variety started to mature (TSS/TA crossed 7) from second week of March (Fig. 3) and can be harvested until the end of April. It was observed that in this variety maturity of fruits overlaps development of new bloom (Fig. 4) and fruits store remarkably well on the trees without much dropping and little loss in quality.

Fig. 3 Change in TSS, TA, TSS/TA ratio over time in late variety: Valencia

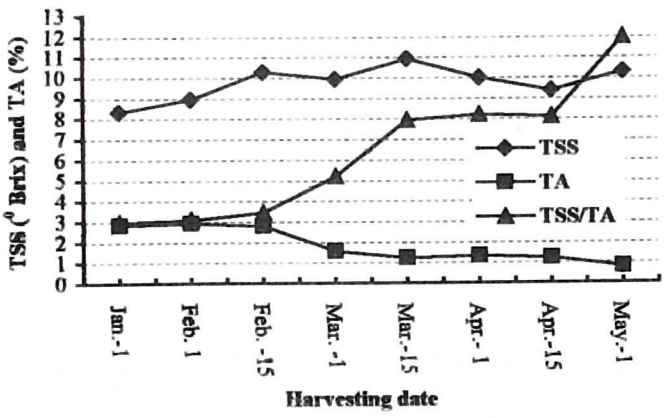
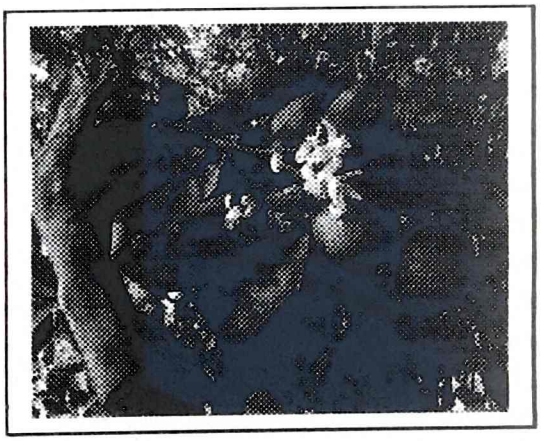


Fig. 4 Overlapping of new bloom and fruit maturity in Valencia sweet orange



Narrow genetic base resulting by the use of single variety could be very vulnerable for biotic and abiotic stresses. To reduce such vulnerability and provide choices on quality to consumers most countries use more than one variety. For example, in India varieties like Mosambi, Sathgudi, Jaffa, Valencia and Malta in India and in USA Pineapple, Cara Cara, Lane Late, Washington Navel, Autumn Gold and Summer Gold in USA are recommended and being cultivated in commercial level. Commercial cultivation of presently selected early, mid and late season varieties can broaden the genetic base of sweet orange and is also appropriate technique for expanding harvesting season in Nepal where storage facilities are inadequate and expensive.

Following conclusions have been drawn from this study:

- Narrow harvesting season of sweet orange in Nepal is due to the use of single variety
- Variation on fruit shape, size, seed number, pulp percent, juice, TSS and TA content, TSS/TA ratio and maturity season was noted among 14 varieties evaluated.
- Navelencia and Washington Navel were early maturing and seedless.
- Pineapple, Shamauti, Rubi, White Taker, Hamlin, Dhankuta Junar, Vanelle, Mosambi and Malta Blood Red were mid-season varieties
- Sevelle Common, Lue Gim Gong and Valencia were late season varieties.
- Based on Maturity period and other desirable fruit characters following varieties are selected and recommended:

  Washington Navel for early season production.

  Pineapple and Hamlin for mid-season production

  Valencia for late season production.

- Commercialization of early and late maturing varieties can extend harvesting period of sweet orange at least for six months (November-April) in comparison to about two months (January-February) at present.

Mandarin (*Citrus reticulata*)

Most of mandarins at Paripatle farm are seedling trees of Khoku local cultivar. Being cross-pollinated species, seedling trees could be different to each other in their genetic composition. The fruit characters and quality of 26 accessions (trees) Khoku mandarin were evaluated in order to select superior mother plants for multiplication. Table 8 presents fruit analysis result (average of 2058 and 2059) of Khoku mandarin accessions and other eight exotic varieties. Average fruit weight of Khoku accessions ranged from 66 gram to 87 gram. Proportion of pulp (percentage of fruit weight) ranged from 65% to 70%. Around 70% pulp content in the fruit is considered very satisfactory from quality point of view. Percentage of juice in the fruit (based on fruit weight) ranged from 37-46%. There was variation in seed content among the trees and most trees were found highly seeded. Seeds content in the fruit also varied among the fruits within a tree. It suggests that seedless mandarin trees should be searched in the farmers' field. There was very less variation in segment number per fruit. It ranged from 8-11. Total soluble solids content in the juice was minimum (10.7) in accession J-23 and it was maximum (12.9) in J-72. Variation in total acids (TA) content ranged from 0.8 to 1.2%. In most cases TSS and TA ratio was higher than 11.

In addition to Khoku local, exotic varieties introduced in the past and were at fruiting stage were also evaluated and compared to Khoku. The evaluated exotic varieties include Frutrel early, Unshu,

Miyagawawase, Okitsuwase and Murkott. Possibly, Unshu mandarin was introduced 15-20 years ago. The exact variety is not known. Therefore, each tree was given a number and evaluated. The maturity period of all the Khoku genotypes (accessions) was Mangsir to Magh (Table 8). This is the normal season for mandarin production in Nepal. There was no variation in maturity period in Khoku land races. All accessions matured from Mangsir to Magh at 1300 m altitude. Among the 26 land races of Lhoku mandarin evaluated during 2058 to 2060 accession number J-75 and J-90 were selected for mother plant based on yield and fruit quality (pulp content, juice content, TSS, TA and TSS/TA ratio.

There was variation in fruit quality and maturity time among the exotic varieties (Table 8). Frutrel early matured about 15 days earlier than Khoku mandarin. Pulp color and aroma of this variety was found attractive but there were very high number (25) of seeds in the fruit and also susceptible to fruit fly. The Unshu genotypes (Unshu-1, 2 and 4) grafted on rough lemon rootstock had medium sized fruits. The maturity period of these accessions was from first week of Aswin to mid Kartik. Due to low TSS content (6-7 ^{0} Brix) the fruit taste was found less sweet than preferred by Nepali consumer. The other two Satsuma (*unshiu*) mandarin varieties: Okitsuwase and Miyagawawase were found suitable for early production (Aswin - Kartik). Both are seedless varieties, having high pulp content with acceptable taste for consumer. Okitsuwase was developed through nucellar selection from Miyagawawase in Japan and is most popular early season mandarin variety in Japan covering nearly 8000 ha. In recent years the popularity of this variety is also increasing rapidly in Spain and Italy for early harvest. Likewise, for late season production variety 'Murkott' has been selected. It is a hybrid between mandarin and sweet orange but fruits resemble to mandarin. It has medium sized fruits (140 gm) with 72 percent pulp content. Fruit skin of Murkott is slightly tighter than in mandarin and therefore, this variety is considered suitable for long transportation and storage. In first week of Phalgun fruit juice contained 11.4 ^{0}Brix TSS, 1.4% total acid and 8.1 TSS/TA ratios. TSS/TA ratio of more than 7 is considered suitable for consumption. Prior to Phalgun 1st week the acid content was higher than 1.8 resulting to lower TSS/TA ratio.

Yield performance of 26 Khoku accessions has been presented in Table 9. Although all trees were about 30 years old there was wide range of variation in fruit yield (total fruit weight and number of fruits per tree). In 2058, yield ranged from 1 kg to 101.5 kg per tree and average was 55.5 kg. Likewise number of fruits per tree ranged from 17 to 1355 and average of 26 trees was 686 fruits per tree. In 2059, fruit yield in most of the trees increased in comparison to previous year. In this year average yield per tree was 91.1 kg which was 64% higher than 2058. But increase in fruit yield was associated with decrease in fruit size. In 2059, fruit size decreased by 7.2%. In 2060, average fruit yield was recorded as 81.2 kg which was 10.9% less than 2059. But fruit size was increased by 3.6% in 2060 in comparison to 2059. It shows that in Khoku mandarin, the year of heavy bearing is followed by a shy bearing year. In the present context, 2058 was shy bearing year followed by heavy bearing year 2059. Again 2060 was a shy bearing year. Researches on reducing yield gap between heavy and shy bearing years should be carried in future.

In 2060, fruits of 26 Khoku mandarin trees were also evaluated with respect to their grades on the basis of size (Table 10). Based on size, fruits were categorized into 4 groups: big (≥100 gm), medium (70-99 gm), small (50-69 gm) and unmarketable (< 50 gm). Number of big fruits ranged from 21-670 among 26 trees and average number of big fruits were 248 per tree. Likewise number of medium fruits ranged from 53-1206 and number of small fruits ranged from 37-1050 among the trees (Table 10). Average number of unmarketable fruits per tree was 91.5 (3.4 kg). In addition to under sized fruits that were rotten, broken and damaged were also considered as unmarketable.

Table 11 presents different grades of fruits in terms of percentage. The percentage of big fruits by weight ranged from 7.4% (in tree # J-4) to 53.5% in J-24. On an average 31.6% of total fruit yield by weight and 24.6% by number were accounted as big fruits. Percentage of medium fruits was found

maximum (42%). Likewise on the basis of fruit weight small sized fruits contributed 26.1 percent of total fruit yield. But on the basis of number 33.2% of the fruits were recorded under small sized category. On an average 4.5 ± 3.2 percent of fruits by weight and 8.9 ± 5.7 percent by number were unmarketable. Technologies to increase the proportion of big and medium sized fruits should be developed in future to generate higher return.

Table 8: Fruit characteristics of local (Khoku) and exotic mandarin genotypes (2-years' mean)

Acc. No.	Fruit wt. (gm)	Pulp (%)	Juice (%)	Seeds/ Fruit	TSS	Total Acid (%)	TSS/TA	Maturity Period
J-4	74.7	65.2	41.2	11.6	12.9	1.2	11.5	Mangsir -Magh
J-9	84.5	68.5	44.5	16.3	11.4	1.0	12.5	Mangsir -Magh
J-13	84.7	69.7	43.8	15.4	11.7	0.9	13.5	Mangsir -Magh
J-16	73.9	69.8	42.6	8.9	12.8	0.9	15.5	Mangsir -Magh
J-21	83.3	65.3	39.3	14.4	12.2	0.8	15.7	Mangsir -Magh
J-23	78.5	66.8	41.4	14.7	10.7	0.8	14.9	Mangsir -Magh
J-24	82.9	69.3	44.5	14.8	11.0	0.9	13.5	Mangsir -Magh
J-26	87.4	68.5	41.3	15.5	11.0	0.8	13.3	Mangsir -Magh
J-34	79.4	65.4	38.3	8.8	11.0	0.8	14.1	Mangsir -Magh
J-35	87.8	65.6	39.9	10.6	11.4	1.0	12.5	Mangsir -Magh
J-40	76.0	64.3	41.1	12.8	10.9	0.8	14.5	Mangsir -Magh
J-41	72.0	69.4	41.7	8.6	11.5	0.9	13.8	Mangsir -Magh
J-42	72.4	65.5	36.7	8.9	11.0	1.4	8.7	Mangsir -Magh
J-48	79.5	68.9	46.5	8.7	11.2	1.2	11.1	Mangsir -Magh
J-50	72.4	66.3	40.0	14.3	11.5	1.2	11.2	Mangsir -Magh
J-52	83.2	66.0	41.6	14.0	11.4	1.0	12.6	Mangsir -Magh
J-58	73.6	66.9	41.0	12.5	11.6	1.0	13.6	Mangsir -Magh
J-68	82.9	65.2	39.3	12.3	11.6	0.8	13.8	Mangsir -Magh
J-70	68.8	68.3	43.7	12.0	11.1	0.9	12.8	Mangsir -Magh
J-71	66.5	67.1	39.7	9.6	12.8	0.9	13.6	Mangsir -Magh
J-72	73.5	66.8	41.6	12.7	12.9	1.1	13.0	Mangsir -Magh
J-75	76.5	66.3	42.5	12.6	11.5	1.1	11.1	Mangsir -Magh
J-82	75.2	65.3	39.9	11.6	11.5	1.1	12.4	Mangsir -Magh
J-84	67.6	64.8	37.8	10.8	11.5	1.1	12.7	Mangsir -Magh
J-90	82.3	65.8	41.0	12.7	11.2	0.9	13.0	Mangsir -Magh
J-91	72.9	65.2	39.5	10.3	12.0	1.1	12.0	Mangsir -Magh
Khoku Mean	77.4	66.8	41.2	12.1	11.6	0.98	13.0	Mangsir -Magh
SD	6.08	1.7	2.2	2.4	0.6	0.16	1.5	
Frutrel early	107.6	66.3	41.5	25.4	9.7	0.96	10.3	Kartik-Mangsir
Unshu-1	85.1	79.7	57.9	0	6.0	1.3	4.6	Asoj-Kartik
Unshu-2	86.3	81.5	57.0	0	6.0	1.2	4.6	Asoj-Kartik
Unshu-4	63.2	78.5	53.7	0	6.6	1.4	4.7	Asoj-Kartik
Miyagawa wase	200.0	76.0	35.0	0	7.4	0.64	11.6	Asoj-Kartik
Okitsuwase	157.0	76.0	44.0	0	8.4	0.68	12.4	Asoj-Kartik
Murkott	140.0	72.0	39.0	17.0	11.4	1.4	8.1	Phagun-Chait

Table 9. Yield performance of Khoku mandarin in three consecutive years

Tree Number	Fruit yield in 2058			2059			2060			% increase/decrease in year 059 compared to 058			% increase/decrease in year 060 compared to 059			Mean of 3 years		
	Yield (kg)	Yield (Fruit #)	Fruit wt (gm)	Yield (kg)	Yield (Fruit #)	Fruit wt (gm)	Yield (kg)	Yield (Fruit #)	Fruit wt (gm)	Yield (kg)	Yield (Fruit #)	Fruit wt (gm)	Yield (kg)	Yield (Fruit #)	Fruit wt (gm)	Yield (kg)	Yield (Fruit #)	Fruit wt (gm)
J-4	39.9	490.0	81.4	89.0	1311.0	67.9	32.0	450.0	71.1	123.1	167.6	-16.6	-64.0	-65.7	4.7	53.6	750.3	73.5
J-9	81.9	850.0	96.4	101.0	1389.0	72.7	40.5	448.0	90.4	23.3	63.4	-24.5	-59.9	-67.7	24.3	74.5	895.7	86.5
J-13	101.5	1050.0	96.7	143.0	1964.0	72.8	72.9	898.0	81.2	40.9	87.0	-24.7	-49.0	-49.2	11.5	105.8	1304.0	83.6
J-16	63.4	740.0	85.7	66.2	1067.0	62.0	91.2	1275.0	71.5	4.4	44.2	-27.6	37.8	19.5	15.4	73.6	1027.3	73.1
J-21	46.5	531.0	87.6	67.0	847.0	79.1	58.5	711.0	82.3	44.1	59.5	-9.7	-12.7	-16.1	4.0	57.3	696.3	83.0
J-23	55.7	632.0	88.1	47.0	683.0	68.8	85.2	1111.0	76.5	-15.6	8.1	-21.9	81.3	63.0	11.5	62.6	808.7	77.8
J-24	49.7	600.0	82.8	20.0	241.0	83.0	75.2	817.0	92.0	-59.8	-59.8	0.2	276.0	239.0	10.9	48.3	552.7	85.9
J-26	20.3	200.0	101.5	75.0	1022.0	73.4	58.8	761.0	77.3	269.5	411.0	-27.7	-21.6	-25.5	5.3	51.4	661.0	84.1
J-34	91.7	1050.0	87.3	15.0	210.0	71.4	97.5	1241.0	78.6	-83.6	-80.0	-18.2	550.0	491.0	10.0	68.1	833.7	79.1
J-35	66.2	926.0	71.5	114.0	1096.0	104.0	124.5	1625.0	76.6	72.2	18.4	45.5	9.2	48.3	-26.3	101.6	1215.0	84.0
J-40	62.0	880.0	70.5	82.0	1006.0	81.5	122.0	1437.0	84.9	32.3	14.3	15.7	48.8	42.8	4.2	88.7	1107.7	79.0
J-41	59.3	813.0	72.9	30.0	422.0	71.1	94.0	1422.0	66.1	-49.4	-48.1	-2.5	213.3	237.0	-7.0	61.1	885.7	70.0
J-42	1.0	17.0	58.8	11.0	128.0	85.9	8.5	111.0	76.6	1000.0	652.9	46.1	-22.7	-13.3	-10.9	6.8	85.3	73.8
J-48	27.1	361.0	75.1	62.0	739.0	83.9	72.0	921.0	78.2	128.8	104.7	11.8	16.1	24.6	-6.8	53.7	673.7	79.1
J-50	15.9	237.0	67.1	34.0	438.0	77.6	38.5	539.0	71.4	113.8	84.8	15.7	13.2	23.1	-8.0	29.5	404.7	72.0
J-52	60.2	695.0	86.6	76.0	952.0	79.8	81.0	995.0	81.4	26.2	37.0	-7.8	6.6	4.3	2.0	72.4	880.7	82.6
J-58	70.7	960.0	73.6	126.0	1711.0	73.6	94.0	1224	76.8	78.2	78.2	0.0	-25.4	25.5	4.3	96.9	1298.3	74.7
J-68	36.9	429.0	86.0	94.0	1177.0	79.9	69.5	836.0	83.1	154.7	174.4	-7.1	-26.1	-29.0	4.0	66.8	814.0	83.0
J-70	76.8	904.0	85.0	137.0	2598.0	52.7	115.0	1591.0	72.3	78.4	187.4	-37.9	-16.1	-38.8	37.2	109.6	1697.7	70.0
J-71	95.5	1355.0	70.5	28.0	448.0	62.5	93.8	1307.0	71.8	-70.7	-66.9	-11.3	235.0	191.7	14.8	72.4	1036.7	68.3
J-72	45.7	597.0	76.5	31.0	440.0	70.5	28.5	385.0	74.0	-32.2	-26.3	-8.0	-8.1	-12.5	5.0	35.1	474.0	73.7
J-75	50.3	617.0	81.5	258.0	3608.0	71.5	95.0	1216	78.1	412.9	484.8	-12.3	-63.2	-66.4	9.3	134.4	1813.7	77.0
J-82	83.5	1064.0	78.5	172.0	2394.0	71.8	151.0	2160.0	69.9	106.0	125.0	-8.4	-12.2	-9.8	-2.6	135.5	1872.7	73.4
J-84	63.6	857.0	74.2	135.0	2217.0	60.9	48.0	633.0	75.8	112.3	158.7	-17.9	-64.4	-71.4	24.5	82.2	1235.7	70.3
J-90	56.3	675.0	83.4	181.0	2227.0	81.3	106.0	1476.0	71.8	221.5	229.9	-2.6	-41.4	-33.7	-11.6	114.4	1459.3	78.8
J-91	20.2	300.0	67.3	175.0	2230.0	78.5	158.5	2039.0	77.7	766.3	643.3	16.5	-9.4	-8.6	-1.0	117.9	1223.0	74.5
Mean	55.5	685.8	80.3	91.1	1252.5	74.5	81.2	1162.7	77.2	+64.1	+82.6	-7.2	-10.9	-7.2	3.6	75.9	1000.3	77.3
SD	25.4	312.4	10.1	61.5	878.5	9.9	36.7	503.4	6.1	248.5	200.7	20.6	137.9	126.6	13.0	31.9	441.5	5.5

Table 10 Yield of Khoku mandarin with different grades of fruits (harvest year 2060)

Tree Number	Big		Medium		Small		Unmarketable Yield		Marketable yield		Total yield	
	No.	Wt (Kg)	No.	Wt (Kg)	No.	Wt (Kg)	No.	Wt (Kg)	No.	Wt (Kg)	No.	Wt (Kg)
J-4	59	6	179	14	212	12	61	1.6	450	32.0	450	33.6
J-9	201	21.5	147	12.5	100	6.5	26	1.0	448	40.5	474	51.5
J-13	150	14.2	458	36.7	290	21.9	173	6.2	898	72.8	1071	79.0
J-16	96	10	707	54.7	472	26.5	190	7.5	1275	91.2	1465	98.7
J-21	230	24	287	23	194	11.5	23	0.7	711	58.5	734	59.2
J-23	285	33	388	27	438	25.2	107	4.0	1111	85.2	1218	89.2
J-24	357	40.2	300	25	160	10	64	2.8	817	75.2	881	78.0
J-26	252	24.8	246	18.5	263	15.5	80	3.0	761	58.8	841	61.8
J-34	204	21	709	57	328	19.5	86	1.6	1241	97.5	1327	99.1
J-35	300	33	714	57	611	34.5	122	4.5	1625	124.5	1747	129.0
J-40	547	59	667	51	223	12	80	3.0	1437	122	1517	125.0
J-41	84	7	288	24	1050	63	246	9.5	1422	94	1668	103.5
J-42	21	2	53	4	37	2.5	24	1.1	111	8.5	135	9.6
J-48	149	15	252	27	520	30	87	3.4	921	82	1008	75.4
J-50	115	12	252	18	172	8.5	64	2.0	539	38.5	603	40.5
J-52	455	45	322	24	218	12	0	0.0	995	81	995	81.0
J-58	183	19	965	68	126	7	81	3.0	1274	94	1355	97.0
J-68	310	33	354	27	172	9.5	52	2.0	836	69.5	888	71.5
J-70	339	33	643	48	609	34	115	4.0	1591	115	1706	119.0
J-71	335	33	551	42	421	18.8	0	0.0	1307	93.8	1307	93.8
J-72	92	9	118	9	175	10.5	77	3.2	385	28.5	462	31.7
J-75	352	33	458	34	406	28	269	10.0	1216	95	1485	105.0
J-82	670	63	1206	76	292	12	0	0.0	2168	151	2168	151.0
J-84	112	12	191	15	330	21	97	3.5	633	48	730	51.5
J-90	265	27	598	46	613	33	93	4.3	1476	106	1569	110.3
J-91	288	32	895	75	856	51.5	161	6.2	2039	158.5	2200	164.7
Mean	248.1	25.8	459.5	35.5	357.2	20.6	91.5	3.4	1062.7	81.2	1156.3	85.0
SD	152.9	15.3	288.2	20.2	240.1	14.3	69.7	2.7	504.7	36.2	529.1	37.1

Table 11 Yeild of Khoku mandarin with different grades of fruits in percentage (2060)

Tree Number	Big fruits (%)		Medium fruits (%)		Small fruits (%)		Marketable fruits (%)		Unmarketable fruits (%)	
	Wt (Kg)	No.	Wt (Kg)	No.	Wt (Kg)	No.	Wt (Kg)	No.	Wt (Kg)	No.
J-4	18.8	13.1	43.8	39.8	37.5	47.1	95.2	88.1	4.8	11.9
J-9	42.6	44.9	44.6	32.8	12.9	22.3	98.1	94.5	1.9	5.5
J-13	19.5	16.7	50.4	51.0	30.1	32.3	92.2	83.8	7.8	16.2
J-16	11.0	7.5	60.0	55.5	29.1	37.0	92.4	87.0	7.6	13.0
J-21	41.0	32.3	39.3	40.4	19.7	27.3	98.8	96.9	1.2	3.1
J-23	38.7	25.7	31.7	34.9	29.6	39.4	95.5	91.2	4.5	8.8
J-24	53.5	43.7	33.2	36.7	13.3	19.6	96.4	92.7	3.6	7.3
J-26	42.2	33.1	31.5	32.3	26.4	34.6	95.1	90.5	4.9	9.5
J-34	21.5	16.4	58.5	57.1	20.0	26.4	98.4	93.5	1.6	6.5
J-35	26.5	18.5	45.8	43.9	27.7	37.6	96.5	93.0	3.5	7.0
J-40	48.4	38.1	41.8	46.4	9.8	15.5	97.6	94.7	2.4	5.3
J-41	7.4	5.9	25.5	20.3	67.0	73.8	90.8	85.3	9.2	14.7
J-42	23.5	18.9	47.1	47.7	29.4	33.3	88.5	82.2	11.5	17.8
J-48	30.5	16.2	32.9	27.4	36.6	56.5	96.0	91.4	4.0	8.6
J-50	31.2	21.3	46.8	46.8	22.1	31.9	95.1	89.4	4.9	10.6
J-52	55.6	45.7	29.6	32.4	14.8	21.9	100.0	100.0	0.0	0.0
J-58	20.2	14.4	72.3	75.7	7.4	9.9	96.9	94.0	3.1	6.0
J-68	47.5	37.1	38.8	42.3	13.7	20.6	97.2	94.1	2.8	5.9
J-70	28.7	21.3	41.7	40.4	29.6	38.3	96.6	93.3	3.4	6.7
J-71	35.2	25.6	44.8	42.2	20.0	32.2	100.0	100.0	0.0	0.0
J-72	31.6	23.9	31.6	30.6	36.8	45.5	89.9	83.3	10.1	16.7
J-75	34.7	38.4	35.8	50.0	29.5	11.6	90.5	77.3	9.5	22.7
J-82	41.7	30.9	50.3	55.6	7.9	13.5	100.0	100.0	0.0	0.0
J-84	25.0	17.7	31.3	30.2	43.8	52.1	93.2	86.7	6.8	13.3
J-90	25.5	18.0	43.4	40.5	31.1	41.5	96.1	94.1	3.9	5.9
J-91	20.2	14.1	47.3	43.9	32.5	42.0	96.2	92.7	3.8	7.3
Mean	31.6	24.6	42.3	42.2	26.1	33.219	95.5	91.1	4.5	8.9
SD	12.6	11.5	10.7	11.5	12.9	14.9	3.2	5.77	3.2	5.7

Acid Lime (*Citrus aurantifolia*)

Pre-bearing evaluation of new collections

After mandarin and sweet orange acid lime (*Citrus aurantifolia*) is the third important citrus fruit crop of Nepal. Traditionally lime has been cultivated in about 60 hilly districts of the country. The plantation of lime in Nepal is very scattered mostly limited to homestead. Most production does not arrive in commercial market. As a result more than 90% of commercial demand is being met by importation. There are no identified or recommended varieties for different harvesting season. Farmers are using sexually propagated, unidentified landraces for plantation. Mother plants are not properly maintained. Seeds for seedling production are collected randomly from locally available sources. To solve the varietal problem of lime, survey was carried out in different hill and Terai districts of Nepal from east to west in 2057. Based on farmers' information and visual observation some promising trees were selected. The seeds of selected trees were collected and seedlings were grown in glasshouse. Collections were also made from India. A total of 25 accessions were collected in 2057 in which 5 were from Terai (Jhapa, Rautahat, Dang and Kailali), 4 from India and 16 accessions were from hilly districts (Table 12). Seedlings were grown in polyethylene bags in glass house. Six-months old seedlings (4 seedlings of each accession) were transplanted in a germplasm variety evaluation block at NCRP, Dhankuta in Asar 2058. After one year these accessions were evaluated for growth behavior and leaf characters following Citrus Descriptors (IPGRI, 1999). Table 12 presents the growth patterns (plant characters) of lime accessions. All the accessions had ellipsoid type of tree shape, straight spine shape and glabrous shoot tip surface. After one year of transplanting most accessions (22 accessions) showed erect type of growth while 3 accessions were spreading type. Growth habit and shape may change as these trees advance from juvenile to maturity phase. Shoot tip color of 6 accessions was purple green while 19 accessions had green color. There was wide range of variation in plant height. Maximum height was 97.3 ± 44 cm; minimum was 38 ± 1.0 cm and mean height of 25 accessions was 62.7 ± 12 cm. The plants, which established and resumed growth immediately after transplanting attained higher plant height. The plants, which did not grow properly, are likely to suffer from root rot problem. Likewise spine length ranged from 5 mm to 12.2 mm with average of 8.95 mm. These accessions will be continuously evaluated for their vegetative and fruit characters in the years to come and superior genotype/s will be selected.

Table 12: Plant characteristics acid lime accessions (Plant age: one year after transplanting)

Acc. No.	Collection Site	Tree growth habit	Branch density	Branch angle	Spine density	Shoot tip color	Height (cm)± SD	Spine length (mm)
Lime 07	Jhapa	Spreading	Dense	Wide	High	Purple	62.8 ± 24.3	9.5
Lime 08	Jhapa	Erect	Dense	Wide	High	Purple	61.0 ± 6.7	7.8
Lime 28	Shankhuwasava	Spreading	Dense	Medium	High	Green	54.3 ± 5.5	9.0
Lime 29	Terathum	Erect	Dense	Medium	High	Purple	63.8 ± 24.3	9.8
Lime 30	Terathum	Erect	Dense	Wide	High	Green	75.5 ± 15.7	12.2
Lime 35	Parbat	Erect	Dense	Wide	High	Green	65.5 ± 4.4	9.0
Lime 37	Syanja	Erect	Dense	Medium	High	Purple & green	67.0 ± 16.9	8.7
Lime 39	Baglung	Erect	Dense	Medium	High	Green	81.8 ± 16.4	10.2
Lime 66	Kailali	Erect	Dense	Wide	High	Purple	49.8 ± 28.3	9.3
Lime 70	Gorkha	Erect	Dense	Wide	Medium	Purple & green	97.3 ± 44.3	7.8
Lime 71	Guhati (India)	Erect	Dense	Wide	High	Purple	52.0 ± 12.7	9.8
Lime 73	Rautahat	Erect	Medium	Wide	High	Green	59.3 ± 12.7	6.0
Lime 74	Tanahu	Erect	Medium	Medium	High	Green	38.0 ± 10.4	5.0
Lime 75	Madras (India)	Erect	Dense	Wide	High	Green	48.5 ± 13.6	9.2
Lime 76	Darchula	Erect	Dense	Wide	High	Green	62.0 ± 15.2	7.8
Lime 78	Dang	Erect	Dense	Wide	High	Green	56.8 ± 6.2	8.2
Lime 81	Dailekh	Erect	Dense	Medium	High	Purple & green	59.8 ± 10.6	7.8
Lime 82	Dailekh	Erect	Dense	Medium	High	Purple & green	73.3 ± 11.0	10.5
Lime 83	Surkhet	Erect	Dense	Medium	High	Green	72.5 ± 27.6	11.0
Lime 85	Rukum	Erect	Medium	Medium	High	Purple & green	79.3 ± 6.7	11.5
Lime 94	Madras (India)	Spreading	Dense	Medium	High	Purple & green	53.3 ± 7.0	8.0
Lime 96	Makawanpur	Erect	Dense	Wide	High	Green	54.8 ± 14.9	10.0
Lime 101	Syanja	Erect	Dense	Wide	High	Green	73.5 ± 10.1	10.0
Lime 102	Parbat	Erect	Dense	Medium	High	Green	53.8 ± 17.1	6.8
Lime 001	Madras (India)	Erect	Dense	Medium	High	Green	51.5 ± 20.4	9.7
Mean							**62.7 ± 12.8**	**8.95**

There was variation among the accessions in leaf characters (Table 13). Leaf margin of all accessions was dentate and leaf lamina attachment was brevipetiolate. Intensity of green color was green in most accessions but in two accessions it was light green. With respect to leaf lamina shape three types of lime accessions were noted: (i) with elliptic leaf, (ii) with lanceolate leaf and (iii) with ovate leaf. Among 25 accessions, two had no petiole wing while 23 has abdeltate type narrow petiole wing. Junction between petiole wing and lamina was articulate in those trees which had petiole wing in the leaf but such joint was fused in the leaves that lack petiole wing. There was very wide variation in leaf lamina length (from 3.9 cm to 8.87 cm) as well as in leaf lamina width (1.7 to 3.97 cm).

Table 13 Leaf characteristics of different lime accessions

Acc. No.	Intensity of leaf green color	Leaf lamina length (cm)	Leaf lamina width (cm)	Leaf lam. Shape	Petiole wing	Petiole wing Shape	Petiole wing width	Joint between petiole & lamina.
Lime 07	Green	4.8 ± 1.0	2.31 ± 0.49	Elliptic	Present	Abdeltate	Narrow	Articulate
Lime 08	Green	4.88 ± 0.74	2.28 ±0.39	Ovate	Present	Abdeltate	Narrow	Articulate
Lime 28	Green	4.02 ± 0.54	1.95 ± 0.23	Ovate	Present	Abdeltate	Narrow	Articulate
Lime 29	Green	3.97 ± 0.69	1.82 ± 0.44	Ovate	Present	Abdeltate	Narrow	Articulate
Lime 30	Green	4.78 ± 1.13	2.20 ±0.59	Ovate	Present	Abdeltate	Narrow	Articulate
Lime 35	Green	4.31± 1.85	2.09 ± 0.49	Ovate	Present	Abdeltate	Narrow	Articulate
Lime 37	Green	4.53 ±1.32	2.02 ± 0.60	Lanceolate	Present	Abdeltate	Narrow	Articulate
Lime 39	Green	4.77 ± 0.68	2.08 ±0.26	Ovate	Present	Abdeltate	Narrow	Articulate
Lime 66	Green	5.17 ± 1.02	2.47 ±0.25	Ovate	Present	Abdeltate	Narrow	Articulate
Lime 70	Light green	8.87 ± 2.86	3.97 ±1.15	Ovate	Absent	Absent	-	Fused
Lime 71	Green	4.62 ± 1.09	2.10 ±0.30	Elliptic	Present	Abdeltate	Narrow	Articulate
Lime 73	Green	5.45 ± 1.01	2.70 ±0.28	Elliptic	Absent	Absent	-	Fused
Lime 74	Green	4.17 ± 1.66	1.97 ±0.45	Ovate	Present	Abdeltate	Narrow	Articulate
Lime 75	Green	3.90 ± 0.79	1.77 ±0.31	Ovate	Present	Abdeltate	Narrow	Articulate
Lime 76	Green	4.32 ± 0.74	2.02 ±0.38	Ovate	Present	Abdeltate	Narrow	Articulate
Lime 78	Green	3.93± 0.40	1.70 ±0.26	Ovate	Present	Abdeltate	Narrow	Articulate
Lime 81	Green	4.27 ± 0.76	2.02 ±0.17	Ovate	Present	Abdeltate	Narrow	Articulate
Lime 82	Light green	5.55 ± 0.63	2.32 ±0.29	Lanceolate	Present	Abdeltate	Narrow	Articulate
Lime 83	Green	4.43 ± 0.40	2.10 ±0.17	Ovate	Present	Abdeltate	Narrow	Articulate
Lime 85	Green	4.80 ± 0.45	2.53 ±0.57	Ovate	Present	Abdeltate	Narrow	Articulate
Lime 94	Green	4.37 ± 0.97	1.85 ±0.53	Ovate	Present	Abdeltate	Narrow	Articulate
Lime 96	Green	5.37 ± 0.85	2.44 ±0.41	Ovate	Present	Abdeltate	Narrow	Articulate
Lime 101	Green	6.46 ± 1.24	3.01 ±0.47	Ovate	Present	Abdeltate	Narrow	Articulate
Lime 102	Green	4.77± 0.46	1.97 ±0.15	Ovate	Present	Abdeltate	Narrow	Articulate
Lime 001	Green	4.58 ± 1.39	1.93 ± 074	Ovate	Present	Abdeltate	Narrow	Articulate
Mean		4.84 ± 1.02	2.22 ± 0.47					

In situ evaluation of lime genotypes for production period expansion

Lime (Kagati), which has been traditionally cultivated in about 60 hilly districts of the country ranks third after mandarin and sweet orange in terms of area and production among the citrus fruit crops. Nearly 16.6 percent of productive area of citrus and 12.3 percent of production is shared by lime. Among development region Eastern Development Region and among districts Terathum is the highest producer of lime in Nepal. Except four months from Kartik to Poush (Nov. - Jan.) almost 100% of the lime fruits supplied in major commercial markets are from India. Lime fruits produced in hill from November to January is considered as 'normal season' lime in Nepal. Normal season lime

production technology is available in the country and fruits produced during this period are supplied in the market although local demand of big markets like Kathmandu is not met by local produce even in normal (winter) season. There is fairly good demand of fresh lime fruits year round. But production in other months does not exist in Nepal due to lack of off-season production technology and varieties. In other months except November to January all lime fruits supplied in Nepalese markets are imported from India mainly from Andra Pradesh commonly known as 'Madrasi Kagati'. It indicates the need of generating and disseminating technology to expand production period within country in order to substitute import of fresh lime fruits from India and increase income of growers. Therefore, with the objective to identify lime genotypes that can be harvested during off-season (rainy season) a survey and germplasm evaluation was carried out using the fruiting trees grown in farmers' fields and research institution covering both hill and Terai districts during 2059/60 and 2060/61.

Germplasm survey and *in situ* evaluation of lime trees was carried out in Terathum (Phakchamara and Tamphula VDC), Jhapa (Sanischare VDC), Morang (Sundarpur and Indrapur VDC), Sunsari (Kaptanganj VDC) and Chitawan (research orchard of IAAS Rampur). Phakchamara and Tamphula VDC) were selected to represent mid-hill climate. Most farmers in these VDCs cultivate lime in commercial scale using seed propagated trees and lime fruits from these areas are prized for better quality. Lime cultivation in Terai is not a common practice. Therefore, the lime growers and fruiting trees in Jhapa, Morang, Sunsari were identified based on information from extension workers, farmers and traders. Selected lime genotypes from a variety collection block of IAAS, Rampur were also evaluated in this study.. A total of 32 lime trees were evaluated for tree and fruit characteristics. Each selected tree was given an accession number for future identification. In the beginning growers were asked to identify superior trees of their orchard and/or in their neighborhood based on fruit quality and off-season flowering/fruiting tendency. Only those trees that were selected by the growers were purposively sampled for further fruit quality evaluation. The traits such as tree age, flowering period, maturity period, market value, frequency of flowering was determined based growers' information as well as visual observation. The qualitative traits such as fruit shape, base shape, apex shape, surface texture, skin color, pulp color, rind, seed, juice were recorded. After recording economically important tree and fruit characteristics, accessions were compared and those trees having superior fruit quality such as thin rind, high juice and acid content, smooth rind surface, medium sized fruit and off-season fruiting type were finally selected for further variety evaluation and commercial production.

Types of lime: Three types of lime namely acid lime, eureka lime and natural hybrid types were identified in survey areas. Acid lime commonly known as Pahade Kagati or Sun Kagati in Nepali was the only type found in Terathum. But in Terai areas of Jhapa, Morang and Sunsari all three types were found grown in kitchen gardens mainly for home consumption. Eureka also known as Chasme Kagati in Nepali is a lemon botanically, however, farmers and consumers of survey areas consider it as lime and being used as substitute of lime. On the basis of fruit shape two types of eureka: ellipsoid and spheroid were identified. Eureka is a popular commercial variety in some of the citrus growing European countries. It was introduced to Nepal several decades ago and planting materials were distributed to farmers especially in lower hills and Terai. The fruits of original eureka are spheroid in shape with very low seed content. Therefore, ellipsoid type of eureka found in this survey could have been introduced by farmers' from India. Possibly it is not a natural hybrid between hill lemon (Nibuwa) and eureka because it does not have thorns on the stem which is a dominant character in citrus species. The third type, possibly natural hybrid between acid lime and some other small-fruited citrus species has been found grown in homestead gardens in Biratnagar and some parts of Jhapa. Its fruits and leaves resemble to that of acid lime but it's trees are less thorny and leaf and fruit aroma differ from acid lime. During survey respondent farmers informed that acid lime has best commercial value in comparison to other two. Eureka and hybrid type are mainly used for home consumption and in Chana Chatpate. Accession numbers L-13, L-17 are round eureka lime, L-20 is ellipsoid

eureka, L-19 is hybrid type and rest of the accessions are acid lime type (Table 14).

Maturity period: Table 14 presents the flowering and maturity period of 32 accessions evaluated in this study. All the 11 accessions from Terathum district (1050-1150 m altitude) were found flowering only once in a year in the month of February-March (Phalgun) and their maturity period was from November to January (Kartik to Poush) but accessions from Terai area exhibited wide variation in flowering and maturity period. Eureka type of limes was found to start flowering from end of January (Magh) and continue until May (Jestha) in Terai climate. Main flowering period of acid lime in Terai area was January - February (Magh - Phalgun), however, it was also noted that most of the evaluated trees continue to flowering and fruiting in low intensity until May (Table 14). The study showed that fruits of some accessions of acid lime from Terai area mature and can be harvested 3-4 months earlier than mid-hills. Maturity period of acid lime in Terai was found from Asar to Kartik (June-November). As mentioned earlier maturity period of lime in hill (Terathum) was from Kartik to Poush. Diversity in maturity period among the selected genotypes is one of the most important attributes for expansion of production period. Obviously such diversity was exhibited in the gene pool of present study and showed the possibility of expanding harvesting period of lime in Nepal from present level of three months (only from hills) to seven months (Table 14) by utilizing location specific appropriate genotypes for Terai and mid-hills climate. Also, it is unlikely that there will be competition in market price between hill and Terai lime since harvesting period does not overlap in two agro-climatic conditions.

Fruit shape and color: Table 15 shows the variation in qualitative traits. The fruits varied in their shape, shape of base and apex, rind color and pulp color. Fruits with three types of shape namely spheroid, ellipsoid and spheroid-ellipsoid were recorded and spheroid types were the most frequent (65.6%). Fruits with three types of bases (convex-71%, Truncate-25% and necked-3.1%) and three types of apices (rounded-50%, truncate-34.4% and mammiform-15.6 %) were found. Of the 32 evaluated trees majority (23) produced fruits with smooth rind, 2 had slightly rough and 7 had medium rough rind surface. Rind and pulp color of fruits at maturity was also recorded. The fruits of all the accessions from Terathum were yellow at maturity. But the accessions from Terai produced three types of fruits with respect to their rind color at maturity namely yellow, light yellow and light green. It was also noted that the fruits that were light green at maturity turned to yellow color gradually when they were stored at room temperature for 3-4 days after harvest. In citrus species, warm temperatures interfere with loss of chlorophyll as well as with the built up of carotinoids and cool temperatures on the other hand enhance the desired rind color development Therefore, the poor rind color development (light green to light yellow) in most accessions of lime from warm climate of Terai seems due to environment reason rather than genetic control. Accessions also differed in pulp color of fruits. Most accessions (81%) had cream pulp while rest had greenish pulp. Occurrence of greenish pulp was more frequent in the accessions from Tarai. Farmers' reported that fruits with cream or light yellow color have better market value than those with greenish pulp.

Internal fruit quality: The ranges of variation on quantitative characters related to fruit quality have been presented in Table 15. Big differences in minimum and maximum values of fruit weight indicated wide diversity in this character. Accession number L-20 which is a eureka type lime from Terai area produced biggest fruits (131.8 gm) while fruits of accession number L-71(5) were very small (17.3 gm). Fruit weight of most accessions of acid limes was between 25-50 gm whereas eureka and hybrid types produced bigger fruits (>50 gm).

Percentage of rind in the fruit was determined on the basis total fruit weight. Fruits of accession number L-101(3) had very thin rind (13.8%) whereas on the other extreme accession number L-20 had highest percentage of rind (36.3). Rind percentage in other accessions was in between in these two values. Number of seeds per fruit ranged from 0 to 38. Fruits of two accessions contained < 5 seeds per fruit, 17 accessions contained 5-10 seeds per fruit, 10 accessions had 10-15 seeds per fruit while rest of 3 accessions were very seedy with more than 15 seeds per fruit.

There was remarkable degree of variation in juice content in the fruit among the accessions. The highest (48.3%) and lowest (13.6%) juice content was found in accession number L-7 and L-A01(6) respectively. In 4 accessions, juice content was less than 20%, in 3 accessions it was 20-30% and in 13 accessions juice content ranged 30-40%. The fruits of 12 accessions were juicier with 40-48.3 % juice content. Of the 21 accessions evaluated from Tarai area only 4 had more than 40 percent juice in their fruits. On the other hand, 8 out of 11 accessions from Terathum district had more than 40% juice content in the fruits. The trends of juice content in the fruits indicated that lime fruits produced in mid-hill climate are more juicy than those produced in Terai climate. The accessions from Terai area were found to possess less quantity of total soluble solids (TSS) and acids in the fruit juice than from mid-hill accessions. TSS ranged from 7.7 to 8.8 ^{0} Brix in accessions from hill while it ranged from 5.5 to 6.7 in Terai accessions. In the same manner, total acid content in hill accessions ranged from 7.0-8.2% and in Tarai accessions it ranged from 4.8 to 6.5%. It is highly likely that low juice, TSS and acid content in lime fruits produced in Tarai climate could be due to environmental (shorter production period) factor as well as genetic reason.

Selection of superior trees: An attempt was also made to select superior trees from the accessions evaluated for diversity. There are no universal quality standards and variety selection criteria for citrus but are sharply determined by species, climate of production area and consumers' acceptability. The selected variety should meet the requirement of producers, traders and even processing industries. Since, all the desirable characters may not present in a single variety/cultivar, there should be some compromise between the requirements and extent of diversity on available gene pool from where selection of elite types are made. Therefore, five traits suggested by lime growers and traders were used as selection criteria. These criteria include juice content (high), total acid (high), rind surface (smooth), fruit shape (spherical) and harvesting season (off-season). Using these criteria three accessions (trees) were selected as superior types for further evaluation and commercial use. The selected accession include L-15 and L-101(3) from Tarai and L-6 from mid-hill. The detailed characteristics of these accessions have been presented in Table 1, 2 and 3. L-101(3) can be harvested from second week of Asar to end of Asoj. It has medium sized fruits with 42.0 % juice and 6.0 % acids in the juice. Another accession from Tarai, L-15 matures from Sawan to Kartik; produces relatively bigger sized (49 gm) fruits with about 40.0 % juice content and 6 % acid. Accession L-6, selected from Tamphula VDC of Terathum district matures during normal season (Kartik to Poush) but produces very high quality fruits. Commercial exploitation of these accessions in appropriate climate conditions can extend the production period of lime in Nepal from present duration of three months (Kartik to Poush) to seven months (Asar to Poush). For this location specific varieties for Tarai and hill climate should be exploited.

The following conclusions have been drawn from this study and recommendations for further research and development have been made.

- Evaluation of morphological characters through survey and fruit analysis revealed the diversity both in qualitative and quantitative characters.
- This study showed that warm climate of Tarai can be exploited for rainy season lime production.
- One accession (L-6) with high quality fruits has been selected for mid-hills for winter season production.
- Two accessions namely L-15 and L-101(3) have been selected for Tarai climate for rainy season production.
- Production period of lime in Nepal can be expanded up to seven months by utilizing presently selected genotypes for hills and Tarai region.
- Unirrigated upland type of land unsuitable for rice/wheat cultivation has been found suitable for lime cultivation in Tarai area.
- A fruiting lime tree (6-15 years old) can generate at least Rs 1500 -2000 net income annually in Tarai.

- Technologies for Tarai region such as selection of appropriate rootstocks, management of canker and phytophthora root rot should be developed.
- Mother plants of selected genotypes for Tarai climate should be maintained, propagated and disseminated to commercial growers. Demonstration production plots should be established at farmers' fields.

Table 14 External fruit characteristics of evaluated lime germplasm

Acc No	Fruit shape	Base shape	Apex shape	Surface texture	Skin color	Pulp col
L-1	Spheroid	Convex	Truncate	Smooth	Yellow	Cream
L-2	Spheroid	Convex	Rounded	Smooth	Yellow	Cream
L-3	Spheroid	Convex	Rounded	Smooth	Yellow	Cream
L-4	Spheroid	Convex	Mammiform	Smooth	Yellow	Cream
L-5	Spheroid	Truncate	Truncate	Smooth	Yellow	Cream
L-6	Spheroid	Convex	Truncate	Smooth	Yellow	Greenis
L-7	Spheroid	Convex	Rounded	Smooth	Yellow	Cream
L-8	Spheroid	Convex	Mammiform	Smooth	Yellow	Cream
L-9	Spheroid	Convex	Rounded	Smooth	Yellow	Cream
L-10	Spheroid	Convex	Truncate	Smooth	Yellow	Cream
L-11	Spheroid	Convex	Truncate	Smooth	Yellow	Cream
L-12	Ellipsoid	Necked	Truncate	Slight rough	Light green	Cream
L-13	Spheroid	Convex	Mammiform	Smooth	Yellow	Cream
L-14	Spheroid	Truncate	Truncate	Smooth	Light yellow	Cream
L-15	Spheroid-ellipsoid	Convex	Truncate	Smooth	Light yellow	Cream
L-16	Spheroid-ellipsoid	Truncate	Rounded	Smooth	Light green	Cream
L-17	Spheroid	Convex	Mammiform	Smooth	Yellow	Greenis
L-18	Spheroid	Convex	Truncate	Smooth	Light yellow	Cream
L-19	Spheroid	Truncate	Rounded	Slight rough	Light green	Greenis
L-20	Ellipsoid	Truncate	Mammiform	Smooth	Yellow	Cream
L-09(1)	Ellipsoid	Convex	Rounded	Medium rough	Light green	Greenis
L-A01(4)	Ellipsoid	Convex	Rounded	Medium rough	Light green	Greenis
L-71(5)	Spheroid	Truncate	Truncate	Smooth	Light green	Greenis
L-B01(17)	Spheroid	Truncate	Rounded	Smooth	Light yellow	Cream
L-A01(6)	Ellipsoid	Convex	Rounded	Medium rough	Light green	Cream
L-B01(25)	Spheroid	Convex	Rounded	Smooth	Light yellow	Cream
L-7II(3)	Ellipsoid	Convex	Rounded	Medium rough	Light yellow	Cream
L-17(2)	Ellipsoid	Convex	Rounded	Smooth	Light yellow	Cream
L-17II(6)	Ellipsoid	Convex	Rounded	Medium rough	Light yellow	Cream
L-101(3)	Ellipsoid	Truncate	Truncate	Smooth	Light yellow	Cream
L-101(2)	Spheroid	Convex	Rounded	Medium rough	Light green	Cream
L-B06	Spheroid	Convex	Rounded	Medium rough	Light green	Yellow

Table 15 Internal fruit characteristics of evaluated lime germplasm

Acc No	Fruit weight (gm)	Skin (%)	Seed Number	Seed weight (%)	Juice weight (%)	Total soluble solids (TSS)	TA	TSS/TA
L-1	26.6 (±2.8)	21.0(±2.3)	6.6 (±1.9)	4.4 (+0.75)	46.1 (+2.5)	7.9 (+0.15)	7.4 ((±0.28)	1.07 ((±0.04)
L-2	30.5(±6.5)	23.2(±3.7)	6.3(±2.4)	4.3(±0.71)	40.4(±6.1)	7.7(±0.33)	7.0(±0.43)	1.10(±0.08)
L-3	37.5(±10.3)	24.5(±5.4)	5.8(±2.7)	3.9(±1.0)	36.0(±1.6)	8.3(±0.97)	7.5(±0.51)	1.10(±0.14)
L-4	30.0 (±5.7)	22.6(±1.3)	6.3(±3.6)	4.2(±1.7)	31.8(±6.1)	7.8(±0.2)	6.9(±0.75)	1.14(±0.12)
L-5	31.4(±6.3)	22.7(±1.4)	8.1(±3.2)	4.7(±0.9)	47.3(±6.6)	8.3(±0.2)	8.1(±0.26)	1.02(±0.03)
L-6	44.4(±3.6)	20.1(±1.8)	7.2(±2.2)	3.0(±0.7)	44.1(±6.4)	8.3(±0.2)	7.8(±0.47)	1.06(±0.08)
L-7	33.8(±4.3)	19.6(±1.6)	8.8(±3.4)	4.1(±1.5)	48.3(±5.2)	8.1(±0.2)	7.9(±0.31)	1.02(±0.01)
L-8	26.6(±7.6)	27.4(±6.4)	6.5(±1.6)	5.7(±2.0)	38.5(±4.0)	8.2(±0.3)	7.6(±0.18)	1.08(±0.01)
L-9	35.1(±3.8)	24.1(±2.8)	6.0(±2.3)	3.5(±0.6)	40.0(±4.1)	8.8(±0.3)	7.8(±0.34)	1.11(±0.03)
L-10	37.6(±3.1)	19.2(±1.2)	9.0(±1.7)	4.4(±0.3)	40.0(±0.7)	8.7(±0.2)	8.2(±0.31)	1.05(±0.02)
L-11	46.7(±5.0)	20.4(±1.9)	10.3(±3.2)	4.1(±0.9)	45.3(±4.8)	7.7(±0.6)	6.9(±0.45)	1.11(±0.09)
L-12	60.0(±10.3)	32.3(±4.6)	15.5(±5.3)	2.6(±0.7)	36.0(±4.9)	6.6(±0.4)	5.9(±0.74)	1.13(±0.13)
L-13	79.7(±5.8)	15.2(±3.2)	0(±0)	0(±0)	38.9(±4.9)	5.5(±0.3)	4.8(±0.47)	1.15(±0.2)
L-14	38.1(±17.9)	15.1(±2.1)	5.4(±4.1)	1.4(±1.0)	42.7(±5.7)	5.8(±0.6)	5.6(±0.66)	1.03(±0.05)
L-15	49.6(±10.5)	24.4(±3.7)	13.4(±5.3)	3.1(±0.8)	40.7(±6.8)	6.2(±0.2)	5.8(±0.33)	1.08(±0.06)
L-16	38.5(±10.9)	24.4(±3.1)	11.3(±7.7)	4.1(±1.9)	40.0(±9.4)	6. (±0.23)	5.7(±0.27)	1.09(±0.07)
L-17	76.9(±4.7)	22.5(±5.7)	36.7(±22.1)	5.1(±3.6)	26.6(±12.4)	6.6(±0.4)	5.9(±0.58)	1.11(±0.11)
L-18	37.6(±2.1)	27.7(±3.8)	6.4(±1.1)	1.7(±0.3)	36.9(±4.2)	6.5(±0.4)	5.7(±0.43)	1.14(±0.0.9)
L-19	50.8(±8.7)	23.4(±0.9)	22.8(±3.3)	4.4(±0.6)	37.4(±3.6)	6.4(±0.4)	5.7(±0.57)	1.13(±0.05)
L-20	131.8(±16.1)	36.3(±3.0)	2.8(1.9)	0.7(±0.4)	34.6(±4.3)	5.6(±0.4)	5.3(±0.53)	1.05(±0.04)
L-09(1)	24.4(±3.1)	29.1(±3.4)	11.0(±2.2)	2.5(±0.7)	16.4(±5.6)	5.7(±0.6)	5.3(±0.45)	1.07(±0.03)
L-A01(4)	30.7(±4.3)	26.4(±2.8)	14.0(±3.3)	3.2(±0.6)	15.3(±4.2)	6.2(±0.3)	4.4(±0.51)	1.40(±0.15)
L-71(5)	17.3(±5.2)	19.1(±3.2)	8.0(±1.6)	5.8(±0.9)	27.0(±3.6)	6.5(±0.2)	6.1(±0.41)	1.05(±0.02)
L-B1(17)	23.3(±4.9)	14.2(±4.8)	9.0(±2.1)	3.6(±0.9)	18.2(±5.6)	6.0(±0.2)	5.0(±0.27)	1.20(±0.09)
L-A1(6)	27.9(±5.6)	29.7(±2.2)	12.0(±3.2)	4.3(±0.4)	13.6(±6.8)	6.2(±0.3)	5.2(±0.31)	1.19(±0.15)
L-B1(25)	24.9(±6.8)	20.1(±5.2)	11.0(±2.4)	4.3(±0.4)	34.1(±4.6)	6.5(±0.6)	6.5(±0.18)	1.00(±0.03)
L-7II(3)	30.6(±6.3)	32.7(±4.8)	9.0(±3.4)	3.3(±0.7)	31.0(±6.1)	6.2(±0.3)	5.8(±0.35)	1.06(±0.02)
L-17(2)	28.0(±8.4)	16.1(±4.6)	11.0(±1.8)	3.4(±0.6)	38.2(±4.8)	6.7(±0.3)	5.7(±0.26)	1.17(±0.13)
L-17II(6)	29.5(±6.6)	26.7(±2.2)	15.0(±3.2)	4.4(±1.2)	20.2(±7.2)	6.5(±0.2)	5.4(±0.42)	1.20(±0.11)
L-101(3)	38.5(±8.2)	13.8(±5.6)	7.0(±2.6)	1.9(±0.9)	42.1(±4.2)	6.2(±0.5)	6.0(±0.62)	1.03(±0.07)
L-101(2)	28.5(±5.4)	25.6(±3.2)	10.0(4.1)	3.5(±0.8)	36.5(±5.6)	6.5(±0.2)	5.1(±0.43)	1.27(±0.15)
L-B06	28.5(±5.2)	22.5(±3.6)	6.0(±2.3)	2.5(±0.7)	37.2(±5.2)	6.0(±0.2)	5.0(±0.32)	1.20(±0.12)
Mean	39.9 (±21.9)	23.2(±5.5)	9.9(±6.4)	3.5(±1.3)	35.0(±9.5)	6.9(±1.0)	6.2(±1.1)	1.1(±0.08)
Maximum	131.8	36.3	36.7	5.8	48.3	8.8	8.2	1.4
Minimum	17.3	13.8	0	0	13.6	5.5	4.4	1.0
CV %	54.8	23.7	64.6	37.1	27.1	14.5	17.7	7.3

Figures in parenthesis are standard deviations.

Hill Lemon (*Citrus psedolimon*)

A total of 24 accessions potentially elite types of hill lemon (Nibuwa) were collected from 21 districts of Nepal based on visual observation of fruits and farmers' information. Seeds of selected accessions were collected at maturity and seedlings were raised in poly-pots. Six months old seedlings (4 plants/accession) were transplanted to variety evaluation plots in the month of Asar 2058. Layout was in contour system and plant-to-plant distance was maintained to 4 m. After on year of transplanting observation were made on plant and leaf characters which are presented in Table 16 and 17.

In all accessions tree shape was ellipsoid, shoot tip surface was glabrous and straight type of spines were present. Spines were present in high density in majority (22) accessions while in 2 accessions spine density was medium. Plant growth habit of most (17) accessions was erect type which is obvious in the early stage of growth of seedling plants. With respect to density of branches accessions were distributed in the ration of 25, 25 and 50 percent respectively for sparse, medium and dense.

Table 16. Plant Characteristics of hill lemon accessions. (one year old after transplanting)

Acc No.	Collection site	Tree growth habit	Density of branches	Branch angle	Spine density	Shoot tip color	Height (cm) ± SD	Spine length (mm)
002	Chitawan	Erect	Sparse	Medium	Medium	Green	91.3 ± 45.0	28.0
003	Chitawan	Spreading	Dense	Medium	High	Pink	87.0 ± 39.2	22.8
005	Chitawan	Erect	Dense	Medium	High	Green	97.5 ± 25.7	23.0
008	Chitawan	Erect	Sparse	Medium	Medium	Pink	59.5 ± 17.3	12.5
19	Bhaktapur	Erect	Medium	Medium	High	Pink	32.0 ± 25.7	22.0
20	Nuwakot	Spreading	Sparse	Medium	High	Pink	110.5 ± 42.2	18.5
27	Shankhuwasava	Erect	Medium	Medium	High	Green	64.0 ± 33.7	12.0
31	Terathum	Erect	Medium	Medium	High	Pink	91.3 ± 45.4	23.0
36	Syanja	Spreading	Sparse	Medium	High	Pink	96.8 ± 12.8	15.7
45	Gulmi	Erect	Sparse	Wide	High	Green	98.0 ± 36.1	19.6
54	Salyan	Erect	Medium	Wide	High	Green	79.3 ± 33.8	22.3
56	Palpa	Erect	Medium	Medium	High	Green	69.8 ± 39.0	14.7
60	Lamjung	Erect	Dense	Medium	High	Green	80.3 ± 32.4	20.7
61	Tanahu	Spreading	Dense	Wide	High	Green	119.5 ± 21.1	27.5
67	Kailali	Spreading	Dense	Medium	High	Green	106.3 ± 41.8	20.0
77	Darchula	Spreading	Dense	Medium	High	Pink	100.5 ± 26.1	23.5
80	Dailekh	Spreading	Dense	Medium	High	Green	84.7 ± 19.0	13.0
84	Surkhet	Erect	Dense	Medium	High	Pink	95.0 ± 29.0	18.7
86	Rukum	Erect	Dense	Wide	High	Pink	80.3 ± 35.4	21.0
88	Makawanpur	Erect	Dense	Medium	High	Green	110.3 ± 31.9	31.7
99	Sindhuli	Erect	Dense	Medium	High	Green	70.0 ± 36.0	12.7
100	Dadeldhura	Erect	Sparse	Medium	High	Green	76.5 ± 25.6	24.0
104	Tanahu	Erect	Dense	Medium	High	Green	97.0 ± 20.1	21.4
105	Salyan	Erect	Medium	Wide	High	Pink	94.3 ± 55	36.0
Mean		–	–	–		–	87.9 ±19.0	21.0

In 84 percent of the accessions angle of the branches to the main trunk was medium and in the rest it was wide. Colour of the shoot-tip at the time of new flush growth was also recorded. In 13 accessions shoot tip colour was green and in 11 accessions it was pink. There was wide range of variation in plant height. Maximum height was 119.5 ± 21 cm; minimum was 32 ± 25.7 cm and mean height of 24 accessions was 88.7± 19 cm. The plants, which established and resumed growth immediately after transplanting attained higher plant height. But the plants, which did not grow properly, are likely to suffer from root rot problem. Likewise spine length ranged from 12.5mm to 36 mm with average of 21 mm. These accessions will be continuously evaluated for their vegetative and fruit characters in the years to come and superior genotype/s will be selected.

Table 17: Leaf description hill lemon accessions

Acc. No.	Leaf lamina length (cm)	Leaf lamina width (cm)	Lamina margin	Leaf lam. Shape	Petiole wing (P/A)	Petiole Wing Shape	Petile wing width	Junction between petiole wing & lamina.
002	13.7 ± 2.7	6.4 ± 1.6	Dentate	Ovate	Present	Obdeltate	Narrow	Articulate
003	13.2 ± 2.4	6.0 ± 0.7	Dentate	Ovate	Present	Obdeltate	Narrow	Articulate
005	13.5 ±2.4	6.7 ± 1.4	Dentate	Ovate	Present	Obdeltate	Narrow	Articulate
008	11.4 ±3.5	5.1± 1.5	Dentate	Elliptic	Present	Obdeltate	Narrow	Articulate
19	11.4 0 ±0.1	5.1 ± 0.6	Dentate	Elliptic	Present	Obdeltate	Narrow	Articulate
20	12.5 ± 1.9	5.3 ± 1.1	Dentate	Ovate	Present	Obdeltate	Narrow	Articulate
27	9.5 ± 1.8	3.0 ± 0.5	Dentate	Ovate	Present	Obdeltate	Narrow	Articulate
31	13.7 ± 2.9	5.9± 1.9	Dentate	Ovate	Present	Obdeltate	Narrow	Articulate
36	11.6 ±1.3	5.4 ± 1.2	Dentate	Ovate	Present	Obdeltate	Narrow	Articulate
45	15.3 ± 1.4	7.0± 0.6	Dentate	Ovate	Present	Obdeltate	Narrow	Articulate
54	12.6 ± 2.9	6.2 ± 1.6	Dentate	Elliptic	Present	Obdeltate	Narrow	Articulate
56	12.2 ± 1.5	4.6± 1.0	Dentate	Ovate	Present	Obdeltate	Narrow	Articulate
60	12.4 ± 1.2	4.9± 0.6	Dentate	Ovate	Present	Obdeltate	Narrow	Articulate
61	11.7 ± 1.2	5.3± 0.4	Dentate	Ovate	Present	Obdeltate	Narrow	Articulate
67	11.9 ± 2.7	5.0 ± 1.0	Dentate	Ovate	Present	Obdeltate	Narrow	Articulate
77	11.5 ± 1.4	5.1 ± 0.7	Dentate	Ovate	Present	Obdeltate	Narrow	Articulate
80	10.5 ± 1.7	4.9 ± 1.1	Dentate	Ovate	Present	Obdeltate	Narrow	Articulate
84	13.0 ± 1.6	5.2 ± 0.6	Dentate	Ovate	Present	Obdeltate	Narrow	Articulate
86	11.1 ± 2.4	5.0 ±1.3	Dentate	Ovate	Absent	-	-	Articulate
88	12.0 ± 1.8	5.4 ± 0.5	Dentate	Elliptic	Present	Obdeltate	Narrow	Articulate
99	11.1 ± 0.6	5.1 ± 0.2	Dentate	Elliptic	Present	Obdeltate	Narrow	Articulate
100	8.8 ± 0.8	3.8± 0.6	Dentate	Ovate	Present	Obdeltate	Narrow	Articulate
104	11.3 ± 2.4	4.5 ± 1.4	Dentate	Ovate	Present	Obdeltate	Narrow	Articulate
105	12.8 ± 1.6	6.6 ± 1.3	Dentate	Ovate	Present	Obdeltate	Narrow	Articulate
Mean	12.0 ± 1.4	5.3 ± 1.0						

The pattern of variation among the accessions in leaf characters has been presented in Table 17. Leaf margin of all accessions was dentate and leaf lamina attachment was brevipetiolate. Like wise in all the accessions the intensity of green color in the leaf was green. With respect to leaf lamina shape two types of lime accessions were noted: (i) with ovate leaf and (ii) elliptic leaf. Among 24 accessions, one had no petiole wing while 23 has abdeltade type narrow petiole wing. Junction between petiole wing and lamina was articulate in those trees, which had petiole wing in the leaf, but such joint was fused in the leaves that lack petiole wing. There was very wide variation in leaf lamina length (from 8.8 cm to 15.3 cm) as well as in leaf lamina width (3.0 to 6.8 cm).

3.2. Use of Tissue Culture for Bud-wood Sanitation

Sweet Orange cv Madame Vinous

In order to initiate *Citrus* Bud-Wood Certification Program to cope with graft transmissible diseases, indexing and cleaning of mother stock from citrus greening disease (CGD) and citrus tristeza virus (CTV) in a routine basis is pre-requisite. Sweet orange variety: Madame Vinous (MVSO) and acid lime are used as indicator plants for biological indexing of CGD and CTV respectively. Virus free plants could be obtained from nucellar seedlings, however, the seeds of MVSO are not available in Nepal. In this context, an effective method to produce indicator plants that are free from all virus and virus like diseases is needed. Therefore, this study was initiated to determine the optimal conditions for *in vitro* multiplication of MVSO for the management of *Citrus* Greening Disease.

About 2 cm long *in vitro* shoot tip explants were used as tissue sources for shoot proliferation. The experimental design was two factor Randomized Complete Block Design. The experiment was carried out using MS medium (1962) containing 3 % sucrose supplemented with five levels of BAP and two levels of IAA (Table 18). The pH was adjusted to 5.7 with 1N sodium hydroxide. Growth regulators were added and the media were solidified by adding 0.7% plant agar before autoclaving at 121° C for 15 minutes. Aliquots of 75 ml of sterilized media were dispensed into baby food jars. Two explants were cultured on each culture vessels and the cultures were incubated at 22 ±2° C under 16 hours light for 3 weeks. In the second experiment, the explants from the first experiment were sub cultured on sterilized fresh MS medium (1962) containing the same concentration of BAP and IAA. Two explants were cultured on each culture vessels and incubated at 22 ±2° C under 16 hours light for 6 weeks. The number of adventitious shoots was recorded for percentage of explants with shoot buds and number of shoots per explant after 3 and 6 weeks respectively. The effect of different levels of BAP and IAA with respect to the number of shoots per responding explant were tested for Analysis of Variance using the computer software package Ginstat5, version 3.22.

Multiple shoots obtained from the shoot proliferation experiment were used as tissue sources for *in vitro* root induction. Five shoot tips of about 3 cm lengths were cultured on MS medium (1962) containing 3% sucrose supplemented with 0.5 mg/l IAA. The cultures were incubated at 22 ±2° C, under 16 hours light for 4 weeks. The observations were made for percentage of explants with roots after 4 weeks.

The roots of *in vitro* raised plantlets were gently washed in tap water and transferred to Cello polyethylene containers containing sterile soil. The humidity inside the container was gradually reduced by enlarging the size of ventilation in the covered plastic bag. The acclimatized plantlets were kept under normal glasshouse conditions after four weeks.

A small amount of white compact callus formed at the cut ends of shoot tip explants within one week of culture, however axillary shoot buds differentiated after two weeks. The analyzed data on number of shoots per explant showed highly significant difference between different treatments ($P = \leq 0.01$). Maximum number of shoots per explant was obtained on MS medium supplemented with 0.5 mg/l BAP and 0.2 mg/l IAA after three and six weeks of sub culture respectively (Table 18). Browning of

the shoots was observed at 4 mg/l BAP. The promotive effect of BAP on multiple shoot regeneration in terms of frequency of responding explants and the number of shoots per explant increased up to 0.5 mg/l in both experiments, while higher concentrations were inferior. The effect of BAP was highly significant while IAA had no effect on multiple shoot formation. There was no evident of interaction between IAA and BAP until first subculture while after second sub-culture IAA x BAP interaction was significant. Shoots obtained on MS medium supplemented with 0.2 mg/l IAA without BAP showed rooting at the cut ends of explants, while shoots obtained on MS medium (1962) supplemented with 4 mg/l BAP were stunted in growth and showed browning of the tips. Root induction was observed near the cut surface at the basal ends of shoot tip explant after two weeks in the root induction medium. All the 50 cultured explants produced roots after four weeks on MS medium (1962) supplemented with 0.5 mg/l IAA. Ninety percent rooted plantlets (45 plants) were acclimatized in Cello plastic containers in room temperature for four weeks followed by transferring of the potted plantlets into the glasshouse.

Based on the results of this investigation, we can conclude that a system has been developed to regenerate shoots from shoot tip explants of MVSO which may greatly contribute for *in vitro* multiplication of true to type virus free planting material. The pathogen free planting materials could be used for biological indexing of mother plants of citrus fruit crops for citrus greening disease caused *Liberibacter asiaticum* from..

Table 18: Response of BAP and IAA on multiple shoot regeneration of Madame Vinous of Sweet Orange after three and six weeks sub culture

Concentration of Hormones (mg/l)		Cultured explants (No)	After 3 weeks		After 6 weeks		Remarks
			Responding explants (%)	Shoots/ explant	Responding explants (%)	Shoots/ explant	
BAP	IAA						
0	0	12	25	0.3	25	0.3	
0	0.2	12	0	0	0	0	Rooting
0.5	0	12	92	1.9	100	3.3	
0.5	**0.2**	**12**	**92**	**2.3**	**100**	**4.8**	
1.0	0	12	92	1.2	100	2.9	
1.0	0.2	12	75	1.2	100	2.6	
2.0	0	12	75	1.3	100	2.5	
2.0	0.2	12	50	0.7	92	1.7	
4.0	0	12	83	1.2	100	1.9	Browning
4.0	0.2	12	58	0.4	67	0.8	Browning
P (BAP)				HS		HS	
LSD (BAP)				0.77		0.71	
CV (%)				22		10	

Trifoliate orange (*Poncirus trifoliata*)

Nepal is perhaps one of the only countries in world where seedling citrus trees still predominate. Citrus trees are propagated on rootstocks in most of the other citrus producing countries. It is proved that *Phytophthora* root rot is one of the major causes of citrus decline in Nepal especially in seedling trees of mandarin and lime. Grafted plants gradually replacing the seedling trees. Trifoliate orange is most commonly used rootstocks for *citrus* trees because of its characters of cold hardiness, resistance to root rot, citrus tristeza virus and nematodes. Tissue culture technique can also be applied in trifoliate orange especially for rapid multiplication of virus free planting material. Therefore, laboratory experiment was carried out at NCRP, Dhankuta in order to standardize reliable and

efficient *in vitro* regeneration systems for trifoliate orange.

The seeds of trifoliate orange were washed thoroughly in distilled water. Then the seeds were sterilized by immersion with 70% ethanol for one minute. The seeds were rinsed with sterile distilled water for three times. Then the seeds were soaked in 4% sodium hypochlorite solution for three minutes. The seeds were rinsed with sterile distilled water for three times. The sterilized seeds were individually cultured in test tubes containing 20 ml of MS medium solidified with 7 g agar. The tubes were wrapped with black cloth and incubated at 23^0 C for 4 weeks

About 2 cm long *in vitro* germinated shoot tips were used as tissue sources for shoot proliferation. The experimental design was two factor Randomized Complete Block Design. The experiment was carried out using MS medium (1962) containing 3 % sucrose supplemented with five levels of BAP and two levels of IAA. The pH was adjusted to 5.7 with 1N sodium hydroxide. Growth regulators were added and the media were solidified by adding 0.7% plant agar before autoclaving at 121° C for 15 minutes. Aliquots of 75 ml of sterilized media were dispensed into baby food jars. Two explants were cultured on each culture vessels and the cultures were incubated at 22 ±2° C under 16 hours light for 3 weeks. In the second experiment, the explants from the first experiment were sub cultured on sterilized fresh MS medium (1962) containing the same concentration of BAP and IAA. Two explants were cultured on each culture vessels and incubated at 22 ±2° C under 16 hours light for 6 weeks. The effect of different levels of BAP and IAA with respect to the number of shoots per responding explants were tested for Analysis of Variance using the computer software package Ginstat5, version 3.22.

A small amount of white compact callus formed at the cut ends of shoot tip explants within one week of culture, however axillary shoot buds differentiated after two weeks. Number of shoots per explant showed highly significant difference between different treatments (P=<0.01). Maximum number of shoots per explant (7 shoots) was obtained on MS medium supplemented with 0.5 mg/l BAP without IAA. Browning of the shoots was observed at 4 mg/l BAP. The effect of BAP was highly significant while IAA has no effect and interaction between IAA and BAP was not evident. Shoots obtained on MS medium supplemented with 0.2 mg/l IAA without BAP showed rooting at the cut ends of explants, while shoots obtained on MS medium (1962) supplemented with 4 mg/l BAP were stunted in growth and showed browning of the tips (Table 19). Protocol for *in vitro* root induction and acclimatization will be standardized later.

Table 19: Response of BAP and IAA on multiple shoot regeneration of shoot tip explants of trifoliate orange at NCRP after three and six weeks sub culture

Concentration of Hormones (mg/l)		Cultured explants (No)	After 3 weeks		After 6 weeks		Remarks
BAP	IAA		Responding explants (%)	Shoots/ explant	Responding explants (%)	Shoots/ explant	
0	0	12	33	0.8	33	0.9	
0	0.2	12	0	0	0	0	Rooting
0.5	0	12	100	5.4	100	7.0	
0.5	0.2	12	100	4.7	100	6.8	
1.0	0	12	92	3.8	100	5.7	
1.0	0.2	12	92	4.3	100	6.0	
2.0	0	12	92	3.5	100	4.3	
2.0	0.2	12	100	3.0	100	3.9	
4.0	0	12	92	2.0	100	3.0	Browning
4.0	0.2	12	83	1.3	83	2.1	Browning

In

In In vitro shoot tip grafting

Eradication of pathogens is highly desirable to optimize the yields and also to facilitate the movement of plant materials across international boundaries. The therapeutic chemicals capable of eradicating virus from infected citrus plants are not readily available. One of the method to recover virus free *citrus* plants is the use of nucellar seedlings from polyembryonic cultivars. The limitation of this method is that nucellar plants have juvenile characters. Thermo-therapy is also an effective way of inactivating some viruses. The apical meristems in the infected plants may generally either be virus free or carry a very low concentration of the viruses. However, in woody species especially in citrus, meristem culture is often impossible. Micro grafting is the best available technique to recover pathogen-free *Citrus* plants. In this technique, the shoot tips are grafted onto a virus free seedling rootstock maintained and propagated *in vitro.*

Seeds of rough lemon (*Citrus jambhiri*) were sterilized by immersion with 70% ethanol for one minute followed by 4% sodium hypochlorite solution for three minutes. The seeds were rinsed with sterile distilled water for three times. The sterilized seeds were individually cultured in test tubes containing 20 ml of MS medium solidified with 7 g plant agar. The tubes were wrapped with black cloth and incubated about 23^0 C for 4 weeks. The shoot tips were excised from *in vivo* germinated green house grown nucellar seedlings of mandarin. The shoot tips were sterilized by detergent for 1 minute followed by 5% sodium hypochlorite solution for five minute. The shoot tips were rinsed with sterile distilled water for three times. *In vitro* germinated seedlings were removed from the test tube under aseptic conditions and decapitated, leaving about 3 cm of the epicotyl. Cotyledons and axillary buds were removed and the root was cut to a length of 5-6 cm. Then, apical meristem of about 0.5mm was excised with a razor blade under binocular microscope and the shoot tip was placed at the top of the decapitated seedling rootstock. Filter paper bridge perforated in its center for insertion of root portion of the rootstock was inserted into test tubes. 25 ml liquid MS medium containing 40 g sucrose was distributed into test tubes and sterilized in autoclave. The grafted plants were cultured in a liquid medium and kept at $20\text{-}24^0$C with 16-hour light condition for 6 weeks. Grafting was performed on the 4^{th} week of Baisakh. Successful grafted plants were transferred into sterile soil after seven weeks. The plants were covered with polyethylene bags and the size of ventilation was enlarged 2 weeks for acclimatization.

Bud initiation was observed 2 weeks after grafting. Three to four expanded leaves arose four to 6 weeks after grafting. Successful grafting percentage and acclimatization percentage was calculated. Out of 80 grafted seedlings, 30 (37%) grafted plants were recovered and 17 (45%) grafted plants were successfully acclimatized. The acclimatized plants were kept under green house.

Large cardamom

Decline of large cardamom due to infestation of virus, introduction and spread of such diseases through saplings to new production areas has been identified as major constraints for large cardamom cultivation. Chhirke and Phurke diseases of cardamom are also spreading to cardamom production pockets of eastern hills. In this context, laboratory experiment was carried out at NCRP, Dhankuta in order to produce disease free planting materials from the mother stock of large cardamom.

Aseptic cultures of large cardamom were initiated by using new suckers in 3^{rd} week of Baisakh. The outer leaves were removed and washed in tap water for 10 minutes. The suckers were treated with Tween 20 for 20 minutes. The shoots were sterilized by 70% alcohol for 1 minute followed by 10% sodium hypochlorite solution for 20 minutes and rinsed 3 times with sterile distilled water. The explants were prepared removing the basal portion and outer skin. The prepared explants were cultured individually in culture jars containing sterile MS medium supplemented with 30 g sucrose, 7 g plant agar and 1 mg BAP. The cultures were incubated in 24^0 C at 16 hours light period for 4

weeks. Due to contamination as well as browning, almost 99% of the explants were damaged. The recovered explants were sub cultured in each 4 weeks.

The aseptic cultures are subjected to continuous sub culturing. However, the frequency of axillary shoot regeneration is very low. Therefore, research is going on for optimizing the level of BAP and NAA in the medium in order to get maximum axillary shoots per explant.

3.3 PARTICIPATORY TECHNOLOGY DEVELOPMENT

Mandarin

In the last 20 years, area under mandarin cultivation has increased by 18 folds but productivity has remained stagnant at around 10 tons per hectare level. The low productivity of this crop is mainly attributed to the poor management of trees with respect to nutrient, training, pruning, diseases and insects in most of the orchards. Therefore, a field study in farmers' orchards has been under taken with the objective to rejuvenate and improve the productivity of poorly managed orchards.

For the verification of improved management practices on mandarin orchard, three poorly managed orchards at farmers' field one each from Dhankuta municipality, Akhisalla V.D.C. and Maunabudhuk V.D.C. were selected. Name of the orchard owner and address are given in Table 21. A total of 18 plants were selected from each selected orchard. Information on orchard management practices adopted by collaborative farmers on these trees was collected through interview. Before the application of treatments, selected plants were grouped into two groups, comprising nine trees in each group. The plants of each group were numbered from 1-9 so that their individual performance can be monitored later. In one group of plants (9 plants) recommended package of technology (IP) was applied while in other group management practices adopted by the farmers' was used (FP). Inputs used and cultural practices adopted by collaborative farmers (FP) were based on the information provided by them during interview. Details of two types of treatments (FP and IP) applied on these trees is given in Table 20. Data on growth patterns of vegetative parts and yield were recorded after fruit harvest.

Table 20. Description of improved technology (IP) and farmers' practice (FP)

SN	Operation	Treatment type	
		IP	FP
1	Pruning	Once in Magh	No pruning
2.	Basin making	Done in Magh	No basin preparation
3.	Compost application	@ 50 kg/plant in Magh	@ About 30 kg/plant in Magh - Phalgun
4.	Chemical fertilizer application	DAP @ 1 kg per plant Ist week of Phalgun and Urea @ 500 gm per plant after first rainfall	No chemical fertilizer application
5.	Bordeaux paste	Applied	Not applied
6.	Insect control	Spraying of Roger @ 1 ml/lit of water before flowering, in Jestha and in Bhadra	Insecticide was not applied
5.	Disease control	Spraying of Insuf @ 2 gm /lit of water during Jestha, Asar and Bhadra	No fungicide application

Table 21 presents second year's data on growth and yield increment of 3 locations achieved as the result of application of improved technology in farmers' orchard. It is apparent from the table that fruit yield in the plants that received improved production technological packages increased by 7.9 to 37 percent over those plants that were managed following the farmers' practices. On an average there was 22 percent increase in the productivity (fruit yield per plant) of mandarin trees when improved technology was applied in poorly managed trees for one year. Average yield of a tree in FP was 35 kg, which is equivalent to national average productivity (10.5 tons/ha). On the other hand, when recommended IP was applied, average fruit yield of a tree increased to 44.0 kg. This productivity level is equivalent to 13.2 tons in a hectare (calculation is based on 300 trees/ha). This productivity is 25 percent higher than national average productivity.

Table 21. Effect of improved technology on yield of mandarin at farmers' field after two year of treatment application

Farmer's name/ address	Fruit yield /tree (kg)			Number of fruit/ tree			Fruit size (gm)		
	FP	IP	IP/ FP (%)	FP	IP	IP/ FP (%)	FP	IP	IP/ FP (%)
Tilak S. Mali (Dhankuta -7)	10.9	13.3	+ 22	112.3	131.3	+ 19.9	96.2	101.3	+ 5.3
A. K. B. Koirala, Maunabudhuk-8 Dhankuta	57.2	78.6	+37.4	583.3	708.6	+ 21.5	98.1	91.6	- 6.6
Purna B. Rai, Akhisalla -7, Dhankuta	37.8	40.8	+7.9	447.0	457.3	+ 2.3	85.4	89.7	+ 5.0
Mean	**35.3**	**44.2**	**+22.4**	**380.8**	**432.4**	**+ 13.6**	**93.2**	**94.2**	**+ 1.2**

The hills of Nepal, which support nearly half of the nation's population has been facing environment degradation due to increasing population pressure as well as expanding cultivation of cereals and overgrazing. In this context, rapid incorporation of high value fruit trees such as mandarin into farming system could be an alternative to improve the welfare of small farmers without impairing the resource base. As the access to urban market improves, commercial demand of mandarin orange is likely to increase. Nepalese mandarin can also enter Indian and Bangladeshi market if we can increase the volume of production and assure supply in terms of time, quantity and quality. Therefore, to meet increasing demand of mandarin fruits, Nepal has to increase its productivity rather than focusing only on area expansion. Initial results of this study support the hypothesis that poor orchard management is one of the major reasons of very low productivity of citrus. Therefore, government strategy presently adopted on citrus development, which is mainly focused on area expansion, should be changed. New strategy should be focused on increasing productivity by encouraging citrus growers to adopt improved technology related to variety, soil and disease paste management system through efficient extension system.

Kinnow Mandarin

Nearly 15 years ago a new mandarin variety: Kinnow was introduced to Nepal from Pakistan. In India and Pakistan this variety has been grown in warmer areas such as Rajasthan and Punjab. Large quantities of Kinnow fruits are imported to Nepal from India during Magh and Phalgun. In Nepal, initially it was planted at various research stations including in Tarai areas. But all trees died before their potentiality of production in lower altitude and Tarai regions was properly evaluated. Therefore, a new activity was initiated to evaluate the production potentiality of this variety in warmer climate.

For this purpose, variety evaluation plots were established in two locations of eastern Tarai namely Damak (Jhapa) and Lahan (Siraha) in Asar (June) of 2057. Evaluation of growth behavior of these plants was continued during reporting period. Several orchards of Kinnow mandarin were also established at Bakrang VDC of Gorkha districts at lower altitude (400-600 m) with the support of Gorakhakali Rubber Industry some 10-15 years ago. Performance of Kinnow in these orchards was also initiated from the harvesting period of 2058/59. To evaluate the performance of Kinnow mandarin in Terai area grafted plants on trifoliate orange rootstocks were planted in two sites namely Damak and Lahan. In Damak, 52 plants are planted in farmer's field at a distance of 3 meters covering an area of two Ropanies. In Lahan, same numbers of plants were planted in the production field of Technical School. The saplings were produced in CRP, Dhankuta. At the time of planting, pit digging and other operations were carried out as per recommendation to other mandarin varieties. Similarly, recommended inputs were also applied. Data on survival rate and patterns of vegetative growth were recorded annually. The study carried out to explore the possibility of Kinnow mandarin cultivation in Terai area is still in initial stage. In each site 52 plants were planted in 2056, Asar. Evaluation of experimental plants at Damak could not be continued because collaborating farmer left the house due to security reason. The experimental plants at Lahan produced vigorous growth for three years but after 4th year of planting these trees started to decline. The decline was caused by root rot. Few plants started fruiting on third year of planting but these fruits dropped prematurely. Plant height, canopy expansion and other observation taken on 3rd year are presented in Table 22. Since most trees showed decline symptoms the activity will be stopped from next year.

Table 22. Growth performance of Kinnow mandarin in Tarai (Lahan, Siraha)

Observations	Age of the tree			Remarks
	One	Two	Three	
Max. North - south spreading (m)	-	1.35	2.50	
Min. North - south spreading (m)	-	0.20	0.13	Replanted tree
Mean North - south spreading (m)	-	0.85	1.13	
Max. East - west spreading (m)	-	1.50	2.45	
Min. East - west spreading (m)	-	0.30	0.14	Replanted tree
Mean East - west spreading (m)	-	0.81	1.22	
Max. Canopy Diameter (m)	-	-	2.45	
Min Canopy Diameter (m)	-	-	0.13	Replanted tree
Mean Canopy Diameter (m)	-	-	1.27	
Max. Plant height (m)	0.80	2.3	2.8	
Min. Plant height (m)	0.25	0.60	0.42	Replanted tree
Mean Plant height (m)	0.37	84.9	1.50	
Max. Canopy volume (m^3)	-	-	11.06	
Min. Canopy volume (m^3)	-	-	0.01	Replanted tree
Mean Canopy volume (m^3)	-	-	2.40	
Fruiting	-	No	Started	2-3 fruits in few trees
Insects	-	Aphids	Mealy bug	
Diseases	-	P/mildew	P/mildew	

Comparative Study of Grafted and Seeding Mandarin

Veneer method of grafting in trifoliate orange rootstocks has been recommended for commercial sapling production of mandarin plants in Nepal. Most nurseries in the country (both government and private) are producing and supplying grafted plants to the growers although some seedling plants are also produced. In lime, all planting materials are seedlings and in mandarin about 50 percent are seedling origin. The grafted plants are considered better than seedlings in many aspects. Despite

several benefits of using grafted plants over seedlings citrus growers of eastern hills of Nepal are reluctant to use grafted mandarin plants (reports of ADOs of eastern hill-districts at technical workshops and meetings). Farmers have also reported that grafted plants are not performing well in their fields due to early mortality and decline in later stage. Therefore, this study was initiated to demonstrate farmers that high density planting of grafted mandarin plants are superior to seedling trees in terms of productivity and quality.

The study involves two phases of activities. The first phase consists of growing of rootstock of trifoliate orange in the nursery and grafting of desirable mandarin scions onto these rootstocks and production of seedlings from the seeds of same tree. For this a healthy tree of cultivar-Khoku local with good fruit quality was selected at Paripatle farm. Good quality seeds and scions from this tree were used to produce seedlings and saplings respectively for the study. Saplings were produced on trifoliate orange rootstocks using veneer method of grafting. Grafting was performed above 15 cm of ground level. Seedlings were produced under screen house. One and half-year old seedlings and saplings were used for planting. In the second phase, seedlings and saplings were planted in the farmers' field of two locations: Ilam municipality W. N. -2 (1200 m) and Phidim VDC Ward No. 6, Panchthar. Both types of planting materials were planted side by side with different planting distance. In each location 16 seedlings were planted at a distance of 6 x 6 m. in an area of 540 sq. m. In case of grafted saplings a total of 32 plants were planted per location maintaining 4 x 4 m spacing. These 32 plants covered an area of 512 sq. m. At the time of planting 50 kg compost was used in a pit without any chemical fertilizer. Experimental plants were planted in June 2001. Several parameters such as mortality, growth rate of trees, bud union characters, tree size, onset of fruiting, fruit quality, yield, disease and insect incidence will be recorded.

3.4 GERMPLASM MAINTAINANCE AND PRODUCTION

Germplasm Maintenance

Germplasm of several types of citrus and other fruit tree were collected locally and from abroad in the past. These garmplasm were maintained with recommended practices at Paripatle and Chungbang farm during reporting period. A total of 3700 trees are being maintained at Paripatle and 500 trees at Chungbang. These germplasm are utilized for (i) as mother stock for sapling production (ii) as research materials for superimposed study (iii) source of rootstocks and (iv) *in situ* conservation (field gene bank).

Monitoring of fruit flies

More than 825 different species of insects and mites are known to feed on citrus throughout the world. According to Rajput and Haribabu (1995) citrus trees in India are attacked by more than 250 insect pests at all stages of growth right from seedling till the plant exists. It is reported that more than 30 types of insects are causing economic loss in citrus in Nepal. One or other species of insect pests attacks roots, trunks, stems, leaves, flowers as well as the fruits. Fruit fly (*Daccus dorsalis*) is most serious citrus insect pest of eastern hills. The insect was first reported from Bhojpur district about 20 years ago. Presently, it is distributed in most hill districts of eastern development region. Integrated techniques to control this pest has been already recommended and being used. Therefore, a field study was carried out in Dhankuta district to monitor the effectiveness (adoption by farmers) of the technique and population dynamic of fruit fly.

The population of fruit flies was monitored using locally made Feromin traps at 1000, 1200 and 1300 m altitudes. In each trap 5 ml malathion and 5 ml methyl eugenal was used and there was one trap per 10 tree. Every week the number of male flies entrapped inside the trap were counted and removed. Fresh methyl eugenal and malthion were added at every 15 days interval.

Table 23: Citrus and other fruit germplasm maintained at NCRP

Name of species	Variety/type	Age	No.
Mandarin (*Citrus reticulata*)	1. Khoku collection	30	1700
	2. Collection from 10 districts		
	3. Kinnow	20	400
	4. Unshu	15	250
	5. Murkott	3	10
Sweet orange (*Citrus sinensis*)	1. Dhankuta local	10-25	1135
	2. Washington Navel	15-25	70
	3. Mosambi	25	5
	4. Pineapple	25	5
	5. Samauti	25	2
	6. Valencia late	25	3
	7. Malta Blood Red	25	3
	8. Ruby	25	3
	9. Jaffa	25	2
	10. Hamling	25	2
	11. Navelencia	25	1
	12. Seville Common	25	3
	13. Vanelle	25	1
	14. Lue Gim Gung	20	1
	15. White Taker	20	1
Lime (*Citrus aurantifolia*)	1. Terathum local	20	200
	2. Collection from different district	2	100
Lemon (*Citrus lemon*)	1. Hilll-lemon (Nibuwa)	20	5
	2. Ureka	2	50
Citron (*Citrus medica*)	1. Local	20	2
Calamondin (*Citrus mitis*)	-	20	1
Trifoliate orange (*Poncirus trifoliata)*	-	10	250
Rangapur lime (*Citrus limonia*)		11	1
Rough lemon (*Citrus jambhiri)*	Local	20-25	10
Citrange (Carizo and Tryor)		10	5
Boxifolia (*Severiana boxifolia*)		5-10	5
Guava	L.-49, A. Safeda	25-30	100
Pear	Bartlett, Pharping	25-30	50
Rose	Different	20	12

The data on monitoring of fruit flies in different altitude of the farm and months of the year are presented in Table 28. It is clearly observed that number of male flies entrapped tended to increase gradually from Baisakh to Bhadra and then dropped down. The number of flies entrapped varied in different sites because of various reasons such as initial population density, micro-climatic condition, intercultural operations, orchard management etc.

Despite several years of efforts the population level of flies were found very high and consequently nearly 50% of sweet orange fruits are damaged by this insect. The major reasons for not decreasing the population of this insect seem to be lack of sanitation in the orchards. It is suggested that for the effective control of citrus fruit flies, Mac Phail traps (which entraps both oriental and Mediterranean flies of both sexes) should be introduced and tested. Similarly, sanitation of orchard in terms of

removing affected fruits as early as possible is very critical. However, until alternative technology is tested and recommended following are the recommendation for fruit fly control:

- Cover spray with sugar + malathion solution during Shrawan and Bhadra when sweet orange fruits start to attain physiological maturity.
- Soil treatment with malathion dust during Feb. - March (before flowering)
- Collection and destruction (burying into soil or boiling in water) of infected fruits within half an hour of their drop from the tree
- Use of Feromin traps from March to September (5 ml malathion + 5 ml methyl eugenal per trap; one trap per 10 trees)

A survey was also carried out at Dhankuta municipality areas to assess the adoption rate of recommended technique on fruit fly control. From the direct communication and interview with the farmers it was found that citrus growers are not educated properly about the integrated control measure of fruit fly. Most farmers do not understand the life cycle of fruit fly, which is very necessary to manage it. In most fruit fly affected orchards, fruits damaged by flies were not collected and damaged in proper time (within half an hour of fruit drop). Farmers were selling affected fruits in the market, which could cause further spreading of this pest in new areas. There was also lack of coordination among the growers of close vicinity in fruit fly control activity. For example all the growers of a locality were not applying control measures. In the same manner many citrus species, which are not much economically important (such as Bhale Junar) but severely affected by fruit flies were not cared for fruit fly control. The affected fruits of such trees were serving as the source of flies for next year. Among the Citrus species grown in Dhankuta district hill lemon (Nibuwa), sweet orange and Bhale Junar (Sweet orange x pummelo?) were found most severely affected by fruit flies

Monitoring of citrus diseases and insects

Major insects pests and diseases of citrus fruit crops were monitored and recorded round the year (Table 26 & 27) Among the insects noted fruit fly, scales, aphids were causing more economic loss to citrus fruits. Similarly, Foot and root rot, powdery mildew, shooty mould and nutrient deficiency were major diseases noted.

Table 24. Calendar of operation adopted at NCRP, Dhankuta for germplasm maintenance.

Months	Operation
Shrawan	Weeding in citrus orchard. Transplanting of rootstock seedling (Trifoliate) in the main nursery block. Removed diseased, new suckers and dry branches. Spray Insuf @ 2g/L of water for the control of powdery mildew Maintenance of Feromin traps
Bhadra	Weeding in citrus orchards and nurseries Application of ATSO mineral oil @ 5ml/L of water to control scale insects. Application of insecticides for the control of green stinkbug. Drenching off the plant affected with root rot by Bordeaux mixture
Aswin	Collect trifoliate seeds for root stock production. Cover spray with malathion + molasses in sweet orange orchards for fruit fly control. Application of insecticides for the control of green stinkbug Weeding and mulching in the orchards Stacking of heavily fruiting branches Collect fruit fly infected sweet orange fruit and burry into pits
Kartik	Collect fruit fly infected sweet orange fruit and burry in pits Prepared new nursery bed and sow trifoliate seed for next year production. Harvesting of early maturing varieties.
Mangsir	Harvesting of mid-season varieties Grafting for sapling production
Poush	Harvesting of mid-season varieties Grafting for sapling production
Magh	Harvesting of late season varieties; pruning and training; Fertilizer and manure application.; ATSO spray to control scale insects
Phalgun	ATSO spray to control scale insects; fertilizer and manure application. Foliar spray micronutrient. Insecticide spray in nursery plants to control leaf minor Irrigation application in orchards and nursery
Chaitra	Irrigate the orchard and nursery bed Uproot the diseased and very old unproductive trees and prepare pits for new plantation
Baisakh	Irrigate the orchard and nursery bed Uproot the diseased and very old unproductive trees and prepare pits for new plantation
Jestha	Make a drainage system in the orchard. Prepared the nursery bed for rootstock transplanting. Prepare compost for next year Application of chemical fertilizers
Asar	Spraying with sulfur containing fungicide to control powdery mildew. Transplant rootstocks for next year sapling. Distribution of healthy saplings to farmers.

Table 25 : Number of male fruit flies (per trap) entrapped in different months and locations

Months	Altitude (meter)			Month mean
	1000	1200	1300	
Baisakh (Apr. 15- May 15	87	59	58	68
Jestha (May 16 – June 15)	135	288	210	211
Asar (June 16 - July 15)	354	629	469	484
Shrawan (July 16 - Aug. 15)	417	467	636	507
Bhadra (Aug. 16 - Sept. 15)	222	306	133	220
Aswin (Sept.16 - Oct. 15)	10	3	3	5
Altitude mean	**204**	**292**	**251**	

Table 26. Major citrus insect pests found at NCRP in 2060/61

Name of insects	Time of occurrence	Crop affected	Damage
1. Fruit fly	Baisakh to Bhadra	Sweet orange, lemon, Bhale Junar	High
2 Scales (red, purple, brown, soft)	Whole year	Sweet orange, mandarin, trifoliate orange	High
3. Green stink bug	Shrawan - Bhadra	All citrus	Medium
4. Aphids	Phalgun -Asar. Also causing shooty mould	All citrus	High
5. Leaf minor	Jestha-Shrawan. In third flush growth	All citrus	Medium
6. Stem Borer	Whole year	Seedling/saplings of all citrus and mature plants of eureka lemon	Medium
7. Lemon butter fly	Chaitra – Asar	Seedlings/saplings	Medium
8. Shoot borer	Chaitra – Asar	Lime and lemon seedlings	High

Table 27: Major citrus diseases found at NCRP in 2060/61

Name of disease	Time of occurrence	Crop affected	Damage
1. Foot and root rot	Whole year. Severe in rainy season	Seedling trees of mandarin	High
2. Gummosis	Whole year. Severe in rainy season	Mandarin, sweet orange	Medium
3. Powdery mildew	Rainy season in more than 1100 m altitude	All citrus	High
4. Shooty mould	Rainy season	All citrus	High
5. Citrus Canker	Whole year	Lime	Medium
6. Damping off	Rainy season	In nursery of all citrus	Medium
7. Nutrient Deficiency	Whole year	Mandarin and sweet orange	High

Production of horticultural commodities

Table 28: Production of saplings and vegetable seeds (2060/61)

Commodity	Unit	Variety	Target	Production	Last Year's stock	Sale
A. Vegetable seed	Kg	Mino early	55.0	101.000	198.400	349.075
1. Radish	Kg.	40days	-	22.625	62.000	
2. Bean	Kg	Trisuli	30.0	100.000	140.000	95.150
3. BL Mustard	Kg.	Tankhuwa	9.0	16.000	39.000	38.725
4. Pea	Kg	Sikkim	-	-	66.000	54.700
5. Cauliflower	Kg	KTM Local	5.0	32.000	39.000	5.362
	Kg	Kibogiant	1.0	2.200	3.250	0.947
Total			**100.0**	**273.825**	**508.650**	**543.959**
B. Sapling Production						
1. Mandarin	No.	Different	1600	7000	-	5007
2. Sweet Orange	No.	Different	4000	4000	-	2185
3. Acid Lime	No.	Tarathum	1000	1000	-	952
4. Rose	No.	Different	500	6000	-	415
Total	No.	-	**7,100**	**12,600**	-	**8559**
C. Fresh fruit production	**Kg**	-	-	**38,000**	-	**37,000**

4. APPENDICES

Appendix 1. List of staff at NCRP, Dhankuta in FY 2060/61

S.N.	Name	Designation	Qualification	Remark
1.	Dr. Krishna Prasad Paudyal	Coordinator (S4)	Ph.D. (Hort.)	
2.	Mr. Bharat Mishra	Senior scientist (S3)	B. Sc. (Path.)	
3.	Mr. Giri Dhari Subedi	Senior scientist (S3)	M. Sc. (Hort.)	
4.	Mr. Ram Lal Shrestha	Senior Tech. Officer (T7)	M. Sc. (Hort.)	
5.	Mr. Rit Raj Bhattarai	Technical Officer (T6)	JTA Training	
6.	Mr. Hari Prasad Subedi	Technical Officer (T6)	B. Sc. Ag.	
7.	Mr. Deep Narayan Chaudhary	Technician (T5)	B. Sc. Ag.	
8.	Mr. Dal Bahadur Ale	Technician (T5)	JTA Training	Chungbang
9.	Mr. Jabhar Lal Mandal	Technician (T5)	I. Sc. Ag.	
10.	Mr. Khagandra Prasad Niraula	Accountant (A5)	B. Com.	
11.	Mr. Kumar Prasad Koirala	Typist (A5)	B. A.	
12.	Mr. Tara Bahadur Khatri	Heavy driver (A5)	SLC	
13.	Mr. Bishnu Prasad Adhikari	Technician (T4)	Literate	Chungbang
14.	Mr. Ganga Ram Guragain	Technician (T4)	Literate	Chungbang
15.	Mr. Shyam Ghimire	Administration (A4)	SLC	
16.	Mr.Man Bahadur Biswakarma	Technician (T3)	Literate	
17.	Mr. Yagya Bahadur Karki	Technician (T3)	Literate	
18.	Mr. Nara Bahadur Tamang	Technician (T3)	Literate	
19.	Mr. Ram Bahadur Darji	Technician (T2)	Literate	
20.	Mr. Amar Bahadur Shrestha	Technician(T2)	Literate	
21.	Mr. Purna Bahadur. Darji	Technician(T2)	Literate	
22.	Mr. Tanka Prasad Timilsina	Technician(T2)	Literate	Chungbang
23.	Mr. Ser Bahadur Tamang	Technician(T2)	Literate	
24.	Mr. Bhabani Prasad Phuyal	Technician(T2)	Literate	
25.	Mr. Jagat Bahadur Karki	Technician(T2)	Literate	
26.	Mr. Buddhi. Man Darji	Technician(T2)	Literate	
27.	Mr. Thir Bahadur Ale	Technician(T2)	Literate	
28.	Mr. Tej Bahadur Darji	Technician(T2)	Literate	
29.	Mr. Hem Bahadur Dahal	Technician(T2)	Literate	
30.	Mr. Man Bahadur Tamang	Technician(T2)	Literate	
31.	Mr. Singh. Bahadur Tamang	Technician(T2)	Literate	
32.	Mr. Ram Prasad Timilsina	Technician(T2)	Literate	Chungbang
33.	Mrs. Suntali Ghising	Technician (T1)	Literate	
34.	Mr. Ashok Kumar Rai	Technician (T1)	I.A.	

Appendix 2. Manpower situation of National Citrus Research Program in FY 2060/61

SN	Name of the post	Approved #	Fulfilled #	Vacant #	Remark
1.	Chief Scientist (S5) -Soil.	1	0	1	
2.	Senior Scientist (S3)-Horticulture	3	2	1	
2.	Senior Scientist (S3)-Plant Pathology	1	1	0	
3.	Scientist (S1) - Soil	1	0	1	
4.	Scientist (S1) – Plt. Breeding (Tissue culture)	1	0	1	
5.	Scientist (S1) - Entomology	1	0	1	
6.	Scientist (S1) – Plant Pathology	1	0	1	
7.	Senior Technical Officer (T7) - Pomology	1	1	0	
8.	Senior Technical Officer (T7) - Olericulture	1	0	1	
9.	Technical Officer (T6) -Pomology	2	2	0	
10.	Technical Officer (T6) - Horticulture	1	1	0	
11.	Senior Technician (T5)	2	2	0	
12.	Technician (T4)	2	2	0	
13.	Technician (T3)	3	3	0	
14.	Technician (T2)	15	14	1	
15.	Technician (T1)	2	2	0	
16.	Typist (A5)	1	1	0	
17.	Accountant (A5)	1	1	0	
18.	Administration Assistant (A4)	1	1	0	
19.	Driver (A5)	1	1	0	
Total		42	34	8	

Appendix 3: Budget expenditure statement of NCRP in F. Y. 2060/61

Budget code	Budget Heading	Budget allocated	Released	Expenditure	Balance
40 JK	**Staff Expenses**	**29,28,000.00**	**29,28,000.00**	**28,85,972.93**	**42,027.07**
4000	Staff Basic Salary	23,01,000.00	23,01,000.00	23,00,089.70	910.30
4010	Staff Allowances	1,80,000.00	1,80,000.00	1,54,783.26	25,216.74
4020	Provident Fund	2,33,000.00	2,33,000.00	2,30,008.97	291.03
4030	Medical	-	-	-	-
4040	Uniform	20,000.00	20,000.00	16,600.00	3,900.00
4050	Dasain Kharcha	1,94,000.00	1,94,000.00	1,84,991.00	9,009.09
41 JK	**Operational Expenses**	**9,92,000.00**	**9,92,000.00**	**9,91,581.14**	**418.86**
4100	Travel expenses	1,47,800.00	1,47,800.00	1,47,789.00	11.00
4110	Vehicle fuel, lubrication	61,000.00	61,000.00	60,900.94	99.06
4120	Wages to labor	3,66,500.00	3,66,500.00	3,66,450.00	50.00
4130	Laboratory research supply	50,800.00	50,800.00	50,750.00	50.00
4140	Farm supplies	2,48,400.00	2,48,400.00	2,48,314.50	85.50
4150	Books, newspaper, periodicals	24,000.00	24,000.00	23,990.00	10.00
4160	Training and Seminar	8,500.00	8,500.00	8,400.00	100.00
4180	Repair	85,000.00	85,000.00	84,986.70	13.30
42 JK	**Administrative Expenses**	**3,52,000.00**	**3,52,000.00**	**3,51,019.46**	**980.54**
4200	Rent, utilities and other services	1,18,000.00	1,18,000.00	1,17,714.54	285.46
4210	Communication expenses	52,000.00	52,000.00	51,616.92	383.08
4220	Repair and maintenance	1,32,000.00	1,32,000.00	1,31,717.00	273.00
4230	Stationary, printing and office supplies	35,000.00	35,000.00	34,966.00	34.00
4240	Board and panel meeting	-	-	-	-
4260	Contingency expenses	15,000.00	15,000.00	14,995.00	5.00
4280	Other administrative budget	-	-	-	-
43 JK	**Capital expenses**	-	-	-	-
4310	Land	-	-	-	-
4320	Building and other construction	-	-	-	-
4330	Furniture and fixture	-	-	-	-
4340	Equipment, machinery and tools	-	-	-	-
4350	Vehicle	-	-	-	-
4360	Computer and computer software	-	-	-	-
4370	Other fixed assets	-	-	-	-
Grand Total		**42,72,000.00**	**42,72,000.00**	**42,28,573.53**	**43,426.47**

Appendix 4: Revenue collection at National Citrus Research Program in FY 2060/61

S.N.	Source of Revenue	Total revenue (Rs.)
1.	Horticultural commodity (Fresh fruit, sapling, Veg. seeds etc)	5,64,789.00
2.	Miscellaneous (Wood, grass, Amliso etc)	20,428.25
	Total	**5,85,217.25**

Appendix 5. Top 10 major citrus producing countries of the world (2003)

SN	Name of the country	Production area (Ha)	Production (Mt)	Production share in world (%)	Productivity
1	Brazil	9,39,341	1,92,15,512	18.18	20.45
2	USA	4,19,416	1,37,71,120	13.13	30.44
3	China	14,09,700	1,25,44,695	11.87	8.90
4	Mexico	5,23,505	64,75,411	6.12	12.36
5	Spain	3,03,948	62,84,153	5.94	20.67
6	India	2,64,500	45,80,000	4.33	17.31
7	Iran	2,24,600	37,03,000	3.50	19.48
8	Italy	1,75,432	31,03,670	2.93	17.69
9	Egypt	1,43,231	25,27,276	2.39	17.64
10	Argentina	1,46,000	24,70,000	2.33	16.91
	World	73,12,706	10,56,77,706	-	14.45

Source: FAO, 2004. In: www.faostat.fao.org/faostat. Website of Food and Agriculture Organization on production statistics.

Appendix 6. Meteorological data of NCRP, Paripatle (1300 m)

Months	**Temperature (^{0} C)**		**Rainfall (mm)**
	Maximum	**Minimum**	
January	19.5	6.9	1.4
February	23.2	11.6	0.0
March	25.4	13.3	0.0
April	28.5	18.3	4.2
May	26.5	18.6	150.4
June	27.2	20.3	299.5
July	26.9	21.1	321.6
August	26.7	20.9	192.3
September	27.4	19.6	132.2
October	26.5	17.7	1.8
November	23.7	12.0	35.6
December	20.9	8.8	0.0