

TRAINING MANUAL FOR COMBATING CITRUS DECLINE PROBLEM IN NEPAL



(Declined Mandarin Tree)

↓
Rejuvenation
Good Agriculture Practices



(Healthy and Productive Mandarin Tree)



Department of Agriculture, Ministry of Agriculture
and Cooperatives, Government of Nepal
Food and Agriculture Organization of United Nations
TCP/NEP/3302: (D) - JULY, 2011





Chapter-I

- 1. ECONOMIC IMPORTANCE AND EXISTING PRODUCTION STATUS OF CITRUS IN NEPAL 1
 - 1.1 Economic importance 1
 - 1.2 Existing production status 1

- 2. GOVERNMENT INITIATIVES FOR COMMERCIALIZING CITRICULTURE 5
 - 2.1 Review of the past initiatives 5
 - 2.2 Strategies for commercial citriculture as well as combating citrus decline in Nepal 6
 - 2.3 Policy and institutional related strategy 6
 - 2.4 Nursery and orchard management related strategies 7
 - 2.5 Disease related strategies 7
 - 2.6 Insect- pest related strategies 7

Chapter-II

- 1. PRODUCTION CONSTRAINTS AND EXTENT OF CITRUS DECLINE 8
 - 1.1 Constraints of different stakeholders 8
 - 1.2 Location specific constraints in Project area 9
 - 1.3 Extent of citrus decline in Nepal and their causes 10

Chapter-III

- 1. IMPROVED PRODUCTION TECHNOLOGIES WITH PARTICULAR FOCUS ON COMBATING CITRUS DECLINE 14
 - 1.1 Good citrus nursery practices 14
 - 1.1.1 Collection of seeds and sowing them 14
 - 1.1.2 Transplanting and care of young seedlings 15
 - 1.1.3 Budding/grafting 15
 - 1.1.4 Aftercare of budded/grafted plants 17

 - 1.2 REJUVENATION OF DECLINED CITRUS ORCHARDS THROUGH IMPROVED CULTURAL PRACTICES 17
 - 1.2.1 Manuring and fertilization 18
 - 1.2.1.1 Factors governing nutrients availability 21
 - 1.2.1.2 Dosage of manures and fertilizers 21
 - 1.2.1.3 Method of manures and fertilizers application 22

Chapter-I

1. ECONOMIC IMPORTANCE AND EXISTING PRODUCTION STATUS OF CITRUS IN NEPAL 1

1.1 Economic importance 1

1.2 Existing production status 1

2. GOVERNMENT INITIATIVES FOR COMMERCIALIZING CITRICULTURE 5

2.1 Review of the past initiatives 5

2.2 Strategies for commercial citriculture as well as combating citrus decline in Nepal 6

2.3 Policy and institutional related strategy 6

2.4 Nursery and orchard management related strategies 7

2.5 Disease related strategies 7

2.6 Insect- pest related strategies 7

Chapter-II

1. PRODUCTION CONSTRAINTS AND EXTENT OF CITRUS DECLINE 8

1.1 Constraints of different stakeholders 8

1.2 Location specific constraints in Project area 9

1.3 Extent of citrus decline in Nepal and their causes 10

Chapter-III

1. IMPROVED PRODUCTION TECHNOLOGIES WITH PARTICULAR FOCUS ON COMBATING CITRUS DECLINE 14

1.1 Good citrus nursery practices 14

1.1.1 Collection of seeds and sowing them 14

1.1.2 Transplanting and care of young seedlings 15

1.1.3 Budding/grafting 15

1.1.4 Aftercare of budded/grafted plants 17

1.2 REJUVENATION OF DECLINED CITRUS ORCHARDS THROUGH IMPROVED CULTURAL PRACTICES 17

1.2.1 Manuring and fertilization 18

1.2.1.1 Factors governing nutrients availability 21

1.2.1.2 Dosage of manures and fertilizers 21

1.2.1.3 Method of manures and fertilizers application 22

1.2.1.4 Time of manures and fertilizers application 23

1.2.2 Irrigation 24

1.2.2.1 Importance of irrigation and water stress effect 24

1.2.2.2 Water requirement 24

1.2.2.3 Method of Irrigation 24

1.2.2.4 Frequency of irrigation 25

1.2.3 Soil tillage 25

1.2.4 Mulching 25

1.2.5 Soil pH and Liming 26

1.2.5.1 Soil pH 26

1.2.5.2 Liming 26

1.2.5.3 Liming materials 26

1.2.5.4 Application of liming materials 26

1.2.6 Inter-cropping 27

Acronyms

ACIAR	-	Australian Centre for International Agriculture Research
AEC	-	Agriculture Enterprise Centre
APP	-	Agriculture Perspective Plan
ARS	-	Agriculture Research Station
CGD	-	Citrus Greening Disease
CTV	-	Citrus Tristeza Virus
DADOs	-	District Agriculture Development Offices
DOA	-	Department of Agriculture
ECARDS	-	Environment, Culture, Agriculture Research and Development Society
FAO	-	Food and Agriculture Organization
FDD	-	Fruit Development Directorate
FNCCI	-	Federation of Nepal Chambers of Commerce and Industry
FYM	-	Farm Yard Manure
GA	-	Gibberilic Acid
GAPs	-	Good Agriculture Practices
HARP	-	Hill Agriculture Research Project
HLB	-	Huanglongbing
IAAS	-	Institute of Agriculture and Animal Science
ICAR	-	Indian Council of Agricultural Research
IOCV	-	International Organization of Citrus Virologist
JICA	-	Japan International Cooperation Agency
MDAP	-	Manpower Agriculture Development Project
MDD	-	Market Development Directorate
MOAC	-	Ministry of Agriculture and Cooperatives
MPHD	-	Master Plan for Horticulture Development
NARC	-	National Agriculture Research Council
NARDF	-	National Agriculture Research and Development Fund
NAST	-	Nepal Academy of Science and Technology
NCDP	-	National Citrus Development Programme
NPC	-	National Planning Commission
OVOP	-	One Village One Product
PPP	-	Public Private Partnership
RONAST	-	Royal Nepal Academy of Science and Technology
SSMP	-	Sustainable Soil Management Project
TCP	-	Technical Cooperation Programme

Foreword

In Nepal citrus in general and mandarin in particular has been traditionally grown as one of the most important fruit crops. However, absence of proper cultivation practices and negligence have resulted in severe decline in its production and productivity in recent times. Without science based knowledge and skills transfer the declined problem can not be controlled. Therefore, know-how and skills up-gradation of extension staff and farmers through training is one of the most immediate needs for addressing the citrus decline problem. This will hopefully lead to a successful transfer of refined technology to the citrus growing farmers.

By launching a TCP project to address the mentioned citrus decline problem in Nepal, FAO hopes to contribute positively by providing technical assistance in: (a) identifying causes of citrus decline, preparing decline mapping and suggesting combat strategies for different ecological regions; (b) social mobilization of citrus growing communities; and, (c) successfully transferring improved technology.

In order to enhance the technical capacity of extension staff and farmers in the management of citrus decline problem, a well designed Training

Manual on “Combating Citrus Decline Problem in Nepal” has been long felt need of the Department of Agriculture. Realizing this need, the TCP project has designed this Training Manual to improve the quality training courses by providing comprehensive subject matters. This Manual has been made user-friendly by providing the technical matters in simple easy-to-understand language and illustrative photos and pictures. Technical information generated by the research and development institutions in Nepal and India has been largely incorporated and duly acknowledge. I believe that the extension staff of the Department of Agriculture and other officials of the related organizations will find this Manual helpful in carrying out training programmes related to citrus growing and management.

I thank consultant team comprised of Dr. S. P. Ghosh, Dr. D. K. Ghosh, Mr. B. R. Kaini, Dr. C. Regmi, Mr. B.B. Karmacharya and project coordinator, Dr. G. S. Niroula for their hard work in bringing this manual in its present form. I also thank Ms. Devi Poudel, Secretary, National IPM Programme, Nepal for formatting this manual.



Ms. Bui Thi Lan
FAO Representative, Nepal

Preface

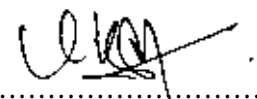
Citrus is one of the most important fruit crops of Nepal in terms of area coverage, production and export potential. It is grown in more than 50 districts out of the total 75 districts. In fact, Nepal is one of the centers of citrus diversity and many species of it are found grown in this country.

It has been long felt need of National Citrus Development Program to have this manual in this form. After going through this manual, I found that this manual has included enough information on how to combat citrus decline problem.

It is expected that this manual will help to upgrade the knowledge and skills of extension staff and thus technical capacity enhanced among them. This will facilitate extension staff in transfer of technology among farmers to fight against citrus

decline problem in Nepal. Furthermore, this manual has been designed to introduce extension workers and mandarin growers to the concept of aligning management practices to the key phenological or growth stages of citrus trees. Phenology is defined as the relationship between climatic and periodic biological events.

Lastly, I would like to congratulate and thank consultant team for their contribution and hard work for bringing out this manual in this form.



.....
Vijoy Kumar Mallick
Director General
Department of Agriculture

Few Words

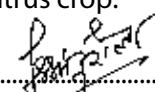
Although, Citrus is grown in 53 mid- hill districts of Nepal, it is now being extended to terai (for instance, kagati, kinnow) area too. The total area is 33898 ha, out of which only 22903 ha is productive. The total production is 2, 59,191 MT; however, the average productivity is only 11.32 mt/ha. The total monetary value of the production @ Rs 20/kg is Rs. 5183.0 million per annum, which is a significant amount in the fruit sector.

Of the fruit area in Nepal, citrus shares nearly 32 % of the total area among which the contribution of mandarin is nearly 21%. Similarly, the share of citrus in total fruit production is 37%, in which mandarin is a major commodity. Its share in total production is nearly 25%. Needless to say, this indicates that citrus is the major fruit in Nepal that has a significant place in the socio-economic well being of the Nepalese farmers.

In fact, citrus crop was identified by APP as the high value crop that can help to improve livelihoods and quality of the mid- hill people. However, not much has been achieved so far, as it has still remained as rhetoric only. Moreover, existing citrus orchards have been declining at faster rate particularly in western development region. Same is case with sweet orange in Ramechap and Sindhuli districts. Decline is syndrome attributed to several factors. However, the extent of decline and losses has not been correctly assessed in Nepal, nor attempts have been made for mapping the malady.

Mismanagement (farmers' reluctance to invest on citrus orchard), wide use and distribution of unhealthy citrus saplings, increasing drought/dryness, lack of using balanced plant nutrition and application of updated technology are some of the major factors contributing citrus decline problem in Nepal. On the other hand, private sector is the major supplier (92%) of citrus saplings; Government's contribution is only 8%. Of the total saplings, 32% are grafted whereas 68% are seeded plants. This scenario is rather discouraging for enhancing citrus industry in Nepal.

This Technical Cooperation Project intends to address these issues by identifying and validating most suitable technologies adapted to local conditions of Nepal. Major activities including training to the citrus growers and government staffs, disease and nutrition mapping, demonstration of rejuvenation technologies and Good Agriculture Practices (GAPs) and development of Bud wood Certification System. I take this opportunity to thank FAO for taking up this initiative, which undoubtedly will contribute towards invigorating the ailing citrus industry thereby uplifting the socio-economic status of the rural farmers. Furthermore, it will also serve as a basis and milestone for drawing more resources in future. I also like to thank the consultants/experts for bringing out this manual, and hope that it will be widely used by the concerned officials to update their knowledge and skills on the citrus crop.



.....
Dr. Gajendra Sen Niroula
Chief, NCDP and National Project Coordinator



Acknowledgement

It is to acknowledge that in this Training Manual, relevant technical information from different published reports of National Citrus Development Program (NCDP) of Govt. of Nepal; Nepal Agriculture Research Council (NARC); Nepal Academy of Science and Technology (NAST); National Research Centre for Citrus of Indian Council of Agricultural Research (ICAR); Nagpur, India and Central Institute of Horticulture, Govt. of India, Nagaland, Publications of University of California, USA and others have been freely used.

Chapter I

1. Economic importance and existing production status of citrus in Nepal

1.1 Economic importance

Citrus is the main fruit crops of Nepal contributing about 36 percent of the total fruit production (FDD, 2007/08). Among citrus, mandarin orange is predominant which shares about 67 percent of the total citrus production in the country. Horticultural crops including citrus are highly profitable crops than the other traditional crops in the mid-hill of Nepal (table 1). This has increased the social acceptability of citrus in Nepal.

1.2 Existing production status

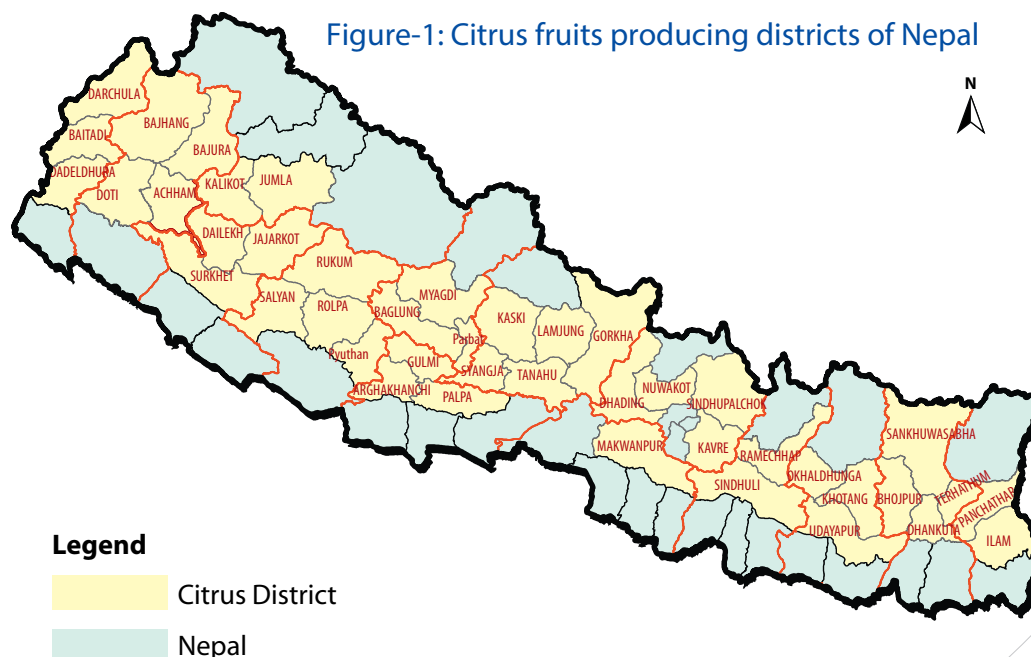
The unique topography and agro-climatic conditions of the mid-hills of Nepal have made it possible to grow many kinds of citrus fruits. At present, all the 39 districts of the mid-hill region and 3 terai districts are producing citrus fruits in considerable amounts (figure 1). Citrus fruits in the mid-hill region have now become business proposition and many pockets of citrus have already been developed. In this chapter, trends in area and production of important citrus fruits of Nepal are discussed.

Table-1: Productivity, net income and output-input ratio for different groups of Crops of mid-hills

SN	Crops	Yield (mt/ha)	Net income (000Rs./ha)	Output-input ratio
1	Cereal	2.2	4.7	1.3
2	Pulses	0.9	11.2	2.7
3	Oil seeds	0.4	1.2	1.2
4	Potato	14.4	72.6	2.9
5	Vegetables	13.7	88.1	3.5
6	Citrus	11.3	78.3	4.1

(Source: MDD, 2002 and market bulletins of various years)

Figure-1: Citrus fruits producing districts of Nepal



Trends in area and production of citrus fruits for the last 10 years are shown in table 2 and 3. The figures presented in table 2 indicate that area under citrus fruits is continuously increasing, though the rate of increase is different for different years.

The average annual growth rate of the last 10 years starting from 1998/99 to 2007/08 in area increase was 6.1 percent. The area increase was maximum in 2007/08 and minimum in 2006/07 (table 2).

Table-2: Area under citrus fruits from 1998/99 to 2007/08

Fiscal year	Area in ha	Increased area in ha	Percentage increase
1998/99	18007	981	5.8
1999/2000	19018	1011	5.5
2000/01	20673	1655	8.9
2001/02	22423	1751	8.2
2002/03	23663	1240	5.8
2003/04	24799	1136	4.6
2004/05	25910	1111	4.4
2005/06	27022	1112	4.2
2006/07	27980	958	3.7
2007/08	30790	2811	10.0

(Source: FDD, 2007/08)

The production of citrus fruits has also increased continuously as in area but the average increase rate is higher than in area increase. The percentage increase in fruit production is the highest in 2007/08 (table 3). Such increase pattern might be the result of increased area as well as increase productivity at higher rates. The possibility of area expansion for any crops including citrus is now limiting due to population pressure and hence, efforts should be made to increase productivity at higher rates as productivity at present is very low compared to other citrus producing countries.

The area and production figures of important citrus fruits are presented in table-4. Mandarin orange, which is the number one citrus fruit of Nepal in terms of area, production and preferability, occupies about 65 percent area under citrus fruits. Junar, an indigenous variety of sweet orange, is the second important citrus fruit of Nepal. Its cultivation is concentrated in Sindhuli, Ramechhap and Dhankuta. The other two major citrus fruits are acid lime and hill lemon. Other citrus fruits grown in Nepal at small scale are rough lemon, pummelo, grapefruit, sour lemon, citron, sweet lime, calamondin and kumquat. Citrus fruits occupy 30.5 percent area under total fruit crops and their share in production is 35.9 percent. The average productivity of citrus is also higher than the average productivity of total fruit crops.

Table-3: Production and productivity of citrus fruits from 1998/99 to 2007/08

Fiscal year	Total production in (000mt)	Percentage increase	Productivity (mt/ha)
1998/99	107	7.0	10.13
1999/2000	115	7.5	10.20
2000/01	122	6.1	10.23
2001/02	131	7.4	10.38
2002/03	139	6.1	10.45
2003/04	148	6.5	10.62
2004/05	157	6.0	10.75
2005/06	164	4.5	10.78
2006/07	172	4.8	10.86
2007/08	226	31.4	11.37

(Source: FDD, 2007/08)

Table-4: Area and production of major citrus fruits (2007/08)

SN	Fruit crops	Area in ha	Production in mt	Productivity (mt/ha)
1	Mandarin	20167	150738	11.9
2	Junar	4866	48408	12.7
3	Lime	3720	17423	8.5
4	Lemon	1198	6315	6.8
5	Others	838	3522	
	Citrus total	30790.3	226404	11.4
	All fruit total	100099.1	630562	9.94
	Citrus percentage	30.5	35.9	

(Source: FDD, 2007/08)

Region-wise details of area and production of citrus are presented in table-5 which shows that both total number of districts and citrus producing districts are the highest in the central region but the production of citrus fruits is maximum in the western region. The far-western region has 8 citrus producing districts out of its total 9 districts. In productivity of fruits, the central

region is on the top of the list followed by the eastern, western, mid-western and far-western region, respectively. The citrus producing terai districts are Chitawan, Nawalparasi, Surkhet, and Kailali. The citrus producing districts falling in the mountain region are Taplejung, Sankhuwashabha, Solukhumbu, Dolakha, Sindhupalchok, Kalikot, Bajura, Bajhang and Darchula.

Table-5: Region-wise area and production of citrus (2006/07)

Region	Citrus districts	Citrus area	Citrus prod.	Productivity
ER	11	6711	45794	10.9
CR	13	6939	46427	11.7
WR	12	7879	46917	10.8
M-WR	8	3674	18026	9.8
F-WR	8	2777	14710	9.9
Total	52	27980	171875	

(Source: MOAC, 2006/07)

2. Government initiatives for commercializing citriculture

2.1 Review of the past initiatives

The onset of citrus development at the government level was started in the early sixties when two citrus research stations were established at Pokhara (1961) and Dhankuta (1962). These stations were mainly involved in research work. Promoting commercial citriculture in the country by the government was initiated with the establishment of the National Citrus Development Programme (NCDP) in 1972. Although, NCDP was mandated for both research and development, it emphasized more on development and started promoting plantation of citrus trees in commercial scale in some of the potential districts.

The Government of Nepal celebrated 1974 as the "Agriculture Year" and priority in terms of resource mobilization was given for agriculture development programmes. Many new programmes including establishment of private nurseries were initiated from this year. The unavailability of planting materials in time and required quantities was a major constraint for fruit commercialization at that time. After this initiative, many private citrus nurseries were established throughout mid-hills of Nepal and as a result, there are now 176 private nurseries producing citrus saplings for sale and distribution.

From 1980/81, a special "Junar production programme" was initiated by the government in Ramechhap and Sindhuli districts with the estab-

lishment of commercial orchards in many pockets. This programme was later supported by a JICA funded project called Horticulture Development Project. Now these two districts are well known for commercial junar production and this is the outcome of the interventions made by this special programme.

A national priority programme was started in the fiscal year 1983/84 with an objective of commercializing citrus production, particularly mandarin in 20 mid-hill districts namely Illam, Dhankuta, Terathum, Sankhuwasabha, Bhojpur, Khotang, Okhaldhunga, Ramechhap, Sindhuli, Dhading, Gorkha, Lamjung, Tanahu, Kaski, Syangja, Palpa, Gulmi, Arghakhanchi, Salyan and Dailekh. The programme was launched with the government resources. Due to strong commitments of the implementing agencies, farmers' willingness, and regular and intensive monitoring of programme implementation, this was one of the successful programmes initiated by the government in the past. Most of the commercial orchards of today in those districts were the impact of this intervention.

Since 1994/95, the Ministry of Agriculture and Cooperatives (MOAC) has implemented a commercial agriculture development programme for some high value crops including citrus. This programme is providing financial support in planting materials, horticultural equipment and plant protection chemicals for commercializing citriculture in the mid-hills.

Formulated in 1995 and implemented from 1997, the Agriculture Perspective Plan (APP) is the government main policy document on agriculture. This policy has recognized citrus as the main high value crop for mid-hills of Nepal. The APP approach for commercializing agriculture including citrus is the pocket-package approach. A pocket is an area of high potential for a particular crop/commodity. A mandarin pocket means a high potential area for mandarin production in commercial scale. The size of the pocket for citrus is 60 ha in the beginning, but it would become larger and intensified over time. The approach of integrating priority inputs at the pocket area is called packaging. The packaging of inputs envisaged by the APP for hills are agriculture roads, rural electrification, fertilizers, credit and technology. After the implementation of pocket-package approach, 210 citrus pockets are developed in the country (FDD, 2009). Besides this, the government has also taken many policy related initiatives which promote commercialization of citriculture. Two policy documents namely National Agriculture Policy 2004 and Agri-business Promotion Policy 2007 are very relevant in this context.

A mission programme of lime has been launched in Dhankuta, Bhojpur, Tehrathum and Makawanpur districts of Nepal from 2007/08 fiscal year for boosting up lime production through commercialization. The main activities of this programme are distribution of planting materials, horticulture equipment and plant protection chemicals at subsidized rates. Activities like aftercare of plants, application of manures and fertilizers, pruning of trees, irrigation etc are lacking in this programme.

Despite many initiatives taken by the government in the past for commercialization of citriculture, the conditions of the orchards have remained the same or even worse. Existing citrus trees are predominantly of seedling origin and plants coexist with various seasonal inter-crops without additional plant nutrients. Hardly any special attention is paid to citrus orchard management and

inputs in terms of labour and materials are minimum. Fertilizers, irrigation and plant protection chemicals are not commonly used. Trees infected with deadly disease like foot rot and greening are not removed usually and they remain as constant sources of infection. Absence of proper cultivation practices and long neglect have resulted severe decline in citrus orchards in many parts of Nepal. The weakness of the government initiatives in the past was mainly in programme implementation. Social mobilization part was very weak. Farmers were not aware about the importance of management practices to increase productivity and quality of fruits.

2.2 Strategies for commercial citriculture as well as combating citrus decline in Nepal

The present policies and plans of Nepal are favorable for the development of citrus. The Master Plan for Horticulture Development (MPHD) prepared in 1991 gave highest priority to citrus particularly mandarin and Junar. Unfortunately, this plan could not be implemented due to various reasons. The other important policy document, which has recognized citrus as one of the main high value commodities and prioritized it for the mid-hills, is the Agriculture Perspective Plan (APP). This plan is also weak in its implementation. Based on the visions of these plans, a project proposal on commercialization of citrus should be developed and implemented.

2.3 Policy and institutional related strategy

- Promote public-private partnership (PPP) approach to speed-up commercialization process.
- Improve access to rural credit and provide them soft loan with project based collateral.
- Instead of providing subsidy, the concept of revolving fund should be introduced to support small farmers.

- ⇒ Link production areas to the markets by improving road access.
- ⇒ Develop collection centers in the production areas.
- ⇒ Formulate and enforce nursery act to regulate uncontrolled flow of nondescript/noncertified planting material across the country by introducing internal quarantine system.

2.4 Nursery and orchard management related strategies

- ⇒ Establishment and management of pathogen-free citrus nursery system in the disease free citrus growing areas.
- ⇒ Training of technicians on virus indexing and shoot-tip micro grafting technology.
- ⇒ Production and distribution of pathogen free planting materials by implementing citrus bud wood certification system.
- ⇒ Packaging of technologies for combating citrus decline.
- ⇒ Promotion of micro-irrigation system.
- ⇒ Enhancing capacity of local manpower in orchard management through training.
- ⇒ Rejuvenation of declined citrus orchards

through implementation of programmes in the form of campaign.

- ⇒ Sensitization and orientation of citrus growers on plant health management.

2.5 Disease related strategies

- ⇒ Detailed survey of citrus greening and virus disease incidence in Nepal.
- ⇒ Survey of distribution of alternate hosts like jasmine orange (*Murraya paniculata*), and their susceptibility test to pathogen.
- ⇒ Study resistance of important citrus cultivars against diseases, particularly HLB and Phytophthora root rot and foot rot.
- ⇒ Identification of disease free citrus growing areas.
- ⇒ Use of disease resistant rootstocks.
- ⇒ Integrated approach of disease management.

2.6 Insect- pest related strategies

- ⇒ Species identification and life cycle study.
- ⇒ Population dynamics and loss assessment.
- ⇒ Vector and host identification.
- ⇒ IPM approach.

Chapter II

1. Production constraints and extent of citrus decline

1.1 Constraints of different stakeholders

Most of the farmers are small with less than 0.5 ha of cultivated land and hence, the production volume is low. Despite Nepal has many opportunities to expand citrus industry, the scale of

production is too small; productivity of crops per unit of land is low; and costs of production and marketing are high. It is because this sub-sector of horticulture is facing with many constraints as shown in the table 6 and these constraints are grouped into 3 categories.

Table-6: Constraints of citrus development

Category	Constraints
Policy a) National Citrus Development Program	<ul style="list-style-type: none">• Bud wood certification system does not exist for the production and supply of quality planting material
Input supply a) Recipients or farmers' constraints	<ul style="list-style-type: none">• Inadequate number of nurseries and other input suppliers in the production areas• Production and supply of low quality planting materials• Weak extension support• Weak research support
b) Input suppliers' constraints	<ul style="list-style-type: none">• Weak linkage between input suppliers and produces• Existing suppliers have limited knowledge and outreach.• Inadequate credit support to the entrepreneurs and input suppliers• Inadequate training to the nurserymen and other input suppliers.• Lack of road access in most of the production areas.• Poor market information service

Category	Constraints
Production	
a) Recipients or farmers' constraints	<ul style="list-style-type: none"> • Low quality planting materials • High cost of planting materials • High cost of orchard establishment • Long gestation period of citrus fruits • Inadequate training to citrus growers • Weak extension support • Weak research support • Incidence of citrus decline • High interest rate of loan • Lack of road access in most of the production areas. • Inadequate numbers of input suppliers in the areas. • Lack of irrigation facilities • Small and fragmented holding of land • High risks due to lack of reliable weather forecasting system and marketing
b) Extension service providers' constraints.	<ul style="list-style-type: none"> • Inadequate number of field staff • Inadequate knowledge on the subjects • Ineffective incentive mechanism • Lack of interaction with the technology generators or researchers
c) Constraint of the technology generators or researchers	<ul style="list-style-type: none"> • Inadequate number of qualified researchers • Lack of adequate laboratory facilities • Lack of continuous research support in citrus • Lack of incentives to get involve in long term research

1.2 Location specific constraints in Project area

Location specific constraints are illustrated in table 7. The information given in table 7 are based on study of the project districts.

Table-7: Project Area specific production constraints

Constraints	Dhankuta Areas	Kavre area	Dhading, Gorkha and Tanahu areas	Kaski and Syangja areas
Management & Nutrition related <ul style="list-style-type: none"> • Poor orchard management • No tree pruning and training • No mulching • Lack of irrigation • Low nitrogen content • Low potash content • Low Zinc and Boron content 	These problems are common in all the areas.			
Disease Related	Less severe	Less severe	Severe	Moderate
• HLB				
• Root and foot rot	Common to all the areas			
• Scab	Non existing	prominent	Non existing	Non existing
• Powdery mildew	Common to all areas with hot and humid weather			
• Felt disease, Pink disease	Not reported	Not reported	Common to these areas	
Insect-pest related	Less common to these areas		Very severe	Moderate
• Citrus psylla				
• Fruit fly	Severe in this area	Moderate	Moderate	Moderate

Constraints	Dhankuta Areas	Kavre area	Dhading, Gorkha and Tanahu areas	Kaski and Syangja areas
• Green stink bug	Moderate	Non existing	Severe	Severe
• Leaf miner	Common to all the areas			
• Scale insects	Severe	Moderate	Moderate	Moderate
• Aphids	Common to all the areas			
• Shoot and stem borers	Common to all the areas but to less extent			
Socio-economic	These problems are common in all the areas.			
• Seedling trees				
• Orchards on marginal lands				
• Inter-cropping with maize and millet				
Legal	This problem is existing in all areas			
• No internal quarantine				

1.3 Extent of citrus decline in Nepal and their causes

The term “citrus decline” denotes a condition of ill health and decadence of citrus trees which may arise from a number of causes. It is a complex problem of citrus resulting from both biotic (diseases and insect-pests) and abiotic (soil, water and nutrition) factors. The general symptoms associated with decline includes: retarded growth of trees, appearance of chlorotic leaves, sparse foliage, die-back of twigs, delayed leaf flushes and blooming, deficiency symptoms (especially zinc), defoliation, off-season flowering, small fruits and less fruit production. Declined trees do not usually die for several years but remain unproductive. Citrus decline generally appear on bearing trees of aged 15-20 years. Although this disease has been spread throughout Nepal, it is reported to be severe in the Western Development Region (NARDF, 2010). The intensity of greening infection is higher in lower belts (up to 900 m altitude) as compared to the higher belts (above 1200m altitude). According to Poudyal and Shrestha (1995), citrus decline is not a specific disease but is a symptomatic expression of many causes.

Causes of citrus decline in Nepal

The possible causes contributing to the decline syndrome are one or more of the following:

Phytophthora diseases

The traditional methods of cultivation (almost 90 % of the orchards are of seedling origin) and are suffering from Phytophthora disease. Phytophthora species cause foot rot, root rot, crown rot, gummosis, leaf fall and brown rot diseases in citrus (Poudyal and Shrestha, 1995) and are responsible for citrus decline to a considerable extent. Phytophthora blight of citrus caused by *P. citrophthora* and *P. parasitica* was reported for the first time from Pokhara during early seventies. In Nepal, most of the mandarin trees are grown from seedlings which are reported to be more susceptible to this disease. Even grafted trees on rough lemon rootstocks are severely attacked by this disease. But the trifoliolate and its hybrids are highly tolerant to Phytophthora. The extent of decline by this disease is more severe in sweet orange than mandarin. In Sindhuli and Ramechhap districts, almost all junar trees (*Citrus sinensis*) grafted on rough lemon are infected with Phytophthora foot rot and root rot. Dull chlorotic foliage is the initial symptom of the disease where midrib, main lateral veins and band of leaf tissue bordering them become yellow leaving rest of the leaf normal in colour. Rotting of foot and crown roots and oozing (gummosis) are the characteristic symptoms of the Phytophthora disease. The nature of this fungus is water loving, so high soil moisture, excessive irrigation; poor soil drainage and prolonged monsoon favor the

development and spread of this disease. Excess moisture in rooting zone during rainy season predisposes the trees for Phytophthora infection. Soil working near the tree bases, which is commonly done in intercropped orchards, results in root injury. For control of root rot and gummosis disease exposure of affected roots during dry season, drenching with Bordeaux mixture in February and May. Spraying of anti-rot @ 10 ml/liter of water at active growth stage is recommended for Nepal (Ghosh, 2007).

Huanglongbing (Greening) disease

It is one of the serious problems of citrus in Nepal and caused by a gram negative phloem-restricted bacterium, *Candidatus Liberibacter asiaticus*. Citrus decline due to the presence of greening disease was first reported in Pokhara valley of Nepal (Thrower, 1968). Later Knorr et al. (1971) reported that citrus decline in many areas of Nepal was caused by this disease. Up to 39-55 % mandarin trees were found infected with greening disease in Pokhara valley (Knorr and Shah, 1970). Regmi (1982) reported more than 50 % greening infected trees in Pokhara valley and up to 100 % in Horticulture Research Station, Malepatan, Pokhara. Citrus decline in Kaski, Lamjung, Gorkha, Syangja and Tanahu are mainly caused by this greening disease and it is spreading very fast and posing a great threat to citrus orchards (Regmi and Yadav, 2007). The pathogen of this disease is graft and vector transmissible. All the citrus species/cultivars are susceptible to this disease, though lime and lemon do not express visible symptoms. No resistant rootstocks to HLB have been reported so far and neither any chemical have been found effective for controlling this disease (Bove, 2006). HLB has completely destroyed very healthy and well managed orchard at Bimal nagar with the span of 6-7 years of time (Regmi et al 2009). The disease was spread by Asian citrus psyllids (*Diaphorina citri*) which prefers lower altitude and hot and dry weather conditions. Roistacher (1996) visited several citrus orchards in Nepal and reported that the Huanglongbing (greening) is the number one disease of citrus in Nepal and

stated that "Greening will destroy citrus industry in Nepal slowly but surely if necessary measures are not taken in time" and suggested to implement the "Certification Programme"

Citrus Tristeza disease

This disease is reported to be responsible for the decline of sweet orange trees of different varieties in Horticulture Center, Kirtipur (Roistacher, 1996). Temperatures at Kathmandu are ideal for Citrus Tristeza Virus (CTV) and the CTV become most active here. He also reported that mandarin is usually a symptomless carrier of severe strains of CTV. Regmi et al. (1999) reported that CTV has spread throughout the country. However, mandarins are non symptomatic and are not damaged; only limes are symptomatic and severely damaged by CTV. Stem pitting and vein clearing are the most important symptoms of CTV. Lime is highly susceptible to CTV and exhibit stem pitting symptom. CTV is a graft-transmissible virus and is primarily transmitted through infected bud wood and insect vector. Brown citrus aphid (*Toxoptera citricidus*) is the most efficient insect vector. The dodder (*Cuscuta*) also spreads this virus complex. However, there is need for proper diagnosis of CTV and stop its spread through propagating material as there is always possibility of natural emergence or accidental introduction of new severe CTV strain that may cause even more serious problem to future citrus industry of Nepal.

The effects of other diseases such as powdery mildew, canker, bud union overgrowth and crease in causing citrus decline is also very important and needs suitable management effort.

Incidence of insect pests

The common insect-pests damaging citrus in Nepal are listed in insect pest related constraint mentioned in table 7. Scales, particularly purple scale and black scale, are major insect-pests of Dhankuta area but they are spread now everywhere in the citrus growing areas. Citrus fruit fly (or Chinese fruit fly) is causing severe damage in Bhojpur and Dhankuta areas. Citrus psylla is now

reported to be widely distributed in Nepal. Similarly, aphid and citrus leaf miner are also widely distributed throughout Nepal damaging citrus crops severely. The scale of damage of green stink bug is severe in some localities of western development region.

- Chinese citrus fruit fly, *Bactrocera* (*Tetracus*) *minax* (Enderlein) causes severe damage although other fruit flies are also present in eastern region. NCRP also revealed that adult flies emerged in the second half of April. The detailed study on: (i) adult emergence period; (ii) adult phenology patterns; (iii) period of crop susceptibility; (iv) period from fruit drop to pupation and (v) developing of controlling measures is yet to be carried out in Nepal.
- Aphids are polyphagous, sap sucking insects whose reproductive potential is immense due to parthenogenesis and fast development. They attack new flushes and twigs of citrus. Some of them directly damage the plants by sucking their nutrients, which causes curling and twisting the tender shoots and general decline of plants.
- Some of the species of aphids such as *Toxoptera citricida*, *Aphis gossypii* and *Toxoptera aurantii* transmit the Citrus Tristeza Virus. They also cause direct damage to the plants by sucking the young flushes.
- Among other pests green stink bug, mealy bugs etc were identified as the major problem of citrus.

Poor orchard management

In Nepal, most of the citrus orchards are either mismanaged or neglected. Absence of management practices and poor orchard hygiene are wide spread in citrus orchards. Excessive inter-cropping with unsuitable crops such as maize, millet potato, mustard etc., and planting trees on the edges of the bench terraces are common practices. As citrus trees are usually planted in unirrigated uplands, maize is commonly grown as inter-crops without leaving any space around the tree trunk. Maize crop needs two times hoeing and cultivation

during its growth period. This is also the period of active root growth stage of citrus trees and any damage of these roots during this period by ploughing and cultivation means inviting root rot disease. This mismanagement practice is causing citrus decline by providing suitable condition for *Phytophthora* root rot. The trees which are growing on the edges of bench terraces are normally found suffering from malnutrition. Inter-cropping with maize and millet without additional manures and fertilizers, and irrigation is also responsible for malnutrition and moisture stress conditions of citrus orchards. Existing orchards are predominantly of seedling origin and no attention is paid to their management. Orchard management costs in terms of labour and materials are minimum. Fertilizers, irrigation and plant protection chemicals are not commonly used. Trees infected with deadly disease like foot rot and greening are not removed usually and they remain as constant sources of infection. Furthermore, citrus orchards are generally established in the marginal lands. Soils of many such citrus orchards are reported to have low level of organic matter and nitrogen. In recent years, soils of citrus orchards are also found deficient in potassium. Wrong site selection and overcrowding of citrus trees are also experienced in some cases. Such poor management or mismanagement practices are contributing citrus decline to a great extent and the low productivity of citrus in general and mandarin in particular is associated with such practices.

Low quality planting materials

There is a lack of awareness about improved technologies such as grafting techniques and scientific nursery management system among the nursery men. They are reluctant to produce grafted saplings as they do not know the comparative advantages of grafted saplings over the seedlings. Most of the private nurseries are in open field hence are infected with several diseases and pests in the nursery and easily spread to new areas. The quality of planting materials from both government and private nurseries is low. In case of seedlings, which are mainly produced and distributed by

private nurseries, both trees and fruits are not selected properly. Selection of nucellar plants is another issue which many nursery owners do not practice. If it is grafted plant, attention is not paid to select scion wood. Some nursery owners use even undesirable rootstocks. Such propagation practices are contributing to the spread of diseases such as CTV and HLB to a great extent. In Nepal citrus plants are generally produced by grafting keeping graft union at about 5-10 cm above the ground level. This grafting height is very low and the grafting union of such plant remains below the ground level after transplanting in the orchard. This exposes the susceptible scion part of the plant to infection by Phytophthora. Use of

such poor quality planting materials is one of the reasons for citrus decline in Nepal.

Unfavorable soil and climatic conditions
Agro-climatic conditions of the mid-hills of Nepal are quite suitable for growing citrus crops. Citrus, particularly mandarin, are believed to be native of Nepal and they are grown in Nepal traditionally for a long time. Except occasionally drought during flowering periods and hailstones just after fruit set, all other climatic factors prevailing in mid-hills favor citrus production. Though poor in organic matter, the sandy loam soil of hilly areas can be considered preferable for citrus growth.

Declined Mandarin Trees caused by :



Phytophthora



Nutritional deficiency



Huanglongbing(HLB)



Poor orchard management

Chapter III

1. Improved production technologies with particular focus on combating citrus decline

1.1 Good citrus nursery practices

Most of the citrus species are propagated through seeds in Nepal. In fact, the share of seed propagation is 85-90 % in mandarin, more than 90 % in lime, 15-20 % in sweet orange and 20-30 % in lemon. Citrus rootstocks are also mostly propagated by seeds.

1.1.1 Collection of seeds and sowing them

- ⇒ Procure sufficient number of fruits from the selected mother trees at harvest time.
- ⇒ Extract the healthy fully developed seeds from the fruits, wash them with clean water (with rubbing in ash to make free from pulp if needed) and dry them under shade.
- ⇒ Treat the seeds with captan/thiram @ 1g/kg of seed to avoid infection. Alternatively extracted seeds should be dipped in 1% 8-hydroxy quinoline sulphate for three minutes, air dried and stored in refrigerator. Hot water treatment of seeds at 52°C for 10 minutes followed by a short dipping in cold water kills the fungus without hampering the seed viability.
- ⇒ Sow the seeds as early as possible after extraction and preferably within 7 days. For raising healthy seedlings sow the seeds in plastic tray (60 x 40 x 12 cm size ideal).
- ⇒ However, seeds can be sealed in a plastic bag and stored at a low temperature (about 4°C) for six months without greatly reducing their vitality.
- ⇒ A potting mixture of soil, sand and well rotten FYM or compost should be used in equal proportion (1:1:1) for filling the trays. This mixture should be sterilized by solarization or by fumigation (use Basamid @ 50g/cubic meter soil mixture).
- ⇒ Soil mixture should be added with both macro and micro-nutrient for better growth of nursery plants.
- ⇒ For drainage of excess water, there should be at least 6 holes in the bottom of trays. Fill the trays with sterilized soil mixture (one part of fertile soil collected from virgin areas where there is no citrus tree + 2 parts sand) and keep the trays at least one feet (30 cm) height from the ground on bricks/stones.
- ⇒ Shade dried, medium sized, bold seeds should be treated with Vitavax or Thiram @ 3g/kg of seeds before sowing
- ⇒ Seeds are then sown at a depth of 1-1.5 cm with a spacing of 2.5 to 3.0 cm in rows 10 cm apart. After sowing, seeds are covered with layers of sand, soil and FYM mixture and then light shower irrigation should be given with water can. Stagnation of water in the trays or beds should be avoided.
- ⇒ Seed sowing time differ from place to place and species to species. Seeds of mandarin and Junar are shown in November-December. But seeds of rootstocks, such as trifoliolate, citrumelo and citrange can be shown during September-October.

1.1.2 Transplanting and care of young seedlings

- Seeds usually begin to germinate within one or two weeks under optimum temperatures of 25 – 30°C.
- Protect the emerging seedlings with some shelter either by plastic cover or shade nets (50% shade).
- Seedlings can be transplanted two or three weeks later, when the first true leaf is fully expanded. But it is safe to transplant them when they are 4-6" tall having 8-10 leaves. Transplanting is done in polybags, filled with sterilized soil mixture, which is same as mentioned above. Citrus seedlings can be transplanted in UV stabilized polythene bags of size 15-20x20-25 cm which can sustain the growth of the seedlings at least for one year.
- Raising of nursery plants in plastic trays, polythene bags etc. is called as containerized nursery management. It is easy to monitor the growth of individual seedling in the polybags than in the conventional nursery beds in the field. Since sowing of seeds is done in perforated plastic trays there is no stagnation of water in the root zone. As a result the incidence of Phytophthora like diseases is minimized in the seed beds. The affected plants can easily be discarded thereby checking the spread of the inoculums.
- Most citrus rootstocks exhibit some degree of polyembryony (i.e. a single seed contains multiple embryos). That means most of the seedlings (nucellars) are likely to be fairly uniform in their genetic make-up and growth, after the off-types have been eliminated. Discard all markedly smaller or too taller seedlings to ensure uniform nucellar seedlings before transplanting to polybags. Generally, 15-20 percent seedlings are rejected. Also discard Phytophthora infected plants if any.
- Seedlings from primary nursery (or trays) should be uprooted with fork carefully to minimize root damage.
- The selected seedlings should preferably be treated with a fungicide solution containing Ridomil Gold (Mefenoxam) @ 2.75g/liter of water and Bavistin (Carbendazim) @ 1/liter of water for ten minutes before transplanting. Seedlings with twisted (hook-necked) tap roots should be avoided for secondary nursery (polybags).
- If seedlings are to be transplanted in nursery beds they are transplanted in a well prepared, manured and leveled nursery bed at the distance of 15cm in rows spaced at 30cm apart.
- Distances of 60cm after every two rows facilitate budding/grafting and cultural operations.
- Just after transplanting, a light irrigation is given to the nursery beds. Then irrigate them as and when necessary.
- As a precautionary measure, plants should be sprayed with Carbendazim @ 1g/liter water at monthly interval
- For controlling insect-pests like leaf miners, thrips, aphids, mites, scale insects etc in nursery necessary measures in IPM approach should be taken. Confider (Imidacloprid) @ 0.5 ml/liter of water or Vertimec (Abamectin) @ 0.42 ml/liter of water or Spinosad (Spin-tor/Success/Tracer) is very effective against all major insect pests in nursery.

1.1.3 Budding/grafting

- The rootstock seedlings are considered ideal for budding/grafting when they become pencil sized thickness at about 25-30 cm from the ground level. Generally the seedlings attain this size after 6 to 12 months of transplanting depending upon time of transplanting and nursery conditions.
- For quality plants, the scions should be true to type, vigorous, productive and free from diseases and insect-pests. They should not have any flowering buds and they should be collected from well matured fruiting trees. Scions should be taken from the recommended source only. Scions should be fully developed, with mature leaves. The epidermis (outer skin)

should still be tender, not woody. The one or two buds at the base which are blind buds or not fully developed should be discarded. After the scion is cut, the leaves should be cut off immediately, and the bud wood washed in detergent. After the cutting has been dried in the shade, it can be used for grafting.

- Scion sticks should be taken from spring growth of the current season. New shoots developed after June are not suitable for grafting/budding as they are too tender and succulent.
- Leaves and thorns should be removed after collecting the scions, and rapped first in plastic sheets and then in banana sheath. But if scion sticks are to be kept in refrigerator, banana sheath is not needed but plastic sheet should be changed in every two-three days.
- The part of the plant used for grafting should be approximately 10 - 15cm long. For veneer grafting, the rootstock is cut at the graft site.
- Other materials needed for budding and grafting are budding/grafting knives and grafting tape. For grafting tape, paraffin film or plastic tape is used to wrap the bud/scion and fix it in place. It takes about two weeks for the graft site to heal.
- Shield or T-budding is a popular and recommended method of vegetative propagation for citrus plants but veneer and side graftings are more common in Nepal.
- For veneer grafting, a pencil sized rootstock is detopped at 20-25cm height. Then two downward smooth slanting cuts are made forming a veneer to hold the scion. A 10-15cm long scion with 2-3 buds is then prepared by giving a similar cut at the bottom end and then

inserted onto the rootstock. After insertion, the graft union is tied with the plastic tape. If the scion remains green after 2 weeks of grafting, it means the union is successful. The veneer grafting can be started from November and continued till February.

- In side grafting, the top of the rootstock is not detached at the time of grafting. Other techniques are the same as the veneer grafting. When the uptake of scion is assured, the top of the rootstock above the graft union is removed. If the nursery is dry, side grafting is better than the veneer grafting. Furthermore, if the first attempt is not successful, grafting is done second time provided season is there.
- Of various vegetative methods, T-budding is by and large the most common method followed in many countries for propagating



Sidegrafting

citrus. In this method, a 'T' cut is given on the rootstock at a height of about 20cm from the ground level. The vertical part of the 'T' cut should be about 2.5cm long and the horizontal part about one-third of the distance around the rootstock. Cut through any bud should be avoided. The selected bud on the scion is cut beginning about 1.5cm below the bud and ending about 2.5cm above the bud. Then remove the shield shaped bud gently. The flaps of the 'T' cut on the rootstock are lifted with the help of the back side of the budding knife and



Veneergrafting

the bud is inserted into it. It is then wrapped with the budding tape leaving actual bud open or uncovered.. The wrap is removed after 15 days and the flaps are cut-off if the bud is green. After 5-7 days of cutting the flap, the rootstock above the bud union is half lopped leaving 2.5cm stub. The lopped rootstock is finally removed after 3-5 days of lopping.



1.1.4 Aftercare of budded/grafted plants

- In case of veneer and side grafting, more than one shoot may grow from the scion part. Keep only one vigorous shoot. When the spring shoots (scion) develop 7-8 leaves, pinch them; when 10 leaves are developed after summer growth, pinch again. Such pinching helps to have uniform and strong growth of plants.
- Any sprout from the rootstock should be regularly removed to encourage rapid growth of the scion.
- Keep the nursery plants well supplied with nutrients and moisture. However, excess of water harmful to the nursery plants. 1-2 dressing of nitrogenous fertilizers followed by light irrigation is helpful in the rapid growth.

- The nursery area should be kept free from weeds. While weeding and hoeing the nursery beds, care should be taken that inserted buds/scions are not disturbed.
- Mulching of nursery beds helps in controlling weeds and retaining moisture in the soil.
- If any diseases and insect-pests appear in the nursery plants, take necessary measures to control them.
- Sometimes, staking may be necessary to train the nursery plants properly.



Healthy and well grown nursery plants with good roots system

1.2 Rejuvenation of declined citrus orchards through improved cultural practices

Most of the orchards of citrus in Nepal, particularly, mandarin orchards, are in different stages of decline. The term "citrus decline" denotes a condition of ill health and decadence of citrus trees which may arise from a number of causes. The general symptoms associated with decline are: retarded growth of trees, appearance of chlorotic leaves, sparse foliage, die-back of twigs, delayed leaf flushes and blooming, deficiency symptoms (especially zinc), defoliation, off-season flowering, small fruit and fruit production declines during the entire decline development period. Declined trees do not usually die for several years but remain unproductive. Although citrus decline start to appear on bearing trees of aged 7-8 years, it generally become severe on trees above 15 years. According to Poudyal and Shrestha (1995), it is not a specific disease but is a symptomatic expression of many causes. The possible causes

contributing to the decline syndrome are one or more of the following:

- ⇒ Poor and or improper orchard management
- ⇒ Incidence of greening and other disease
- ⇒ Incidence of insect-pests
- ⇒ Low quality planting materials
- ⇒ Unfavorable soil and climatic conditions.

Agro climatic conditions of the mid-hills of Nepal are quite suitable for growing citrus crops. Citrus, particularly mandarin, are believed to be native of Nepal and they are grown in Nepal traditionally for a long time. Except occasionally drought during flowering periods and hailstones just after fruit set, all other climatic factors prevailing in mid-hills favour citrus production. Though poor in organic matter, the sandy loam soil of hilly areas can be considered preferable for citrus growth. Therefore, the effects of climatic and soil factors on citrus decline are assumed to be minimal and they will not be discussed further in this review. In fact, this paper covers only the rejuvenation of citrus orchards through improved cultural practices to address poor and/or improper orchard management factor. Yellowing of mandarin trees (aged 5-8 years) due to decline is shown in the picture of declined mandarin orchard. This is an




Declined mandarin orchard

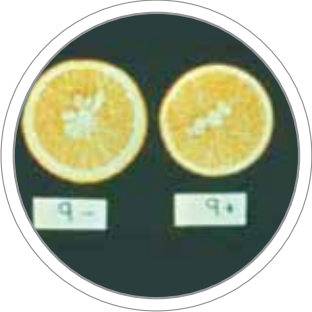
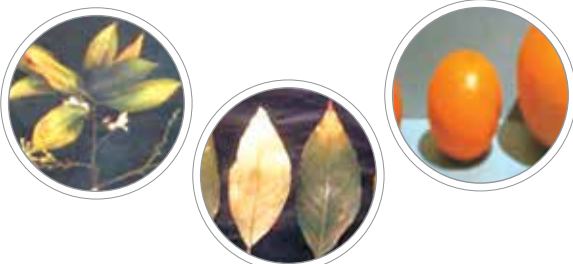


early stage of citrus decline which generally, appears in orchard trees aged 5 years or more.





1.2.1 Manuring and fertilization

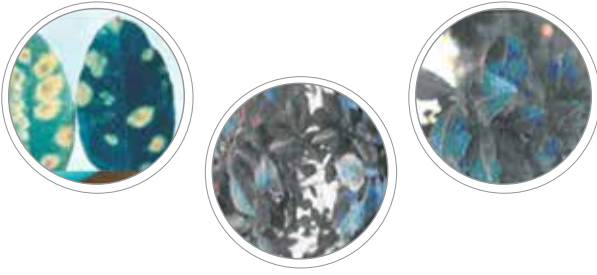
Like other crop plants, citrus also requires a number of mineral nutrients for growth, development and production and this includes nitrogen, phosphorus, potassium, calcium, magnesium, zinc, iron, copper, manganese, boron, and molybdenum. Sulphur, chlorine and sodium are not generally applied due to sufficient quantities available in the soil. Deficiency symptoms and corrective measures of these plant nutrients are summarized in the table 8.

Table-8: Plant nutrient deficiency symptoms and corrective measures

Plant nutrient	Deficiency symptoms	Corrective measures
Nitrogen	General and uniform yellowing of leaves; limited twig and leaf growth; prolonged deficiency leads to die back of twigs; trees undersized; excessive flowering;; fruit size is reduced and yield get declined. 	Application of 1500 g nitrogen/tree in three split doses. In early March. May and late September.

Plant nutrient	Deficiency symptoms	Corrective measures
Phosphorus	<p>Defective formation of buds; discoloration of leaves; reduced number of lateral shoots with reduced growth; limited and delayed blossoming; poor fruit setting; premature fruit dropping; coarser fruits with thick rinds</p> 	<p>Application of 600 g phosphate/tree in single dose during late winter or early spring.</p>
Potassium	<p>Foliage is sparse, somewhat bronzed and lusterless; necrosis on one side of leaves; die back of twigs; Gum exudes from the trunk portion; fruits small but smooth with thin peel and decay rapidly and fruit acidity decreases. Irregular yellow blotching from potassium-deficiency is more common in late summer.</p> 	<p>Application of 600 g potash/tree in single dose during late winter or early spring.</p>
Magnesium	<p>Yellow areas developed between the large veins and on both sides of the mid-rib; bronzed leaves; chlorosis in the old leaves; poor root growth; alternate bearing, poor fruit quality and reduced yields</p> 	<p>Spraying of 0.25% magnesium sulphate twice at 15 days interval on new flushes.</p>
Zinc	<p>Interveinal chlorosis; small leaf size; dieback from terminal twigs; twigs rosette-like appearance; fruits small, insipid and misshapen. Zinc deficiency is found in many mandarin orchard all over the country.</p> 	<p>Spraying of 0.5% zinc sulphate at 15 days interval on new flushes</p>

Plant nutrient	Deficiency symptoms	Corrective measures
Iron	<p>Chlorosis appears on young leaves while older leaves remain green; in acute cases fruits are small, hard, coarse and light in color.</p> 	<p>Spraying of 0.1% ferrous sulphate at 15 days interval on new flushes</p>
Copper	<p>Gum exudation and dieback of twigs; dark green leaves on S-shaped twigs; fruit show gum pockets around the central pith</p> 	<p>Spraying of 0.1% copper sulphate at 15 days interval on new flushes</p>
Manganese	<p>Similar to zinc deficiency except that the leaf size is not reduced; and symptoms are prominent in shady areas</p> 	<p>Single spraying of 0.2% manganese sulphate on new flushes</p>
Boron	<p>Enlargement, corking and splitting of leaf veins of matured leaves; and brown gum pockets formed around seeds and albedo of the fruit.</p> 	<p>Spraying of 0.1% borax twice at 15 days interval on new flushes</p>

Plant nutrient	Deficiency symptoms	Corrective measures
Molybdenum	<p>Water soaked areas appeared on the leaves with the start of new growth in early spring. Subsequently these areas develop into larger interveinal yellow spots with gum on the lowersides. Fruits show marked break-down</p> 	<p>As molybdenum deficiency usually occur in acidic soils, soil pH should be maintained at 5.5 to 6.7.</p>

1.2.1.1 Factors governing nutrients availability

If the soil conditions are not favorable, nutrients may not be available to the plants even if they are sufficiently present in the soils. In citrus the nutrient availability is governed by the following factors:

i. Soil reaction

Soil reaction is expressed in terms of soil pH and this is one of the most important factors influencing the nutrition of citrus. Most of the soils of citrus growing areas of Nepal are acidic in nature. Under such soil conditions, the solubility of nutrients increases and they are leached-out. Citrus trees thrive well in the soil with a pH of 5.5-6.5. Therefore, where soils are having pH less than 4.5, lime should be added to the soil.

ii. Nutrient element balance

Plant growth is a function of two variables of the nutrition, viz., intensity and balance. Here intensity refers to the actual total concentrations of all the functional elements in the leaf, while balance is the relative proportion among the essential elements. An increased supply of nitrogen will result in increased production when other elements are present in optimum balance and intensities. It is reported that leaf nitrogen levels decrease with the addition of lime. Even in the case of optimum supplies of nitrogen, increasing the calcium supply results in decreased uptake of nitrogen. It is also reported that the nitrogen/calcium ratio plays a role in the concentration of potassium and mag-

nesium in leaves. Potassium can accumulate in citrus leaves only when nitrogen/calcium is rather large.

iii. Rootstock effects

The significance of rootstocks influence on the mineral nutrition of scion in citrus was first brought into light by Haas and Halma, 1929. They reported that not only is the amount of mineral nutrient in the scion affected by the rootstocks, different scions are able to obtain nutrients in different degrees from different rootstocks. For example, citrus trees budded on rough lemon are less susceptible to boron deficiency in the soil due to more efficient uptake of boron. Influence of rootstocks on concentration is to a much greater extent in micronutrients than in macronutrients.

1.2.1.2 Dosage of manures and fertilizers

The following points are to be considered while determining the dosages of fertilizers in citrus:

- ⊖ Nutrients uptake by the trees from soils.
- ⊖ Location specific field trials.
- ⊖ Soil and leaf analysis.
- ⊖ Field observations on deficiency symptoms.
- ⊖ Available literature.

Citrus trees require huge amounts of plant nutrients uptake from the soils for their growth and development. The table 9 shows the amount of removal of nutrients from the soil. In order to maintain soil fertility, and growth and develop-

ment of the citrus trees, the dosages of manures and fertilizers should be based on the amounts of depleted nutrients. The data presented in the table 9 indicate that removal of nutrients from the soil varies not only from species to species but also from trees to trees depending on their fruit habit.

Soil and leaf analysis and location specific field trials are reliable parameters to determine dosages of manures and fertilizers. Neither soil surveys have been done nor have field trials been conducted in most of the citrus growing pockets in Nepal. The manures and fertilizers dosages suggested here are therefore based on the experience of the technicians, farmers and literature available.

It is recommended that 50 % nitrogen should be applied in organic form, i.e. FYM or compost and the remaining 50 % in the form of inorganic fertilizers. Apply 10 kg of FYM or 15 kg of compost in the first year and go on increasing by 10 kg each

year until 10th year. The table 9 gives a general guide and hence, dosages presented in the table 10 need to be adjusted taking into account soil fertility and tree condition of the specific orchard.

1.2.1.3 Method of manures and fertilizers application

In general practices, there are two types of methods of manure and fertilizer application. They are:

- i. Soil application (root feeding)
- ii. Foliar application (foliar feeding)

Soil application (root feeding)

- It is a common method of applying manures and fertilizers for all crops including citrus. Organic manures and chemical fertilizers supplying macronutrients are usually applied in the soil.
- This method is cheaper, easier, and the residual effect is longer.
- Tree basins are first prepared by light hoeing and then manures and fertilizers are broad-

Table-9: Nutrient uptake (kg/ha) by various citrus species

Fruit & type	N	P ₂ O ₅	K ₂ O	CaO
Mandarin				
High yielding	182	54	205	273
Medium yielding	116	36	130	214
Low yielding	58	20	64	141
Sweet oranges				
High yielding	243	54	205	316
Medium yielding	169	41	146	297
Low yielding	36	22	77	206
Lemons				
High yielding	270	54	209	358
Medium yielding	183	34	140	242
Low yielding	94	21	77	193

Source: Rajput and Haribabu, 2004

Table-10: Age-wise dosages of manure and fertilizers for citrus

Tree age in years	Rates of nutrients/trees in gram.		
	Nitrogen	Phosphorus	Potash
Mandarin			
1	75	50	75
2-3	100-110	50-70	75-100
4-5	110-130	70-100	100-150
6-7	130-200	100-150	150-200
8-9	200-300	150-200	200-250
10 and above	300-500	200-250	250-350

- casted. After broadcasting, they are mixed well into the soil by giving a second hoeing.
- ⇒ Alternatively, a trench of 15-20cm wide and 15cm depth is dugout around and below the drip of the tree and then manures and fertilizers are applied in the trench. This is followed by covering with the dugout soil.
 - ⇒ The placement of fertilizer varies with the age of the plant. In case of young trees fertilizers should be applied in the tree basin only and as the trees grows the basin size should be enlarged. In case of bearing trees, a good rule is to cover an area twice the diameter of the tree canopy, because the feeding roots have spread beyond the drip of the canopy. In older groves entire field may be fertilized since the roots are found to spread the whole orchard area.
 - ⇒ While fertilizing the trees, care should be taken to keep the trunks of the trees free from the contact of fertilizers.
 - ⇒ Application of lime in alternate years is essential to maintain optimum soil reaction and to improve the soil structure.
 - ⇒ Localized concentration of fertilizers granules or crystals should be avoided.
 - ⇒ Deep placement of fertilizers should also be avoided. It is because 80-95% feeder roots are spread in the top 10 cm.
 - ⇒ Immediately after manuring and fertilization, trees should be irrigated. If no irrigation, apply fertilizers just after the rain or when there is sufficient moisture in the soil.

Foliar application (foliar feeding)

- ⇒ Micronutrients and urea with low biuret content (less than 0.25%) can be applied through foliar spray.
- ⇒ Any fertilizers, that are to be applied through foliar spray, should be completely water soluble and neutral in reaction.
- ⇒ Foliar application of elements should be done on young leaves or young flushes, when leaves attain half expansion in growth.
- ⇒ It is better and safe to have repeated applications at low concentrations rather than a single heavy dose.

- ⇒ These days, there are some instant mixtures of micronutrients available in the markets. The combined spray of micronutrients as shown in table 11 has been recommended for mandarin.

Table-11: Combined spray of micronutrients

Nutrient supplement	Quantity (kg)
Zinc sulphate	2.5
Copper sulphate	1.5
Magnesium sulphate	1.0
Manganese sulphate	1.0
Ferrous sulphate	1.0
Boric acid	1.0
Slaked lime	1.0
Urea	4.5
Water	450 liters

Note: This mixture should be sprayed on major flush of the leaves expanded to at least two thirds of their normal size

1.2.1.4 Time of manures and fertilizers application

- ⇒ Time of application of manures and fertilizers in citrus depends on types of manures and fertilizers, and phenological stages of the tree.
- ⇒ Organic manures, which are slow to release minerelements, should be applied well before the initiation of new growth and flowering.
- ⇒ Inorganic fertilizers, which are generally quick to release nutrients, should be applied just before the initiation of new growth or at the start of new growth.
- ⇒ 50% of the annual nitrogen requirements and all of the phosphorus and potassium requirements are generally applied in February-March (15-20 days before flowering).
- ⇒ The remaining 50% of the nitrogen is applied after fruit set and during the fruit enlargement period (June-July).
- ⇒ In case of non-bearing young trees, nitrogen fertilizers are applied in 3 split doses depending upon the soil conditions and plant growth. In this case the 3rd dose is applied just after the rainy season. Generally three split doses of nitrogen are recommended only when trees are in poor condition due to root rot.

- ⇒ In India, however, it is recommended to apply Nitrogen in three split doses, during the month of April, August and November, Phosphorus in two split doses during the month of April and August, while Potassium in one dose during the month of November.

1.2.2 Irrigation

1.2.2.1 Importance of irrigation and water stress effect

Irrigation is of great importance in citriculture but it has not been realized by the Nepalese farmers. Citrus fruit trees are grown on uplands where there is no irrigation facility and soil fertility is also low.

Based on the studies in India, it is suggested that about 2000 mm of well distributed annual rainfall is required to maintain good soil moisture condition in citrus orchards. In Nepal, total annual rainfall in citrus growing areas ranges from 1200 mm to 3000 mm which is adequate in totality. The problem is in the distribution of rainfall. More than 80 percent rainfall occurred during the 4 months of the monsoon period (June-July to Sept.-Oct.). This is the fruit growth and maturity periods of citrus and no supplemental irrigation is necessary during this period. Soil moisture in citrus orchards is at tolerable levels up to December. After then, dry season starts and soils of citrus orchards also start to dry.

Water stress can affect citrus at all development stages. Water availability strongly influences flowering and fruit set and can affect fruit drop, fruit size, yield, internal fruit quality characteristics and canopy development. Water stress in spring and summer (February to May) during flowering, fruit set and early cell division will have a big impact on reducing fruit numbers, fruit size and overall yield. Water stress can also restrict vegetative growth and reduce canopy development, which is especially important in young trees and for next seasons flowering sites. During this period, soil moisture of citrus orchards should be at 55-65

percent field capacity. As this is a dry period in Nepal and citrus orchards are not irrigated, moisture level goes far below from this level and this condition results in low productivity.

1.2.2.2 Water requirement

As citrus trees are evergreen in nature, they require water all year round. Normally the peak demand for water is during the warmer and dry months from February to May. Water comprises 85-90% of the citrus fruit mass by weight, so after harvesting the fruit in late autumn or early winter water requirement of citrus trees is reduced for 1-2 months. Rootstocks also vary in their tolerance to water stress levels. Rough lemon, and Carrizo citrange, has good drought tolerance, Cleopatra mandarin and Troyer citrange have moderate tolerance and P.trifoliata and Sweet orange have poor tolerance. Drought tolerance is related to rooting depth.

Irrigation requirement of citrus is also closely related with soil, climate, kind of crops, cultivation practices, variety, age and bearing capacity of the tree. Hence, it is rather difficult to make a general recommendation. However, Lemons require much larger quantities of water than mandarin and sweet oranges. Irrigation requirements of young trees are less than bearing trees. Closely spaced trees require more water than widely spaced trees. Similarly, orchards with inter-crops need more water than the orchards without inter-crops. Fine textured deep soil, soils rich in organic matter and land on a north slope generally need less water than their opposites.

It is estimated that 60 liters of water is required to produce one kilogram of fruits.

1.2.2.3 Method of Irrigation

As already mentioned, citrus trees are not irrigated in Nepal but other citrus growing countries in the world do irrigate citrus orchards by using different methods of irrigation. The commonly used irrigation methods or systems are as follows:

- ⇒ Basin system
- ⇒ Furrow system
- ⇒ Flooding system
- ⇒ Sprinkler system
- ⇒ Drip or trickle system
- ⇒ Pitcher system

Out of these irrigation systems, basin, furrow and flooding systems are conventional surface irrigation methods which need more water. Even if Nepalese farmers want to irrigate their citrus orchards using one of these methods, they do not have water sources. Considering the water sources and efficiency of water use, the sprinkler and drip irrigation systems can be recommended for irrigation of citrus orchards. The rates of water use efficiency of sprinkler and drip systems are 70-80 percent and 80-90 percent, respectively. Micro irrigation which also includes sprinkler system and drip or trickle system has the following advantages:

- ⇒ Water saving up to 40-45%.
- ⇒ Yield increases around 55-60%.
- ⇒ Weed reduction by 40-50%.
- ⇒ The plant growth, fruit development, yields and quality is excellent.

However, the initial installation costs of these systems are high and farmers need support from the government. The pitcher system, which is a modified of drip irrigation developed at Tirupati, India, can also be used by Nepalese farmers to irrigate citrus trees. In this system, earthen pots of 20 liter capacity with narrow mouth and lid are buried up to their necks in the basins of the citrus trees at about 35cm from the trunk. A small hole of 0.3 to 0.4 cm at a height of 5 cm from the bottom of the pot is kept facing the tree trunk. Then pots are filled with water. Water trickle from the pots by force of gravity and soils at the root zone are wet. About 60 percent water is reported to be saved by this method and this system is more suitable for young trees. Nepalese farmers can use this system practically and hence, introduction of this system in Nepal is recommended.

1.2.2.4 Frequency of irrigation

Generally, citrus trees are irrigated at 15 days intervals during winter and it is much shorter during the dry season. In Nepal, it is not possible to irrigate citrus trees in such short intervals. From irrigation perspective, there are three critical stages of citrus trees during the dry season starting from February to May. They are new growth and flowering, fruit setting, and early stage of fruit growth. Citrus trees are very active from February to May in which bud differentiation, bud breaking, flushing, flowering, and fruit setting occur. During this period, soil moisture of citrus orchards should be at 55-65 percent field capacity. As this is a dry period in Nepal, moisture level goes far below from this level and hence, at least 3 irrigation- 10-15 days before flowering, 15 days after flowering and 1 month after second irrigation- are recommended.

1.2.3 Soil tillage

Soil tillage includes all the practices from clean cultivation throughout the year to no cultivation at all or zero tillage. In Nepal, clean cultivation is favored which have the following advantages:

- ⇒ It helps in controlling and eradication of weeds.
- ⇒ It also helps in conservation of soil moisture.
- ⇒ It provides adequate aeration by increasing the porosity of the soil.
- ⇒ It helps in killing of many pests hibernating in the soil.

However, if cultivation is deep and close to the tree trunk, it may injure roots and creates favorable condition for Phytophthora root rot. This situation is commonly found in those orchards where maize is grown as an inter-crop. Therefore, clean cultivation, though desirable, should not be overdone at the expense of tree health.

1.2.4 Mulching

Mulching around tree basins with organic materials such as straw, saw dust, rice hulls, dry leaves,

weed scrapings, plastic or compost will have the following advantages:

- ⇒ Assist in suppressing weeds by excluding light from the soil surface.
- ⇒ Mulch will also help retain moisture in the top-soil by reducing surface evaporation, as well as moderating soil surface temperatures.
- ⇒ It also helps in preventing soil erosion by reducing run-off water.
- ⇒ Enhance the decomposition process of organic matter.
- ⇒ NPK contents of the soil are increased.
- ⇒ Help maintain the soil organic matter at desirable levels.
- ⇒ Soil structure is improved.
- ⇒ It also increases the content of available potassium, thus helping to overcome potassium deficiency.

However, the mulch should not be in contact with the trunks of the trees, as this can provide a site for pests and diseases to attack the tree. The bark becomes soft and vulnerable to cold and to attack by pest and disease if it is covered by moist organic matter. In Nepal, the best time for mulching citrus orchards is September-October. It is because the moisture is available in the soil and organic materials, such as scrapings of weeds, are also easily available for mulching. If mulching is done before surface soils are dried, it helps to retain moisture. Mulching the soil conserves the moisture to the extent of approximately 10 percent as against non-mulching. It is recommended to do mulching to a depth of 8 cm. Mulching should particularly be an established practice for those orchards which are established on uplands.

1.2.5 Soil pH and Liming

1.2.5.1 Soil pH

The soil pH (whether a soil is acidic or alkaline) is an important property. It affects the availability of nutrients and also the activity of microbes and other tiny creatures in the soil.

In general, the best soil pH for citrus trees is between 5.5 and 6.5. If the pH falls below 5.0, aluminum toxicity and manganese toxicity often occur in citrus roots. A low pH also causes a deficiency of nutrients such as calcium, magnesium and phosphorus (which are easily fixed by soil particles) and molybdenum.

Liming with limestone or dolomite is the usual action taken to correct soil pH. Growers should also avoid applying too much ammonium, in the form of nitrogen fertilizers such as urea or ammonium sulphate. This is because there is a danger of making the soil more acidic.

1.2.5.2 Liming

Lime materials should be applied if the orchard is on sloping land from which the soil cations have been leached, and where the soil pH is lower than 5.0, indicating strong acidity.

1.2.5.3 Liming materials

Limestone is normally applied to acidic soils of citrus orchards where there are no symptoms of magnesium deficiency. However, if magnesium deficiency is observed, growers are strongly recommended to supplement the magnesium with dolomite limestone.

Liming materials can be compared and evaluated in terms of their neutralizing value or calcium carbonate equivalent. If the neutralizing value of pure limestone (CaCO_3) is considered to be 100%, then the corresponding values for other lime materials are:

- ⇒ 179% for burnt lime, CaO ;
- ⇒ 135% for slaked lime, Ca(OH)_2 ;
- ⇒ 119% for magnesium carbonate, MgCO_3 ;
- ⇒ 100-119% for dolomite limestone, $\text{CaO} + \text{MgCO}_3$.

1.2.5.4 Application of liming materials

- ⇒ In orchards where the soil pH is found to be below 5.0, liming materials should be applied after the fruit is harvested. They should be

incorporated into the soil at a depth of at least 15 - 30 cm, since lime has poor mobility in the soil.

- ⇒ In terms of quantity, lime is normally recommended @ 5-7 kg/tree. Another way of calculating the application rate is one metric ton/hectare for sandy loam, 1.5 metric tons/hectare for silt loam or loam, and two metric tons/hectare for clay loam.
- ⇒ Mixing manure or compost with the lime materials is recommended. This helps to keep the soil aerated, and avoids compaction. Chemical fertilizers should not be applied at the same time as lime, since this would reduce the fertilizer efficiency of the nitrogen. Inorganic fertilizers may also be applied separately, one month after applying the lime materials.
- ⇒ Routine soil monitoring of soil pH is needed to determine whether there is a need for lime materials. Growers should not apply lime unless it is needed. Not only is it wasteful, but micronutrient deficiencies may occur if growers apply too much lime. For this reason, annual lime applications should be discontinued when the soil pH has been modified to more than 6.0.

1.2.6 Inter-cropping

- ⇒ As most of the citrus growers in Nepal are small farmers, they cannot wait 5-6 years to get income from their lands by growing citrus. They need quick and additional income from their lands which is possible by inter-cropping in the orchards. In fact, inter-cropping or growing additional crop not only provides additional income to the orchardist but it also checks weed growth, conserves soil moisture and prevents soil erosion.
- ⇒ Wide range of inter-crops like maize, millets, potato, mustard, vegetables including garlic, and even paddy are grown in mandarin orchards. Exhaustive crops like Maize, millets, wheat and paddy are not suitable for inter-cropping in citrus orchards for many reasons. Therefore, selection of inter-crops is of utmost impor-

tance. The inter-crops should be shallow rooted and short duration ones with higher income potential. Pea, cowpea (dwarf), French beans (dwarf type), soybean, black gram, moong, mustard, chili, garlic and gram could be beneficial inter-crops in mandarin orchards. Short duration fruit crops, like pineapple and papaya, can also be grown in citrus orchards as fillers provided these fillers are well spaced from the main trees and removed when citrus trees attain bearing stage.

- ⇒ Inter-cropping should be practiced only in the early stages of the orchard (up to 5th year). It should not be overdone in a way to cause injury to the trees. Inter-crops should be additionally manured and fertilized. The pests and diseases of the inter-crops should not attack the main crops.
- ⇒ Inter-cropping during flowering and fruit setting period is not desirable because orchard trees require maximum nutrients and moisture during this period

1.2.7 Weeding

Weeds are a serious problem in mandarin orchards particularly, young plantations. It is because citrus trees have a shallow fibrous root system compared with some other tree crops. Consequently citrus is susceptible to weed competition. Hence, citrus trees, particularly young ones, respond well to a weed-free growing environment. Tree basins up to the canopy spread should be kept free of weeds all the time of the year. Otherwise they compete with fruit trees for moisture and nutrients; and provide shelter for pests and diseases.

Major weeds can be controlled by hand pulling, cutting, hoeing, burning and tillage. However, frequent tillage may destroy the surface structure of soil, thus lowering the water holding capacity and permeability of soil.

An alternative way to eradicate weeds is use of herbicides. Pre emergence application of Diuron (5kg/ha) or Terbacil (4.5 kg/ha) or post emergence

application of Atrazine (5-6 kg/ha) controls weeds significantly. Further, Bromocil (6 kg/ha) is most effective in controlling both monocot and dicot weeds. Glyphosate (5 liters/ha) is most effective in controlling perennial grasses. Simazine (5 kg/ha) is also highly effective.

Weed matting is also used in some countries which is a woven polypropylene material that is used to cover the soil surface to prevent weed growth. Weed matting allows passage of water and air but excludes light from the soil surface, preventing weed germination. It is widely used in the nursery industry and has been successfully used to a limited extent in citrus groves to eliminate weed competition without the use of herbicides.

1.2.8 Training and pruning

In Nepal citrus trees are not generally pruned but to give an ideal shape and to keep the tree healthy, tree training and pruning is essential. An ideal mandarin tree should be low headed with a dome like crown. This can be achieved by pruning young trees. Pruning of young tree to give them proper shape and size is known as training. To give a desirable shape to the plant, pruning is restored to during initial years of planting. Trees are trained to single stem with 4-6 well spaced branches for making the basic framework. Further, the lowermost branches should be allowed not to grow below the height of 50 cm from the soil surface.

The bearing trees require little or no pruning. Main objective of pruning the bearing trees is to maintain the framework and to secure higher yields with better quality fruits. Pruning of bearing trees though differs with variety but chiefly consists of removal of dead, diseased, criss-cross and weak branches. Removal of water sprouts and sucker of rootstocks is also highly essential. Pruning of non-bearing trees can be done at any time of the year, but for bearing trees the best time is after harvesting, during late winter or early spring when these are in somewhat dormant

stage. Root pruning is also practiced in some countries including India to regulate flowering season. However, such pruning is not beneficial in the long run.

1.2.9 Soil organic matter

Soil organic matter is often referred to as humus. This is the product of the decomposition of crop or animal residues by soil microorganisms. It is a dark-colored and relatively stable material which is resistant to further rapid degradation. Soil organic matter is very important for sustainable soil management in citrus production as it enhances the formation of soil aggregates. These in turn help to maintain a good soil structure for drainage and aeration. Humus also increases the cation exchange capacity, strengthening the soil's ability to hold fertilizer (nutrients) and water. It also serves as a nutrient reservoir, because part of the organic matter is being decomposed by a continuous soil mineralization process. In the process, it supplies crops with different kinds of nutrients including nitrogen, phosphorus and sulfur.

In Nepal, it is not realistic and possible to increase the level of organic matter in orchard soils by applying organic fertilizers alone, especially if the local materials and labour taken into account. We need to apply at least 20 metric tons of organic fertilizer to the soil if we are to increase the soil organic matter level by 1%. Growers must endeavor to keep the soil organic matter content above 2%. The use of grass cover and plant residues is a practical and economical way of increasing or maintaining the level of soil organic matter in orchards. If organic fertilizers with high nitrogen content are being used, the amount of nitrogenous chemical fertilizers can be reduced considerably. Farmers should not apply fresh livestock manure. Citrus roots may be injured by incompletely decomposed manure. Large quantities of readily available organic matter can be supplied by the roots of grass cover, grass mulch from weeding, and pruned twigs which have been shredded into small pieces.

Green manures or green manuring crops are also other sources of organic matter. They also help in conserving soil and water in the orchards. Common green manure crops in citrus orchards are various legumes such as perennial peanut, Berseem, clover etc.

1.3 Major Diseases of Citrus and their Management

Despite many diseases reported to attack citrus crops in Nepal, Huanglongbing (greening) disease is the number one threat to the citrus industry followed by Phytophthora induced diseases. Other diseases associated with citrus decline in Nepal are Tristeza, canker, twig blight and powdery mildew diseases. Management of major citrus diseases is discussed below.

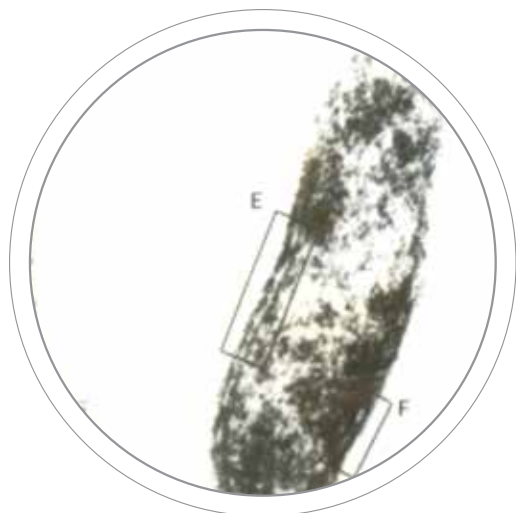
1.3.1 Huanglongbing (Greening) disease

It is one of the serious problems for citrus fruit production in Nepal. The disease was reported by different names; "Likubin" in Taiwan, Leaf Mottling in Philippines, Huanglongbing in China and Citrus Greening Disease in South Africa, India including Nepal. The 13th Conference of International Organization of Citrus Virologists (IOCV) held in Fuzhou, China in 1995 has recommended naming this disease as HUANGLONGBING in honour of

the Chinese scientist Prof. Lin who first described the disease by this name during 1940-1955. Therefore, it has to be called as Huanglongbing (HLB) worldwide. The disease caused by the phloem-restricted gram negative bacterium known as *Candidatus Liberibacter asiaticus*. It is a gram negative bacterium. It is polymorphic in nature and cannot be cultured in artificial media.

Symptoms

- ⊖ At the beginning yellowing of single or few branches is observed in some trees of the orchard which gradually spreads out to other branches.
- ⊖ Thus, slightly infected tree becomes severely affected with symptoms like open growth, stunting, twig die back, sparse foliage and severe leaf and fruit drop.
- ⊖ The whole orchard declines within 2-3 years
- ⊖ Leaves are reduced in shape and size.
- ⊖ Leaf mottling and specific mosaic symptoms are common.
- ⊖ Matured leaves often show irregular patches between the main veins.
- ⊖ Sometimes vein corking is also observed.
- ⊖ The veins are often prominent and yellow.
- ⊖ Excessive leaf drop and unseasonal flushing with very small but erect type of leaves are developed.



Pathogen: *Candidatus Liberibacter asiaticus*



HLB infected mandarin tree



Symptoms of HLB on mandarin leaves



Two half infected fruits at the center

- ⇒ Infected fruits are under developed and reduced in size with lopsided shape.
- ⇒ Most of them remain green or poorly colored even after maturity specially at the rind part.
- ⇒ Fruits have aborted seeds.
- ⇒ The juice contains higher percentage of organic acids, lower percent of sugar and other soluble solids as compared to that of normal ones.

Transmission-

A. By Insect Vector- Citrus psylla- *Diaphorina citri* is the vector of HLB in Nepal. Single individual of citrus psylla either adult or at the stage of 3rd, 4th and 5th instars are capable of transmitting the disease. The type of transmission is persistent type i.e. once the individual acquires the infection it becomes capable of transmitting the disease for

lifelong because the HLB bacterium is multiplied within its body.



Adults of citrus psylla

Nymphs of citrus psylla

B. By Grafting - HLB is graft transmissible disease. It is easily transmitted to new areas if the scion is used from the infected mother plant. Therefore development and implementation of "Bud Wood Certification System" is must.

C. Anthropogenic transmission- This type of transmission is related to the transmission of the disease from one place to another by men. Man carries planting materials of citrus from HLB infected areas to new areas. Prominent example of such type of transmission is the distribution of seedlings from the nurseries of Mungling areas where both the source of infection of HLB and vector - citrus psylla are in abundance. Problem of HLB is becoming severe in the areas such as Syadul of Kavre district where farmers have planted saplings produced in Mungling and nearby areas below 100m altitude where the vector multiplies very fast.

Management

- ⇒ Strict maintenance of internal and external quarantine.
- ⇒ Removal of infected trees and their replacement by disease free planting material.
- ⇒ Use of certified healthy planting material (use of citrus saplings raised only within insect proof screen house nurseries and or saplings raised only above 1300 m).
- ⇒ Removal and destruction of alternate host plants of psylla vector - *Murraya paniculata* (Kamini) and *Murraya exotica* (Kadipatti or Asare or Boke jamun or Ban Bakaino).
- ⇒ Control of psylla (*Diaphorina citri*) vector through application of insecticides 0.05% Dimethoate or 0.02% Chlorpyrifos or Imidacloprid at bud burst stage or as and when infestation noticed during March-April and when and as it is necessary.
- ⇒ Two sprays of Ledermycin @ 600 ppm (6 g/10 liters of water) at monthly interval during winter suppresses symptom severity.
- ⇒ Soil application of Zinc Sulphate, Iron Sulphate and Manganese Sulphate @ 150-200 g/tree/year improves general health of HLB infected plants.
- ⇒ Injection of trees with tetracycline antibiotics.
- ⇒ Infected bud-wood could be deactivated by either hot (moist) air, hot water, or 21 days in the heat therapy chamber.

1.3.2 *Phytophthora* induced citrus diseases

Phytophthora infection of citrus is a serious problem in the countries such as Nepal, Bhutan and north eastern states of India where cultivation of citrus is yet through seedlings. It is a soil borne pathogen and remains in the soil for long and infects whenever susceptible host is available. Phytophthora is one of the main causes of citrus decline in Nepal. The disease is caused by different species under genus *Phytophthora* and important species includes *Phytophthora citrophthora*, *Phytophthora parasitica* and *Phytophthora palmivora*.

Symptoms

Different types symptoms developed due to *Phytophthora* infection are:

- ⇒ Damping off of seedlings in seed bed.
- ⇒ Root rot of grown up seedlings in nursery bed or in grown up citrus trees especially when the roots are injured during the cultivation of inter-crops.



Damping off and Root rot in nursery



Gummosis

Crownrot



Foot rot



Declined mandarin tree (left) due to Phytophthora

- ⇒ Foot rot, collar rot, gummosis (gum oozing from bark lesion on the trunk). Foot rot is an injury of bark on the trunk or roots near ground level. Profuse gumming on the surface of the affected bark is the main symptom when gumming starts close to the soil. Exudation of the gum is not conspicuous as is partly absorbed by the soil. As a result of severe gumming the bark becomes completely rotten and the tree dries owing to girdling effect, prior to death the plant usually blossoms heavily and dies before the fruits mature.
- ⇒ Leaf blight and leaf fall.
- ⇒ Brown rot of fruits.

Disease development - *P. parasitica* and *P. citrophthora* produce sporangia and release large number of biflagellate zoospores. In heavy soils which have poor drainage, prolonged and excessive rainfalls during monsoon leads to prolonged contact of the trunk and crown with water and this increases the susceptibility of the host to zoospores and causes foot rot disease. The disease spreads into the main roots and then around the base of the trunk. The gummosis was more in heavy soils than in light soils and that high water table leads to high incidence of diseases. There is

a general practice to inter-cropping in the citrus orchards in Nepal. It is permissible to some extent until the roots of citrus plants are yet limited to a small area. But crops such as maize, millet and vegetables that require heavy weeding and tilling of soil are generally cultivated that attributes to heavy injury of rootlets of citrus and the pathogen of *Phytophthora* easily enters into the roots causing severe root rot. Mandarin and sweet orange of seedling origin are very susceptible to *Phytophthora* and naturally most of them are declined throughout the country.

Management

Nursery Orchards

- ⇒ Produce citrus saplings inside screen house using either solarized and / or fumigated soil media.



Containerized Nursery System



Soil Solarization

- ⇒ Use containerized nursery with sterile media.
- ⇒ While budding, care should be taken to keep bud union at least 25-30 cm above ground level.
- ⇒ Field nursery/ seed bed should be well drained.
- ⇒ Plants from field nurseries should not be taken directly to planting site. Bare roots should be thoroughly washed and dipped in Ridomil Gold (Mefenoxam) solution (2.75 g/liter) + Carbendazim (1 g/liter) for 10 min.
- ⇒ Establish new citrus orchards using only grafted saplings grafted on *Phytophthora* resistant rootstocks viz *Poncirus trifoliata* and citranges. Cultivation of grafted plants on these rootstocks has become the simplest way of controlling *Phytophthora* worldwide.

Since the more than 90 % of mandarin orchards in the country are of seedling origin and prone to Phytophthora, special measures have to be undertaken not only to save these trees but also keep them economically viable. These measures could be as follows:

Inarching or Nechugi- It is most suitable to the plants of below 5-6 years of age. Seeds (2-3) of resistant rootstocks such as Trifoliolate or citranges are sown at the radius of about 40-50cm from the trunk of plant. They are allowed to grow in the field for about 1-1.5 years and then grafted on the trunk in the form of bridge grafting. This gives additional roots to the mandarin plants and becomes tolerant to Phytophthora.



Rejuvenation of foot rot affected plant by inarching

Drenching + foliar spray with 1% Bordeaux mixture- Drenching the soil around the foot of the tree is carried out if the tree is prone to root rot i.e. the roots have been injured during inter-cropping

or due to some other reasons or simply if there is a need to prevent the root rot due to Phytophthora. In this process 1% Bordeaux mixture is freshly prepared, the surface soil around the foot is slightly removed and the Bordeaux mixture already prepared homogeneously poured. After drenching slight irrigation is applied.

Spraying + drenching the diseased plants with either Ridomil Gold (Mefenoxam) @ 2.75 g/liter of water or with Fosetyl-AL @ 2.5 g/liter to cover the full canopy drip area and the basin.



Control of Gummosis by pasting Ridomil Gold

Trunk painting with Bordeaux paint- Scrap the disease portion with a sharp knife without causing injury to the wood. Paste the scrapped portion with Ridomil Gold (Mefenoxam) or Bordeaux paint. Bordeaux painting of tree trunk is recommended twice in a year- before rains and after monsoon period. To prepare Bordeaux paint it is suggested to use monohydrated copper sulphate (1 kg), hydrated lime dust (2 kg) and boiled linseed oil (3 liters).

Preparation of Bordeaux mixture

Bordeaux mixture is very effective fungicide that is used for drenching to protect root from Phytophthora and for foliar spray to protect from several fungal and bacterial diseases such as anthracnose, Phytophthora and others and even bacterial disease of citrus like canker.

Bordeaux mixture is prepared from Copper Sulphate (CuSO_4) and Slaked Lime (CaO).

There are very specific steps for the preparation of Bordeaux mixture that has to be strictly followed otherwise the mixture with inferior quality might be produced. Application of such under quality Bordeaux mixture may do more harm than benefit.

Generally 1% Bordeaux mixture is prepared for foliar spray and drenching.

Tips for the preparation of 1% Bordeaux mixture for required volume of 100 liters

- ⇒ Prepare three non metallic vessels or buckets two small (10-12 liters) and one just double their size (20-25 liters) good enough to contain the required volume of your mixture
- ⇒ Dissolve one kilogram of good quality Copper Sulphate (Powdered) in five liters water overnight. Similarly in a separate vessel dissolve one kilogram good quality Slaked Lime in five liter of water overnight
- ⇒ When both the solutions are ready, pour them together slowly into the third bigger bucket.

- It is better to mix the current of the solutions while pouring and continue stir the mixture
- ⇒ The reaction of the mixture must be neutral. To check the quality of mixture whether it is neutral or not, take clean iron tool/ nail and dip in the mixture for one minute. Take it out and check the color of the surface you dipped after removing the mixture. If it is unchanged, the mixture is of good quality you can spray it. If the surface has changed the color as rusting then it is acidic and cannot be sprayed on plants. In such case add some lime solution in the mixture and mix it thoroughly and check its reaction as above until it becomes neutral. This solution can be used for Pasting/Painting.
 - ⇒ To make 1% Bordeaux mixture solution, add 90 liters of water to this to make a total volume of 100 liters. This mixture is ready for spraying.
 - ⇒ The Bordeaux mixture should be sprayed fresh within six hours of preparation.

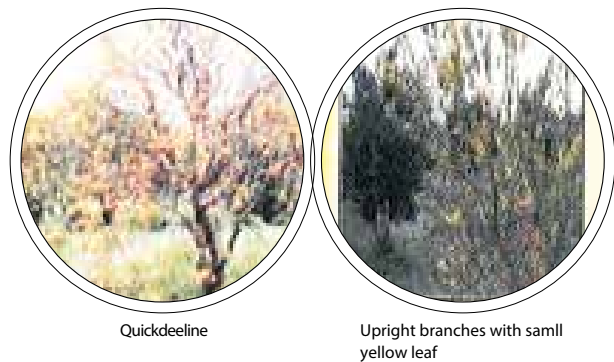
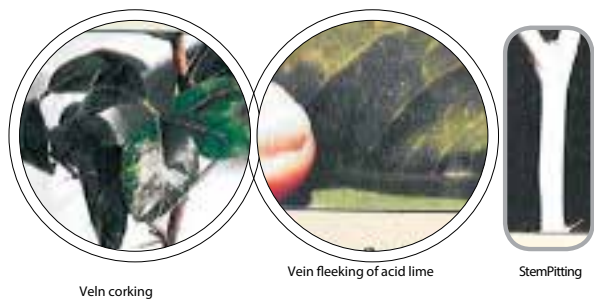
1.3.3 Citrus Tristeza Disease

Tristeza (a word that described the sad appearance of a tree) disease is caused by Citrus Tristeza Virus (CTV) and responsible for serious damage to citrus industry in many countries. It was severe problem in Brazil and South Africa till 1960s when the citrus industry was established on sour orange rootstocks. Now the resistant stocks have been developed and used that minimized the damage of citrus due to CTV. However, it is still a severe problem in many countries where the severe strains of CTV exists or introduced from abroad without following strict quarantine procedures. There are reports of about 12 strains in the world varying from very mild strain to very severe strain. The strain that causes stem pitting on lime has been reported from Nepal.

Symptoms

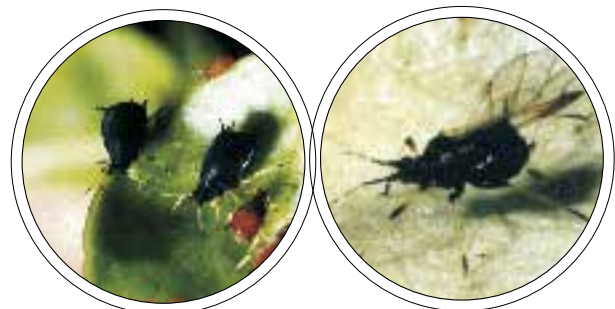
The virus causes diverse field symptoms based on citrus cultivar, environment condition and virus strain involved. Sudden and quick decline of trees, leaves develop various deficiency symptoms,

and leaf falling, root decay and twig die back and ultimate death of the tree are also conspicuous. Affected trees have a tendency to blossom heavily in off-season. Specific symptoms of CTV infection are honeycombing, pitting of inner face of the bark of the trunk, severe stem pitting develops in species like lime, grape fruit, pummelo, sweet orange, sweet lime etc. The definite test for presence of CTV requires greenhouse assay through indexing on indicator plants like Indian Kagzi lime, Mexican lime, etc. where definite symptoms of vein clearing and stem pitting confirm the virus.



Transmission-

CTV is a graft transmissible disease. It can be transmitted through the infected scions during grafting and also with the grafting knives. Different species of aphids viz. *Toxoptera citricida*, *Aphis gossypii*, *Toxoptera aurantii* etc transmit the CTV efficiently in field condition.



Brown citrus aphid: *Toxoptera citricida*

Management

- ⇒ The disease can be kept under control by use of tolerant rootstocks, such as rough lemon, trifoliolate orange, citranges, etc.
- ⇒ The bud wood to be used for propagation should be free from CTV.
- ⇒ The aphid (vector) population can be reduced considerably by insecticidal spray. For recommended insecticidal spray see management of brown citrus aphid (page 38).
- ⇒ If virulent stem pitting strains and *T. citricida* are endemic, citrus scion varieties tolerant to CTV should be planted. These include mandarins, pummelos, tangelos and tangor. Only CTV-tolerant or resistant rootstocks should be used.
- ⇒ Use healthy bud-wood and nursery rootstock that are free of disease.
- ⇒ Trees that decline or become stunted can either be replaced or simply removed and neighboring trees allowed filling in.
- ⇒ Encourage natural enemies (predators and parasitoids) against these aphids.
- ⇒ Most CTV spread occurs during spring and autumn when temperatures are mild. This is concomitant with when CTV titre (virus replication) in infected citrus trees is highest and when shoots growth and migration of *T. citricida* peak. Therefore, this time frame should be targeted if chemical control is attempted. Vector control using insecticides: 0.05% Dimethoate or 0.02% Chlorpyrifos. Imidacloprid is also effective against aphids. Neem seed extract (azadirachtin) had a marked effect on the survival, longevity and fecundity of *T. citricida*.
- ⇒ Exercise internal plant quarantine. A strong regulatory component is necessary, covering both propagation and inoculum control (detection and removal of wild and possibly urban reservoirs of CTV).
- ⇒ Use effective biological control agents against nymphs and adults of psyllids like syrphids, chrysopids and lady beetles

CTV is spread throughout the country, however, mandarins are non-symptomatic and somewhat tol-

erant. There is a need for proper diagnosis of CTV and stop its spread through propagating material as there is always a possibility of natural emergence or accidental introduction of new severe CTV strain that may cause more serious problem in future. Similarly, one has to be very careful not to introduce severe strains of CTV from other countries.

1.3.4 Citrus Canker

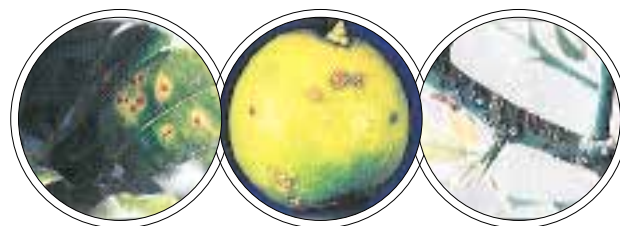
This disease is caused by bacteria named *Xanthomonas axonopodis* pv. *citri*

Symptoms

Conspicuous raised necrotic lesions develop on leaves, twigs and fruits.



Healthy (left) and Canker infected (right) leaf



Canker infected acid lime leaves, fruit and twig

Management

- ⇒ Pruning and destruction of infected twigs before monsoon.
- ⇒ Three to four sprays of Copper Oxychloride (0.3%) in combination with Streptomycin 100 ppm or Streptomycin Sulphate (500 ppm) at monthly interval after the onset of monsoon is recommended.



White powdery mass on the infected leaves and twigs

1.3.5 Powdery Mildew

The disease is caused by fungi *Acrosporium tingitaninum* (synonym *Oidium tingitaninum*). Powdery mildew was found to be a major problem in eastern Nepal since 1977 where high humidity with high temperature remains for long. The disease damages plants in orchards as well as in nursery. It not only damages the new flushes causing defoliation but also causes die back and fruit drop.

Management

- ⇒ Avoid dense planting. maintain the recommended planting distance.
- ⇒ Remove unnecessary branches from tree by pruning to allow air and light to pass.
- ⇒ This disease is prevalent in new flushes therefore remove false branches and water shoots from the base and stem of the tree.
- ⇒ Prepare spray solution by mixing 1 part cow urine and 2 part water and spray tree at 5 days interval at the time of new flushes. However, the quantity of spray solution varies (two to three liters/tree) with the stage of the tree.
- ⇒ 80% Wettable Sulphur such as Sulfex, Cosan or Insuf at the rate of 2 g/liter of water can be sprayed at the onset of this disease at 10-15 days interval. Alternatively, Karathane at the rate of 2 ml/liter of water at 10-15 days interval is also effective against this disease. While spraying foliage must be thoroughly wet. A full grown tree may require up to 3 liter spray solution.

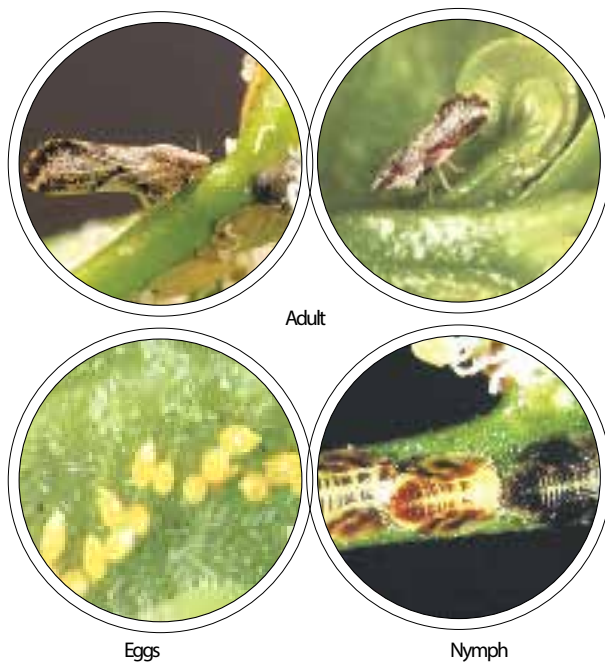
1.4 Major Insect Pests of Citrus and their Management

Different insect pests caused damage to citrus leading to their decline. Major pests found in Nepal are illustrated here under.

1.4.1 Citrus Psylla, *Diaphorina citri* (Kuwayama)

Damage

Citrus psylla sucks sap from the foliage and excretes sugary liquid that covers leaves with honey dew. It attributes to the heavy development of sooty mold on honeydew-covered leaves and whole tree. Most important role of citrus psylla is transmission of bacteria that causes Huanglongbing (greening) disease. Feeding by psyllids in the diseased plant for a minimum period of 15 minutes is sufficient to transmit causal agents (phloem limiting organisms) of greening disease in the healthy plants.



Citrus psylla thrives and multiplies on all the species of citrus and some other species of Rutaceae family. The most important host plants are *Murraya paniculata* (Kamini) and *Murraya exotica* (Kadipatti/Bokejamun/Asare/BanBakaino). These

plants are preferential hosts of citrus psylla on which it multiplies very fast during May-October. *Murraya exotica* grow in wild at low altitude of Dhading, Tanahun and Lamjung district and HLB also is severe problem in this area.

Management

- ⇒ Uproot and burn wild host plants *Murraya exotica* and *Murraya paniculata*.
- ⇒ Insecticide application: Treat plants with aqueous solution of either of the insecticides as follows: 0.05% Dimethoate or 0.02% Chlorpyrifos or Imidacloprid at bud burst stage or as and when infestation noticed during Feb.-Mar, Jun.-Jul. and Oct.-Nov. Neem oil and petroleum spray oil are also used against *Diaphorina citri* in India and China.
- ⇒ Use effective biological control agents against nymphs and adults of psyllids. Predators like syrphids, chrysopids and lady beetles, and parasitoid like *Tamarixia radiata* are effective against them.

1.4.2 Citrus Leaf Miner, *Phyllocnistis citrella*

Damage

Larval feeding causes serpentine silvery mines on young leaf leading it to wrinkling and curving up. Such leaves when developed are mottled and curved due to the unbalanced growth of leaves between infested and non-infested parts of leaves. Injury to acid lime leaves predisposes it to canker infection.



Adult

Infested leaves

Affected seedlings



Symptom on leaf-serpentine mines with a silvery appearance

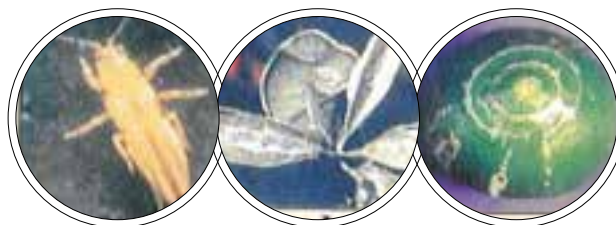
Management

- ⇒ Prune growth flushes
- ⇒ Mechanical control of mining larvae.
- ⇒ Fertilize in late winter to promote strong spring growth.
- ⇒ Do not over-water in autumn.
- ⇒ Do not fertilize during summer use summer oil at 0.25 to 2.0 % concentration.
- ⇒ Treat plants with insecticides: 0.05% Dimethoate or 0.02% Chlorpyrifos at weekly intervals on new flush as soon as infestation is noticed.
- ⇒ A single application of 0.02% Imidacloprid resulted in the control of leaf miner for more than 100 days.
- ⇒ Planting goat weed, *Ageratum conyzoides*, as ground cover under citrus plant.

1.4.3 Citrus Thrips, *Scirtothrips dosalis*

Damage

Attacked leaves become cup shape, leathery, crinkled and mottled and have whitish two parallel lines on either side of mid rib. Infested fruits have silvery ring around the neck.



Adult

Infested leaves

Affected fruit

Management

Foliar spray either with 0.05% Dimethoate or 0.02% Chlorpyrifos at bud burst stage and berry size fruits.

1.4.4 Brown Citrus Aphid, *Toxoptera citricida* (Kirkaldy)

Damage

T. citricida only feeds on newly developed terminals including unexpanded and young expanded leaves and flower buds of citrus and citrus relatives.

- ⇒ Withdrawal of large quantities of sap from the foliage.
- ⇒ Heavy development of sooty mold on honey-dew-covered leaves.
- ⇒ Transmission of Citrus Tristeza Virus (CTV), a phloem-limited closterovirus.
- ⇒ *T. citricida* also transmits citrus vein enation (woody gall) luteovirus.



Parasitized brown citrus aphids: *Toxoptera citricida*

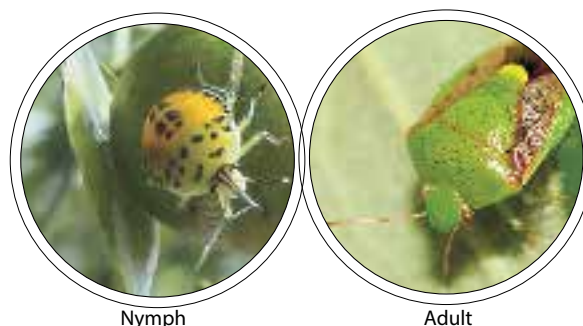
Management

- ⇒ If only few plants in an orchard are infested, monitor these plants and spray only selected plants with insecticides like Quinalphos (0.5%) or Phosalone (0.5%) at 10 days interval.

1.4.5 Green Stink Bug, *Acrosternum hilare*

Discolouration or deformation of immature fruits. Fruits with black dots surrounded by chlorotic field. Premature fruit drop. Secondary fungal and bacterial infections in fruits.

Fruit drop due to incidence of bugs ranged from 92-100% depending upon their population.



Management

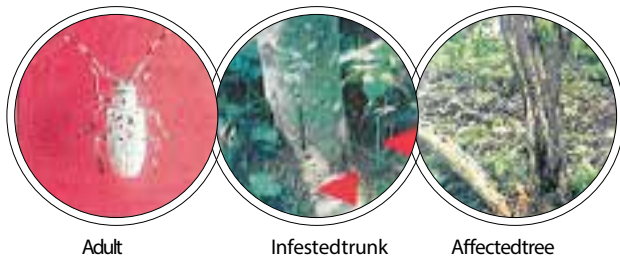
- ⇒ Collection and destruction of eggs on leaves. Sweepnet collection and destruction of adults. Collection and destruction of gregariously feeding nymphs on immature fruits.
- ⇒ Spraying with 0.05% Fenitrothion or 0.03% Chlorpyrifos gives good result.
- ⇒ Spraying demoulting hormone such as Buprofezin (aplaud) at the rate of 1 g/liter of water gives good result.
- ⇒ Biological control of eggs by means of *Trissolcus laticulcus*, *Anastatus* sp. and *Ooencyrtus utithea* sae.

1.4.6 Citrus Trunk Borer, *Chelidonium cinctum*

Damage

It occurs in neglected orchards and high rainfall area of hilly region. Grub bores the trunk at

ground level horizontally up to the pith and then tunnels vertically and again horizontally for exit. Attacked trees gradually dry up.



Adult

Infested trunk

Affected tree

Management

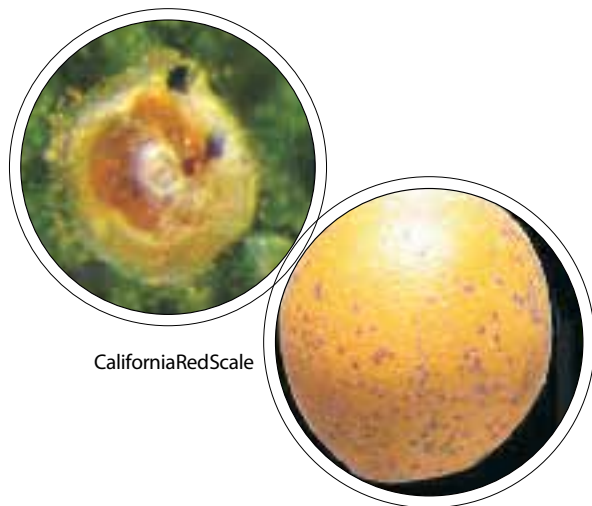
Swabbing of tunnel either with Dichlorvos (0.1%) or Carbaryl (0.1%) kills the grub effectively. Even injecting petrol in the borer holes and plugging with wet mud reduces damage.

1.4.7 Scale Insects

1.4.7.1 California Red Scale, *Aonidiella aurantii* (Maskell)

Damage

- ⇒ Withdrawal of sap from foliage.
- ⇒ Leaf yellowing and drop.
- ⇒ Dieback of twigs and limbs.
- ⇒ Occasionally death of the tree.



California Red Scale

Tree damage is most likely to occur in late summer and early fall when scale populations are highest and moisture stress on the tree is greatest.

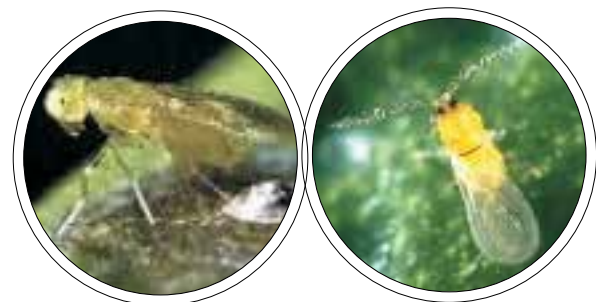


Infested fruit

colony

Management

- ⇒ Burn the dropped infested leaves and fruits.
- ⇒ Prune the infested and dead twigs.
- ⇒ Brushing or high pressure washing of twigs and trunks is recommended.
- ⇒ Treat plants with 0.05% Dimethoate or 0.02% Chlorpyrifos.
- ⇒ Use summer oil at 0.25 to 2.0 % concentration.
- ⇒ Lady beetles are efficient scale regulators.



Red scale parasitoids

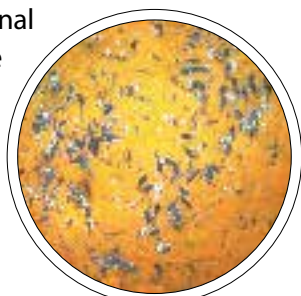
Citrus red scale parasitoids

1.4.7.2 Citrus Purple Scale, *Lepidosaphes beckii* (Neumann)

Damage

- ⇒ Yellowish halos develop on leaves.
- ⇒ Young fruit the feeding sites remain green.
- ⇒ Defoliation and twig dieback in limited patches on the lower north side of trees.

Purple scale is an occasional pest in areas where the climate is mild and humid. It attacks all parts of the tree. It is noted that young orange trees are not attacked by *L. beckii*.



Citrus purple scale, *Lepidosaphes beckii*, on orange

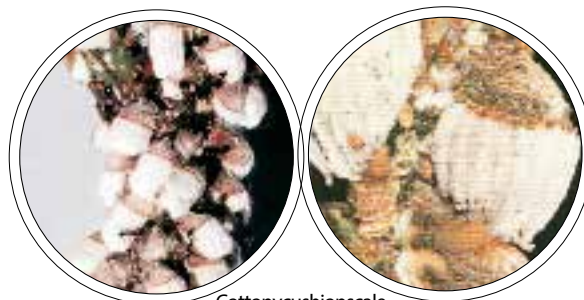
Management

- Dispersal from plant to plant occurs through the activity of crawlers at points where adjacent plants touch. Thus, spread of infested material can be reduced by pruning and allowing adequate spacing between plants throughout cultivation. Mechanical control can be achieved by scraping and scrubbing to remove scales.
- Burn the dropped infested leaves and fruits.
- Prune the infested and dead twigs.
- Brushing or high pressure washing of twigs and trunks is recommended.
- Treat plants with insecticides: 0.05% Dimethoate or 0.02% Chlorpyrifos. It is suggested that treatment should be begun as soon as scales are detected, even in small numbers.
- Use summer oil at 0.25 to 2.0 % concentration.
- Lady beetles are also efficient scale regulators.

Purple scales are most likely to build up on dusty trees, such as those next to dirt roads. If a treatment is needed, it may be sufficient to spot treat with an oil spray or wash the dusty trees with water.

1.4.7.3 Cottony Cushion Scale, *Icerya purchasi* (Mask)

Nymphs are shiny reddish insects located under waxy covering. They are mostly found on the lower surface of particularly along the midrib. Adult female is a flat, oval, grey colored soft-bodied insect with a white fluted ovisac at its anal end. Males are rarely seen.



Cottony cushion scale

Damage

The insect sucks plant sap. When they occur in large numbers the infested leaves turn yellow and fall prematurely. Young shoots may die. The insect excretes a lot of honeydew upon which sooty mould develops.

Females lay up to 700 eggs within the ovisac. Incubation period is about 24 hours in summer but it may extend to several weeks in winter.

The newly-hatched nymphs move about for some time and finally establish themselves on leaves and twigs. The nymphs undergo three moults in case of females. Although the males rare the sexual differentiation is initiated in the 2nd instars.

Management

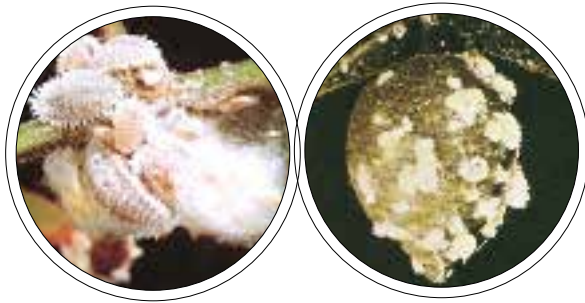
- Spraying of infested plants with 0.025% chlorpyrifos gives satisfactory reduction of pest population.
- Foliar spray of 0.025% dizonon, busudin is also effective against this pest.
- Vedalia lady beetle (*Rodolia cardinalis*) and parasitic fly (*Cryptochactum miceryae*) are used to control cottony cushion scale population.

1.4.8 Citrus Mealy Bug, *Planococcus citri* (Risso)

The insect normally occurs on the lower surface of leaves. Their presence is conspicuous by the white mealy covering.

The nymphs suck sap from the plant. Affected plants become weak, yellowish and may die. They

also excrete honeydew which is responsible for development of sooty mould and interference with the photosynthetic activity of plants.



Citrus mealybug

The females lay eggs in cluster on the plants. The eggs remain under protective covering of cottony masses. Each egg cluster consists of about 300 eggs. Incubation period occupies 10-12 days.

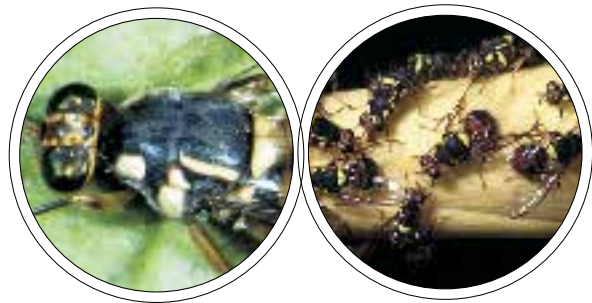
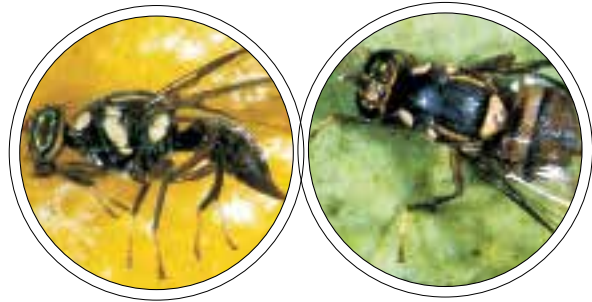
Nymphs upon hatching move about and settle by piercing the leaf tissue. Soon after, a white waxy coating is formed over the insect body. The male nymphs pass through a pupal stage. They spin cottony cocoons for pupation. Nymphal period lasts for 2-3 weeks. In case of female nymphs there is no pupal stage and they become adults after a nymphal period of 1 ½ -2 months.

Management:

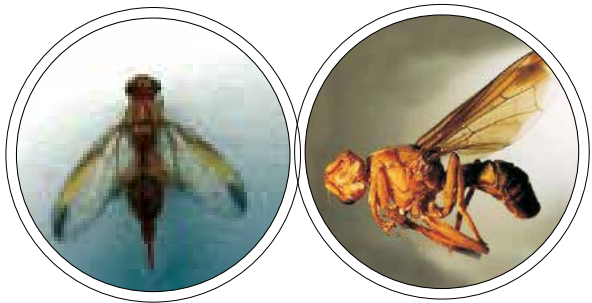
- Agrispray or servo oil spray at the rate of 10 ml/liter of water can be used against this pest.
- Spraying of Dimethoate (0.6 ml/liter of water) or Malathion 50EC (1 ml/liter of water) gives satisfactory results (reduction in pest population and damage).

1.4.9 Oriental fruit fly, *Bactrocera dorsalis* (Hendel) and Chinese fruit fly, *Bactrocera minax*

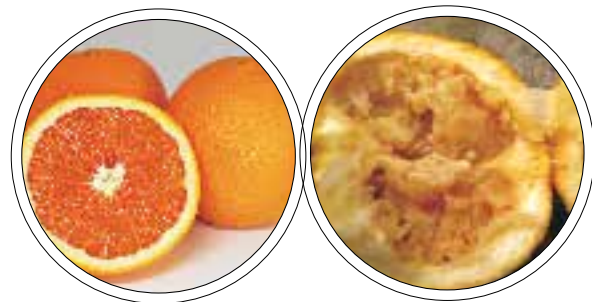
These fruit flies are reported economically impairing the citrus crops in the eastern middle mountains. About 60 to 70 percent citrus fruit dropping occurred in an infested fruit orchard in Bhojpur and Dhankuta districts due to these pests.



Oriental fruit fly: *Bactrocera dorsalis*



Chinese citrus fly: *Bactrocera aminax*



Healthy fruit

Damaged fruit

Management:

- ⇒ Install simple physical barrier to oviposition but it has to be applied well before the fruit is attacked.
- ⇒ Regular collection of dropped infested citrus fruits and feed them to domestic animals. Never put into manure pit.
- ⇒ Frequently shallow ploughing of soil under the canopy of tree in an orchard.
- ⇒ Regular collection and destruction of fruit flies trapped in methyl eugenol trap installed with a minimum density of one trap/hectare.
- ⇒ Neem seed kernel extract can deter oviposition.
- ⇒ Treatment of soil under the canopy of a tree with 0.025% Chlorpyrifos (Trade names: Dursban, Classic, Tarkash or others).
- ⇒ Applying poison bait prepared of protein hydrolysate and Malathion 50 EC (at 10:1 ratio) in early may to late july at 15 days interval is effective against *B minax* where as pheromene traps containing 0.1% methyl eugenol and 0.05% malathion is effective against *B dorsalis*.
- ⇒ Spray 0.025% Chlorpyrifos @ 20 to 60 ml/tree as spotspray to the inside, northeast quadrant of the tree every 10 to 15 days.
- ⇒ Cover insecticide spray of Malathion 50EC @ 1 ml/liter of water in a week prior to flowering and subsequent applications a week after fruit setting and a month prior to harvesting fruits.

2 Fruit Drop Management in Mandarin orange

In case of high fruit drop the following schedule has been found to be effective

Early Drop Control.

- ⇒ Spray 2,4-D 15 ppm + Benomyl/Carbendazim 1000 ppm + Urea 1% one month after fruit set (fruit size 8-10 mm).
- ⇒ Spray Gibberellic Acid (GA3) 10 ppm + Potassium Nitrate 1% two month after fruit set (fruit size about 18-20 mm).

Pre-Harvest Drop Control

- ⇒ Spray 2,4-D 15 ppm + Benomyl/Carbendazim 1000 ppm + Urea 1% in September.
- ⇒ Spray Gibberellic Acid (GA3) 10 ppm + Potassium Nitrate 1% in October.
- ⇒ For ensuring complete solubility, dissolve 2,4-D and GA3 first in alcohol.

Control of Entomological fruit drop

- ⇒ Poison baiting for fruit sucking moths with 20 g Malathion 50WP + 200g jaggery with some vinegar or fruit juice in 2 liters of water (two bottles containing poison bait/25-30 trees are sufficient).
- ⇒ Light traps can also be used for collecting moths.
- ⇒ For control of fruit flies also bait containing Malathion (0.05%) +1% crude sugar, about two months before fruit ripening and spray Carbaryl 50 WP @ 2 g/liter of water.
- ⇒ Male attracting traps containing 0.1% Methyl Eugenol and 0.05% Malathion reduces pest

population. Use 25 traps / ha starting from 60 days before fruit harvest and change solution after every seven days.

Guidelines for bait spraying to control chinese fruti fly

Materials

- ⇒ Protein hydrolysate (attractant) available in 30 grams plastic packages.
- ⇒ Chlorpyrifos (as chemicals) in 100ml tins/malathion.
- ⇒ Sandovit (as sticker) in 1 liter tin.

Procedure for bait preparation

Prepare the bait spray solution. For one liter of mixture use.

- ⇒ 1 liter of water.
 - ⇒ 5 grams of protein hydrolysate.
 - ⇒ 4ml chlorpyrifos or 2 ml malathion.
 - ⇒ few drops of sandovit or any branded sticker.
- If you have to prepare 10 liter of bait spray solution, mix 50 grams of protein hydrolysate with 20ml malathion/40 ml chlorpyrifos and 10ml sandovit sticker in 10 liter water. Stir well.

Splashing

Throw 50ml of the solution in every second tree. Concentrate the splash on a few higher branches. Splashing should be done on dry and sunny days. Take protective measures.

Timing : The first splash should be done around 15 April, when flies start emerging. The best

method for fixing the starting date is as follows: collect pupae in October-November, keep them in a bottle with some loose humid soil, and start splashing when the first flies emerge. Repeat the treatment every week until mid May; every two weeks till 15 August. In villages with low level of infestation, splashing can be stopped after 15 May.

Duration

Farmers obtain best results if bait spraying and collection of dropped fruits are carried out for two to three years in a row.

Community effort

Collection of dropped fruits and bait spraying need to be done by the whole community for better results.

Note: Protein hydrolysate is highly hygroscopic, so it attracts water and spoils easily. Close and seal the packages well after use.

General recommendation to control fruit drop

- ⇒ Maintain balanced nutrition in the plants to develop sufficient foliage to support developing fruits.
- ⇒ Prune the plants after harvesting to minimize the risks of diseases.
- ⇒ Avoid stagnation of water in the field and maintain good drainage.
- ⇒ Ensure supply of water to the plant at crucial stages.
- ⇒ Dispose off the dropped fruits from the orchard immediately and regularly.

3. Tips for good citriculture Practices

Favorable climatic conditions for the growth of citrus

Citrus trees grow well in temperature range of 15-30°C. To produce fruits of high quality and obtain high yields, citrus crops like sweet oranges and mandarins require subtropical climate with cool winters and warm summers.

The annual rainfall required for good citrus

Proper distribution of rainfall is more important than total rainfall. Citrus species perform well in regions with an annual rainfall of 1250 to 1850 mm. Continuous rains predispose plants to certain disease.

The advantages of polyembryony in citrus

Due to polyembryonic character of most of the citrus species we get many seedlings. The nucellar seedlings are true to type and are usually vigorous while zygotic (sexual) seedlings are relatively weak. High percentage of polyembryony is desirable in rootstock species, to get uniform planting materials.

Ideal soil for raising citrus nursery

Nursery should be located away from existing citrus orchards. The soil should be well drained preferably virgin or at least which has not been planted earlier with citrus. A well-drained soil near a water source is preferred. Seed beds should preferably be prepared in a good, deep and rich soil.

Ideal composition of root medium for raising a nursery

The composition of the soil medium depends upon the texture of the soil. In sandy soil, normally 1:1 mixture of soil and farm yard manure (FYM) is ideal. For a soil high in clay soil, sand and FYM mixture in 1:1:1 proportion is ideal. Before making raised beds it is necessary to treat the soil mixture with solarization. Soil solarization is done by covering nursery bed with polyethylene sheets in hot summer months.

Containerized nursery management

Rising of nursery plants in plastic trays, polythene bags etc. is called as containerized nursery management. It is easy to monitor the growth of individual seedling in the polybags than in the conventional nursery beds in the field. Since sowing of seeds is done in perforated plastic trays there is no stagnation of water in the root zone. As a result the incidence of Phytophthora like diseases is minimized in the seed beds. The affected plants can easily be discarded thereby checking the spread of the inoculum.

Control **Phytophthora** in the nursery bed

To control Phytophthora in the nursery Ridomil Gold (Mefenoxam) @ 2.75g or aliette @ 2.5g /liter of water should be sprayed at the interval of 40 days. Also, Phytophthora affected plants should be removed from the nursery and destroyed.

Suitable time for budding

March-April months are considered better for budding. It results higher success.

Mother plants for collection of bud wood

The mother plant for bud wood should be healthy, productive and free from graft transmissible viruses and mycoplasma like diseases with an excellent performance. The age of such trees should not be less than 15 years.

Separating bud from bud stick

Using a sharp budding knife having a blade of excellent quality steel and with a rounded end, the bud is cut from below the petiole with a slice of thin wood. It has been observed that the buds cut with a sharp knife give a higher percentage of success than those cut with a blunt knife. All tools should be disinfected regularly by dipping in 1-2% sodium hypochlorite solution for few minutes.

Storage of the bud wood

In fact, bud sticks should be cut just prior to use. Care must be taken not to allow bud wood to dry and it should be kept in sphagnum or peat moss or in wet cloth.

Bud wood selection

While selecting the bud wood care to be taken on:

- The bud stick of current season growth and with 5 to 9 plump buds, not yet bursted.
- The bud stick should be in sap flowing condition with distinct streaks which is an indication of its maturity.

Ideal size of the polythene bags for transplanting the citrus seedlings

Citrus seedlings can be transplanted in UV stabilized polythene bags of size 15-20 x 20-25 cm which can sustain the growth of the seedlings at least for one year.

Nucellar seedlings selection in the nursery bed

It is difficult to judge in the field which one is a sexual seedling. The most practical way of selecting nucellar seedlings from seedbeds is to discard all the slow growing and fast growing seedlings and select only average growing seedlings.

Rootstocks with high degree of resistance of *Phytophthora* root rot

Trifoliate orange and sour orange are tolerant to *Phytophthora* pathogen. Among Trifoliate orange, Flying Dragon and Argentine trifoliate have great response regarding resistive power over *Phytophthora* root rot.

Placement of fertilizer application

The placement of fertilizer varies with the age of the plant. In case of young trees fertilizers should be applied in the tree basin only and as the tree grows the basin size should be enlarged. In case of bearing trees, a good rule is to cover an area twice the diameter of the tree canopy, because the feeding roots have spread beyond the drip of the canopy. In older groves entire field may be fertilized since the roots are found to spread the whole orchard area. It can also be applied in trench. Usually a trench of 15 to 25 cm wide and 15 cm depth around and below the drip of the tree is dug, where fertilizer and manures are added and finally covered with the dugout soils.

Fertilizer application schedule

Time of application of manures and fertilizers in citrus depends on types of manures and fertilizers, and phenological stages of the tree.

Organic manures, which are slow to release mineral elements, should be applied well before the initiation of new growth and flowering. Inorganic fertilizers, which are generally quick to release nutrients, should be applied just before the initiation of new growth or at the start of new growth. 50% of the annual nitrogen requirements and all of the phosphorus and potassium requirements are generally applied in February-March (15-20 days before flowering). The remaining 50% of the nitrogen is applied after fruit set and during the fruit enlargement period (June-July).

In case of non-bearing young trees, nitrogen fertilizers are applied in 3 split doses depending upon the soil conditions and plant growth. In this case the third dose is applied just after the rainy

season. Generally three split doses of nitrogen are recommended only when trees are in poor condition due to root rot.

Water saving

In citrus, about 50-55% of water is saved by using drip irrigation as compared with conventional basin method of irrigation.

Frequency of irrigation in citrus orchard

Generally, citrus trees are irrigated at 15 days intervals during winter and it is much shorter during the dry season. In Nepal, it is not possible to irrigate citrus trees in such short intervals. From irrigation perspective, there are three critical stages of citrus trees during the dry season starting from February to May. They are new growth and flowering, fruit setting, and early stage of fruit growth. Citrus trees are very active from February to May in which bud differentiation, bud breaking, flushing, flowering, and fruit setting occur. During this period, soil moisture of citrus orchards should be at 55-65 percent field capacity. As this is a dry period in Nepal, moisture level goes far below from this level and hence, at least 3 irrigation- 10-15 days before flowering, 15 days after flowering and 1 month after 2nd irrigation- are recommended.

Combating climate change effects, untimely rains coupled with the hail storms during February-April, cause heavy drop of fruitlets and inflicts damage to the foliage and to the tree

Research reports in neighboring countries indicates that application of Carbendazim @ 0.1 % (1000 ppm) followed by an additional dose of 100g each of nitrogen and phosphorus along with foliar sprays of naphthalene acetic acid at 15 ppm concentration at 15 days interval reduces bad effects of hail storm. Remove the affected twigs as a sanitary measure, collect and bury the fallen fruits.

Measures to be taken on rise in temperature in the month of September-October causing sun scorching

Foliar application of 4% CaSO_4 checks the effects of sun scorching.

Steps to ensure better flowering

The soil having any hard layer up to top 60 cm should be avoided as far as possible. The presence of sufficient moisture in the feeder root zone of soil is a must. Adoption of drip irrigation system ensures optimum moisture during the fruits growth period.

Control of termite infestation in citrus orchards

Remove broken / dried branches, regular irrigation and drenching the soil around plant and spray the trunk with Chlorpyrifos @ 4 ml or Imidacloprid @ 1 ml/ liter of water reduces the termite incidence.

Control of Mealy bug infestation in citrus orchards

Pruning of affected shoots and raking the soil around trunk during summer prevents the spread of the pest. Ant colonies in the orchards should be destroyed. Sticky bands of 7-8 cm should be smeared around the trunk at about 0.5m height from the ground during 2nd week of December. Spraying with Chlorpyrifos 0.05% or Carbaryl 0.1% or Diamethoate 1.5ml+kerosene 2.5ml/liter of water checks the mealy bug infestation.

Damage by mites and their management

Mites attack mature leaves and fruits of all stages, causing pale stripping on the upper surface of leaves, which looks like ash-sprayed and unpleasant blemishes on fruit surface, initially becomes silvery and later turn brownish in color. The fruits fail to develop properly and fetch lower price due to their unpleasant appearance. Trees should be well irrigated particularly during stress periods, foliar spray of Dicofol @ 1.5ml or Wettable Sulphur @ 3g or Dimethoate @ 1.5ml/liter water should be given as and when incidence noticed.

Quality parameters of fruits for mandarin orange export

Mandarin fruits with the uniform reddish orange color of rind, smooth texture without blemishes

and globose shape are preferred in most importing countries. Seedlings fruits are preferred than seeded ones. European markets prefer smaller fruits with 5.0-5.5 cm diameter while south-east Asian markets prefer fruits with 6-7 cm diameter.

Processed products from citrus fruits

Single strength juices, juice concentrates, beverages including carbonated drinks, squashes, acid lime and lemon pickles, cordials, canned segments, jams, jellies and marmalades are the processed products manufactured from citrus fruits.

4.Steps followed in rejuvenation



Application of lime in basin



Micronutrient application



Bordeaux pasting



Fertilizer application



Rejuvenated orchard

Source: Success story of citrus industry in Nagaland, Ed. by S. P. Ghosh, Akali Sema and N. Benjong Aiyer. Tech Bull, Central Institute of Horticulture, Government of India, Nagaland, March 2010.

5. Calendar of operations to be followed in demonstration orchards

January-February (Magh)

Phenological stage. I: In this period, buds are differentiated. Roots are still inactive.

Calendar of operation:

- ⇒ Clean the orchard and make tree basins up to the area of canopy spread by light hoeing.
- ⇒ This is a peak month for pruning and manuring. Pruning should be completed by this month.
- ⇒ Full amount of FYM or compost (60kg/tree), phosphorus (300g/tree) and potash (500g/tree) and half dose of nitrogen (300g/tree) fertilizer should be applied in this month.
- ⇒ Do approach grafting with trifoliolate rootstocks if there is a problem of Phytophthora root and foot rot.
- ⇒ After manuring and fertilization, irrigate the trees if possible.
- ⇒ Spray 1% Bordeaux mixture to all trees to protect trees from fungal diseases and paint tree trunk up to 1 meter with Bordeaux paste.
- ⇒ Spray servo oil @ 10ml/liter of water, if there is problem of scale insects, aphids and mealy bug.
- ⇒ Remove parasites like Loranthus.

April-May (Baishakh)

Phenological stage. II: Fruits are in cell division stage with pea size. The first natural fruit drop starts in this stage. Second flush may start from the end of this month.

- ⇒ If chemical fertilizers are not applied in late winter or early spring, apply them now.

- ⇒ The period is dry but the demands of plants for water are high, so irrigate trees at 15 days intervals if possible.

- ⇒ Monitor new growth and young fruit lets for the presence of powdery mildew and if it is severe, apply sulphur containing fungicides such as sulfex @ 2g/liter of water.

- ⇒ Spray the tree canopy with a cocktail of micronutrients:

Zinc sulphate	100 g
Copper sulphate	60 g
Magnesium sulphate	40 g
Ferrous sulphate	40 g
Manganese sulphate	40 g
Lime	180 g
Water	20 liters

In acidic soil with pH 4.5-5.0 apply 100 g of Dolomite lime/plant once in 3 years

- ⇒ Rot or gummosis affected portion should be scrapped with a sharp knife taking care that no wood is damaged and paint with Bordeaux paint (1:2:3 lin seed oil).
- ⇒ Spray infected trees with 1% Bordeaux mixture.
- ⇒ Drench the soil at tree base of those trees affected severely with Phytophthora with Ridomil Gold (Mefenoxam). Dissolve Ridomil Gold @ 2.75 g/liter of water. Use 10-15 liter of Ridomil Gold solution/tree for drenching.
- ⇒ Avoid injury to trunk and crown.
- ⇒ If oriental fruit fly is a problem, keep methyl eugenol pheromone trap @ one trap/10 trees but for chinese fruit fly use poison bait as mentioned above (see page 43).
- ⇒ Remove waterspouts or suckers arising from the rootstocks

July-August (Shrawan)

Phenological stage. III: Fruits of mandarin are enlarging to the size of big sized lime.

Second flush is at growing stage

- ⇒ Continue thinning of fruits maintaining leaf-fruit ratio to 50-55: 1.
- ⇒ Spray ATSO or servo @ 10ml/liter of water if trees are heavily infested with aphids and scale insects.
- ⇒ During this period, when the attack of green stink bug is more, yellow fruits can be seen on the tree. For the control, collect eggs, nymph and bugs, and kill them; and if necessary spray roger or Malathion @ 2ml/liter of water.
- ⇒ Due to high temperature and humidity, the incidence of powdery mildew, anthracnose, melanose, and foot rot may be severe during this period. Take necessary measures such as application of Bordeaux paste, draining excessive water and cleaning orchards to suppress the diseases.
- ⇒ Crisscrossing branches should be pruned. Pruning should be clean and close to the main stem but wounding of other parts of the tree should be avoided while pruning. Treat cut ends with Bordeaux paste.
- ⇒ Disinfect pruning tools by dipping it in 1-2% sodium hypochlorite solution.
- ⇒ Keep the orchard clean by weeding and good sanitation practices.
- ⇒ Avoid standing water around tree trunk
- ⇒ Provide staking to support heavy fruiting branches.

October-November (Kartik)

Phenological stage. IV: This is the end of fruit growth stage and 60-70 % fruit colours developed by the end of this month. New flush start yellowing due to decreasing temperature.

- ⇒ This is a crucial time for mulching from moisture conservation aspect. Mulching materials are also easily available at this time. Mulch around tree basins with organic materials such as straw, saw dust, rice hulls, dry leaves, weed scrapings and compost.
- ⇒ The population build up of insect vector citrus psylla (*Diaphorina citri*) is maximum during May, June and July before the monsoon and minimum during the winter months. It has been recommended that measures for control of *D. citri* should be undertaken at the end of the rainy season. Routine spray of insecticide in orchard trees with Azadirachtin (0.03%) and Neem oil is recommended.
- ⇒ Early varieties of mandarin can be harvested from this month.
- ⇒ This is also the right time to harvest local mandarin oranges for storage.
- ⇒ This is a time to contract-out fruits from the trees. Be careful while signing the agreement that fruits will be harvested carefully in time.
- ⇒ Prepare materials for harvesting fruits from the coming months.
- ⇒ If fruits are dropped due to fruit fly, remove them from the orchard.
- ⇒ Keep record of fruit yields.

SUGGESTED READINGS

Acharya, L.N. 2004. Citrus: introduction, orchard establishment and management. A book in Nepali version published by Shree Comple Pvt., Pokhara.

ACIAR and DOA, 2010. Production Guide for Mandarin Orchards in Bhutan. Australian Centre for International Agricultural Research and Department of Agriculture, Bhutan.

AEC/FNCCI, 2009. Junar Kheti Pustika. published under OVOP programme.

Anonymous 2007. District Profile of Nepal 2007/08 (A Socio Economic Development Data Base of Nepal) Intensive Study and Research Centre Kathmandu.

Anonymous 2007. Statistical Information on Nepalese Agriculture 2006/2007. Agri-business Promotion and Statistics Division, MOAC, Nepal.

Anonymous 1999. Horticulture Development Project (Summary report). MOAC, Nepal and JICA, Kathmandu. pp.53.

Anonymous 1990. Report: Seventh Five Year Plan. National Citrus Development Programme, NARSC, Nepal. pp.97.

Anonymous 1987. Citrus die back, Mapping and Control Project in Darjeeling district. Citrus die back research station, Kalimpong and Bidhan Chandra Krishi Biswavidyalaya, West Bengal. pp.27.

Annual Report 2063/64 District Agriculture Development Office, Dhankuta.

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

Dorji, C., A.R. Clark, R.A.I. Drew, B.S. Fletcher, P. Loday, K. Mahat, S. Raghu and M.C. Romig 2006. Seasonal phenology of *Bactrocera minax* (Diptera; Tephridae) in western Bhutan. Bulletin of Entomological Research. N.96 pp.531-538.

ECARDS –Nepal 2001. Citrus Decline Problem in the SSMP area of Baitadi district. pp. 27.

FDD, 2009. Annual Report 2008/2009. Fruit Development Directorate, Kirtipur, Kathmandu, Nepal.

FDD, 2010. Annual Report 2009/2010. Fruit Development Directorate, Kirtipur, Kathmandu, Nepal.

Ghosh, S.P. and R.B. Singh, 1993. Citrus in South Asia. FAO Regional Office for Asia and Pacific, Bangkok, Thailand.

Ghosh, S.P. and Ganesh Kumar KC, 2008. Draft Report on Combating Citrus Decline Problem in Nepal. FAO-Nepal.

HARP, 2002. Summary of HARP Project, Vol. I. Hill Agriculture Research Project, Kathmandu.

Kaini, B.R. 1987. Junar production and Preservation. A book in Nepali version published by Horticulture Development Project, Kirtipur, Kathmandu, Nepal.

Kaini, B.R. 2004. Rejuvenation of declined citrus trees. Nepalese Horticulture, vol.4, Issue 1 pp.1-7.

Knorr, L.C. S. Moin Shah and O.P. Gupta, 1970. Greening disease of citrus in Nepal. Plant Report. Vol.54, N.12, pp 1092-1095.

Knorr, L.C. S. Moin Shah and O.P. Gupta, 1971. World citrus problems – V Nepal FAO Plant Protection Bulletin. Vol.19, N.4, pp 74-78.

Lama, T.K., C. Regmi and B. Aubert 1988. Distribution of the Citrus Greening Disease vector (*Diaphorina citri* Kuwayama) in Nepal and Attempt of Establishing Biological Control against it Proc. X. Conf. IOCV A Riverside. pp.255-257.

Lama, T.K. and C. Regmi 1986. Preliminary investigation on frequency of active pathogenic elements responsible for citrus decline in Pokhara. J. Inst. Sc. Tech. Vo. 11, pp.23-26.

MDAP, 1992. Training Manual on Citrus Fruits, No16. Manpower Development Agriculture Project. Hariharbhawan, Lalitpur, Nepal.

Miyakawa, T. and A. Yamaguchi 1981. Citrus diseases in Japan. Japan Plant Protection Association, Tokyo. pp.64.

MOAC/Winrock, 1998. The "Pocket-Package" Approach to Agriculture Led Growth under the APP.

NARDF, 2010. Project Compilation Report. National Agriculture Research and Development Fund, Singh Durbar Plaza, Kathmandu, Nepal.

- Nepal District Profile 2006.
- NCDP, 2008. Citrus Fruit Fly and its control management (a booklet in Nepali version). National Citrus Development Program, Kirtipur, Kathmandu, Nepal.
- NCDP, 2008. Identification and control of citrus Psylla (*Diaphorina citri*), a booklet in Nepali version. National Citrus Development Program, Kirtipur, Kathmandu, Nepal.
- NPC, 1995. The Agriculture Perspective Plan (1997-2017). National Planning Commission, Singh Durbar, Kathmandu, Nepal.
- Paudel, K.P. and Y.H. Shrestha, 1995. Citrus Decline and its Management in Nepal. An unpublished report.
- Paudel, K.P. and R.L. Shrestha, 2004. Evaluation of indigenous mandarin germplasm at different locations of Dhankuta district. In *Advances of Horticultural Research In Nepal*. Proceedings of the Fourth National Workshop on Horticulture held during 2-4 March at Khumaltar, Lalitpur, Nepal.
- Rajput, C.B.S. and R.Sri Haribabu, 2004. *Citriculture*. Kalyani Publishers, India.
- Regmi, C., I.P. Kafle, K.P. Paudel, R.P. Devkota G. Awasthi 2008. Screen house system to produce Quality Planting Materials in Banepa. Proceedings of Fifth National Seminar of Horticulture, Kathmandu. p.89-92.
- Regmi, C. and B.P. Yadav, 2007. Present status of Huanglongbing in some western districts of Nepal. Proceeding of the Fourth National Horticulture Seminar on Horticulture for Food Security, Employment Generation and Economic Opportunities, Jan. 18-19, Kirtipur, Kathmandu, Nepal.
- Regmi, C. 2000. Prospect of citriculture for environmental protection and population health. *Agriculture and Environment Millenium Issue*, HMG Ministry of Agriculture and Cooperatives Nepal pp 46-49.
- Regmi, C. and S. Shrestha 2000. Study on different soil mixtures for growing *Poncirus trifoliata*. *Environment and Agriculture Biodiversity ECOS Nepal*. Vol. II p. 334-336.
- Regmi, C., S. Shrestha, & B.P. Yadav 1999. Distribution of Citrus Tisteza Virus in Nepal. Proc. III Nat. Con. on Sc. & Tech., Kathmandu. pp. 847-851.
- Regmi, C., Monique Garnior and J.M. Bove 1998. Distribution of citrus greening disease and its vector in Nepal. Proc. First Nat. Hort. Res. Workshop, NARC, Khumaltar. pp 251-253.
- Regmi, C., Monique Garnior and J.M. Bove 1996. Detection of The Asian Huanglongbing (Greening) Liberobactor in Nepal by DNA-DNA. Hybridization Proc. XIII Conf. IOCV, IOCV, Riverside. pp. 267-270.
- Regmi C. 1990. Citrus Greening Disease .RONAST Kathmandu, Nepal. pp.39
- Regmi, C. and T.K. Lama 1988. Greening incidence and Greening Vector Population dynamics in Pokhara. Proc. X. Conf. IOCV, Riverside, p. 238-242.
- Regmi, C., 1982. Mycoplasma-like disease of citrus in Nepal and USSR. Ph.D. Dissertation. Moscow Agricultural Academy, 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 programme for Nepal, ATSP, Nepal pp 37.
- Roistacher, C.N. 1991. Graft Transmissible diseases of citrus; Hand book for detection and diagnosis. IOCV and FAO, Rome. pp. 31-151.
- RONAST, 1990 Citrus Greening Disease- a compiled study. Royal Nepal Academy of Science and Technology. Kathmandu, Nepal.
- Sah, D.N. 2002. Integrated Mandarin Tree Health Improvement Research in the hills of Nepal. NARC, ARS Lumle. Pp.14.
- Sah, D.N., 2002. Citrus decline problems in the hills of Nepal and its management. Agriculture Research Station, Lumle, NARC.
- Satyanarayana, G. and M.R. Reddy, 1994. Citrus: production and protection. Wiley Eastern Limited, India.
- Shrestha, P.P. and Verma, S.K. 1998. Development and Outlook of Citrus Industry in Nepal. Pro. National Horticulture Workshop, January 19-21, Kirtipur, Kathmandu.
- Shrestha, S., C. Regmi, N. Rana, A. Giri and S. Sijapati 2003. Polymerase Chain Reaction (PCR)-based Diagnosis of Citrus Huanglongbing (HLB) Disease in

Nepal. Nepal Journal of Science and Technology v.5 p. 107-113.

Shrestha, R. L. 2066 (B.S.). Causes of citrus decline and management technology. National Citrus Research Program, Paripatle, Dhankuta Nepal.t.

Subedi Fulprasad, D. D. Dhakal and N.P. Khanal, 2003. Integrated Citrus Decline Management Proceeding (Nepali version). IAAS, Rampur and DADOs of Tanahu, Gorkha and Lamjung.

Subedi, Fulprasad, 2004. Integrated Citrus Management. A book in Nepali version published by IAAS, Rampur, Chitwan, Nepal.

Thapa M.B, 2003. Evaluation of mandarin orchard management practices in Dhankuta .A training report submitted to Central Agriculture Training Center,

HariharBhawan,Lalitpur, Nepal.

Thrower, 1968. Report on visit to Nepal. FAO Report : PL T/21 (12 page mimeograph).

Tomiyasu,Y. and S.K.Verma 1990. Reports on diseases, insects/pests of citrus by short term experts and the citrus development division (1986-1990). Horticulture Development Project, Kirtipur, pp.51-52.

Tomiyasu, Y, S.K.Verma and D.B.Thapa, 1998. Citrus Ciltivation in Nepal. A book in Nepali version published by Horticulture Development Project Kirtipur, Nepal.



Food and Agriculture Organization
of the United Nations
UN House, Pulchowk
P.O. Box 25, Kathmandu, Nepal
Tel: 977-1- 5523239
Fax: 977-1-5526358
Email: FAO-NP@fao.org
Website: www.fao.org/world/Nepal