STRENGTHENING AGRO-ECOSYSTEMS RESILIENCE FOR CLIMATE CHANGE ADAPTATION TO IMPROVE FOOD AND NUTRITION SECURITY (TCP/NEP/3701)

Conservation and Management Package of Practices for Agro-ecosystem Services

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INTRODUCTION

Agriculture has been considered as the backbone of the national economy, food security of the country and livelihood of farm families. Farmers have recognized the accessibility of favorable biological and agro-ecological environmental opportunities to produce crops in different agro ecological regimes. However, both biotic and abiotic factors affect crop production. Increasing trend in external input uses mainly chemical fertilizers and pesticides and depleting soil fertility affect crop production and lack of knowledge among the farmers on the fate of chemicals used in the crop production has been observed to be the root cause of poisoning and environment pollution. Lately there is growing concern of chemical residue in foods. Therefore, it is necessary to produce crops without depleting soil fertility, without pesticide residue on the produce thereby creating a healthy agro-ecosystem for maintaining diversity and conservation of all organisms for getting good ecosystem services. The practices begin from soil preparation to harvesting of crops.

OBJECTIVES

- To aware farmers and consumers on the importance of crop production technology.
- To extend eco-friendly production technologies of individual crops to farmers for maximizing crop production and productivity.
- To solve food insecurity and secure food security with a balanced diet for people.
- To document best management practices for development agents and farmers who are engaged in crop production.
- To use the crop production package as a practical guide for investors, experts, and development agents.
- To supply raw materials for agro industries.

PRODUCTION FACTORS AND MANAGEMENT PRACTICES

1.1 Abiotic factors affecting crop production

- Fertile soil and water are essential for good seed germination and plant growth.
- Optimum light, temperature and humidity are necessary for plant growth, development of microbes, like bacteria, fungi, viruses, and insects like predators, parasites, pollinators and decomposers, in addition, wind for dispersion of seed of plant, pests and change in crop growth and production.
- Balanced fertilizer and bio-rational pesticide are essential for plant growth and pest protection.

1.2 Biotic factors affecting crop production

- Plants (vegetable or weed or trees) compete for nutrients, lights and acts as host for beneficial and harmful organisms.
- Insects and micro-organisms (both beneficial and harmful) interact with plants and influence growth and production.
- Other vertebrates, including birds and wildlife either cause pest problems or help for pest control and play role in nutrient cycle.

1.3. Crop production technology supports sustainable agro-ecosystems services.

- Ensure safe and nutritional food production.
- Maintain biodiversity in farming systems.
- Judicious use of chemical pesticides and chemical fertilizer.
- Maintain long term fertility of soil.
- Use of renewable resources in crop production systems.
- Reduction of all forms of pollution during agricultural operations.

1.4. Agroecosystem based crop production and management practices

1.4.1 Basic practices

- Well decomposed FYM or compost and balanced fertilizer use.
- Use of effective microorganism (EM) for the compost.
- Use of the micronutrients and microorganism like Trichoderma, Beauveria and metarhizium in the soil preparation
- Good land preparation, field sanitation and hygienic condition.

- Use of quality seed/seedling/planting materials.
- Selection of pest/disease tolerant varieties and good planting/sowing time.
- Provide the irrigation on the appropriate time.
- Practice of appropriate cropping system (trap crop, mix crop, relay crop etc)
- Regular field monitoring for pest incidence, and timely use of bio-rational pest control measures.
- Restriction of chemicals listed as hazardous by GoN prohibited to use (red marked pesticides), rather choosing safer and newer eco-friendly pest control measures.
- Record keeping of all operations for analyzing cost benefit of farming.

1.4.2 Specific practices

1.4.2.1 *Cultural and physical measures*

- Planting distance and crop canopy as per crop and varieties.
- Host and non-host combination for pest and disease management.
- Appropriate tillage, residue management, preservation of organic matter in the soil.
- Practice timely irrigation to maintain optimum soil moisture.
- Use of mulch (biological and plastic materials) and intercropping to suppress pests and conserve soil moisture.
- Balanced use of well decomposed manure and chemical fertilizers as per recommendation of crops.
- Practice of growing crops inside tunnel to maintain temperature and restrict entry of pests.
- Practice of timely pest management practices.

1.4.2.2 *Mechanical measures*

- Digging, hand picking, pruning/removing pest or disease affected plant parts and destroying them.
- Sticky traps and light trap catches of pests.

1.4.2.3 *Biological measures*

- Disrupting pest mating, use of pheromone traps.
- Conservation of predators and parasites.
- Use of well decomposed compost for soil micro-floral activity.
- Use of botanical plant materials and their extracts.
- Use of microbial pesticides (entomo-pathogenic fungi, bacteria, virus, nematodes etc.), and hormonal analogues.

1.4.2.4 *Chemical measures*

- Use of blue and green label pesticides strictly following recommendation with personal safety precaution.
- Selection of appropriate pesticide and using the in the morning or in the evening.
- Following waiting period strictly after each chemical application.

1.4.3 General practices

It differs based on the crops, seasons and different crop growing regimes. However, a general procedure to be followed while growing crop is outlined here under.

1.4.3.1 *Field selection*

- Layout of the field for crop production.
- Regular soil test for pH, OM, NPK and nutrient management for maintaining soil fertility
- Crop rotation plan and practices with legume cropping pattern for soil fertility and pest management.
- Crop field with enough sunlight and well managed irrigation and drainage facility.
- Area free from pollution and protection from external enemies.

1.4.3.2 *Nursery management*

- Nursery site with enough sunlight and well managed irrigation and drainage facility.
- Area free from pollution and protection from external enemies.
- Soil solarization using chemical and plastic mulch before seeding.
- Use of well decomposed FYM or compost mixed with sand, wood ash (1.5 to 2 kg/m^2) for nursery raising.
- Healthy raising of saplings in raised bed or plastic cups using above soil or cocopeat.

- For producing fruit saplings, proper selection of rootstocks and good size of scions and raising them for at least 6-12 months before transplanting.
- Regular monitoring and management of pests to produce pest free seedlings/saplings.

1.4.3.3 ***Field soil management***

- Green manuring with legume or other approaches to maintain soil fertility.
- Preparation of lands according to requirement of crops.
- Use of recommended well decomposed FYM and balanced use of chemical fertilizer.
- Test of pH, organic matter and NPK once in two year or as per recommendation.
- Field soil improvement following crop rotation, avoiding same family crop as follow up crop, use of antagonistic crop for soil borne disease, nematodes or some soil insects, conservation tillage, mulch etc.
- Regular monitoring and management of pests.

1.4.3.4 ***Planting and production***

- Spacing varies from crop to crop, so follow the spacing as per the recommendation.
- Use pest/pathogen free planting materials from recommended nursery or quality seeds.
- Use of recommended well decomposed FYM and balanced use of chemical fertilizer for growing crops.
- Timely irrigation with drainage facility and intercultural operation for healthy crop production.
- Regular monitoring and management of pests and timely harvest of crops.

1.4.3.5 ***Pest management***

- Regular monitoring of crop field to identify pest problems and beneficial bioagents of the pests.
- Practice diversification of farm landscape for maintaining diversity and conservation of bioagents.
- Intercropping with *Tagates petula* that suppress nematode and plant like mint, basil repellent pests.
- Maintain inter-linkage with other elements like shade, mulch and intercropping/habitat.
- Use neem & other plant extracts, petroleum oil based Servo, jholmol to repel insect pests, and microbial pesticides to manage insect pests.
- Use mineral extracts like lime/sulfur to suppress diseases.
- Use colored traps, light traps for monitoring insect pests.
- Use rodent baits for controlling house and field rats.
- Read carefully label of pesticides, their dose, safety measures, and waiting period after spray in the field.

1.4.3.6 ***Pollinators management***

- Scale up beekeeping among farmers for managed crop pollination and various hive production.
- Use native flowering plants that are adopted to local climate, soil and growing seasons.
- Choose nectar and pollen-rich plants like wild flowers attractive to pollinators.
- Select diverse color and flower structure that attract multi-pollinators.
- Create habitat for nesting, like grounds, branches, tall grasses and shrubs.
- Never use pesticides during flowering, which kill pollinators.
- Maintain flowers that bloom through the growing season.
- Provide foods and water sources, which are necessary to pollinators.
- Adopting good agriculture practices (i.e. IPM/IDM, organic farming, community forestry, declaration of protected area, and establishing biodiversity garden etc.)
- Avoiding bad practices (i.e. over-grazing, honey hunting, slash-burning, deforestation, firing, soil erosion, multiple tillage, flooded irrigation, use of agro chemicals, mono cropping etc.).

1.4.3.7 ***Climate change resilience***

- Identifying and using various cropping patterns to promote integrated and long-term conservation.
- Cropping with agro-forestry in mitigating climate change by sequestrating carbon and in regulating weather patterns.
- Helping farmers to plant new crops and seeds, build home garden, practice mixed farming, establish community seed banks, and multi-use water systems.
- Improving current practices of in situ conservation of crop and livestock genetic resources, using local seeds and research and promotion of adaptive traits of local crops to help farmers.
- Awareness and training farmers on ecosystem-based approaches to tackle current and future climate change impacts.

- Funding to increased research, monitoring, and conservation efforts.
- Integrating climate-change adaptation into existing planning processes.

1.4.3.8 ***Harvest and post-harvest management***

- Consider crop maturity appearance, texture soft/coarse, rigidity, aroma, taste, season and marketing.
- Use appropriate tools (sickle/cutter, scissors, etc.) or hand picking to harvest the crops.
- Collect and keep the products in appropriate and hygienic condition.
- Protect from sunlight, rain, dust or other unwanted elements and possible microbial contact.
- Proper grading, cleaning and packing of produce in appropriate container before storing or marketing.
- Calculation of production cost, selling price and net benefits to the farmers.

CROP SPECIFIC PRACTICES

Agro-technological practices imply all activities which need to be undertaken for development of specific agricultural crops, like land preparation, soil fertility, crop varieties, sowing, inter-culture practices, bio-rational pest management and harvesting of crops with least disruption to the environment. Over 2/3rd of Nepal's population depend on agriculture, which is highly climate sensitive and increasingly at risk from climate change impacts and so needs serious thinking. Key effects of climate change on agriculture include declining water availability for irrigation, increasing peak flood flows, changing pest status and declining crop yields. For example, 4°C increase in temperature would lead to increase in rice yield in the terai by 3.4%, in the hills by 17.9% and in the mountains by 36.1%. At the same time, climate change can delay crop maturity and destroy local species. Thus, climate change will not only affect eco- biodiversity but also the livelihood of millions of people who depend on it. These all in harmony keep balance in crop production and maintaining diversity of all in an agro-ecosystem (Refer Annexes). This eco-friendly farming practices aims to address present challenges related to: i) conservation and management of ecosystem services and the population of natural enemies, beneficial organism, pollinators, decomposers and symbiotic agents; ii) increase the crop yield and farm income through the restoration of agro-ecosystem services to attain the of goal of sustainable agriculture; and iii) enhancing food security and nutrition and can contribute to ecological resilience against climate change extremes and environmental degradation.

1. Apple (*Malus domestica* Borkh.)

Background

The apple is an important temperate fruit and is grown in area where winter is cold, springs frost free and summer mild. It is commercially a most important temperate fruit, which is widely produced in the world after orange, banana and grape. It can be grown at an altitude of 1800-2800masl.

In Nepal, apple is grown in selected districts of high hill region. Commercial apple production is done in Jumla, Mugu, Kalikot Mustang, and part of Rasuwa, Sindhupalchok, Dolakha, Solukhumbu, Rukum, Rolpa. It has covered 5,674 ha of land with production and productivity of 48,946 mt and 8.63 mt/ha, respectively (MOAD, 2018). The apples from high hills have high export potential, which can earn foreign currency and reduce reliance on foreign import as well. In spite of its high significance there are many constraints faced by the farmers in Nepal, which requires due attention.

Importance

1. Apple farming is an important source of income for the high hill farmers.
2. Apple farming occupies an important place in fruit development in the country.
3. It is important fruit for health; fruit is rich in carbohydrate (15%) protein (0.3 %) and nutrients, like K, P & Ca.
4. It is exportable fruit to foreign countries, which provide an opportunity for earning foreign exchange.
5. Organic apple farming is a system that excludes the use of synthetic fertilizers, pesticides, and growth regulators and is best suited for eco-farming.

Farmers' practices and production gaps

The apple is an important temperate fruit in the world. Apple production dominating countries are New Zealand, USA, Brazil, Chili and some EU countries (i.e. France and Italy), where the annual yields range between 20 to 50 mt /ha/yr (FAO, 2016). Although China ranks in the first in fruit industry in terms of growing area, but its production is low. In 1990 it was less than 5 mt/ha/yr and even in 2015 the productivity has remained less than 20 mt/ha/yr. In 2014/15, the

national production of fruit was 8.96 mt/ha and apple 7.8 mt/ha in Nepal (MoAC 2016). This productivity is very low and many problems are associated with low productivity, mainly due to farmers' traditional practices rather than following improved practices. Major contributing factors are: favorable weather, soil fertility and balanced use of fertilizers, irrigation facility, proper cropping practices, pollinators' management, bio-rational management of pests and Agriculture Policy enabling good environment for agriculture and innovation.

Worldwide climate has a significant effect on citrus yield, growth, fruit quality and economic returns. Apple production in Morocco is highly affected by pests and adverse weather conditions (Moinina et al., 2018). For example, apple production decreased due to pests, temperature and rainfall fluctuations by 40% in 2016. In Nepal, the average fruit yield has been estimated 6.25 mt/ha based on the farmers' answers and this yield is less by 3.32 mt/ha if compared with national average of 9.5 mt/ha (Shahi, 2005).

Intercropping study in Kasmir India, has shown significant improvement in Red delicious apple trees intercropped with legumes followed by control and non-legume type crop (Bhat et al., 2018). For example, Fruit yield (37.51 kg/tree), fruit weight (155.72g), fruit volume (165.56 cm3) and leaf nutrient status, N P, K, Ca and Mg with higher B:C ratio were found to be highest in trees intercropped with legumes than with the non-legume type of crops.

In pest management, while reviewing for 100 years, orchard monitoring, pheromone traps, economic thresholds, and degree-day models are practiced by growers, and use of alternate row spraying, biological control, and reduced chemical rates have all increased dramatically in US (Brunner et al., 2003).

Integrated pest management was always better option apple orchard in Kentaky, USA (Bessin, 1994).
Mite density was positively related to the total grams AI (or number of applications) of acetamiprid, and thus reducing the number of applications per season lower the probability of mite outbreaks, which decreased from six sprays to only 2 sprays in US apple orchard (Beers et al., 2005).

After the application of selective insecticides rather than broad spectrum insecticides the arthropod diversity increased in apple orchard in Hungary (Jenser et al., 1999). Adoption level of IPM practice was estimated to increase by 45.8% in Mustang if training provided to farmers and 53% farmers were satisfied with the practice (Ghimire and Kafle, 2014).

Honey bee colonies (2-3 colonies) in apple orchard beginning 10% to over 90% flowering. However in Kasmir India, 86.5% of apple growers are unaware of compatible pollenizer variety and 60-70% doesn't know about the important role of honey bees in apple production (Rather et al., 2017). Among the two domesticated species of honey bees studied in Kashmir valley, *A. cerana* foraged for a significantly longer time, reached its peak activity, visited more flowers per minute and took greater time for completing a single forging trip on apple bloom than *A. mellifera* (Ahmad et al., 2016). In US in context of CCD, out of about 450 other wild bees, over 100 of them visited apple orchard and their conservation was necessary (Parker et al., 2015). Apple pollination was studied through different modes by selfing by bagging, hand pollination, open pollination in Himanchal Pradesh, Red Baron' was fertilized with all the seven pollinizers tested and fruit set ranged from 86.2 to 92.4 % and retention from 58.5 to 86.2% (Sharma et al., 2014). According to Sheffield et al. (2016) apple production depends on insect pollination - therefore, understanding pollinators, their requirements and behaviors within and around apple orchards, at both small and large-scale production levels, will allow for better pollination management strategies and increase apple production. Therefore, for apple orchards with <15% pollinizers, 8 hives; orchards with >30% pollinizers, 2-3 hives and for high density planting adjustment needed accordingly (Verma, 2015).

In Europe, scientists have better opening for research towards IPM improvement, including the use of bio-rational pesticides, semio-chemicals and biological control including forecasting models, new tree training systems and innovative sprays (Damos et al., 2015).

Agriculture Policy of the European Union, is providing a good enabling environment for agriculture innovation and knowledge is transferred from innovation to farmers rapidly in Italy and apple production area in South Tyrol supplies up to 50% of the Italian apple market, 15% of the European and 2% of the global apple market (Meyer, 2014).

Production practices need to follow step-by-step from the beginning to end of apple production cycle to ensure healthy production and higher productivity, and farmers are not following properly, i.e. why they are not getting higher yield.

SN	Production practice	Ideal practice	Farmers practice

1	Soil testing	Periodic soil analysis for nutrient status	Nutrient status unknown
2	Orchard health	Timely cleaning, weeding, ploughing	Unhealthy orchards
3	Training/pruning	Training/pruning to assure healthy orchard	Not following properly
4	Optimum soil pH	Lime application @ 5-7 kg/tree 15-30cm depth to correct acidic soil	Not following correctly
5	Balanced nutrient	Based on soil analysis optimum dose use	Not following properly
6	Micronutrient use	Based on soil analysis micronutrient use	Not following properly
7	Irrigation	Critical at veg growth, flower, fruiting stage	No facility or not following
8	Intercropping	Short duration legume crops, vegetables	No intercrop or other than legume crops
9	Pollinators use and conservation	Conservation and use of pollinators (bees) to assure good pollination and fruit setting	Unknown about pollinators of apple flowers
10	Pest management	Biorational and ecofriendly pest management	Indiscriminate use of pesticides
11	Harvest/postharvest	Proper care at harvest and after harvest for maintaining quality fruits	Poor care during harvest/ postharvest

Apple farmers groups

Three apple farming groups organized in the project district Mustang and oriented them in IPPM-FFS for production and management of apple:

- Planning for technology based apple orchards.
- Keeping prior history and yield of apple.
- Recording soil test, pH, OM, NPK.
- Selecting orchard and variety with managed irrigation and drainage facility.
- Recording temperature, rainfall, especially during flowering & fruiting period.

Nursery/ Orchard Management

- Using rootstock- Crab apple or clonal rootstocks for good sapling production.
- Keeping nursery site & soil free from insect pests and diseases.
- Maintaining quality mother plants.
- Buying planting materials from reliable source/registered nursery.
- Maintaining appropriate planting distance (P-P 6m x 6m) in apple orchard.
- Preparing pit $1m^3$ size for planting of good quality sapling.
- Using compatible pollinizers well maintained in the orchard.
- Planting and maintaining windbreak trees around the orchard.
- Growing legume crops as intercropping to improve soil fertility, trap crops for insect pests and cover crops for moisture retention.

Manure and Fertilizers

- Using balanced nutrients, a ten years mature apple tree requires 100 kg FYM, 400 gm N, 200 gm P, 80 gm K/plant (MOAD, 2016).
- The final dose of manure / fertilizer is decided as per the soil test result.
- Applying manure and fertilizer in the basin.
- Treated the FYM with the jivatu or EM.
- After 10^{th} year, fertilizer use can be minimized gradually but use of organic manure, mulching needs to intensify.
- Foliar spray of major and micro nutrients in winter before bud initiation is necessary

Intercultural Operation and Irrigation

- Keeping basin area around the tree weed free with manual weeding and hoeing.
- Thinning fruits after June drop, usually leaving 3 fruits per spur for good quality fruits.
- Intercropping leguminous crops and seasonal vegetables, like green peas, beans, broad leaf mustard crops etc.
- Mulching especially during summer season to prevent weeds and moisture retension.
- Irrigating apple orchard in ring basin system after each fertilizer application.
- Drenching during summer (March to June) at least the 30cm soil depth.

Training/Pruning

- Removing water shoots, unwanted and overlapping and disease twigs and branches.
- Training/pruning of apple orchard considering the flowering and vegetative, buds space, nutrient, light and air.

- Applying Bordeaux paste on the cut surface after pruning and de-suckering from rootstocks.

Pest management

- Weekly monitoring as survey and surveillance to maintain the record of the pests.
- Promoting conservation of natural enemies by augmentation and inundation.

Cultural Practices

- Practicing apple orchard sanitation.
- Irrigating timely for managing soil insects in the orchard.
- Using pest repellent flowers, like marigold, chrysanthemum depending upon the suitability around the apple orchard.
- Applying Bordeaux paste or other indigenous materials to cover cut/wounds.
- Avoiding injuries to roots or collar of trees during intercultural operations.
- Staking/supporting poles for fruiting branches to keep free from any insects, borer etc.

Mechanical Approaches

- Inserting cotton soaked with kerosene and petroleum oil into the hole made by stem borer.
- Installing light traps in near apple orchard to collect insect pests.

Biological and Botanical Practices

- Treating FYM with *Trichoderma* 1.5 kg in 50 kg of FYM and applying fortified FYM compost to each matured tree foe minimizing root rot disease of apple.
- Using plant extracts or local materials like jhomal to suppress sucking insect pests.

Chemical Approaches

- Applying Naphthalene Acetic acid (NAA) @ 10 ppm for fruit drops 2 weeks before fruit harvest.
- Using chemicals **blue and green labeled** only as the last option, if required.

Disease Management

Apple Scab

- Removing and destroying affected parts of fruit trees, because pathogen over winters in the infected leaves on the ground.
- Pruning overlapping branches for good sunlight penetration on fruiting spur, twigs and stem.
- Spraying 5% urea after fruit harvest and using fungicide, like Copper Oxychloride or Bordeaux mixture.
- Practicing biocontrol agent, like *Pseudomonas syringae* @ 1.5-2 g/l water.

Powdery Mildew

- Wet spot in the fruit due to this disease deteriorates the quality market value.
- Collecting and destroying fallen pars, as immature fruit and leaf fall is common.
- Removing the infected twigs and branches.
- Using Copper Oxychloride, Bordeaux mixture, Sulphur dust and Karathene.

Papery Bark

- The disease starts from main trunk, branches and twigs having wounds, then bark/ skin dry, crinkle and become leathery and feathery.
- Planting only healthy saplings.
- Applying Bordeaux paste immediately after pruning.

Insect Pest Management

Wooly Aphids

- It is one of the serious pests in apple, the reddish purple color aphids covered with wool infest in mass in underside of the leaves on the terminal growth.
- Using of parasite, like *Aphelinus mali* for its biological control.
- Using coccinellid predators, which are useful in predating this pest.
- Spraying Servo @10-15ml / l of water or Neem based pesticide @ 3 ml/l water.
- Using systemic pesticide (only blue and green labeled) in severe case.

San Jose Scale Insects
- Using petroleum oil products, like Servo during dormancy period.
- Applying lime-Sulphur mixed with Servo oil.
- Spraying botanicals, like Neem oil @ 3 ml/liter of water and spray.
- Spraying Petroleum oil Servo oil @ 8-10 ml/liter of water.

Zygaena Moth
- Encouraging use of spiders and earwigs that predate on it.
- Removing old apple, pear, walnut trees which may act as hosts for the pest.
- Spraying botanicals, like Neem oil @ 3 ml/liter of water.
- Spraying petroleum oil Servo oil @ 8-10 ml/liter of water.
- Using Bt.@ 2gm/l of water at 7 days interval.

Weed Management
- Chemical herbicide not allowed.
- Encourage manual and mechanical weeding.
- Management the weeds on time (at least two times weeding is required).
- Proper disposal of weeds, or using as composting materials.

Harvest and Post-harvest
- Harvesting at full maturity stage with appropriate TSS content and color (generally TSS should be at around 12-14^{O} B), and checking color of the seed to turn black.
- Avoiding damage to tree branches while harvesting, no bruises or injury to fruits.
- Using appropriate tools (clippers, knife, shear etc) to harvest fruits.
- Harvesting during day time in dry weather as far as possible.
- Preventing loss of moisture by surface evaporation, transpiration, and respiration resulting shriveling and weight loss, and storing in cool place not contacting harmful substances.
- Grading fruits on size and color categories (if the fruit size is 80mm or more extra-large, 75mm large, 70 mm medium, 65mm small).
- Packing in box best in size not bigger than 45cm x 30cm x 30cm size.
- Managing cushion materials in between the fruit in the pack.

2. Citrus (*Citrus* spp.)

Introduction
Citrus includes: Lime *Citrus aurantifolia* (Christm.) Swingle, Rough lemon *Citrus jambhiri* Lush., Indian sweet lime *Citrus limetttoides* Tanaka, Lemon *Citrus limon* (L.) Osbeck, Pumelo *Citrus grandis* (L.) Osbeck, Citron *Citrus medica* L., Grapefruit *Citrus paradisi* Macfad, Mandarin *Citrus reticulate* Blanco, Sweet orange *Citrus sinensis* Osbeck).

Citrus is leading tree fruit crop in the world. Mandarin (*Citrus reticulate* Blanco) is the excellent quality fruit with blend of acidity and sweetness enriched with vitamins and other nutritive values. It is the most important commercial fruit crop grown in the mid hills of Nepal. Of the total fruits with 26.3% coverage in the country, citrus fruit occupies 65.16% and mandarin is cultivated in area of 25123 ha with production and productivity of 149212 mt and 5.9 mt/ha, respectively (MOAD, 2018). Mandarin in mid hills is good source of income for the farmers and fruits have high export potential, which can earn foreign currency, and reduce reliance on foreign import as well. In spite of its high significance there are many constraints faced by the farmers in Nepal, which requires due attention.

Importance
1. Citrus farming is an important source of income for the mid hill farmers.

2. Citrus farming occupies an important place in fruit development in the country.
3. It is important fruit for health.
4. It is exportable fruit to foreign countries, which provide an opportunity for earning exchange.
5. Organic citrus farming is a system that excludes the use of synthetic fertilizers, pesticides, and growth regulators and is best suited for eco-farming.

Farmers' practices and production gaps

Fruit loss due to pest is major constraint of fruit growers. Devraj et al (2019) reported up to 100% loss of Junar fruits due to Chinese fruit fly in Sindhuli. Panth and Dhakal (2019) surveyed in Parbat district, which reveals 7.26 mt/ha productivity and price NRs.102.5 per kg of mandarin. The national production of fruit was 8.96 mt/ha, citrus 8.82 mt/ha and orange 9.2 mt/ha in 2014/15. There are many reasons for low productivity and yield gap in national/international contexts. The problems are associated with low productivity, are mainly due to farmers' traditional practices. Major contributing factors are: favorable weather, soil fertility and balanced use of fertilizers, irrigation facility, proper cropping practices, pollinators' management, bio-rational management of pests and Agriculture Policy enabling good environment for agriculture and innovation.

The highest technological gap was found in intercrops, pest management, and seed treatment in India. Study also revealed that variables like Education, Extension participation, Contact with extension agencies, innovative proneness and cosmopoliteness were found to be significant and negatively correlated with the technological gal of orange production technology (Yomgam et al., 2019).

Trifoliate orange seedlings are used as rootstock for citrus crops due to cold hardiness and Phytopthora disease tolerance, for which seeds sown in September inside plastic tunnel with open sides resulted 80% germination compared to 46% in tunnel side closed nursery in Dhankuta (Acharya and Pakka, 2019).

The challenge is to understand the interactions of the changing climatic parameters because of the interactions among temperature, CO2, and precipitation on plant growth and development and also on the biotic stresses of weeds, insects, and diseases. Agronomists will have to consider the variations in temperature and precipitation as part of the production system if they are to ensure the food security required by an ever increasing population (Hatfield et al., 2011)

Intercropping practices in orchard not only generate an extra income but the practice also helps to check the soil erosion through ground coverage and improves the physio-chemical properties of the soil. Intercropping in Kinnow orange orchard in Punjab has shown improved yield, fruit quality and economic aspect (Gill et al., 2018). Intercropping cucumber with citrus (mandarin) orchards improved the yields of citrus in India (Ouma and Jeruto, 2010). Intercroping in organic citrus orchards also suppressed weeds and thus improved the yield of citrus fruit (Linares et al., 2008).

More than 170 species of invertebrate natural enemies are produced and sold worldwide for use in augmentative biological control of more than 100 pest species (Cock et al. 2010). Benefit/cost ratio and the developmental costs are much more favorable for biological control than for chemical control (Bale et al., 2009; van Lenteren, 2011).

While evaluating 3 pest management modules (bio-intensive, IPM and farmer practices) in citrus orchard, IPM was the best one with higher net returns (3.95 B: C ratio over control) in North India (Deka et al., 2018). So, Integrated Pest Management strategy, based on the reduction of insecticide treatments and the use of selective insecticides and moreover augmentative, periodic releases of bio-agents to maintain the pest populations below economic damage limits.

Agriculture Policy of the European Union, is providing a good enabling environment for agriculture innovation and knowledge is transferred from innovation to farmers rapidly.

Production practices need to follow step-by-step from the beginning to end of citrus production cycle to ensure healthy production and higher productivity, and farmers are not following properly, i.e. why they are not getting higher yield.

SN	Production practice	Ideal practice	Farmers practice
1	Soil testing	Periodic soil analysis for nutrient status	Nutrient status unknown
2	Orchard health	Timely cleaning, weeding, ploughing	Unhealthy orchards
3	Training/pruning	Training/pruning to assure healthy orchard	Not following properly
4	Optimum soil pH	Lime application @ 5-7 kg/tree to correct acidic soil	Not following correctly

5	Balanced nutrient	Based on soil analysis optimum dose use	Not following properly
6	Micronutrient use	Based on soil analysis micronutrient use	Not following properly
7	Irrigation	Critical at veg growth, flower, fruiting stage	No facility or not following
8	Intercropping	Short duration legume crops, vegetables	No intercrop or other than legume crops
9	Pollinators conservation	Conservation and use of pollinators (bees) to assure good pollination and fruit setting	Unknown about pollinators of citrus flowers
10	Pest management	Biorational and ecofriendly pest management	Indiscriminate use of pesticides
11	Harvest/postharvest	Proper care at harvest and after harvest for maintaining quality fruits	Poor care during harvest/ postharvest

Citrus farmers groups

Three citrus farmers groups organized in the project district Gulmi and oriented them in IPM-FFS for production and management of citrus especially orange:

- Planning for IPPM technology based citrus orchards.
- Keeping prior history and yield of citrus.
- Recording soil test, pH, OM, NPK.
- Selecting orchard and variety with managed irrigation and drainage facility.
- Recording temperature, rainfall, especially during flowering & fruiting period.

Nursery/ Orchard Management

- Establishing citrus nursery at 1000m and above from sea level for sapling production.
- Keeping nursery site & soil free from insect pests and diseases.
- Well drained soil, in clay soil 1:1:1 soil, sand and FYM mixed for maintaining quality saplings.
- Using rootstock Trifoliate or sour orange are used and for grafting mother plant should be healthy, productive and free from any graft transmissible diseases.
- Buying planting materials from reliable source/registered nursery.
- Maintaining appropriate planting distance (P-P 6m x 6m) in orange orchard.
- Preparing pit $1m^3$ size for planting of good quality sapling.
- Planting and maintaining windbreak trees around the orchard.
- Growing legume crops as intercropping to improve soil fertility, trap crops for insect pests and cover crops for moisture retention.

Manure and Fertilizers

- Using balanced nutrients, a ten years mature orange tree requires 40 kg FYM and 300-500:200-250:250-350 gms NPK per tree.
- The final dose of manure / fertilizer is decided as per the soil test result.
- Applying manure and fertilizer in the basin, FYM well before the initiation of the new growth / flowering; 50% of the annual requirement of N and total P and K applying in Feb- March, usually 15 days before flowering and remaining 50% during the fruit enlargement period.
- Applying micronutrients Znso4:2.5kg, Cuso4 1.5, $MgSo_4$:1Kg, MnSo4:1kg FeSo4:1kg Boric acid: 1kg Slaked Lime: 1kg urea 4.5kg water 450 lit per ha, which is based on plant growth and soil test.

Intercultural Operation and Irrigation

- Keeping basin area around the tree weed free with manual weeding and shallow hoeing.
- Avoiding injuries to roots/collar of trees during interculture and disposing dropped fruits properly.
- Intercropping legumes and seasonal vegetables, like green peas, beans, broad leaf mustard crops.
- Mulching with straw, dust, rice husk, and wood dust especially during summer season to prevent weeds and moisture conservation.
- Irrigating citrus orchard in ring basin system after each fertilizer application and peak demand of water for the tree is during Feb-May. Forth-nightly irrigation is useful during flowering and fruit setting time.
- Drip/sprinkler irrigation system is appropriate for citrus in hills.

Training/Pruning

- Removing water shoots, unwanted and overlapping and disease twigs and branches of fruiting trees.
- Training/pruning of orchard considering the flowering and vegetative, buds space, nutrient, light and air.

- Applying Bordeaux paste on the cut surface after pruning and de-suckering from rootstocks.

Pest management
- Weekly monitoring as survey and surveillance to maintain the record of the pests.
- Promoting conservation of natural enemies by augmentation and inundation.

Cultural Practices
- Practicing citrus orchard sanitation.
- Irrigating timely for managing soil insects in the orchard.
- Using pest repellent flowers, like marigold, chrysanthemum depending upon the suitability around the orchard.
- Applying Bordeaux paste or other indigenous materials to cover cut/wounds.
- Avoiding injuries to roots or collar of trees during intercultural operations.
- Staking/supporting poles for fruiting branches to keep free from any insects, borer etc.

Mechanical Approaches
- Inserting cotton soaked with kerosene and petroleum oil into the hole made by stem borer.
- Installing light traps in near citrus orchard to collect insect pests.

Biological and Botanical Practices
- Treating FYM with *Trichoderma* 1.5 kg in 50 kg of FYM and applying fortified FYM compost to each matured tree foe minimizing root rot disease.
- Using plant extracts or local materials like jhomal to suppress sucking insect pests.

Chemical Approaches
- Applying Naphthalene Acetic acid (NAA) @ 10 ppm for fruit drops 2 weeks before fruit harvest.
- Using chemicals **blue and green labeled** only as the last option, if required.

Disease Management

HLB
- Removing and destroying of infected plants and alternate hosts or control vector in these host.
- Using sapling from registered nursery maintained above 1000masl.
- Pruning overlapping branches for good sunlight penetration on fruiting spur, twigs and stem.
- Controlling the disease vectors (Citrus psylla (*Diaphornia citri*), with systemic insecticide (blue/green label).

Phythopthora rot
- Use resistant rootstocks grafted saplings in new orchard.
- Drench/paste/foliar spray the infected trees with 1% Bordeaux mixture.
- Paste twice a year (before and after the monsoon rains).

Citrus Tristeza
- Using the plants grafted in tolerant rootstocks and clean grafting tools in the orchard.
- Rouging of infected plants by uprooting and burning them.
- Controlling virus vector black aphids and conserving its predators and parasites.

Citrus canker
- Removing and destroying of affected twigs or branches of tree.
- Using of copper fungicide, 1% Bordeaux mixture or Copper Oxychloride 50% WP @3gm/liter of water in combination with Streptomycin 500 ppm.

Powdery Mildew
- Following timely training/pruning to remove overcrowded branches and twigs.
- Removing the infected twigs and branches and destroying them properly.
- Spraying fermented urine helps to minimize the disease.
- Using Wettable Sulphur 2 gm/liter of water and Copper Oxychloride 4 gm/liter of water.

Insect Pest Management

Citrus psylla

- Conserving predators like ladybeetles, syrphid flies.
- Uprooting and burning infected plants, and destroying alternative hosts.
- Spraying with blue /green labeled insecticides-Neem oil, servo oil.

Citrus Leaf Miner

- Fertilizing during the winter and pruning infected flushes.
- Using Neem cake soaked in water and spraying Neem oil 2-3 ml/liter of water.
- As last resort spray with blue/green labeled chemical pesticide.

Citrus Aphids

- Conserving predators and parasites of parasitoids for its biological control.
- Spraying Neem oil or Servo oil @ 2-3ml / l of water.
- Using systemic pesticide (only blue and green labeled) in severe case.

Citrus Mealybugs

- Conserving predators and parasites of parasitoids for its biological control.
- Spraying Neem oil or Servo oil @ 2-3ml / l of water.
- Using pheromone traps- Sex Pheromene- Planococcyl acetate.

Citrus Scales

- Conserving predators and parasitoids for its biological control.
- Removing and burning infested fruits/ or twigs/ leaves.
- Removing and burning infested fruits/ or twigs/ leaves.
- Spraying Neem oil or Servo oil @ 2-3ml / l of water.

Citrus Thrips

- Conserving predators and parasitoids for its biological control.
- Spraying Neem oil or Servo oil @ 2-3ml / l of water.

Citrus Green Stink Bug

- Hand picking of eggs, nymphs and adults and destroying them.
- Maintaining orchard sanitation and spraying de-moulting hormone (applaud).

Citrus Fruit Fly

- Collecting infested fruits and burning or feeding to animal.
- Disturbing tree basin soil frequently to expose pupae and predating by birds.
- Using pheromone traps with recommended poison baits.
- Treating soil under the tree with insecticide (green/blue label).
- Practicing area-wide control with spot treatment weekly starting week before flowering till fruit mature.

Harvest and Post-harvest

- Harvesting at full maturity stage during day time with appropriate TSS content and color (Yellow-orange color by> 65-70 %).
- Avoiding damage to trees while harvesting using appropriate tools (clippers, knife, shear etc).
- Collecting harvested fruits on specified trays or baskets to prevent damage.
- Storing in cool place, preventing loss of moisture through surface evaporation, transpiration, and respiration resulting shriveling and weight loss.
- Preventing loss of moisture by surface evaporation, transpiration, and respiration resulting shriveling and weight loss, and storing in cool place not contacting harmful substances.
- Avoiding use of any chemical for aroma, outlook, brightness of crop.

3. Rapeseed (*Brassica* spp)

Introduction

Rapeseed is one of the most important cruciferous oilseed crops in the world. The commonly grown oilseed crops in Nepal are: rapeseed *Brassica campestris var. toria* L., mustard *Brassica campestris var. juncea* L., and yellow rapeseed *Brassica campestris var. sarsoo* L., Among them, rapeseed (tori) is the major oil extracting crop in Nepal. It occupies about 85% of the oilseed crops in Nepal. Rapeseed and mustard seeds contain 40-45% oil and 24% protein respectively, which are considered safe for people with weak heart and suffering from chronic diseases. It is cultivated in area of 173,228 ha with production and productivity of 182,917 mt and 1.1 mt/ha, respectively (MOALD. 2018). Rapeseed in terai and mid hills is good source of income for the farmers and its oil has high export potential, which can earn foreign currency, and reduce reliance on foreign import as well. In spite of its high significance there are many constraints faced by the farmers in Nepal, which requires due attention.

Importance

1. Rapeseed farming is an important source of income for the farmers.
2. It occupies an important place in oilseed production in the country.
3. It is safe for people with weak heart and suffering from chronic diseases.
4. It is exportable to foreign countries, which provide an opportunity for earning exchange.
5. Organic farming is a system that excludes the use of synthetic fertilizers, pesticides, and growth regulators and is best suited for eco-farming.

Farmers' practices and production gaps

According to Kumar (2017) loss in seed yield due to mustard aphid and cabbage caterpillar infestation varied from 18.3 to 24.5% and major insect pests were mustard aphid and cabbage caterpillar in Ludhiana, India. productivity of rapeseed is less than one mt/ha in the national context. This productivity is very low and many problems are associated with low productivity, mainly due to farmers' traditional practices. Major contributing factors are: favorable weather, soil fertility and balanced use of fertilizers, irrigation facility, proper cropping practices, pollinators' management, bio-rational management of pests and Agriculture Policy enabling good environment for agriculture and innovation.

From organized studies during the last ten years on rapeseed-mustard in India, the average productivity gap of 10 to 25% is estimated between the improved and farmers' practices. The production is only 28, 44 and 54% of EU, Canada and China productivity, respectively (Sharma et al., 2018). The yield of rapeseed-mustard in improved practices under irrigated conditions ranges from 15.89 to 1.86 mt/ha and in farmer's practice between 1.25 to 1.4 mt/ha. The increase in yield with improved over farmer practice recorded in the range of 26.82 to 33.14% in India (Meena et al., 2012).

The aphid population differs significantly among variety and weathers parameters. Prasad (1983) evaluated the relative susceptibility of 20 cultivars of sarson, 30 cultivars of brown sarson and 40 cultivars of rai (*Indian mustard*) to infestation of *L. erysimi* in field trial in Delhi, India. The minimum mean aphid infestation was recorded in mustard cultivar IB- 680 and maximum in yellow sarson variety IB-787, respectively.

Intercropping mustard + coriander also reduced aphid infestation by 60.3% over control, which was better than Thiamethoxam chemical treatmentin in UP, India (Reddy et al., 2018). Intercropping combinations also showed positive and significant ($P \leq 0.01$) effect on water capture efficiency compared with sole cropping treatments (Koocheki et al., 2014).

Balanced nutrient is important for maximizing potential production of brassica. Ara et al. (2014) obtained the highest seed weight per plant, 1000 seed weight and oil content percent of rapeseed at 120kg Nitrogen/ha and 2 kg Boron /ha in Bangladesh.

Honey bee visitation to the brassica flowers is important for pollination and increasing seed yield. Among the three brassica crops tested in Almora, more number of bees were found visiting broccoli under net house condition (6.05 bees/plant) with the highest net benefits followed by kohlrabi (5.35bees/plants) and Chinese cabbage (5.05 bees/plant), respectively (Sushil et al., 2013). The seed weight and yield (gm) with pollination was 26 and 7.6 (gm) and without pollination was 9.3 and 1.51 (gm), respectively in Pakistan (Munawar et al., 2009). Chandel et al (2000) compared the performance of two honey bee species and reported that A. cerana collected more nectar load (mean 13.8mg) than A. mellifera (mean 12.1mg) from torai in Himanchal Predesh, India. *A. mellifera* visits on the blooms of *B. napus* and *B.*

juncea resulted in the highest seed weight per pod (106.09 and 98.58 mg, respectively), On *B. napus, A. mellifera* pollination resulted in 127.14, 23.69 and 49.65% increase in the number of pods per plant, number of seeds per pod and seed yield over exclusion of pollinators, while on *B. juncea*, the corresponding figures were 83.78, 35.39 and 43.46%, respectively in India (Kumari, 2014). Kevan and Eisikowitch (1988) reported that presence of pollinators, i.e. honey bees, on canola (cv. 0.A.C Triton) increases the germinability of resulting seeds from 83% to 96%, while pollination excluded seeds from bees germinate less than 83%. In Brazil, two cultivars self-compatible, but free visitation of insects tested increased productivity by 17% in the Hyola 420 cultivar and by approximately 30% in the Hyola 61 cultivar (Blochtein et al., 2014).

Among the several natural enemies in brassica field, few are very common, i.e. coccinellids, *Coccinella septumpunctata* L.; Syrphid fly, *Ischiodon scutellaris* F. and *Diaeretiella rapae* MacIntosh. Among the 7 insecticides (Imidacloprid, Thiamethoxam, Clothianidin, Thiaclorprid, Flonicamid, Dinotefuran, and Dimethoate) tested, thiamethoxam 25 WG, 0.01%recorded higher activity and proved comparatively safer to natural enemies and honey bees (Chaudhary et al., 2016).

Insect-resistant GM cultivars of oilseed rape are also being developed. For example, plants are being modified to contain *Bt* toxins and proteinase inhibitors (PIs), and these have potential to reduce insecticide application (Alford, 2003).

The economic yield of C_3 plants at elevated CO_2 can involve larger seed or grain size, more seeds/pod, ear or panicle, and/or more reproductive structures per plant, and C4 plants can't benefit. However, all C3 oilseed and grain crops had a lower harvest index at elevated CO_2. Franzaring et al. (2008) reported 18% economic yield, 18% individual seed weight and 17% above ground biomass increase of oilseed rape at elevated CO_2.

Considering human health and environmental pollution and pest resistance, for their management early sowing, yellow sticky traps, bio-agent conservation and application of safer chemical insecticides has been recommended.

Production practices need to follow step-by-step from the beginning to end of rapeseed production cycle to ensure healthy production and higher productivity; farmers are not following properly, so they are not getting higher yield.

SN	Production practice	Ideal practice	Farmers practice
1	Soil testing	Periodic soil analysis for nutrient status	Nutrient status unknown
2	Field hygiene	Timely cleaning, weeding, ploughing	Unhealthy orchards
3	Optimum soil pH	Lime application to correct acidic soil	Not following correctly
4	Balanced nutrient	Based on soil analysis optimum dose use	Not following properly
5	Micronutrient S use	Based on soil analysis micronutrient S use	Not following properly
6	Irrigation	Critical at veg growth, flowering stage	No facility or not following
7	Pollinators use and conservation	Conservation and use of pollinators (bees) to assure good pollination and fruit setting	Unknown about pollinators of rapeseed flowers
8	Pest management	Biorational and ecofriendly pest management	Indiscriminate use of pesticides
9	Harvest/postharvest	Proper care at harvest and after harvest for maintaining quality seeds	Poor care during harvest/ postharvest

Rapeseed farmers groups

Three farmers groups organized in the project district Dang oriented in IPPM-FFS for production and management of Brassica especially rapeseed:

- Planning for IPM technology based rapeseed production.
- Keeping prior history and yield of rapeseed.
- Recording soil test, pH, OM, NPK.
- Selecting farmer's field and rapeseed variety with managed irrigation and drainage facility.
- Recording temperature, rainfall, especially during flowering & fruiting period.

Field preparation and Sowing

- Farmer's field drained fertile sandy loam to clay loam soil with 6-8 pH.
- Ploughing and preparing field for FFS conduction and learning by farmers groups in their local situation.
- Selectiung varieties- Moran Tori-2, Preeti, Unnati, Pragati, Bikash, T-9, JY-16.F1 etc.
- Treating seeds with 2.5-3 gm fungicide for blight & rot.
- Planting in rows 30 cm apart with plant-plant distance of 10-15 cm

Manure and Fertilizers

- Using well decomposed FYM 10 mt/ha 20-25 days before seed sowing.
- Using chemical fertilizers @ 60: 40: 20 kg NPK/ha, half dose of N and full dose of PK as basal, and remaining N after 20-25 days with first irrigation.
- Using sulfur 20 (Sulfur dust) and boron 10 (Borex) per ha, and if soil deficient in zinc adding 10 kg zinc sulfate is recommended.

Intercultural Operation and Irrigation

- Thinning of rapeseed field to maintain uniform plant population and removing of weeds simultaneously.
- Manually weeding Orobanke in the rapeseed field and destroying properly.
- Irrigating field with first light irrigation at 25 days and another at 55 days.
- Introducing lentil as intercropping or two row rapeseed and one row lintel is beneficial.

Diseases Management

Alternaria Blight

- Using tolerant variety of rapeseeds.
- Adopting timely sowing of seeds,10-25 October.
- Removing weeds particularly collateral host plants.
- Applying recommended dose of potash to reduce disease incidence.
- Using *Trichoderma harzanium, T. virens, Streptomyces arabicus* as biocontrol.
- Spraying before flowering Metalaxyl 8% + mancozeb 64% WP @1500 g in 600 l of water/ha as last resort.

White Rust

- Following timely sowing of rapeseed and following rotation.
- Removing and destroying crop debris particularly stag heads of previous year crop.
- Avoiding over irrigation or water stagnation in the field.
- Using *Penicillium citrinum, Aspergillus ochraceous, Bacillus subtilis, Pseudomonas fluroscens etc* as biocontrol.
- Using Metalaxyl 35% WS @ 0.75- 1.0 kg/100 kg seed treatment before sowing.

Downy Mildew

- Following long crop rotation with cereals and adopting proper field sanitation.
- Avoiding over irrigation or water stagnation.
- Applying potash at recommended dose.
- Using *Penicillium chrysogenum, Trichoderma viridi* as biocontrol.
- Spraying carbandazim 0.1% or mancozeb 0.25% as last resort.

Powdery Mildew

- Adopt proper field sanitation and destroying crop infected and residues.
- Applying potash at recommended dose.
- Using fungal hyperparasite, *Ampelomyces quisqualis* as biocontrol.
- Spraying just before initiation of flowering with wettable sulphur 0.02% or carbandazim 0.03% and repeating at 10-14 days intervals taking care of considering pollinators.

Powdery Mildew

- Soil amendement with agriculture lime.
- Using healthy seeds and following crop rotation.
- Destroying infected plants and their roots.
- Using Flusulfamide @10-15 kg/ropani.

Insect Pests Management

Mustard Aphid

- Early sowing to scape and avoid damage.
- Using yellow sticky traps for attracting and trapping aphids.
- Using 2% Neem oil or 5% Neem Seed Kernel Extract (NSKE).
- Conserving prasitoids *Aphelinus,* predators ladybird beetle, lacewing, syrphid flies.

- Using Entomopathogenic fungus *Cephalosporium and Verticillium.*

Painted Bug

- Deep ploughing the soil to destroy eggs of painted bug.
- Early sowing to avoid pest attack.
- Conserving bio-agents *Alophora spp.* (tachinid fly) that parasitize eggs of painted bugs.
- Spraying dichlorvos76% EC @ 350 ml in 300-500 l of water/ha taking care of pollinators.

Mustard Saw Fly

- Summer ploughing to destroy the pupae and early sowing to scape damage.
- Collecting and destroying larvae of saw fly in morning and evening hours.
- Conserving *Perilissus* and *Serratia species* that infect the larvae of sawfly.
- Spraying dimethoate 30% EC @350 ml in 300-500 l of water/ha taking care of pollinator.

Harvest and Post-harvest

- Harvesting usually in the morning at maturity stage, i.e. 75% pods turning yellowish color.
- Uprooting or using appropriate tools sickle to harvest crops.
- Drying 3-4 days on sunshine and then separating seeds by beating against hard wood or flat stone.
- Cleaning and drying seeds on sunshine and storing at 8-9% moisture.

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ANNEXES

Area, production and productivity of some crops in Nepal

SN	Crop	Area (ha)	Production (mt)	Productivity (mt/ha)
1.	Cereal	3,428,986	10,012,742	2.920
2.	Oilseed	224,595	245,867	1.095
3.	Citrus	25,964	245,176	9.400
4.	Vegetable	286,864	3,958,230	13.798
5.	Coffee	2650	513	0.193
6.	Pulses	311,382	368,741	1.194
7.	Beekeeping	242,000 (Colony)	3,980	-

Source: CBS, 2019.

Fertile soil harboring numbers of diverse arrays of abundant organisms as indicators

SN	Organisms	Quantity
1.	All arthropods (including insects)	725 million/ha
2.	Insects	23 million/ha
3.	Bacteria	2.5 billion /gm
4.	Algae	50,000 /gm
5.	Earthworm	6 million/ha

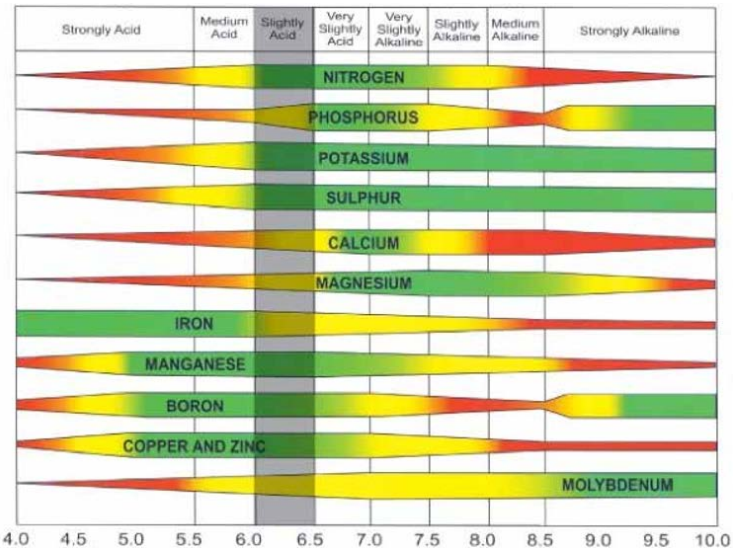
Source: USDA, 1985.

Plant growing in fertile soil is reservoir of nutrients which are essential elements required for plant growth, production and productivity

SN	Element	Form primarily absorbed by plants	Mass (%) in dry tissue	Major functions

	Macronutrients			
1.	Carbon	CO_2	45	Major component of plant's organic compounds
2.	Oxygen	CO_2	45	Major component of plant's organic compounds
3.	Hydrogen	H_2O	6	Major component of plant's organic compounds
4.	Nitrogen	NO_3^-, NH_4^+	1.5	Component of nucleic acids, proteins, hormones, chlorophyll, coenzyme
5.	Potassium	K^+	1	Cofactor that functions in protein synthesis; major solute functioning in water balance; operation of stomata
6.	Calcium	Ca^{2+}	0.5	Important in formations and stability of cell walls and in maintenance of membrane structure and permeability, activates some enzyme; regulates many responses of cells to stimuli
7.	Magnesium	Mg^{2+}	0.2	Component of chlorophyll; cofactor and activator of many enzymes
8.	Phosphorus	$H_2PO_4^+$, HPO_4^{2-}	0.2	Component of nucleic acids, phospholipids, ATP, several coenzymes
9.	Sulfur	SO_4^{2-}	0.1	Component of proteins, coenzymes
	Micronutrients			
1.	Chlorine	Cl^-	0.01	Requiring for water splitting step of photosynthesis; functions in water balance
2.	Iron	Fe^{3+}, Fe^{2+}	0.01	Components of cytochromes; cofactor of some enzymes, needed for photosynthesis
3.	Manganese	MN^{2+}	0.005	Active in formation of amino acids; activates some enzymes, required for water splitting step of photosynthesis
4.	Boron	$H_2BO_3^-$	0.002	Cofactor in chlorophyll synthesis; may be involved in carbohydrate transport and nucleic acid synthesis; role in cell wall formation
5.	Zinc	ZN^{2+}	0.002	Active in formation of chlorophyll; cofactor of some enzymes; needed for DNA transcription
6.	Copper	Cu^+, Cu^{2+}	0.001	Compound of many redox and lignin-biosynthetic enzymes
7.	Nickle	Ni^{2+}	0.001	Cofactor of enzyme functioning in nitrogen metabolism
8.	Molybdenum	MoO_4^{2-}	0.0001	Essential for mutualistic relationship with nitrogen-fixing bacteria; cofactor in nitrate reduction

Source: Huang et al., 2008.



Soil pH affects the availability of plant nutrients. Gray area depicts a neutral pH of soil, when all nutrients are soluble.
Source: Barimdze et al. 2015.

Mean number of individual group of arthropods/month and their percentage/month in non-cultivated (NCP) and cultivated (CP) plots

Arthropod	Nov		Dec		Jan		Feb		Mar		Apr	
	NCP	CP	NCP	CP	NCP	CP	NCP	CP	NCP	CP	NCP	CP
Acarina	34 (12.27)	19 (19.79)	42 (15.16)	16 (16.66)	66 (23.82)	27 (28.12)	72 (25.99)	22 (22.9)	35 (12.63)	9 (9.3)	28 (10.10)	3 (3.12)
Collembola	57 (11.72)	55 (14.70)	101 (20.78)	67 (17.91)	112 (23.04)	92 (24.59)	121 (24.89)	96 (25.66)	53 (10.90)	33 (8.82)	42 (8.64)	31 (8.28)
Hymenoptera	12 (9.67)	21 (10.09)	15 (12.09)	26 (12.50)	26 (20.96)	37 (17.78)	30 (24.79)	49 (23.55)	21 (16.93)	33 (15.86)	20 (16.12)	42 (20.14)
Coleoptera	15 (12.93)	5 (11.11)	16 (13.79)	4 (8.88)	22 (18.96)	11 (24.44)	31 (26.72)	12 (26.66)	18 (16.51)	7 (15.55)	14 (12.06)	6 (13.33)
Diptera	2 (2.2)	4 (20)	3 (3.3)	2 (10)	4 (4.4)	1 (5)	22 (24.44)	3 (15)	27 (30.0)	4 (20)	32 (35.55)	6 (30)
Insect larvae	20 (13.42)	5 (16.66)	26 (17.44)	4 (13.33)	37 (24.83)	9 (30)	42 (28.18)	5 (16.66)	11 (7.38)	3 (10)	13 (8.72)	4 (13.33)
Others	7 (3.19)	2 (8.69)	11 (26.82)	4 (17.39)	9 (21.95)	6 (26.08)	7 (17.07)	6 (26.08)	5 (12.19)	2 (8.69)	2 (4.87)	3 (13.04)
pH	6.3	6.1	6.2	5.9	6.9	6.1	6.8	6.2	5.5	5.7	5.3	5.2
Moisture (%)	27.80	27.7	24.30	24.4	26.70	27.2	29.70	29.4	23.50	27.3	21.5	25
Temp (ºC)	28.00	27.50	22.30	24	21.50	22	24.60	24.20	33.50	32.50	34.00	33.70

CP= Cultivated plot & NCP= non-cultivated plot. **Source**: Paul et al. 2011.

Some beneficial insects in an agro-ecosystem

SN	Insect	Picture	Use
1.	Lady beetle		Ladybeetles often feed on mites, thrips, scales and aphids.
2.	Lace wing		Lace wings feed on aphids.

3.	Preying mantid		Preying mantids are general predators that catch and feed on moving insects.
4.	Assassin bug		They are general feeders with sucking mouthparts.
5.	Ground beetle		They are fast moving insects and prey on other insects.
6.	Syrphid fly		Adult flies are beneficial for pollination, while the larvae feed on aphids.
7.	Tachnid fly		They feed on other insects.
8.	Braconids		They parasitize on other insects.
9.	Trichogramma		The minute wasps attack insect eggs.
10.	Honeybee		Bees are the best pollinators of plants.
11.	Bumble bee		They are important pollinators of plants.
12.	Wasps		Wasps make mud nests and prey on other insects.

Source: Barbosa, 1998.

Pesticidal value of Nepal's indigenous plants

SN	Scientific name of plant	Nepali name	Part and mode of preparation	Action and properties
1.	*Acorus calamus* L.	Bojho	Bulb	Insecticide, repellent & contact poison
2.	*Agave Americana* L.	Ketuki	Plant sap	Insect repellent and fish poison
3.	*Allium sativum* L.	Lashun	Bulb	Insect repellent
4.	*Annona squamosa* L.	Sarifa	Leaves, immature fruits & seeds	Insecticide and parasiticide due to glycerol of hydroxilated acid
5.	*Artemisia vulgaris* L.	Tite pati	Green or dried foliage	Repellent and fumigant against insects due to Santonin, an alkaloid
6.	*Boenin ghausenin albiflora*	Ankuri	Plant, leaf extract	Insect repellent especially to flies
7.	*Canna indica* L.	Sarbada	Extract of flower	Insecticide
8.	*Cinnamomum camphora* Nees	Kapoor	Wood solid crystal	Insect repellent used in preparation of insecticides
9.	*Crotalaria juncea* L.	Chhinchhine	Flower extracts	Effective against many insects
10.	*Chenopodium botrysis* L.	Bethe	Whole plant	Insect repellent
11.	*Derris elliptica* Bench.	Deri	Lateral line root & powdered root	Rotenone extracted from root is active ingredient of many insecticides. Root powder used as insect powder for pets
12.	*Digitalis purpurea* L.		Leaves and seeds	Pesticide
13.	*Feenum graeccum*	Methi	Seed	Source of insect repellent and insecticide, due to an alkaloid Trigenelline
14.	*Gynandropsis*	Marcha	Seed oil	Vermicide
15.	*Hedera helix* L.	Kathe lahare	Whole plant	Resistance to some insects
16.	*Heynea trijuga* Rexb.	Ankha taruwa	Foliage	Insect repellent
17.	*Hedychium spp.*	Kewara	Rhizome	Effective against harmful bacteria & fungi due to essential oil
18.	*Kalanchoe pinnata* pers.	Ajambari	Plant juice	Insect repellent
19.	*K. spathulata* DC	Hatti kane	Plant juice	Insect repellent
20.	*Litsea cubeba* Pers	Siltimmur	Leaves & fruits	Insect repellent, wormicide
21.	*Lannea grandis* Engle	Hallongre	Wood	Resistant to termites due to jingan gum
22.	*Mangifera indica* L.	Aap	Powdered plant	Fumigant against mosquito
23	*Mesua ferrea* L.	Nageswar	Wood	Resistant to some types of termites
24.	*Melia azedarach* L.	Bakaino	Foliage, fruit, wood & seed oil	Insecticide & insect repellent. Insecticide preparation due to Nimbidin

25.	*Nicandra phaseoloides* Gaertn.	Madisetil	Fresh foliage	Insecticide
26.	*Nicotiana rustica*	Beleyati surti	Leaf	Insecticide and wormicide due to an alkaline Nicotine
27.	*Nicotiana tabacum*	Lampate surti	Leaf	Insecticide and wormicide due to an alkaline Nicotine
28.	*Nerium odorum* Ait	Pahelo karabir	Extracts of root, stem, leaves, flower & fruit	Contact and stomach poison to rodents, due to Nerin, an alkaloid
29.	*Sapindus mukorossi* Gaertn	Rittha	Fruit	Insecticide and fish poison
30.	*Sesamum indicum* L.	Sesame	Till	Major ingredient of insecticidal preparation
31.	*Tagetes minuta* L.	Sanosayapatri	Foliage	Insect repellent
32.	*Zanthoxylum armatum* DC	Timur	Fruit decoction foliage	Wormicide, insect repellent & fish poison, due to Neehercullin insecticidal component
33.	*Zingiber officinale* Rose	Aduwa	Ingression of rhizome extract	Body immunity against mosquitoes. Insecticide due to essential oil.

Source: Dahal et al. 1995.

Farm soil properties under vermi-compost and chemical fertilizer

SN	Chemical and biological properties of soil	Vermi-compost	Chemical fertilizers
1.	Availability of nitrogen (kg/ha)	256.0	185.0
2.	Availability of phosphorus (kg/ha)	50.5	28.5
3.	Availability of potash (kg/ha)	489.5	426.5
4.	Azatobacter (1000/gm of soil)	11.7	0.8
5.	Phospho-bacteria (100,000/kg of soil)	8.8	3.2
6.	Carbonic biomass (mg/kg of soil)	273.0	217.0

Source: Suhane, 2007.

Some beneficial organisms used as bio-fertilizers in vegetables

SN	Organism	Mode of action	Use in crops	Method of treatment	Dose (g/ha)
1.	Rhizobium	Symbiotic N fixation	Leguminous vegetables	Seed treatment	600
2.	Azotobacter	Asymbiotic N fixation	Vegetables	Seed treatment	3,400
3.	Azospirillum	Asymbiotic N fixation	Vegetables	Seed treatment Soil application	1,000 2,000
4.	PSM	Phosphorus solubilization	Vegetables	Seed treatment	600

Source: Chaudhary et al. 2014.

New insecticides recommended (gm/ha) for insect control in vegetable crops in India

Common name	Formulation	a.i. (gm)	Formulation (gm/ml)	Dilution in water (liter)
Buprofezin	25 % SC	75-150	300-600	500-750
Chlorantranilprole	18.5% SC	10	50	500
Chlorfenpyre	10 % SC	75-100	750-1000	500
Difenthiuron	50 % WP	300	600	500-750
Emamectin benzoate	5 % SG	6.75-10	135-200	500
Fenazaquin	10 % EC	125	1250	400-600
Fenpyroximate	5 % EC	15-30	300-600	300-500
Fipronil	5 % SC	40-50	800-100	500
Flufenoxuron	10 % DC	40	400	500-1000
Flumite/ Flufenzine	20 % SC	80-100	400-500	500-1000
Hexythiazox	5.45 % EC	15-25	300-500	625
Imidacloprid	70 % WG	21-24.5	30-35	375-500
Imidacloprid	48 % FS	300-540/100 kg seed	500-900	-
Imidacloprid	70 % WS	350-700/100 kg seed	500-1000	-
Imidacloprid	17.8 % SL	25-20	125-250	500-700
Indoxacarb	14.5% SC	30-75	200-500	400-750

Indoxacarb	15.8 % SC	40	266	500-1000
Lufenuron	5.4% EC	30	600	500
Metaflumizone	22 % SC	165-220	150-1000	500
Milibectin	1 % EC	3.25	325	500
Novaluron	10% EC	33.5-75	750-375	500-1000
Pyridalyl	10%EC	50-75	500-750	500-750
Spinosad	2.5% SC	15.0-17.5	600-700	500
Spinosad	45% SC	73	160	500
Spiromesifen	22.9% SC	96	400	500
Thiacloprid	21.7% SC	54-72	225-300	500
Thiamethoxam	25% WG	25	100	500-1000
Thiamethoxam	70% WS	200	286	-

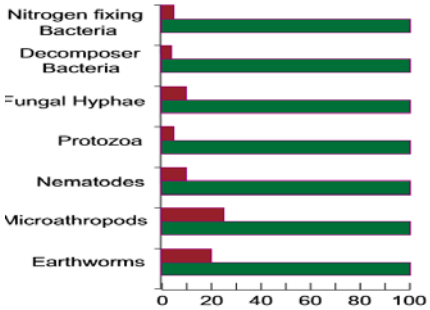
Source: Kodandaram et al. 2010.

Status of pesticide residues in tomato samples from IPM and non-IPM plots

SN	Pesticide	Residues in IPM samples (ppm)	Residues in non-IPM sample (ppm)	MRL (ppm)
1.	No residues detected	(6)	(0)	-
2.	Acephate	-	0.003 (1)	2.0
3.	Carbendazim	0.01-0.112 (5)	0.014 (1)	0.5
4.	Chloropyrifos	0.003, 0.01 (2)	0.003, 0.02 (2)	0.5
5.	Chlorothalonil	0.001 (1)	-	2.0
6.	Cypermethrin	0.038, 0.001 (2)	-	0.5
7.	Deltamethrin	0.001, 0.002 (2)	0.001 (1)	0.2
8.	Dicofol	0.01 (1)	-	1.0
9.	Dimethoate	0.001 (1)	-	1.0
10.	Endosulphan	0.002, 0.087 (2)	0.019 (1)	3.0
11.	Ethion	0.08 (1)	0.05 (1)	0.5
12.	Fenamiphos	-	0.01 (1)	0.2
13.	Fenvalerate	0.003 (1)	-	1.0
14.	Fluvalinate	0.35 (1)	-	0.5
15.	Imidacloprid	0.01 (1)	0.04, 0.05 (2)	0.1
16.	Lamda cyhalothrin	0.01 (1)	0.70 (1)	0.1
17.	Lindane	0.01 (1)	0.011 (1)	1.0
18.	Malathion	0.01 (1)	-	3.0
19.	Methyl parathion	0.002 (1)	-	0.01
20.	Monocrotophos	0.08 (1)	-	1.0
21.	Profenofos	0.003 (1)	-	2.0
22.	Triazophos	0.35 (4)	0.01-0.04 (4)	0.1

*Figures in parenthese show number of samples with residues of a particular pesticide, **No. of samples: Total = 31, IPM = 26 (none above MRL), non-IPM=6 (3 above MRL). It was observed that vegetables grown as per IPM practices were safer to consume at harvest compared to those grown as per conventional cultivation practices. **Source**: Sharma et al. 2019.

Long term effect of different management systems



Relationship of organisms in 1 kg surface soil after 10 years of different management systems (Traditional management (red bar) included burning and conventional tillage, Sustainable management (green bar) used stubble retention and reduced tillage). **Source**: Gupta et al. NA.

Conventional agricultural technologies for climate change adaptation and mitigation

SN	Measure	Technology	Application
1.	Climate change mitigation	No-till practices	Coffee and banana and horticultural farming
2.	Reduced artificial fertilizer use	Biofertilisers	Composting and use of animal manure
3.		Agroforestry	Mycorrhizal and actinorrhizal symbiosis
4.	Carbon sequestration		Inoculation of nitrogen fixers Biogas from agro wastes
5.		Biofuels production	Bioethanol from sugarcane Biodiesel from jatropha, palm oil
6.		Mulching	Horticlutural practices
7.	Adaptation to climate change: Adaptation to biotic & abiotic stress	Tissue culture	Drought tolerant sorghum, millet, sunflower
8.		Cross breeding	Drought resistant Pearl millet
9.		Agroforestry	Shading coffee and banana plantations
10.	Improved productivity	Increased crop yield per unit area of land	Crop rotation, traditional pesticides

Source: Ranabhatt and Kapor. 2018.

Conventional agricultural technologies for climate change adaptation and mitigation

SN	Measure	Technology	Application
1.	Climate change mitigation	Engineering herbicide resistance to reduce spraying	GM soybeans, GM canola
2.	Less fuel consumption	Engineering insect resistance to reduce spraying	Bt maize, cotton and eggplants
3.	Reduced artificial fertilizer use	Engineering nitrogen fixation	Genetic improvement of Rhizobium; inducing N-fixation to non-legumes
4.	Carbon sequestration	No-till farming Biotechnological advances	Herbicide resistant GM soybeans, canola
5.	Adaptation to climate change	Green energy Nitrogen- efficient GM crops Molecular marker assisted breeding for stress resistance	GM energy crops, N-efficient GM canola Drought resistant maize, wheat hybrids
6.	Adaptation to biotic & abiotic stress	Engineering drought tolerance	GM Arabidopsis, Tobacco, maize, wheat, cotton, soybean
7.		Engineering salt tolerance	GM tomato, rice
8.		Engineering heat tolerance	GM Arabidopsis, GM Brassica sp
9.	Improved productivity per unit area	Increased crop yield per unit area of land	Fungal, bacterial and viral resistant GM cassava, potatoes, bananas, maize, canola

Source: Ranabhatt and Kapor. 2018.

Ecosystem service, descriptions and related on-farm benefits

SN	Ecosystem service	Description	On-farm benefits
1.	Provision of food, feed, fuel biochemical	Harvestable goods from agroecosystem	Foods and other goods for on farm consumption or sale
2.	Soil structure and fertility enhancement	Soil structure and processes of nutrient cycling and delivery of nutrient to plants; processing of organic matter and transforming detritus and waste	Support for crop growth and can limit need of chemical fertilizer
3.	Erosion protection	Soil retention limiting soil loss through wind and water erosion	Maintain soil, and the nutrients it contains, to support production

4.	Hydrologic services: Water flow regulation	Buffering and moderation of the hydrologic cycle, including water infiltration into soils and aquifers, moderation of runoff, and plants transpiration	Water in soils, aquifers, and surface bodies available to support plant growth
5.	Hydrologic services: Water purification	Filtration and absorption of particles and contaminants by soil and living organisms in the water and soil	Clean water available for human consumption, irrigation, and other on-farm uses
6.	Pollination	Transfer of pollen grains to fertilize flowers	Necessary for seed set and fruit production in flowering plants and crops
7.	Pest control	Control of animal and insect pests by their natural enemies – predators, parasites, and pathogens	Minimize crop damage and limit competition with crops
8.	Weed control	Botanical component of pest control; suppressing weeds, fungi, and other potential competitors through physical and chemical properties of cover crops, intercrops, and other planted elements	Minimize weed competition with crops
9.	Carbon sequestration	Atmospheric carbon dioxide is taken up by trees, grasses, and other plants through photosynthesis and stored as carbon in biomass and soils	Few demonstrable on-farm benefits
10.	Genetic resources	Pool of genetic diversity needed to support both natural and artificial selection	Distinct genotypes (cultivars) allow fruit set in orchards and hybrid seed production; trait diversity (from landraces and wild relatives) supports disease resistance, new hybrids, and climate adaptations
11.	Cultural and esthetic services	Maintaining landscapes that support: esthetics and inspiration; spiritual and religious values; sense of place; cultural heritage; recreation and ecotourism	Esthetics and inspiration; spiritual and religious values; sense of place; cultural heritage; recreation and ecotourism

Source: Garbach et al. 2014.