CITRUS RESEARCH AND DEVELOPMENT IN NEPAL

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ABSTRACT

*Citrus species mainly mandarin, sweet orange and lime are major fruit crops of Nepal. Government of Nepal has given high priority for research and development (*R *and D) of citrus in mid-hill region of the country. Since 1960s systematic* R *and D efforts were made from public sector resulting to evolution of various institutions including donor aided projects to commercialize these crops. Technologies are generated on variety improvement, nursery management, orchard husbandry, plant protection and post-harvest aspects. Commercial production has been expanded to nearly 50 districts of the country. Despite all the efforts Nepal is still importing significant quantity of citrus fruits annually. In this context, this chapter presents various research activities undertaken in the past along with their significant results. Additionally, extension and technical delivery mechanism and production and export- import trend are also briefly stated.*

BACKGROUND

Citrus species constitute major fruits of Nepal in mid-hill region. Nepal has suitable agro-climatic conditions for quality citrus fruit production in mid-hills ranging from 800-1500 m altitude. Although there are many citrus species grown in Nepal, mandarin (*Citrus reticulata* Blanco), sweet orange (*Citrus sinensis* Osbeck) and acid lime (*Citrus aurantifolia* Swingle) are cultivated in commercial scale. Hill lemon (*Citrus pseudolimon*), commonly known as *Nibuwa* in Nepali is also a popular species in Nepal for juice and pickle production.

Scientists believe that citron and mandarin were originated in this part of the world and are being grown since pre-historical period. Citrus fruits are also associated with Nepalese cultures and rituals. Citron (Bimiro) is one of the items needed during *Bhaitika, Mahapuja* and *Chhat* festival. Economically citrus is 4-5 times more profitable than cereals in hill terraces and slopes (Gauchan, 2000). There is plenty of

scope of increasing production for domestic and export markets. Nepal Government has given priority for research and development (R and D) of citrus fruit crops since decades including recent policy documents such as Agriculture Perspective Plan (1995) and Agriculture Development Strategy (2015). Therefore, this report tries to gather overall information on various efforts made on R and D of citrus fruit crops from different organizations in Nepal.

HISTORICAL PERSPECTIVE

Mandarin and citron are considered indigenous crops of Nepal. Chinese travelers have mentioned Nepal as "the country of golden fruits" in about 2000 years ago when they saw the yellow color of mandarin fruits at ripening (Lohar and Lama, 1997). 'Suntala' the Nepali name for mandarin means golden story which has similar meaning as described by Chinese travelers. The Sanskrit word for mandarin is 'narangi' which also indicates the antiquity of the crop to Nepal. Bonavia (1890) as cited by Shrestha and Verma (1998) has considered mandarin as an indigenous fruit of Nepal. Tanaka (1954) considered the Himalayan foothills throughout subtropical range from eastern corner of Burma, Assam, and Sikkim to Punjab as the native habitat of *Citrus medica* and *C. limon* and termed this region as Medica-Limon chain. Farmers of Darchula and Shakhuwasava district claim that their forefathers had collected mandarin trees from wild form (Shrestha and Verma, 1998). These historical facts clearly indicate that citron, mandarin and hill lemon (Nibuwa) are native fruits of Nepal and being cultivated from pre-historical period. Other species like sweet orange, lime, pummelo are relatively new introduction to Nepal.

INSTITUTIONALIZATION OF CITRUS R AND D

Although citrus are historical fruits Nepal, systematic research and development of citrus was initiated from 2013 along with periodical development plans of Nepal. It gradually evolved as described below.

- Citrus R and D was initiated by establishing Citrus Research Station in Dhankuta and Sub Station in Pokhara in 1961 (BS 2018) with the support of the Indian Aid Mission (IAM). In 1966 (BS 2022)

name Citrus Research Station, Dhankuta and Sub Station, Pokhara was changed to Agriculture and Horticulture Research Station respectively.

- In BS 2020, the first horticulture seminar was held at Horticulture Research Station, Kirtipur. Junar fruits from Dhankuta were exhibited in the seminar. Junar cultivation in Sindhuli particularly at Ratanchura area was specially discussed first time at the seminar and regarded as an important commodity for Nepal.
- National Citrus Development Program (NCDP) was established in 2029 BS (1972) in Pokhara and moved to Dhankuta in 2031 giving full responsibility for citrus R and D of the country. In 1977 (2034) Horticulture Research Station, Dailekh was established in Mid-western region with major mandate on citrus. Thus, Dhankuta, Pokhara and Dailekh Stations were identified as major centers for citrus R and D. Agri. Sindhuli, Papa and Dhunibesi Horticulture Farms were also attached with Citrus Development Program at that time.
- Dhankuta Agriculture Research station was handed over to Nepal Agricultural Research Council (NARC) after the establishment of NARC in 2048 and named as Agriculture Research Station (Horticulture) Dhankuta. From July 2000 (Shrawan 2057 BS) the station was officially recognized as National Citrus Research Program (NCRP).
- In 2050, NCDP was moved to Kirtipur from Dhankuta under Department of Agriculture. In 2060 (2003) Horticulture Centre, Palpa was recognized as Citrus Development Centre, Palpa.
- Horticulture Development Project (HDP) was implemented with the support of Japanese government from 1985 to 1997 with the objectives of increasing production of citrus (mandarin and sweet orange) and deciduous fruits through technological development, training and extension in six districts – Sindhuli, Ramechhap, Kathmandu, Nuwakot, Banke and Bardiya in first phase and in Sindhuli, Ramechhap, Kavre, Kathmandu, Lalitpurand Bhaktapur districts in second phase. Some exotic citrus species and varieties were introduced from Japan and established evaluation blocks at

Horticulture Centre, Kirtipur. Studies on evaluation of local land races (mandarin, sweet orange and pummelo), cultivation techniques, rootstock evaluation, harvesting and storage techniques were carried out. Long and short-term training to JT/JTA and farmers and establishment of demonstration farms were other activities of the project.

- With the objective to increase the production of mandarin and sweet orange government launched citrus priority program in Dhankuta, Sindhuli, Ramechhap, Kaski and Dailekh districts in 1985 focusing on to increase citrus area, establish nurseries, training to farmers and demonstrate integrated orchard management approach (Shrestha and Verma, 1998).
- Asian Development Bank provided loan assistant to implement Hill Fruit Development Project in 11 hill and mountain districts of Eastern Development Region from 1985 to 1995. Main thrust of the project was to increase the production of citrus in mid-hill region, apple in temperate region and banana and pineapple in terai and lower altitude. It supported to improve research facilities at National Citrus Research Program, Dhankuta, to improve extension services, construction of market yards and cellar storage and establishment of nurseries in private sector.
- Hill Agriculture Research Project (HARP) implemented with financial support of British Government introduced competitive grant system (CGS) first time in Nepal in Agricultural Research. The project was implemented from 1997 to 2004. It is estimated that HARP supported at least Rs 40 million for 13 citrus research projects (Table 1).

Table 1. Research Projects funded by HARP.

SN	Name of the project	Duration	Implementing organization
1	Management of fruit drop in mandarin	1998-2001	ARS Dailekh
2	Improvement of post-harvest shelf life and marketing of mandarin orange in the hills of Nepal	1999-2002	ARS, Lumle
3	Improvement of post-harvest shelf-life of horticultural commodities (citrus, apple, tomato and cauliflower) in the hills of Nepal	2000-2003	IAAS Rampur
4	Integrated mandarin tree health improvement research in the hills of Nepal	1999-2001	ARS, Lumle
5	Integrated citrus rehabilitation research in the hills of Nepal	2000-2003	IAAS, Rampur
6	Citrus decline research in the hills of Nepal: development and use of tissue culture technology against citrus decline	2000-2003	GREAT Nepal
7	Citrus declining management project in the hills of Nepal	2000-2003	IAAS Rampur
8	Development of improved package of technologies for increased productivity and quality of mandarin orange in eastern hills of Nepal	2000-2003	NCRP, Dhankuta
9	Marketing of mandarin orange (Citrus reticulata) in Nepal.	2000-2001	IAAS, Rampur
10	Promotion of marketing of high value agricultural commodities (citrus and vegetables) to Bangladesh and Tibet markets	2001-2003	ABTRACO
11	Management of citrus green stink bug through integrated approaches	1999-2002	ARS, Lumle
12	Regulation of flowering for off-season production of lime and lemon in the hills of Nepal	2000-2003	IAAS, Rampur
13	Breaking Seasonality for off-season lime and lemon production in the hills of Nepal	2000-2003	IAAS Rampur

Source: HARP, 2001 and HARP, 2004

- After the phase out of HARP, government of Nepal created National Agriculture Research and Development Fund (NARDF) in 2001 to continue the CGS in agriculture research and development. NARDF has been funding R and D projects. The citrus related projects completed by 2010 are listed in table 2.

Table 2. NARDF funded citrus research projects completed by 2010

SN	Name of the project	Duration	Implementing organization	Project cost
1	Improvement of post-harvest handling and marketing system of mandarin orange in Dhading, Gorkha and Lamjung districts.	2004-2007	GREAT, Nepal	2,95,100
2	Selection and dissemination of elite genotype of acid lime and hill lemon for off-season production in the hills and terai of Nepal.	2004-2007	IAAS, Rampur	2,534,715
3	Improvement of production and quality of citrus fruits through sustainable soil management practices in FWDR of Nepal.	2005-2008	NCRP, Dhankuta	1,745,700
4	Productivity improvement of citrus fruits through effective fruit drop management techniques in the mid and far western development regions of Nepal.	2006-2009	NCRP, Dhankuta	1,993,295
5	Mitigation of citrus decline problem in western hills of Nepal through integrated management of huanglongbing disease.	2008-2011	NCRP, Dhankuta	2,798,525

Source: NARDF, 2008 and 2010.

- At present, National Citrus Research Program (NCRP) under NARC and National Citrus Development Program (NCDP) under Department of Agriculture (DOA) are the two government institutions solely involved on citrus research and extension respectively.
- NCRP is primarily involved on germplasm collection and conservation, variety selection to increase production season, quality and productivity, nursery management, soil and nutrient management, citrus fruit fly and other insect control, dissemination of technologies to farmers' fields and nationwide coordination on citrus research activities at present.
- Major role of NCDP is to provide extension services to citrus growers in the form of **regular** and **special programs.** Regular programs are either implemented directly by NCDP (central level program) or through District Agriculture Development Offices (DADO). Central level regular programs on citrus fruit crops include study and observation, monitoring and supervision, fruit exhibition, nursery and commercial orchard competition at national level, technical support to districts, collection and update citrus statistics and information at national level and support government on developing citrus policy and its implementation. Regular extension programs implemented by DADO include technical and financial support to farmers' for commercial citrus orchard, private nurseries and homestead garden establishment, trainings, tools distribution, problem solution campaign, cellar store establishment, orchard management demonstration, nursery and commercial orchard competition, organize farmers' tour and exhibition, collection centre establishment, district level information compilation and other technical services as needed (NCDP, 2071 BS).

Considering the importance of citrus fruits some special programs are also being implemented in Nepal. NCDP is taking leading role to implement such programs. Special projects are briefly described below:

Mission Program (Kagati): With the objective to decrease import of acid lime (kagati) the program was launched from 2064/65 in ten

districts of the country. In first phase (2064/65) Bhojpur, Terathum and Dhabkuta district were included. Makawanpur was added in the second phase (2067/68) and another six districts namely Nuwakot, Nawalparasi, Palpa, Gulmi, Surkhet and Jajarkot were included in the third phase (2070/71). Major activities of the mission program are (i) screen house construction for mother plants at DOA farms (Kirtipur and Palpa) (ii) area expansion of lime (iii) lime sapling production (iv) nursery establishment at government and private sector (v) construction of irrigation water collection pond (vi) drip irrigation demonstration and (vii) training, workshop, interaction, visit, audio-visual production.

Value Addition Program: In FY 2066/67 and 2067/68, the program was implemented to improve fruit quality and commercial market promotion in Panchthar, Dhankuta, Gorakha, Tanahu, Syanja, Parbat, Argakhachi, Dailekh and Dadeldhura, Gulmi, Salyan, Rolpa and Kailali districts.

Budget Speech Program: In FY 2068/69 the program was executed through District Agriculture Office of Panchthar, Dading, Syanja, Parbat, Salyan, Dailekh, Gorkha and Nawalparasi.

Citrus Orchard Improvement Program: In FY 2070/71, the program was executed in Dhading, Gorkha, Lamjung, Tanahu, Kaski, Syanja, Parbat and Myagdi districts to improve declining orchards. Subsidy was provided @ Rs 76,000 per hectare for 50 hectares in each district. The program was continued in FY 2071/72 to cover 20 ha per district with same amount of subsidy.

AREA AND PRODUCTION

Fresh Fruit Production

Citrus fruits are priority commodities of government. Various institutions and development programs are engaged in the promotion of citrus industry in the country. As a result of past efforts area and production of citrus fruit crops increased significantly over the years (Table 3). However, production increase is mainly attributed to area expansion.

Despite numerous efforts on R and D of citrus through regular government program and time bound special projects as mentioned in

above section the productivity of citrus in Nepal is very low and ironically it is in decreasing trend in recent years. Mandarin contributes about 65% in production followed by sweet orange (16 %) and acid lime (11 %) (table 4).

Table 3. Area, production and productivity of citrus fruit crops.

Year	Total area (ha)	Productive area (Ha)	Production (mt)	Productivity (mt/ha)
2000/01	20,673	11,892	121,665	10.23
2001/02	22,423	12,615	130,928	10.38
2002/03	23,663	13,312	139,110	10.45
2003/04	24,799	13,931	148,010	10.62
2004/05	25,910	14,606	156,956	10.75
2005/06	26,681	15,206	164,075	10.79
2006/07	27,980	15,832	171,875	10.86
2007/08	30,790	19,915	226,404	11.37
2008/09	32,322	22,482	253,766	11.29
2009/10	33,898	22,903	259,191	11.30
2010/11	35,576	23,607	263,710	11.20
2011/12	37,565	24,089	240,793	10.00
2012/13	36,975	23,645	216,188	9.14
2013/14	38,987	25,497	224,356	8.80

Source: Statistical information of Nepalese Agriculture 2013/14, MoAD

Table 4. Production share of different citrus fruit crops in 2013/14

Crop	Total area (ha)	Productive area (ha)	Production (mt)	Productivity (mt/ha)
Mandarin	25,407 (65.2)	16,527 (64.8)	149,315(66.6)	9.0
Sweet orange	4,996 (12.8)	3,504(13.7)	35,393(15.7)	10.1
Lime	6,432(16.5)	3,724 (14.6)	25,582(11.4)	6.9
Lemon	964 (2.5)	807(3.2)	6,667 (3.0)	8.3
Others	1,186 (3.0)	934 (3.7)	7,364 (3.3)	7.9
Total	38,987 (100)	25,497 (100)	224,356 (100)	8.8

Note: Figures within parenthesis are percent of total

Source: Statistical information of Nepalese Agriculture 2013/14, MoAD

Planting Materials

Citrus planting materials are mainly produced by private nurseries which are distributed throughout the country. Although of seedling as planting materials was stopped more than 100 years ago in developed countries in Nepal even now most of the planting materials used by the farmers are seedling origin (Table 5). Thus, use of seedlings and poor quality vegetative propagated materials is one of the reasons for high mortality of planted trees and low productivity.

Table 5. Number and type of citrus planting material produced in 2070/71 (2013/14).

Sector/ region	No. of nurse-ries	Mandarin		Sweet orange		Lime		Total
		Grafted	Seedling	Grafted	Seedling	Grafted	Seedling	
Private								
Eastern region	24	76000	267500	5000	49000	14200	140600	552300
Central Region	23	71500	65600	83500	0	500	238700	459800
Western Region	37	197700	258750	12000	6000	2400	66650	543500
MW region	38	8000	132300	500	38800	0	41550	221150
FW region	7	400	12650	183	11660	0	13800	38693
Sub-total private	129	353600	736800	101183	105460	17100	501300	1815443
Government								
DOA	2	8700	2500	3500	0	800	10000	25500
NARC	1	2654	0	232	0	3934	0	6820
Sub-total Gov.	3	11354	2500	3732	0	4734	10000	32320
Grand total	132	364954	739300	104915	105460	21834	511300	1847763
% grafted saplings		32.8		49.8		3.4		26.2

Source: Annual Report of NCDP, Kirtipur and NCRP Dhankuta (2013/14).

RESEARCH AND TECHNOLOGY GENERATION

Diversity Study and Variety Improvement

Diversity study and evaluation of local and exotic germplasm has been a major component of citrus research in Nepal since the establishment of National Citrus Research Station, Dhankuta in 2018. Lama et al. (1984) found locally collected sweet orange genotypes - Junar-LS, JunarSyj-S and Junar-HM and mandarin genotype GRKH superior upon field evaluation at Horticulture Station, Pokhara. Various exotic sweet orange varieties introduced from India during 1960s were stablished at Horticulture Station, Pokhara and Citrus Research Station, Dhankuta. The plants at Pokhara station died later because of Huanglongbing diseases. Trifoliate orange and other rootstock species and hybrids were also introduced during that period. Till the date trifoliate orange is commonly used rootstock for grafting scion varieties.

Hill Fruit Development (HDP) further introduced mandarin, sweet orange and pummelo varieties from Japan and established at Horticulture Centre, Kirtipur. In 2005, NCRP, Dhankuta introduced a total 31 new scion varieties including mandarin (16), sweet orange (6), grapefruit (4) and tangor (3) and tangelo (3) from INRA-CIRAD, France. These varieties are being evaluated at NCRP, Dahnkuta and at farmers' field. In addition to scion varieties, seven rootstock varieties were also introduced from France. Table 6 presents various citrus germplasm maintained at government farms.

Table: 6. Indigenous and Exotic genetic resources maintained at different stations.

Species	Stations	
	NCRP, Dhankuta	CHRS, Kirtipur
Common mandarin (Suntala)	Bashkharka local, Sikkime, Khoku selection, Gorkhalisuntala, Pogan, Kamala, Fortune, Kara, Nova, Pixie, Dancy, Avana, Page, Hernadina, Oroval, Commune, Marisol, Nules, Kinnow, Frutrel early, Kalamadarin	Clementine, Dekopongan, Frutrel early, Hayaka, Kiyomi, Kinnow, murkott, Ota pongan, Thai tangarin, Yoshida pongan.
Satsuma mandarin	Miyagawawase, Okitsuwase, Satsuma wase, URSS Satsuma, Unshiu (NCRP 04)	Imamura unshu, Miyagawawase, OkitsuWase, Miyauchi Iyo, Aoshimaunshu, Otsu-4
Sweet orange (Junar)	Dhankutajunar, Blood red, Cara Cara, Delicious seedless, Hamlin, Lane Late, Madame Venous, Malta Blood Red, Meisheu-9, Mosambi, Navalencia, Newhall Navel, Pineapple, Ruby, Salutsiana, Samauti, Sevelle Common, Skage Bonanza, Succari, Valencia late, Vanelle, Washington Navel, White Taker, Yoshida Navel, Tomango.	Fukuwara-1, Fukuwara-4, Kiyomi, Nepali Junar, Malta Blood Red, New Taracco, New Valencia, Washington Navel, Yishida Navel.
Acid lime (Kahati)	20 accessions collected from Nepal. Among then two (Sun Kagati-1 and Sun Kagati-2) released.	Local, Madrasi
Lemon (Nibuwa and Chasmekagati)	ChasmeKagati: Ureka, Panta-1 Nibuwa: Dhanuta collection, Thimura local, BRT Nibuwa, Prembasti local	Lisbon, Ureka
Tangor (Tangarin x S. orange)	Ellendale, Murkott, Ortanique, Murkot (seedling)	Murkott
Tangelo (Tangarin x pummelo)	Minneola, Orlando, Seminole	Orlando
Grapefruit	Shamber, Hendeson, Star Ruby, Reed, Pink Rubi	Unidentified variety -1

Pummelo (Bhogate)	Nam Roi, Phultrac, Phodium	Amanatu, Ohtachibana, Banpeiyu, Kawachibankan, Thai pummelo, Local collections
Kumquat (Muntala)	Oblong type, Round type	Oblong type, Round type
Rootstocks	Trifoliate orange: Trifoliate (unknown variety), Pomeroy, Flying dragon Citrange: Carrizo, C-35, Troyer Others: Citrumelo, Rangapur lime, Volkameriana, Rough lemon.	Trifoliate orange: Trifoliate (unknown variety), Rubid, USDA Citrange:Carrizo, Troyer

Source: Gotame et al., 2014

Seedling plants of local mandarin germplasm from 10 districts (Dailekh–Gamaudi, Gulmi–Bhatkhola, Palpa-Rupse, Syanja-Bahunmara, Kaski-Pokhara, Tanahu-Jamune, Dhankuta-Khoku, Shankhuwasabha-Mantewa, Terathum-Piple and Illam-Namsaling) were collected in 2034 and established in evaluation plot at Dhankuta Agriculture Station in 2035 BS (DAS, 2046). These germplasm were not continuously evaluated to generate conclusive results possibly due to frequent changes in organization setup and transfer of researchers. After long gap Hockey et al. (1996) classified these genotypes based on morphological characters using multivariate cluster analysis technique.

In 2039, Kinnow mandarin plants were presented to late king Birendra by the then Pakistani President Mr. Zia Ul Haq. These plants were planted at Horticulture Farm, Panchkhal, Palpa, Agri. Centre Dhankuta, Terahara, Jankapur, Nawalpur (Sarlahi), Trisuli, Nepalganj, Surkhet and Doti. Initial performance report of these Kinnow plants is available in Seventh Five Year Plan Report of National Citrus Development Program (NCDP, 2047). However, the conclusive results of the research were never published. Possibly evaluation was not continuously undertaken in succeeding years. At present, Kinnow plants in most stations have already perished while Nepal is importing significant quantity of Kinnow annually from India (Table 8).

Pahari and Bimba, (2004) revealed phenotypic variation in *Citrus reticulata* and *C. limon* population of Nepal through isozyme analysis.

Shrestha and Paudyal (2004) found Khoku superior for fruit quality from among evaluated from various pockets of Dhankuta district. In another study a total of 26 mandarin seedling trees of 25 years age, collected from Khoku and maintained at NCRP, Dhankuta, were evaluated for yield and fruit quality (Paudyal et al. 2011). Tree number: J-90 which obtained highest score (18) in selection parameters and free from graft-transmissible diseases (indexed in Nepal and Corsica, France) and was selected as mother plant. Since J-90 was the tree was multiplied, primary mother plants maintained under screen house condition at NCRP, Dhankuta and saplings supplied to private nurseries for secondary mother plants. Paudyal and Chalise (2007) evaluated two satsuma mandarin varieties namely Okitsuwase and Miyagawawase to explore the possibility of early production in under plastic house and open field conditions. The fruit taste was found sweet enough when TSS/TA ratio crossed 6 and this value is recommended as maturity index for these varieties. TSS/TA reached 6 in first week of September in Okitsuwase and 10 days later in Miyagawawase under plastic house condition with annual maximum mean temperature 32^0 C, minimum temperature of 14.4^0 C and total heat unit of 3639. The trees grown under plastic house produced better quality fruits earlier. Based on this information the researchers have recommended the areas between 900-1000 meter altitudes for quality fruit production of these varieties.

Paudyal and Subedi (2008) evaluated 14 sweet orange varieties of NCRP, Dhankuta for fruit quality and maturity period. Washington Navel and Nevelencia were selected for early season (November-December) and Valencia Late, Sevelle Common and Leu Gim Gong identified for late season (March-April) production. Paudyal and Shrestha (2004) evaluated 32 trees (11 trees from hills and 21 from Terai) of acid lime grown in farmers' fields. Nine genotypes selected from *in situ* characterization were further evaluated in multi-location trial. As a result of these study two lime varieties namely Sun Kagati-1 (NCRP-55) and Sun Kagati-2 (NCRP-49) have been released from National Seed Board in 2015 for Terai and river basin areas. These are the first fruit varieties released in Nepal by National Seed Board. Paudyal (2000) carried out farmers' participatory survey in Terai and mid-hills Nepal to assess the diversity, farmers'

preference for quality fruit and to select superior pummelo tree. In this study, a total of 132 trees from 114 homestead gardens were evaluated. A wide range of variation in fruit shapes, size, pulp color, tree shape, weight, pulp content, juice content, TSS, TA and taste was recorded. Six superior genotypes were selected based on farmers' preference criteria.

Propagation

Asexually propagated planting materials have many advantages over seedling type. Until 1970s all citrus planting materials used in Nepal were seedling origin. During 5th Five Year Plan Period (1975/76-1979/80) rootstock trial on mandarin and sweet orange was initiated by National Citrus Development Program in Dhankuta and Pokhara for the first time in Nepal using different rootstock species (NCDP, 1978). Among the evaluated rootstocks Troyer citrange, Carrizo citrange and Citrus macrophylla were recommended based on their tolerance ability to Phytopthora root rot. Despite the recommendation these rootstocks were never used in Nepal for commercial sapling production. NCDP also studied appropriate date of shoot tip grafting of sweet orange on trifoliate orange rootstocks at Dhankuta and recommended that last week of December to last week of February is appropriate period with over 90% success in shoot tip grafting. This method is still being commercially used by most nurseries to propagate citrus species. Poon (1999) found veneer-grafting of mandarin on trifoliate orange more than 95% success during 2nd to 4th week of December in Dailekh (1300 m) condition. NCDP, Dhankuta studied appropriate date of T-budding in mandarin and sweet orange in 1977 and recommended that the best time for budding of mandarin and sweet orange is 3rd week of May under Dhakuta condition. NCDP (1978) recommended that bare rooted seedlings can be packed with moss and safely kept for 25 days. A model nursery to produce disease–free citrus sapling under insect-proof screen house (10 mess net) condition using inverted T-budding technique was commercially exploited at Banepa by ECARDS (non-government organization) with the support of French Government. Mandarin genotype, J-90 selected by NCRP, Dhankuta was used as mother plant for propagation (Regmi et al., 2008). Shrestha et al. (2011) recorded vigorous growth (84 cm)

and stem diameter (7.1 mm) of trifoliate orange seedling in one year of period when grown under poly-house with vermi-compost + soil mixed in 1: 1 ratio.

Niraula and Rajbhandary (1988) developed a protocol for *in vitro* propagation of trifoliate orange rootstock in MS basal medium supplemented with 1 mg/lit BAP and 0.1 mg/lit NAA using cotyledon node as explant. Sweet orange variety Madam Vinous is used as indicator plant for biological indexing of citrus huanglongbing (HLB) disease. Tissue culture protocol was developed for rapid propagation of this cultivar using MS media supplemented with 1 mg/lit BAP and 0.1 mg/lit NAA (Ranjit and Karki, 1999).

Soil and Orchard Management

In Nepal, generally soils are neither tested for nutritional requirements of specific fruit crops, nor are leaf tissues analyzed for mineral contents. NCDP initiated major and micronutrient trials on mandarin at Pokhara and Dhankuta station in 1977. Fertilizer trials in fruit crops are long term nature. But these trials could not continue for longer period and did not produce conclusive results (NCDP, 2046). Baral et al. (2008) reported that majority of the majority of mandarin trees at high altitude orchards of Gorkha, Lamjung and Tanahu districts are deficient in Zn, Ca, Mg and Mn; at mid altitude deficient in Zn, B and Mn and at low citrus growing belts mostly N and Zn were deficient. Based on various literatures NCRP (2014) recommended 300-500 g nitrogen, 200-250 g phosphorous and 250-350 potassium for a bearing mandarin tree to obtain desirable yield. However, to improve the health of severely malnourished full grown mandarin tree the recommendation from NCRP (2014) is FYM 50 kg, N 500 g, P 250 g, K 500 g, Boric acid 20 g, Zinc sulphate 150 g and copper sulphate 75 g to be applied in the ring around the tree canopy.

Tripathi and Dhakal (2005) suggested soil drenching of Paclobutazol (25%) @ 5 ml per tree at the collar region of the tree during July to induce early (4th week of December) in acid lime which is 70 days ahead of normal flowering date under Chitawan condition. Vascular-arbuscular mycorrhiza (VAM) is formed by the symbiotic association between certain Phycomycetous fungi and angiosperm roots. From a study of

mycorrhizal status of citrus in Baitadi district, Khadgi (2011) reported 27-92% mandarin root colonized by VAM fungi; roots that were colonized higher percentage by VAM were healthier.

Disease Management

Citrus diseases that are commonly prevalent in Nepal are powdery mildew, wither tip/Anthracnose, damping-off, root rot, foot rot, Gummosis (Phytophthora spp,), pink disease, citrus canker, sooty mould, citrus greening, green/blue mould, citrus scab and tristeza virus (NCDP, 2071). In a generic pest risk analysis (PRA) of citrus, Mahato (2008) recorded 30 pathogens including 24 fungi, 4 bacteria and 2 viruses in Nepal and classified six diseases/pathogens as quarantine pests with high alert, 25 significant and 13 non-significant while 8 having no detail information.

Huanglongbing (Greening) disease is one of the serious problems for citrus fruit production in the world including Nepal. Mass citrus decline was reported for the first time in Pokhara valley by FAO expert Thrower (1968). Later, Knorr et al. (1970) confirmed using thin-layer chromatography that the disease was greening. They also suggested that the disease was introduced from Saharanpur, India with the planting material. Regmi (1982) and Regmi et al. (1996) reported more than 50% greening infested trees in Pokhara valley and up to 100 % in Horticulture Research Station, Malepatan, Pokhara. Further studies confirmed that citrus decline in Kaski, Lamjung, Gorkha, Syangja and Tanahu is mainly due to Huanglongbing (Regmi et al., 2010). The disease is spreading very fast completely destroying healthy and well managed orchards within 6-7 years after infection (Regmi et al., 2009). Bove (2006) and Roistacher (1996) have confirmed that HLB is the major cause of citrus decline in Nepal and cautioned that "Greening will destroy citrus industry in Nepal slowly but surely if necessary measures are not taken in time". They recommended implementation of **Certification Programme** in Nepal.

Nepal Academy Science and Technology (NAST) has been a leading organization to conduct HLB research in Nepal since 1985. Major works undertaken by NAST HLB management include standardized *in vitro* shoot tip grafting (STG) method in Nepal, adoption of DNA probes

technique for diagnosis of CGD, development PCR facilities for the rapid diagnosis of HLB, survey and identification of main endemic centres of HLB and study on life cycle and population dynamics of citrus psylla.

Citrus canker disease caused by the bacterium *Xanthomonas citri*, is another important disease of citrus particularly in acid lime. Dhakal et al. (2008) recommended spraying of Boareaux mixture at very early stage of first symptoms appearance to control the disease to a minimum level. Earlier, spraying of Karathane and Kalixin was recommended to control powdery mildew (NCDP, 1978). NCRP (2013) recommended cheaper fungicide such as Insuf or Sulfex (sulphur containing fungicides) to control this disease. NCRP (2013) has also recommended spraying Anti-rot @ 10 ml/l water at 15 days interval during Magh to Falgun and Jestha to Bhadra for the control of gummosis and root/foot disease caused by *phytophthora spp*.

Insect Management

Blue beetle, black aphid, brown aphid, red mites, lemon butterfly, stem borer, bark eating caterpillar green stink bug, Chinese fruit fly, oriental fruit fly, citrus psylla, leaf minors, whiteflies and scale insects are common citrus insect pests in Nepal. Research activities initiated after the establishment of NCDP at Dhankuta on insect management include (i) insecticide trial on black scale insects (ii) insecticidal trial on leaf minor and (iii) fruit fly control program in Bhojpur district. Regular spray of insecticides like Metacid, Folithion and Metasystocks was recommended for the control of black scale (NCDP, 1978). Recently, NCRP (2013) has recommended that spray of mineral oil (Servo Agro-spray or ATSO) @ 20 ml + 2 ml Rogor/l of water during Falgun and Asar is more effective to control most scale insects of citrus fruit crops. In case of leaf minor, recommendation of NCDP (1978) was use of Metasystock @ 0.05% active ingredient followed by Rogor E 25 @ 0.05% active ingredient.

Fruit flies have been a serious problem in many citrus growing areas of the world. In Nepal, the problem of fruit fly was first reported by Mrs. R. B. Pradhan in 2039 BS. In 2043, Mr. Ram Badal Sah estimated the economic loss caused by the insect in Bhojpur district (NCDP, 2047). The farmers brought the problem into notice of the Royal Camp, Dhankuta

(Regional visit of king, Birendra) in 2044. On the directive of Ministry of Agriculture, National Agriculture Research and Service Centre sent a joint team of expert from NCDP, Dhankuta and Entomology Division, Khumaltarin in Asar 2045 to conduct survey and initiate action research to control the insect (NCDP, 1978). The team conducted survey in Sidhdeswor, Gupteswor, Tima, Chhinamakhu, Annapurna and Khawa VDCs of Bhojpur district and noted that 75-90% of citrus fruits were damaged by fruit flies at that time; sweet orange, sour orange, citron and hill lemon most affected while lime and mandarin were least affected. Following the survey and loss assessment, a 3-year (2045/46-2047/48) action research was initiated in above mentioned VDCs for further study and technology demonstration. It was claimed that after one year of treatment application (see below) farmers of study area were able to harvest and sell at least 70% of sweet orange. However, the authors could not find the complete report of this study in the literatures. The package of control measures used in this demonstration (NCDP, 2047) was:

- Treatment of soil with BHC 5% dust @ 50 kg/ha in Aswin-Kartik to kill the maggots and new pupa in soil.
- Collection and disposing of the infected and dropped fruits into 3 feet deep pit during Aswin-Mangsir.
- Use of Pheromone traps (ethyl euginol) to trap and kill the male flies.
- Poising baiting to control adult fruit flies during Chaitra-Aswin
- Regular spray of insecticides during active period (Jestha-Bhadra) avoiding the blooming period.

Above mentioned strategy was employed in citrus research farm, Dhankuta for more than decades. Likewise, District Agriculture Offices launched fruit flies control campaign in eastern hill districts for several years using the male annihilation (through methyl eugenol) and field sanitation tactic. Despite of all these efforts the intensity of fruit damaged by fruit flies did not decrease in eastern hills. In later years, the insect was also reported from other parts of the country. The feromone - methyl eugenol is used to attract and kill male flies of *Bactocera dorsalis* (Oriental

fruit fly). In addition to oriental fruit flies, citrus fruits are also affected by Mexican, Mediterian and Chinese citrus fly and management strategy varies depending upon the species affecting the fruit. Therefore, NCRP, Dhankuta hypothesized that fruit flies affecting citrus fruits in eastern hills may not be oriental fruit fly but could be some other species; thus the above-mentioned management technique NCDP (2047) may not has worked. With this hypothesis NCRP, Dhankuta initiated a research work to identify the species and develop management techniques accordingly. Initial achievements of the research are as follows (NCRP, 2013, NCRP, 2014):

Dr. Krishna P. Paudyal (the then Coordinator of NCRP, Dhankuta) reared adult flies from the maggots of affected sweet orange fruits for identification of species in 2007. The reared flies were much bigger than *Batrocera dorsalis* (captured in methyl eugenol).

First of all Dr. Paudyal tried to identify reared species by comparing it with reference photographs (Reference: Fruit Flies of Economic Significance, their Identification and Bionomics by Ian M. White and Marlene M. Elson-Herris; publisher–CAB International). The description and the reference photograph indicated that the fruit flies affecting citrus fruits in eastern hills could be Chinese citrus fly (*Bactocera minax*).

The reared adult fly samples were also sent Entomology Division, Khumaltar for species identification and conservation. The scientists at Entomology Division confirmed that it is not *Batrocera dorsalis*. So, 16 samples reared and collected on 27thApril 2007 by Dr. Paudyal were sent to The Museum of Entomology, Florida State Collection of Anthropods for identification on 30thApril 2007 with the help of Entomology Division and Dr. Ken Sorensen, Professor, North Carolina State University. Dr. Gray J Steek, Curator of Diptera, Florida State Collection of Anthropods identified the specimens of flies as *Bactocera* (Tetradacua) *minax* (Enderlein) and reported it to Nepal on 26th Sept. 2007 confirming that the fruit fly species affecting citrus fruit in Dhankuta is not oriental fruit fly (*Batrocera dorsalis*) but it is Chinese citrus fly (*Bactocera minax*).

NCRP, Dhankuta continuously collected affected fruit samples (sweet orange, hill lemon and mandarin) from Dhankuta, Terathum, Bhojpur, Parbat, Myagdi, Gulmi and Ramechhap districts. All the adults

emerged from these samples were found *Bactocera minax* upon comparison with reference samples.

Upon identification of appropriate species of fruit fly affecting citrus in Nepal as *Bactocera minax* further studies on (i) identification of oviposition period and (ii) assessment of attractiveness of lures for the species were initiated at NCRP, Dhankuta (NCRP, 2012, 2013 and 2014). The studies showed that (i) maximum infestation (89%) is on second week of Jestha followed by next two fortnights (ii) the oviposition period *Bactocera minax* is between 15th Jestha to 15th Asar suggesting that control measures during this period should be employed for minimizing the population of the species (iii) maximum pupal emergence from infested fruit occurs on 7th day onward after fruit dropout. (iv) Australian fruit fly lure (autolyzed protein) @ 50 ml/l was found more effective lure to attract *Bactocera minax*. The studies are on-going in NCRP, Dhankuta.

Green stink bug (*Rynchocoris humeralis)* is another insect that causes fruit drop in citrus. Pandey and Rana (1992) studied the magnitude of fruit drop caused by the bug in mandarin and the parasites associated with it at farmers' orchards in Tanahu district. Mandarin fruits were more susceptible to damage in early growth stage of the crop. About 50% pre-matured fruit drop was caused by this bug in the month of August and September. They recorded natural parasitiode of the bug in mandarin orchards and out of 365 eggs of *R. humeralis* incubated, 23 (6.3%) were parasitized by the parasitoide, 135 (37%) hatched and 207 (57.7%) did not hatch. NCRP (2013) has recommended spraying of contact + systemic insecticide (Rogor @ 1 ml + Doom 1 ml/l of water) at the nymph stage of the bug (white to yellow color) in the month of Jestha to Bhadra in 15 days of interval to control this insect. Citrus psylla (*Diaphorina citri*) is the insect vector of *Candida liberibacto*r bacteria that causes citrus greening disease. Regmi and Lama (1988a and 1988b) studies biology, range of host plants and natural enemies of citrus psylla in Pokhara Valley during 1985-1989.

Post-harvest

NCDP had initiated studies on storage of mandarin and sweet orange under cellar store condition at Agriculture Research Station,

Dhankuta in late 1980s. Storage of mandarin in perforated polythene bag was recommended from the study (DAS, 2046). Gautam and Adhikari (1989) reported that mandarin fruits either stored in sand or husk, both in pit or room are better in overall quality as loss of luster and shriveling are reduced in such storage. Thapa and Shrestha (2000) suggested grading of mandarin fruits based on diameter into extra-large (68-77 mm), large (60-66 mm), medium (55-62 mm) and small (51-56 mm). Based on various studies on harvesting, packaging and storage of mandarin, Bhusal (2002) recommended that fruits harvested by clipping by scissors at 26-50% yellow color stage to store in underground cellar storage for 3 months. Transportation loss in plastic crates is only 1% compared to 15% in truck (Dhala) and decay loss in storage is more than twice in Dhala transported fruits. Treating with Bevistin 0.1% as well as Bevistin 0.1% + wax 10% are most effective ways to control decay of the fruits in storage (Bhusal, 2002). Paudel et al. (2004) recommended modifies cellar storage with precooling chamber to store mandarin fruits up to 120 days treated with garlic extract solution. Bastakoti and Gautam (2007) also conducted storage studies mandarin in modified cellar stare. They noted that different maturity stages influenced the storability and quality of mandarin fruits. The fruits harvested at 26-50% yellow stage had minimum weight loss and rotting percentage along with good taste, freshness, firmness and higher degree of overall acceptability after the storage of 105 days (Bhusal et al, 2007). Dipping the fruit in wax (10%) emulsion minimizes weight loss and dipping waxed fruit in Bebomyl (0.1%) reduces rotting percentage (Bastakoti and Gautam, 2007). Some of the citrus varieties attain internal maturity while peel color is green. Guatam et al. (2004) recommended dipping fruits in 100-200 ppm ethylene solution to develop yellow color in the peel of mandarin.

Socio-economic and Marketing

Citrus fruit crops in the hills of Nepal are considered as one of the remunerative production options because of its agro-ecological suitability in fragile and marginal hill-slopes and high value nature. Various studies have been conducted on marketing aspects of citrus fruits. Shrestha and Shrestha (2000) characterized the mandarin

marketing system of Nepal as (i) rudimentary in nature (ii) season glut and chaotic in market price (iii) lack of specialized marketing function (iv) small scale and scattered production and (v) lack of appropriate post-harvest technologies, transportation facilities and market facilities. There are various technological, socioeconomic, institutional and policy constraints providing hindrance to smooth adoption, commercialization and sustainability of citrus farming in the hills (Gauchan, 2000). The marketing problems include low price of the produce, lack of transportation facilities, problems in selling, unorganized nature of market, monopoly of contractor and lack of storage and processing facilities. Bloom and fruit drop due to long spell drought and strong hailstorm during flowering and fruiting season as well as citrus green stink bug, shoot borer, leaf minor, lemon butterfly and citrus aphids, canker, gummosis and tristeza virus are the major problems of lime/ lemons (Dhakal, et al, 2002).

In western hills, pre-harvest orchard contract to both local and nonlocal contractor is pre-dominated mode of mandarin selling through verbal contract with lump sum advance money or without receiving advance money from the third week of August to first week of January (Gurung, 2001). The farmers' choice to choose contract mode of selling is affected by the number of fruiting trees, age of the orchard, location, category of farmers, maturity stage of the fruits and buying agents. The farm gate price of mandarin is affected by last year's price, bargaining capacity of the farmers, location, and ethnicity of farmer, mode of selling and category of the farmers. The farmers who sell by contract system generally get fewer prices than in non-contract system selling. There is also a distinct seasonal variation in the price of mandarin (Gurung, 2001). Since there are different marketing channels for different livelihood status farmers available of technology, produce market, infrastructures and facilities are not the sufficient conditions for inclusive citrus development in Nepalese hill context; the necessary conditions are appropriate institutional rules, laws and policies that can ensure access of rural marginal farmers to marketing of high value commodities like mandarin (Ghimire, 2010).

In some parts of the country such as in the hilly area of Chitawan

district farmers strongly believe that requirement of fruit trees are not so different from that of forest species. Therefore overall management of mandarin orchards has been left on the nature with minimum intervention from growers (Pant, 2001). Khoku village of Dhankuta district is very famous for high quality mandarin production in Nepal. In this village, about 32% of the total annual income is contributed by mandarin. In this village anual income from the sale of mandarin ranges from NRs 30,000 to 250,000. Except sulphur spraying cost no external inputs are used to produce mandarin in this VDC (Gautam et al., 2011).

After mandarin and sweet orange, lime is third important citrus commodity in Nepal used for fresh salad, juice, and processed products such as juice, squash, *chuk* and pickle. Dhakal et al., (2002) conducted a survey on lime and lemon cultivation system in Nepal. The survey showed that average size of holdings for lime and lemon was 45 trees/orchard, dominated by local land races, maximum production 235 (lime) and 147 (lemon) kg per tree per year in 2001. Annual commercial consumption of lime in 14 major cities of Nepal was 2,327 ton of which 85 percent was consumed in Kathmandu valley in 2001 (Dhakal et al. 2005). More than 90 % (2108 ton; valued Rs 50.4 million) was imported from India and only 5.5 percent was from domestic lime. Despite of several R and D efforts like 'Lime Mission' undertaken by the government the situation has not changed even after a decades. The recent data from Kalimati Fruits and Vegetables Whole Sale Market Development Board shows that 98.4 percent (2,340 t) of the lime supplied from Kalimati Market in 2014 (2071 BS) was from in India.

IMPORT AND EXPORT

As described in above sections, systematic citrus development was initiated by the government since 1960s. Research stations were established for technology generation. Extension and other services including subsidies are being provided through District Agriculture Offices. Government's policies and periodic plans have given due priority to citrus fruit crops. In fact, it is number one priority fruit crop of Nepal. From time to time donor supported special projects are also implemented for R and D of citrus fruit crops. Because of such efforts

production of citrus fruit crops is increasing over the years (Table 3). But production increase in citrus fruit crops is due to area expansion. Productivity is either stagnant or decreasing in recent years. It indicates that improved technologies are not properly used in production system. The domestic production is not sufficient to meet growing market demands of the country. The country's dependency on imported citrus fruit crops particularly in lime (Kagati) and sweet orange (Junar) is above 80 percent. Import of mandarin (Suntala) is also increasing at alarming rate (Table 7 and 8).

Table 7. Trade situation of citrus fruit crops in Nepal

Year	Export (Rs)	Import (Rs)	Trade deficit
2010/11	427,373	54,975,348	(54,547,975)
2011/12	299,329	303,758,177	(303,458,848)
2012/13	5,454,189	358,733,525	(353,279,336)
2013/14	3,429,523	550,285,188	(546,855,665)

Source: MoAD, 2011, 2012, 2013 and 2014.

Table 8. Proportion of imported citrus fruits distributed from Kalimati Wholesale Fruit and Vegetable Market, Kathmandu.

Nepali Year	Lime		Mandarin		Sweet Orange		Lemon		Sweet Lime		Kinnow	
	Total trade (mt)	Share of import (%)	Total trade (mt)	Share of import (%)	Total trade (mt)	Share of import (%)	Total trade (mt)	Share of import (%)	Total trade (mt)	Share of import (%)	Total trade (mt)	Share of import (%)
2060	1863	98.1	5111	7.2	89.3	72.8	14.6	0.0	2.7	0.0	12.2	100.0
2061	2520	99.9	3689	1.3	165.7	79.7	16.7	0.0	32.8	0.0	25.3	100.0
2062	1973	99.4	3422	5.8	270.9	86.8	7.3	0.0	4.2	0.0	47.2	100.0
2063	1592	99.5	4874	12.9	396.5	93.1	78.2	34.4	52.8	0.0	31.2	100.0
2064	1591	98.4	6271	8.6	466.1	91.0	10.6	0.0	17.8	0.0	68.3	100.0
2065	1650	98.4	4660	29.4	273.0	71.9	17.5	68.6	4.5	0.0	0.0	0.0
2066	1526	95.9	4801	48.6	294.2	75.2	3.0	0.0	4.0	0.0	1.3	100.0
2067	1753	99.3	14580	27.3	355.0	73.5	16.0	0.0	5.5	0.0	1.4	100.0
2068	2004	99.3	13230	15.0	538.9	97.7	21.0	0.0	91.0	0.0	24.0	100.0
2069	1854	96.7	11891	19.6	475.2	74.1	42.1	52.3	15.0	0.0	22.9	100.0
2070	2431	99.3	8235	19.3	595.2	74.5	13.7	0.0	18.0	0.0	10.0	100.0
2071	2340	98.4	6540	23.4	222.7	94.7	18.0	16.7	1.5	0.0	107.6	100.0
Mean	1924	98.6	7275	18.2	345.2	82.1	21.6	14.3	20.8	0.0	29.3	91.7

Source: Yearly Report of Kalimati Fruit and Vegetable Whole Sale Market.

REFERENCES

Baral. D.R., D.D. Dhankal, G.K. Shrestha and SC Jha. 2008. Foliar nutritional level of mandarin orchards at different altitude, age and health in mid-hills of Nepal. Proceedings of the 5th National Conference on Science and Technology, Nov 10-12, 2008, Kathmandu, Nepal Academy of Science and Technology.

Bastakoti, B. and D.M. Gautam. 2007. Effect of maturity stage and post-harvest treatments on self-life and quality of mandarin oranges in modified cellar store. J. Inst. Agric. Anim. Sci. Vol. 28.

Bhusal, Y.R., D.M. Gautam, D.D. Dhakal and P.P. Subedi. 2007. Effect

of maturity stages on post-harvest self-life and quality of mandarin orange. IAAS Research Advances Vol. 1, 2007, Institute of Agriculture and Animal Sciences, Rampur, Chitawan.

Bhusal, Y,R. 2002. Improvement of post-harvest self-life of mandarin orange (*Citrus reticulata*). M. Sc. Thesis, Department of Horticulture, IAAS Rampur, Chitawan, Nepal.

Bove, J.M., 2006. Huanglongbing: a destructive, newly emerging, century old disease of citrus. Journal of Plant Pathology, 88 (1), 7-37

Chalise, B., R. L. Shrestha, K.P. Paudyal, H.P. Subedi and S.P. Srivastava. 2011. Effect of different doses of GA_3 and nitrogen under open and plastic tunnel condition on trifoliate orange seedling growth. Proceedings of the Seventh National Horticulture Workshop, June 12-14, 2011, Nepal Agriculture Research Council and Nepal Horticulture Society.

DAS. 2046 B.S. Research Report, 2045/46 (1988/89). Dhankuta Agriculture Centre.

Dhakal, D., C. Regmi and S.R. Basnyat. 2008. Etiology and control of citrus canker disease in Kavre, Nepal. Proceedings of the 5th National Conference on Science and Technology, Nov 10-12, 2008, Nepal Academy of Science and Technology.

Dhakal, D.D., K.M. Tripathi and S Bhattarai. 2005. Marketing survey of lime and lemon production in Nepal. J. Inst. Agric. Anim. Sci. Vol. 26.

Dhakal, D.D., T. P. Gotame, S Bhattarai and HN Bhandari. 2002. Assessment of lime and lemon production in Nepal. J. Inst. Agric. Anim. Sci. Vol. 23.

Dhakal, D. D. 2008. Assessment of production and marketing of lime in hills of Nepal. J. Inst. Agric. Anim. Sci. Vol. 29.

Gauchan, D. 2000. Economics and sustainability of citrus farming in Nepal: A case study of mid-hills. Proceedings of the 3rd National Horticulture Research Workshop, 7-8 June, 2000, Khumaltar, Nepal Agricultural Research Council.

Gautam, D.M. and R. R. Adhikari. 1989. Study on modified local methods of orange (*Citrus reticulata*) storage. J. Inst. Agric. Anim. Sci. Vol. 10.

Gautam, I. P., K. B. Paudel and K. P. Upadhyay. 2004. De-greening of

mandarin orange for early market in the hills of Nepal. Proceedings of 4th National Conference on Science and Technology, March 23-26, 2004, Nepal Academy of Science and Technology.

Gautam, S., S. Amatya, B. Sharma, M. B. Nepali and S. Srivastav. 2011. Contribution of mandarin in household income and livelihood of mandarin growers in the eastern hills of Nepal: A case study of Khoku VDC, Dhankuta district. Proceedings of the 7th National Horticulture Seminar, June 12-14, 2011. Nepal Agricultural Research Council and Nepal Horticulture Society.

Ghimire, Y.N. 2010. Access of rural hill farmers of Nepal to agriculture marketing of high value crops: Implication for poverty reduction. Proceedings of the 9th Outreach Research Workshop, June-7-8, 2010, Khumaltar, Lalitpur, Nepal Agricultural Research Council.

Gotame, T.P., K. P. Paudyal and P.P. Khatiwada. 2014. Status of Fruits and Genetic Resources in Nepal. Horticulture Research Division, Nepal Agricultural Research Council.

Gurung, C.B., 2001. Marketing of mandarin orange (Citrus reticulate) in western hills of Nepal: Analysis of price behavior and contractual arrangement. M. Sc. Thesis, Department of Agri. Economics, IAAS, Rampur, Chitawan, Nepal.

HARP. 2001. Profiles of Hill Research Programme Funded Projects in Nepal. Hill Agriculture Research Project (HARP).

HARP. 2004. Summary of HRP Projects Completion reports, Volume II. Hill Agriculture Research Project.

HDP. 1995. Annual Report 1994/95. Horticulture Development Project Phase II, Kirtipur, Nepal.

Hockey, H., U.L. Chaudhary and M.S. Ghale. 1996. Comparison of seven provenances of mandarin orange using graphical and cluster analysis techniques Proceedings of the First National Horticulture Research Workshop, 1-2 May, 1996, Nepal Agricultural Research Council.

Khadgi, B.R. 2011. Study on Mycorrhizal status of citrus in Baitadi. Proceedings of the Seventh National Horticulture Seminar, June 12-14, 2011, Nepal Agricultural Research Council and Nepal Horticulture Society.

Knorr, L.C., S. M. Sah and O.P. Gupta. 1970. Greening Disease of Citrus

in Nepal. Plant Disease Reporter. 54: 1092-1095
Lama, T.K, N.P. Ghimire and C.M. Baral. 1984. Research note on performance of some selected cultivars of citrus at Pokhara. Journal of Institute of Agriculture and Animal Science: 5
Lohar, D. and T.K. Lama. 1997. Status Report on genetic resources of citrus in Nepal. IPGRI Project No. B06. IPGRI Regional Office for Asia and Oceania, Malaysia.
Mahato, B. N. 2008. Generic pest analysis (PRA) of citrus. Proceedings of the 5th National Conference on Science and Technology, Nov 10-12, 2008, Nepal Academy of Science and Technology.
MoAD. 2011-14. Statistical information of Nepalese Agriculture, 2010/11, 2011/12, 2012/13, 2013/14. Ministry of Agriculture Development, Government of Nepal.
NARDF. 2008 and 2010. Project Completion Reports of 2008 and 2010. National Agricultural Research and Development Fund.
NCDP. 1978. Report 1975/76-1977/78 (2032/33-2034-35). National Citrus Development Program, Dhankuta, Nepal.
NCDP. 2046 (1989). Report Sixth Five Year Plan 1980/81-1984/85 (2037/38-2041/42). National Citrus Development Program, Dhankuta.
NCDP. 2047 (1990). Report: Seventh Five Year Plan – 185/86-1989/90 (2042/43-2046/47). National Citrus Development Program, Dhankuta.
NCDP. 2071. Annual Report (in Nepali). Narional Citrus Development Program, Kirtipur, Nepal.
NCRP. 2013 and 2014. Annual Report 2069/70 (2012/13) and 2070/71 (2013/14). National Citrus Research Program, Paripatle, Dhankuta.
Niraula, R. and S. B. Rajbhandari. 1988. In vitro propagation of trifoliate orange (Poncirus trifoliate). Proceedings of the National Conference on Science and Technology, April 24-29, 1988, Royal Nepal Academy of Science and Technology.
Pahari, S. and H.P. Bimba. 2004. Assessment of genetic diversity of Citrus reticulata Blanco and Citrus limon (L.) Burn F. of Nepal through isozyme analysis. Proceedings of 4th National Conference on Science and Technology, March 23-26, 2004, Nepal Academy of

Science and Technology.
Pandey, R.R. and R.B. Rana. 1992. Green stink bud (Rynchocorishumeralis) damage of mandarin fruits and its natural parasitisation by Trissolcus sp. J. Inst. Agric. Anim. Sci. Vol 13.
Pant L.P. 2001. Local knowledge about management of mandarin orchards in Chitawan hills of Nepal. J. Inst. Agric. Anim. Sci. Vol. 21-22.
Paudel, K.B., H.N. Regmi, I.P. Gautam, J.N. Chaudhary, K.P. Upadhya, D. Pokharel and B. Khatri. 2004. Modified cellar store: An efficient and economically sustainable means for storage of mandarins in Nepal. Proceedings of 4th National Conference on Science and Technology, March 23-26, 2004, Nepal Academy of Science and Technology.
Paudyal. K.P. and B. Chalise. 2007. Evaluation of Satsuma mandarin (Citrus unshiu) for early season production in Nepal. Proceedings of the Fourth National Horticulture Seminar, January 18-19, 2007, Nepal Horticulture Society.
Paudyal, K.P. and H. Subedi. 2008. Selection of sweet orange (Citrus sinensis Osbeck) varieties for production period expansion. Nepalese Horticulture: 6, Nepal Horticulture Society.
Paudyal, K.P., H. Subedi and B. Chalise. 2011. Selection of elite mandarin (Citrus reticulata Blanco) mother plants from local genotypes. Proceedings of the 7th National Horticulture Research Workshop, 12-14, June, 2011, Khumaltar. Nepal Agricultural Research Council.
Paudyal, K.P. 2000. Farmers' participatory selection of superior pummelo (Citrus grandis L. Osbeck) trees in Nepal. Proceedings of the Third National Horticulture Research Workshop, 7-8 June. Khumaltar, Nepal Agricultural Research Council.
Poon, T.B. 1999. Effect of grafting methods and time on mandarin sapling production at Dailekh. Proceedings of the Second National Seminar on Horticulture Research, June 1999. Nepal Agriculture Research Council.
Ranjit, M. and A. Karki. 1999. In vitro propagation of sweet orange (Citrus sinesis L. Osbeck) cv. Madame Venous for production of disease-free indicator plants against citrus disease. Proceedings of

III National Conference on Science and Technology, Volume II, March 8-11, 1999, Royal Nepal Academy of Science and Technology.

Regmi, C. and T.K. Lama. 1988 a. Greening incidence and greening vector population in Pokhara. Proc 10th Conf. IOCV, IOCV, Riversie. pp. 238-242.

Regmi, C. and T.K. Lama. 1988 b. Range of host plants of DiaphorinacitriKuw – a vector of citrus greening disease. Proc. Nat. Cong. Sc. and Tech, RONAST, pp. 158-160

Regmi, C, I.P. Kafle, K.P. Paudyal, G. Aryal and G. Awasti. 2008. Screen house system to produce quality planting materials of citrus in Banepa. Proceedings of the Fifth National Seminar on Horticulture Research, June 9-10, 2008, Nepal Academy of Science and Technology, Nepal Agriculture Research Council and Nepal Horticulture Society.

Regmi, C., R.P. Devkota, K.P. Paudyal, S. Shrestha, A.J. Ayres, N. Murcia, J.M .Bove and Duran-Vila. 2010. Shifting from seedling mandarin trees to grafted trees and controlling Huanglongbing and viroids; a Biotechnological Revolution in Nepal. In Proc.17th IOCV Conf. IOCV Riverside. p. 116 -122.

Regmi, C, M. Garnier and J.M. Bove.1996. Detection of the Asian Huanglongbing (Greening) Liberobactor in Nepal by DNA - DNA. Hybridization Proc. XIII Conf. IOCV, IOCV, Riverside. p. 267-270.

Regmi, C., 1982. Mycoplasmlike diseases of citrus in Nepal and USSR (spread, effect aetology, varietal resistance, possible vectors) Ph.D. dissertation. MoscowAgricultureal Academy, Moscow. pp. 144.

Roistacher, C.N. 1996. Assessment of the greening problem, the severity and prevalence of virus and virus-like diseases and development of an appropriate set of procedures for a citrus certification program for Nepal. A consultancy report, ATSP, Kathmandu.

Shrestha, B. and R.L. Shrestha. 2000. Marketing of mandarin orange in the western hills of Nepal: Constraints and potential. Proceedings of the 3rd National Horticulture Research Workshop, 7-8 June, 2000, Khumaltar, Nepal Agricultural Research Council.

Shrestha. P.P. and S.K. Verma. 1998. Development and outlook of citrus industry in Nepal. Proceedings of the National Horticulture

Workshop, January 19-21, 1998, Kirtipur, Kathmandu. Nepal Horticulture Society.

Shrestha, R.L. and K.P. Paudyal. 2004. Proceedings of the Fourth National Horticulture Research Workshop, March 2-4, 2004, Nepal Agricultural Research Council.

Shrestha, R.L, K.P. Paudyal, B. Chalise, H.P. Subedi and J.L. Mandal. 2011. Growth of trifoliate orange seedlings at different management conditions in NCRP, Dhankuta. Proceedings of the Seventh National Horticulture Workshop, June 12-14, 2011, Nepal Agriculture Research Council and Nepal Horticulture Society.

Thapa, M.B. and Shrestha, M. B. 2000. Study on grading, packaging and transportation of mandarin orange. Proceedings of the Third National Horticultural Research Workshop, 7-8 June, 2000, Nepal Agricultural Research Council.

Thrower, L. B. 1968. Report on visit to Nepal. FAO Report PL: T51

Trpathi, K. M. and D.D. Dhakal. 2005. Effect of paclobutazol on off-season flower induction in acid lime land races under Chitawan condition. Journal of the Institute and Animal Science, Vol. 26.