Package of Organic Practices from Uttaranchal

for

Chili, Mustard, Potato and Soybean

The Institute of Himalayan Environmental Research and Education

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Prepared by
The Institute of Himalayan Environmental Research and Education

INHERE
Masi, Distt. Almora, Uttaranchal

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Prepared by Institute of Himalayan Environmental Research and Education (INHERE)
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INHERE CONTACT:
Ms. Sonali Bisht
Institute of Himalayan Environmental Research and Education
Masi Bazar, Masi 263 658
Almora, Uttaranchal
Tel: 05966-257217/257374/246342
Fax: 05966-257217
E-mail: inhere@rediffmail.com
Website: www.inhereindia.org

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INHERE

Preface

In India, the use of chemical fertilisers and pesticides increased with the beginning of the green revolution. Since then, the non stop use of chemicals in the form of fertilizers and pesticides in agriculture for increasing the productivity to meet the needs of the growing population of the country has resulted in adverse effects on the health of human beings, soils and animal and plant kingdoms. Today the world is again very seriously looking to rejuvenate the practices of organic agriculture for the betterment and sustainable future of mankind.

In this context today, all conscious people and institutions, government and non-government organizations, formal and non formal groups and individuals are making sincere and committed efforts to promote organic agriculture for protecting the soil and the environment, promoting human health as well as supporting the economy of the small and marginal farmers across the globe.

With the help of the present project on 'Documentation of packages of practices of four potential crops of Uttaranchal,' a similar effort is being jointly made by the National Centre of Organic Farming, MOA, Government of India and the Food and Agriculture Organization (FAO), New Delhi, of the United Nations to promote and strengthen the efforts for organic agriculture.

We believe that the present project will help farmers across the globe through this sharing of the rich practices of the small farmers of Uttaranchal described and explained in the present document by INHERE, a non profit making organization working for the development and welfare of the people of the Kumaon and Garhwal Himalayas of Uttaranchal, India.

The agriculture of the Himalayan states has always been nature- and eco-friendly due to its rich traditional and distinctive practices. These areas have always been prosperous in biomass. Despite the limited irrigation facilities, fragmented and small land holdings, and non availability of modern inputs, agriculture in the Himalayas has supported its people for generations in adverse conditions and continued to remain, even today, the principal source of livelihood.

The present study has documented the package of organic practices of the Himalayan farmers used in the cultivation of potato, chili, mustard and soybean. The basic objective of the study is to make available information and literature on these packages of practices to the small and marginal

farmers who need them the most and who can then use them to strengthen the movement for organic farming.

Contents

GLOSSARY OF LOCAL TERMS

Bhakhar, wooden box

Chalni, sieve

Danyala, comb hoe, used for weeding

Dalot, wooden hammer

Kulna, storage vessel

Kudal, hand harrow

Mosta, local fibre mat

Pata, wooden plank

Supa, winnowing fan

Tumdi, a storage vessel made from gourds

PRA, Participatory Rural Appraisal

Kutla, hand harrow

Khals, water ponds

Goth, cattle-shed

Guhls, minor irrigation channels

Simar, waterlogged area.

INTRODUCTION

AGROLOGY OF UTTARANCHAL

Uttaranchal is rich in biodiversity. The wide differences in climate within the state create an environment for diverse agricultural crops and natural vegetation, thereby enhancing the potential of the small and fragmented land holdings that farmers in the Himalayas generally possess. Diverse crops can be grown due to the mountain topography and the varied elevation levels.

The total reporting area of Uttaranchal is 53,483 sq. km., of which 62.5 percent is forest and 14.02 percent is agriculture. Of the latter, agricultural land in the hills and in the plains is 56.8 percent and 43.2 percent respectively. Irrigated land is only 9.43 percent. The largely rain-fed agriculture, with very low use of chemical fertilizers and pesticides, provides an opportunity to make farms environment and farmer-friendly by converting them to organic agriculture, whose produce commands better value in the market. Other factors supporting organic agriculture include the following: the land holdings are marginal; there exists a culture of rearing indigenous cattle; traditional agricultural practices are still followed to a great extent; and accessibility of farmers to chemicals in these remote areas is very low.

The practice of cultivating *barahanaja* crops (i.e., growing twelve types of food grains as a mixed or multi crop) – or variations on that pattern – is common among the mountain farmers. The cultivation of mixed and multi-crops is believed to enhance the fertility of the soil, maintain its essential nutrients and naturally reduce the chances of pest infestation.

In most parts of the state, two harvests, one of *kharif* and the other of *rabi*, are taken. The main *kharif* crops are paddy, *mandua* or ragi (*Eleusine coracana*), *jhangora* (*Oplismenus frumentaceus*) and pulses while wheat, mustard, and in some areas barley, form the principal *rabi* crops.

The system of cultivation, type of crops grown and method of crop rotation are determined by the nature of the soil, the physical features and the special needs of the cultivators.

Agro climatic zones

Due to micro climate differences, the agro climatic zones in the region can be divided broadly as follows:

- Plains and tarai, bhabhar zone (up to 1000 ft.)
- Middle Himalayan zone (1000 to 3000 ft.)
- Higher Himalayan zone (above 3000 ft.)

Within these broad geographical divisions, there are again differences in the practices of cultivation reflected in the use of different terms:

Katil

Katil is a primitive form of hill agriculture and considered as the first stage of terracing. It is comparable with *jhuming* (shifting cultivation) in north-eastern India. Forest land covered with shrub and bush is cleared and burnt. Seeds are then broadcast over the ashes, which is the only form of manure. The land is then broken with a hoe or dug with a pickaxe to cover the seeds. Neither irrigation nor weeding is done but regular rotation of crops such as *mandua* or ragi (*Eleusine coracana*), *chua* (*Amaranthus frumentaceus*), *gohat* (horsegram or *Delichos biflorus*), *ogal* (buckwheat), turmeric, etc., is followed. After every crop, the land is left fallow for three or more years. This form of agriculture is now almost extinct.

Upraon

The *upraon* method of cultivation is followed on the upland slopes which are permanently terraced. The quality of the land varies according to the available soil nutrients, the evenness of the fields, their proximity to the forests, accessibility of the slopes, nearness to homesteads, transport facilities and their position on the sunny or shady sides of the ridge. However, these fields are all at relatively higher levels without any means of irrigation and are adaptable mostly to dry crops.

The *kharif* crops are *mandua, jhangora, kauni* (*Panicum italicum*), *bhat, gohat, chua*, etc.

The type of cultivation in *uproan* is an indication of the dominating influence of topography and the people's adaptation of agriculture to it. The steep and rugged mountainous terrain, the scarcity of tracts of level ground and the small proportions of cultivable land have all necessitated the practice of terracing in the region. Mountain sides have been cut into hand-made fields, rising in succession, like gigantic flights of steps, ascending from the banks of streams towards the summits of the hills. The construction of these terraces involves enormous labour, time, capital, skill and perseverance. Terraces vary in length, breadth and height according to the form and slope of the ridge on which they are built. The usual width varies between three to six metres, length between five to 25 metres, height between 1.5 metres to three metres and the area they occupy is between 50 to 200 square metres. Terraces that are three to six metres wide are common in the *upraon* lands and in some places as many as 500 terraces can be counted in continuous flight. Their repair and maintenance is even more difficult and labourious than their construction, as 25 to 40 percent of the terrace walls break down each year during the rainy season.

Talaon

Talaon lands are located generally at the foot of the hills and are permanently irrigated or irrigable. They are characterized by proximity to the rivers and their tributaries. They have mild climate, broad, level valleys and low lying fields that are fertile and have fine alluvial soil.

Three types of *talaon* lands can be classified. The first class *talaon* lands are known as the *seras*. In the *seras*, water supply is perennial and flows gently, the fields are low lying, the soil comprises the finest clay and double cropping is the normal practice. *Seras* are always under cultivation and never allowed to lie fallow.

Paddy is the main crop during the *kharif* season, and wheat, barley and mustard are grown in valley areas as *rabi* crops.

Pancher

Pancher lands are irrigated by the intermittent streams on the hillsides. They are situated at higher levels and possess comparatively low productivity. In the water-logged lands of fens and marshes in the tarai and foot hills, *simar* cultivation is also practised.

Cropping systems

The most dominant crops in the mountain regions of Uttaranchal are paddy, wheat and *mandua* and these three crops account for over 70 percent of the gross cropped area.

The objective of any cropping system is efficient utilization of all resources, i.e., land, water and solar energy, maintenance of stability in production and high returns. In case of Uttaranchal, the following cropping systems are followed:

Mono-cropping: Both chili and potato are cultivated mostly as single crops in the hills. In this cropping system the same crop is cultivated in the same land year after year.

Multi-cropping: Multi cropping systems are common systems in both the hills and also the plains of the state. The following cropping systems are common under multi-cropping:

Inter-cropping: Growing of wheat and mustard simultaneously on the same piece of land is done in the plains and tarai bhabhars of Uttaranchal. In this cropping system definite row arrangements are made with a fixed seed ratio of 9 : 1.

Parallel cropping: Cultivation of radish and spinach with potato, chili with coriander and soybean with maize or ragi as parallel crops is a common practice in the hilly region. In this cropping system, crops of different durations are cultivated together.

Companion cropping: Here, the production of both the inter crops is equal to that of their solid planting.

In the plains, mustard or potato is cultivated as a parallel crop with onion and sugarcane respectively.

Relay cropping system: This type of cropping system is mostly used during the kharif season in the higher Himalayan zones. Cultivation of mustard with the potato crop in the month of July is a common practice in this cropping system.

Mixed cropping: This practice is commonly used for the cultivation of millets and vegetables in the hill areas. The seed is generally sown by broadcasting.

Management and maintenance of appropriate habitats for the sustenance of different life forms is an essential component of organic farming. This can be achieved by maintaining crop diversity and conserving the natural biodiversity of the area around the fields as much as possible.

In the state of Uttaranchal, different type of trees, bushes and shrubs can be seen near the agriculture fields. These plants help the crop to obtain valuable nutrients to supplement their growth. The mixed vegetation also provides shelter and food for birds and friendly insects which in turn protects the crop from pest attacks and thus enhances the productivity of the field.

Since the inputs for agriculture are farm-based, the farmer enjoys a great deal of self reliance and independence and escapes indebtedness, which is the bane of farmers today.

Manuring

Manuring occupies a significant place in hill agriculture due to the poor, shallow and stony texture of the soil and its quick impoverishment by the scouring action of the rains. In *katil* cultivation, the burnt ashes are the only form of manure spread over the land to give fertility to the soil. In *talaon* lands, silt brought down by *guhls* (small channels) is sufficient to keep them fertile. Manuring is, however, needed most in *upraon* lands. Cow and buffalo dung is usually used for manuring. Leaf manure,

prepared by the mixing of leaves, dung, urine and litter, and kept to decompose for some months, is also used. Farmyard manure, usually stacked in heaps outside the dwelling houses, is also utilised as and when required. In the greater part of the state, the *goth* system is prevalent. This involves construction of a shed formed by *palla* or *pharkha* – a sort of thatched hurdle about 2.5 x 1.5 m and made of wood and bamboo, thatch and leaves.

The shed is called a *goth* and it is moved from field to field along with the cattle, wherever manuring is required. Nowadays, the practice appears to be getting extinct.

Irrigation

In the mountain areas, irrigation is done by means of *guhls* which draw their water from the rivers or streams that flow through the valleys. The length of the *guhl* will vary according to the height of the land that is to be irrigated measured from the lowest parts of the valley and the more or less rapid fall in the stream. Like the system of terracing, *guhl* irrigation is also an arduous task. It requires not only capital, labour and patience but also skills suitable to the local needs and conditions.

Importance of the crops selected for the study

For the documentation of organic package of practices for Uttaranchal, the potato, soybean, chili and mustard have been selected for the following reasons:

- 90.57 percent of agricultural land in Uttaranchal is rain-fed and these crops require little or no irrigation.
- Cultivation of the selected crops entails fewer risks because they are drought resistant.
- These crops form a part of the daily food intake of the population and hence have a good local market.
- They are valued as high quality mountain crops and market demand is good even outside the state.

Salient features of the study

The present study is based on the guidelines provided by the Food and Agricultural Organization (FAO).

- It focuses on the indigenous organic agricultural practices used by farmers.
- Uttaranchal is taken as a representative region for conducting the study, due to its diverse geography.
- The study is mainly based on primary data and is supported by secondary data collected during a literature survey as well as by personal interviews.

Methodology used

- Development and testing of survey format.
- Orientation of the survey team.
- Selection of sample villages representing:
  - Higher mountain areas
  - Middle mountain and valley areas
  - Tarai and plains
- Sample size – 32 villages
- Institutions contacted – 11
- Techniques used:
  - PRA
  - Village level workshops
  - Individual interviews
  - Transect walks
  - Literature surveys

Coverage

- Cultural and physical agricultural practices
- Management of soil and soil fertility
- Management of pest and diseases
- Other indigenous agricultural practices
- Suggestions and recommendation

Limitations of the study

- Period of the study was short; time for surveys was also short.
- Study took place in the off season (in north India).
- Fewer persons having indigenous knowledge were available for interviews during the period.

REFERENCE

Dobhal G.L. 1987, *Development of the Hill Areas*, Concept Publishing Company, New Delhi.

CHILI

Hindi – *mirch;* Bengali – *lanka morich;* Gujarati – *marcha;* Kannada – *mainsina kaai;* Marathi – *mirchi;* Telugu – *mirapakaya*

BACKGROUND TO THE CROP

The chili plant (*Capsicum annum L*) is an important member of the family *Solanaceae*. It is a spice crop, valued for its diverse commercial uses. Only a few perennial chili varieties, characterized by small-sized pods and high pungency, which are rarely cultivated commercially, belong to *C. frutescens*. India is a major producer, consumer and exporter of chili. Indian chili reaches over 90 countries in the world including Bangladesh, Bahrain, Canada, Italy, Israel, Japan, Malaysia, Netherlands, Philippines, Singapore, Spain, Sri Lanka, Saudi Arabia, USA, and UAE.

Origin

Chili cultivation originated in south America. The Portuguese introduced the plant into India in the fifteenth century.

Area and distribution

In India, chili is grown in almost all the states. Andhra Pradesh is the largest chili growing state and accounts for 32 percent of the country's total chili cultivation area. Next in importance are Karnataka and Maharashtra. As per statistics of 2002–03, the total area of chili cultivation was 7,58,000 hectares, annual yield 12,87,000 tonnes, i.e., with a productivity of 16.98 quintals/ha.

Climate

The chili plant requires a warm, humid climate during early stage of growth and dry weather at the maturity stage. Chili is grown both in tropical and subtropical areas up to 2100 m above sea level. In rain-fed areas, annual rainfall should not exceed 75–100 cm. Excessive rainfall causes defoliation and rotting. In north India, chili is grown in the summer season. Ideal temperature for the growth and budding of the crop is 21–27 ^{0}C. Excessively high or excessively low temperature and dry winds adversely affect the crop.

Cropping system

Chili is usually cultivated as a single crop but in some places it is cultivated along with *ugal*, brinjal, carrot, etc. Mixed cropping is usually adopted in those areas where the transplantation method is used. In non-irrigated areas, the field is kept fallow for some time before chili is cultivated and after it is harvested, wheat, mustard or a mixed crop of wheat and mustard is cultivated in the field. The following crop cycle is followed in the cultivation of chili:

Kharif	***Rabi***	**Period**
Chili	**Wheat**	**1 year**
Chili	**Mustard**	**1 year**
Chili	**Wheat + mustard**	**1 year**
Chili	**Potato**	**1 year**

Growing season

Chili is cultivated as a *kharif* crop. The schedules of chili cultivation in different geographical areas are as follows:

Hill areas

Nursery preparation: second week of March.

Transplantation: last week of April–first week of May

Broadcast sowing: third week of February–first week of March

Plain areas

Nursery preparation: in the month of May

Transplantation: last week of June–second week of July

Soil

Chili is grown in different types of soils, ranging from sandy to heavy clay. A well drained, fairly light, fertile loam with fair moisture holding capacity and pH ranging from 6.5–7 is considered to be ideal. Heavy soil is not suitable for raising chili during the rainy season. Water stagnation for more than 24 hours leads to the death of chili plants. Light soils produce better quality chili when compared with heavy soils.

Duration

Due to its cultivation at different temperatures and timings, the duration of the crop also varies. In the high hills, it takes 7–8 months while in the valleys, tarai and plains the duration is 6–7 months.

Seedlings are kept in the nursery for around 30–35 days before being transplanted in the main field.

VARIETIES

There are several varieties of chili with large variations in fruit colour, shape and size. Varieties having thin pericarp, low seed content and strong spike are suitable for use as dry chili.

Traditional varieties

Red chili: A variety that can survive with minimum irrigation. The fruit hangs from the plant, inclined downward.

Yellow chili: Its yield is higher than that of the red chili variety. Its fruit hangs downward from the plant.

Lakhauri chili: Small in size, light yellow in colour and very pungent. Commercially preferred due to its pungency.

Janjiri chili: Larger in size and even more pungent than the Lakhauri chili. It points upwards while growing on the plant.

Improved varieties

Pusa Jalwa: Developed by the Indian Agricultural Research Institute, New Delhi, this variety is resistant to fungus-caused diseases. Its fruits are thin and approx. 8–12 cm long and they hang vertically on the plant. The yield as dry chili is 10–25 quintal/ha.

Pusa Sadabahar: A red-coloured variety developed by the Indian Agricultural Research Institute, New Delhi. The plant can last for 2–3 years. Its fruits are 6–8 cm long and stand straight on the plant while it is growing in the field. Its yield as dry chili is 8–15 quintal/ha.

Punjab Lal: Developed by the Punjab Agricultural University, Ludhiana, this red coloured variety is 4–5 cm long and stands straight on the plant. Its yield as dry chili is 6–8 quintal/ha.

Bhagya Laxmi: This variety can be cultivated even in dry and arid areas. Its leaves are small and the fruit is 4–5 cm. long and dark in colour. Its yield as dry chili is 8–11 quintal/ha.

Besides these, Andhra Jyoti, Aparna, Arka Lohit, Kashi Anmol, Kashi Vishwanath, Utkal Ava, CH-1, CH-21, NS-101, 3, Jawahar, K1,

K2, MDU1, Musalwadi, NP 46a, Pant C-1, Pant C-2, Sankeshwar 32, Sindhur, Ujjwala are the other varieties grown.

SEED

Selection

Generally, seed is selected from locally grown crops. In fact, the seed plants are selected in the field itself from the standing crop. Tall, dark plants with greater pungency are chosen for the purpose. The selected plants must be healthy and free from disease. The fruit must taste good. Chilies from selected plants are separately dried and stored to avoid contamination from infected fruit.

Threshing of beans for seed

Seed from plants grown in higher altitude areas is preferred as seed from colder climate germinates faster in lower altitudes. Early germination helps to control the growth of weeds and early maturity of the crop protects it from pests.

Treatment

Chili seeds are carefully dried for 10–12 days in the sun before storage. In regions where chili is cultivated by transplantation of seedlings, the chilies are first broken in a well-cleaned vessel, 2–3 days before the sowing and the seed is soaked in cow urine and water. Chili seed remains viable for two years. Extracting seed from the fruit one week before use ensures best results. If chili is cultivated by broadcasting, the chilies are threshed lightly to spread the seeds.

Recommendations

- Treatment of seed with cow pat pit, *beejamrut*, *amrut pani*, *panchagavya* or *trichoderma* ensure a good yield and a healthy crop.
- Treatment of seedlings with *jeevamrut* will protect the crop from disease.

CULTIVATION

The appropriate time to cultivate chili depends upon temperature, rainfall and the availability of irrigation facilities.

Before sowing the chili seed by the broadcasting method, the field is ploughed at least thrice. About 3–4 tonnes of FYM are applied to the field. The field is tilled three to four times to get rid of pests. Tilling

ensures that the insects together with their eggs, larvae and pupae hidden in the soil are brought to the surface where they are eaten by birds or insects or destroyed by exposure to the heat of the sun.

Recommendations

In the highlands which are prone to snowfall, FYM is spread over the field to protect the seed from the snow and to assist in its timely germination.

Burning of crop residues and other vegetation in the field is not an eco-friendly practice. It affects the health of the soil as burning destroys beneficial microbes too. Instead of burning weeds and shrubs, farmers should be encouraged to follow any of the following practices:

- Plough the field to uproot weeds and the residue of the previous crop and compost the material.
- Mulch the field with the unwanted vegetation.
- Remove the unwanted vegetation from the field and burn it outside the field area.

Sowing methods

Chili is cultivated both by direct broadcast of seed in the field and also by transplanting seedlings from a nursery. Approximately 1.5 kg seed is sufficient for one hectare.

Broadcasting

Seed broadcasting is done in the rain-fed areas and areas with deficit irrigation facilities. In the broadcasting method, the seed is sprayed after the third ploughing. Thereafter, the field is levelled with the help of a hand harrow or *kudal* and the seeds are covered with a thin layer of soil to prevent them from sinking too deep into the ground. Seed is sown in rows, in alternate lines made by the plough. The distance between two seeds in the line is 15–20 cm. After sowing, the *pata* (plank) is applied to the field to level it and FYM @ 2–3 tonnes/acre is spread over the field. FYM supplies nutrients to the plants by providing necessary mulch.

In order to maintain uniformity of seed distribution in the field and to protect the seed from flying away, the seed is mixed with dung before being broadcast. Goat dung also enhances the germination power of the seed.

Nursery preparation techniques

In areas with appropriate irrigation facilities, seedlings are grown in a nursery and subsequently planted in the main field. Nursery beds are preferably located in partially shaded areas. The nursery beds are raised by repeated ploughing. Weeds and shrubs are burnt and the ash spread over the portion of the field selected as the nursery. Thereafter, FYM is applied by spreading it all over the nursery. Then, with a hand harrow or a spade, the nursery is tilled and levelled so that the ash and the FYM are mixed with the soil. The treated seed is then uniformly spread all over the nursery. It is covered with paddy straw and grass as mulch material to provide optimum conditions for quick germination. This helps to retain the moisture of the soil and protect the seed from birds and other creatures. The plants in the nursery are watered every morning and evening. Watering by hand or sprinkling reduces the possibility of seed displacement.

Field preparation: ploughing and planking

Transplanting

In Maharashtra and Karnataka, spacing of 75 x 75 cm or 90 x 90 cm is generally practised whereas in Andhra Pradesh and Tamil Nadu, closer

spacing of 45 x 45 cm is followed. The short stature chili Jwala and NP-46 require a spacing of 60 x 45 cm. Generally, closer spacing is ideal in light soil. For rain-fed chili cultivation, closer spacing of 90 x 20 cm is recommended.

Weeds

Weeds are found in plenty in chili cultivation and if the fields are not periodically weeded, the weeds compete with the chili plants and prevent their growth, thus affecting production. In hilly areas, the major weeds found in chili fields are *dudhia* (*Euhorbia geniculata*), *doob* (*Cynodon dactylon*), *kodon* (*Eleusine indica*), etc.

To protect the crop from weeds, the field is harrowed and weeded three to five times during the crop season. Weeding is first done after 20–25 days of plantation. In case of crops sown by broadcasting, the first weeding is done after the growth of 4–5 leaves on the plant. The second weeding is done 15 days after the first one. Gap filling and spacing is also done during the second weeding. The weeded out plants are left in the field itself to dry up in the heat of the sun. They act as cover for the plants, and subsequently transform into manure. The third weeding is done at the stage of 8–10 leaves. The first and the second weedings are done using a *kutla* with a long sharp edge whereas the third weeding is done with a *kutla* having a small edge. The fourth weeding is completed before the flowering of the plants so that the flower does not fall during the process. During this period, soil is heaped around the plants.

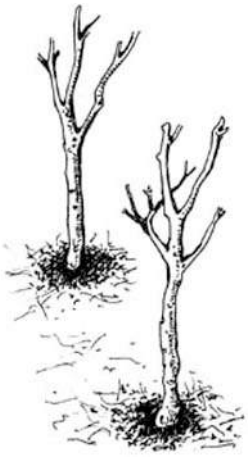
Weeding equipment: Hand harrow

Recommendations

Mulching soon after sowing is recommended to prevent infestation by weeds.

Other crop-specific agronomic practices

To protect the crop from pests and disease, the field used for chili cultivation is changed every year and is left fallow for 3–4 months before planting the next crop.



Ratoon

To increase the intensity of chili seeds, branches of the plant are trimmed at a distance of 2–3 cm and dung manure is applied to it. This protects the plant till the next crop, and they start budding again in March–April. The chili fruit obtained from these plants is more pungent. In the local language, such plants are called *muni/pedi* (ratoon).

MANAGING SOIL FERTILITY

A variety of fertilizers are used depending on the area in which chili is grown and on the fertility of the soil. FYM is used before and after sowing and compost is supplied by the disintegration of the weeds after the first ploughing. Phosphorus and potash are supplied by burning weeds, shrubs and leaves kept in the field before the first ploughing.

Recommendations

Application of 4–5 tonnes of vermi/BD compost, supplemented with one spray of BD 500 in the evening will increase the yield by increasing the fertility of the soil.

Nutrients

Major nutrients required for good production of chili are nitrogen, phosphorus and potash.

Green manure, cultivation of legumes, incorporation of cow pat pit manure, supplemented with one spray of BD 500, application of *amrut pani* through the irrigation water and frequent sprays of vermiwash/*panchagavya* fulfill this requirement.

Use of biofertilizers, e.g., azotobacter and azospirillum is recommended for chili cultivation. Azospirillum is more effective than azotobacter. It can be applied as seed treatment, seedling treatment or directly mixed with the soil.

WATER REQUIREMENTS

During the first month of transplanting, the plants are lightly irrigated. In summer, irrigation on alternate days is sufficient.

Chili farming in Uttaranchal is by-and-large dependent on the rains. In case of inadequate rain, the crop is irrigated in accordance with the variety of the seed and the quality of the soil. After transferring from the nursery to the main field, the plants are watered for a month, at intervals of 4–5 days.

In case of directly sown chili seed, weekly irrigation is needed during peak summer. Traditional *khals* are also used for irrigation.

PLANT DISEASES

Damping off (*Pythium aphanidermatum*)

Damping off disease is caused by a fungus. It generally infects the plants at the nursery stage. Under its impact the plant becomes weak and its leaves fade and fall. This disease is sighted at nursery stage itself and is caused by excessive number of plants or crowding, lack of appropriate drainage and high temperature.

Management measures

- Before preparing the nursery, green leaves and bushes in the field are destroyed.
- Proper drainage in the nursery is maintained.
- Weaker plants and weeds are weeded out to ensure proper plant density in the nursery.
- Ash is sprayed in the field.

Recommendations

- A mixture of 100 gm of garlic and 30 gm khadi soap dissolved in 0.5 litre of water mixed with five litres of water may be sprayed on the standing crop on one *nali* of land.
- 50 gm of *Trichoderma viride* compost for an area of 8x8 metre chili nursery is reported to be effective in protecting the seedlings from damping off disease.
- Seed treatment by azotobacter is recommended to protect the crop from fungal infestations.

Anthracnose (*Collectotrichum caprici*)

This fungus-based disease causes maximum harm to the chili crop. The top of the infected plant starts drying, leading to the eventual death of the plant.

The infection also affects the beans when they are ripening, causing black spots to appear on them and gradually the beans themselves become black and fall. This disease infects the plants from budding stage onwards.

Management

- To protect the infection from spreading, the infected plants are weeded out from the rest of the crop.
- Extract of one kg leaves of khin (*Sapium insigne*) mixed with 20 litres of water is sprayed on the crop.

Recommendations

- Treatment of the seed using *jeevamrut*, *beejamrut*, azospirillum and azotobacter is recommended to protect the crop from anthracnose.
- Dusting of ash, spraying of sour butter milk and spraying of cow/goat urine also help to control the spread of the disease.
- Treating the seedlings with 20 gm of *trichoderma* mixed with one litre of water is also useful.

***Chitti rog* (*Xanthomonas vesicatoria*)**

This disease infects the crop during September–October. It affects the leaves, stem and the fruits. Small spots are sighted on the infected leaves and the fruits (beans) gradually become yellow and fall. This disease infects the standing crop during the rains and continues to have impact till the ripening of the crop.

Management

- To avoid this disease, only healthy seeds treated with cow urine are used and the crop cycle is be strictly adhered to.

Recommendations

- Two foliar sprays of BD 501 are effective in controlling this disease.

- Use of castor cake, *karanj* cake and neem cake is also effective.
- One kg of *trichoderma* mixed with vermicompost/compost and applied per acre to the field during field preparations protects the crop from *chitty rog*.

Powdery mildew (*Leveillula taurica*)

White spots appear on the leaves and stems and white wounds on the lower sides of the leaves. This disease appears at the time of flowering of the plants and infects the older leaves more easily. Gradually it spreads to the other leaves as well.

Management

- Infected chilies are avoided when selecting seed.
- A solution of 100 gm of crushed chili, boiled in one litre of water and mixed with 10 litres of water is sprayed over one *nali* of land.

Recommendations

- A solution of milk and water in a ratio of 1 : 9 sprayed on the plants is highly recommended.
- At the stage of flowering, foliar spray of BD 501 is effective.
- One litre of a mixture of cow urine, garlic, yeast and salt mixed with eight litres of water and sprayed per acre of land protects the crop from powdery mildew.

PROBLEM INSECTS

Thrips (*Scintothrips dorsalis*)

This insect infects the standing crop. It sucks the juice of the plants and causes maximum harm at the time of flowering. The leaves fade and the yield is adversely affected.

Recommendations

- Leaves of ayar (*Lyonia ovalifolia*) used as green manure minimize damage from this pest at night.
- Spray of BD 501 before flowering is useful to check the pest infestation.
- Light traps in the field are also a useful measure to control the pest.

- Spraying per acre one litre of liquid manure (mixture of cow dung, local herbs/grasses, cow urine, yeast and BD preparations) mixed with eight litres of water helps in protecting the crop from the insect.

Cutworm (*Agrotis ipsilon*)

It is a thin, brown-coloured insect, 2–4 cm in length. Its shape is like that of a white grub and in the local language it is called *uksu*. This worm grows underground and infects the roots of the chili plant. It cuts the plant on the surface of the field in the initial stages itself and the plant dies.

Management

- The infected plants are removed and the pest inside the earth located and killed.
- The pests are killed by spraying an extract of 2 kg bakain leaves mixed with 10 litres of water on one *nali* of land.

Recommendations

- Neem cake extract @ 1gm/acre protects the crop from cut worms.
- Foliar spray of BD 501 at the stage of 3–4 leaves during the northwards lunar position is also recommended.

Aphids (*Aphis gossypii*)

This light-green coloured insect sucks the juice from the flowers and the soft leaves, mutilating them and causing them to fall.

Management

- The insects are killed with a spray of the extract of 2 kg of *bakain* leaves mixed with 10 litres of water per *nali* of land.

Recommendations

- Light traps can be used to protect the crop from aphids.
- Spray of 1 gm BD 501 in one acre land at the stage of flowering protects the crop from infestation by aphids.

Other general solutions

- Apply 4–5 tonnes of vermicompost/BD compost supplemented with one spray of BD 500 in the evening. Application of BD 500 in the evening before sowing increases the yield.
- For better yield and tolerance to fungal diseases two foliar sprays of BD 501 are recommended.
- In case of bunchy top disease, dusting with ash, or spraying with sour butter milk or liquid waste of tanned leather or cow/goat urine are also resorted to by some tribes.
- In the case of soil borne diseases such as root rot and collar rot, castor cake, *karanj* cake or neem cake are applied to the soil.
- Milk solution (one litre milk in nine litres of water) effectively controls powdery mildew and viral diseases.

Grading of chili

POST HARVEST MANAGEMENT

The chili beans are cleaned during the process of drying. Unhealthy, infected or rotten chili fruits are separated from the good ones.

Drying

Chili beans are plucked 5–6 times, between mid-August and the last week of October. After plucking they are dried in the sun for 10–15 days, generally on the terraces of the houses, so that the harvest receives intense heat from the sun for the maximum period of the day. While drying, it should be ensured that no moisture is left in the chili beans.

Drying of chili

Packaging

Dried chili beans are generally stored in jute sacks or in baskets made of ringal, covered with lids.

Storage

Chili is generally stored in jute sacks, which are then kept either in boxes or are hung on the terrace just outside the house, well protected from rain and fog. To protect the produce from pest infestation during storage, the chili beans are dried well to ensure absence of moisture. Moisture also makes the produce prone to fungus infestation. During the storage period, from time to time, the chili beans have to be repeatedly dried to ensure complete absence of moisture.

REFERENCES

Chadha, K. L. 2002. *Handbook of Agriculture*, ICAR, New Delhi

Rai, M, Kumar, S; Pandey, S. Singh, and Singh B, 2004, *Popular varieties of vegetable crops in India*, IIVR, Varanasi,

Rai, Singh, M. Pandey, K. K. Singh, J. Kumar, S. Singh, B 2006, *IIVR: A decade of accomplishments*: Indian Institute of Vegetable Research, Varanasi.

INSTITUTIONS ENGAGED IN RESEARCH AND EXTENSION

Indian Institute of Horticultural Research, Hassarghata, Bangalore.

Indian Institute of Vegetable Research, Varanasi, Uttar Pradesh.

State agricultural universities and KVKs.

MUSTARD

Hindi – *Raai, Kaali Sarson*; Gujarati – *Raai*; Kannada – *Saswe*; Kashmiri – *Sorisa*; Sanskrit – *Bimbata*; Telugu – *Avalu*

BACKGROUND TO THE CROP

The rapeseed-mustard (*Brassica spp*) group of crops is the second most important oilseed after groundnut. This species belongs to the family *Cruciferae* and contributes nearly 25–30 percent of the total oilseed production in the country. The genus Brassica comprises 37 species, mainly annual or biennial herbs, and many of them are similar in appearance. Apart from their use as an oilseed, the plants are used as a vegetable and also as a fodder. Mustard seeds are also used as medicine for ailments like anemia, leprosy and throat and stomach-related diseases. In India, major mustard producing states are Rajasthan, Uttar Pradesh, Haryana, Madhya Pradesh and Gujarat.

Origin and distribution

Southern Europe is generally considered to be the place of origin of yellow mustard. White mustard is abundantly cultivated in countries such as Australia, China, Japan, Italy and England. Black mustard came to India from China.

According to 1998-99 statistics, mustard was cultivated in India on 6.65 million hectares. Rajasthan contributes the largest share (46.5 percent) of the total quantity of mustard produced in India. Other major contributors to mustard production are Uttar Pradesh (fifteen percent) and Madhya Pradesh (nine percent). Smaller quantities of rapeseed and mustard are grown in the extreme north and northeastern states of the country.

Climate

Rapeseed and mustard are grown in tropical as well as temperate zones and require relatively cool temperatures for satisfactory growth. In India, they are grown as *rabi* crops, from September–October to February–March. These crops grow well in areas having 25–40 cm of rainfall.

Though a warm climate is considered to be ideal for mustard cultivation, it is grown even at heights of 2,500 metres above sea level.

Cropping systems

Mustard is usually cultivated in the *rabi* season as a sole crop in rain-fed areas and in the fallows of the *kharif* season. It is also intercropped with chickpea or wheat. Mustard remains an important crop in different crop sequences in rain-fed and irrigated areas.

In the lower mountain valleys, mustard is cultivated both as a single and mixed crop. In mixed cropping, it is generally sown with wheat as the main crop.

At higher altitudes, where it is a *kharif* crop, it follows the same pattern of single and mixed cropping. In higher areas it is generally sown with potato. In July, when the potato leaves start falling, the spaces between the rows of potato crop are lightly tilled with a hand harrow. Mustard seeds are then sown and covered with soil with the help of a broom fashioned out of a bunch of shrubs.

In the *rabi* season, mustard is cultivated in the fields of the *kharif* crops of *mandua* (ragi), *gahat* (*kulath*), *kaala bhat* (black soya) or mixed soybean crop. It is mostly grown after the leguminous crops and thus gets a good quantity of nitrogen for fast germination and growth. After the harvesting of mustard is complete, paddy is cultivated as the next crop in the *kharif* season.

In the case of *kharif* crops, mustard farming is followed by the *rabi* crops of potato, *chaulai* (amaranth), soybean, *mandua* (ragi), chili etc. After harvesting the mustard, the same fields are used for the cultivation of wheat. The following are the prevalent cropping patterns for mustard:

Table 1. Prevalent cropping pattern

Kharif	*Rabi*	Period
Ragi + soybean	Mustard	1 year
Soybean	Wheat + mustard	1 year
Chili/paddy	Mustard	1 year
Potato + mustard	Wheat + mustard	1 year

Growing seasons

In Uttaranchal, mustard is cultivated during both the *rabi* and *kharif* (winter and monsoon seasons respectively). In the valleys, at altitudes below 6,500 feet, it is cultivated as a *rabi* crop whereas in places at higher altitudes, it is a *kharif* crop.

Depending upon the location of the place vis-a-vis the sea level, the timings of sowing and harvesting of mustard vary.

Soil

Mustard can be grown in all kinds of soil but black soil is most suited. Required wetness of the soil for germination must be ensured before sowing the seed. Wetness is ascertained by feeling the soil with one's fingers.

Duration

In the mountain valleys (below 6,500 feet) sowing of the crop begins by the last week of October and is over by the second week of November. The crop takes approximately four months to grow and ripen. Harvesting begins in February.

In the upper regions, due to possibility of snowfall in winter, mustard is cultivated in the *kharif* season only. In these areas, sowing begins in the second week of July and the crop is harvested after the second week of October.

VARIETIES

Traditional varieties

The local varieties of mustard traditionally grown are:

- Yellow mustard (*peeli sarson*) – *rada, toda*
- Black mustard (*kaali sarson*) – *sarson, dain, jadi.*

Black mustard is cultivated in larger areas as compared to yellow mustard. The yield of yellow mustard is relatively low but the extracted oil per unit weight is relatively high. To extract one kilogram of oil, 2.5 kg yellow mustard is required, whereas for the same quantity of oil, 3 kg seeds of black mustard would be needed.

New varieties

A large number of high yielding varieties have now replaced the traditional varieties and with them an increase in productivity of at least 15–20 percent has been noted.

The main improvements seen in the new varieties of mustard are:

- Higher seed and oil content, low erucic acid and glucosinolates.
- Resistance to biotic and abiotic stresses.
- More varieties for different cropping systems and non-traditional areas.

The following varieties of mustard are recommended for different regions and climates:

- Mustard: GM1, GM2, Laxmi, Narendra Rai, Pusa Jaikisan, Agni, Jagannath, Pusa Bahar, Pusa Barani, Samjukta, Sarma, TM2, TM 4
- Brown Sarson: KBS 3, KOS 1
- Yellow Sarson: Pusa Gold, NDYS 921, Rajendra Sarson 1, Subinoy, YS93
- Toria: Jawahar Toria 1, Panchali, RAUT 917, RH 68, TLC 1, TS 29.
- Taramira: RTM 314, TMC 1
- Gobhi Sarson: GLS 2 PGSH 51, Sheetal

A brief account of a few varieties is given below:

Brown mustard

BS2: This variety is recommended for the non-irrigated regions of southwest Uttar Pradesh. It takes 115–120 days to grow and yields 12–15 quintals/ha. The crop is drought resistant.

BS70: This variety is recommended for the irrigated fields of eastern Uttar Pradesh. It takes 130–140 days to ripen and yields of 12–15 quintals/ha can be harvested.

KBS 3: This variety is recommended for cultivation in Himachal Pradesh. Its crop duration is 145–150 days and the yield is 10 quintals/ha. This variety is also resistant to *gerua rog* and to excess cold.

KOS 1: This variety is recommended for the high mountainous regions. It takes 230–235 days to ripen and yields 10 quintals/ha. This variety is resistant to snow and hailstorms.

KOS 101: This variety is recommended for high altitude areas. It takes 230–250 days to ripen and yields 15 quintals/ha. It is resistant to snow and hailstorms.

SEED Selection

Seed selection follows the traditional pattern of using indigenous seeds. During the standing crop period, some plants are identified for seed in the field itself. The seed plants are selected from fields with higher yield. Once the plants are identified, the selected crop is separately cut, carried in bundles and arranged in the form of heaps that makes threshing easier. Threshing is done after 10–12 days by feet or by bullocks.

Winnowing with the help of a winnowing fan (*supa*) follows threshing. Winnowing is generally done in the evening due to the availability of sufficient wind. Also there is a popular belief that the evening winds refine the seeds and protect them from pests during storage. It is to be noted that the selected seeds have to be separately treated at every stage, from cutting, threshing, winnowing and drying to storage.

After winnowing and cleaning, the seed is dried in the sun for 4–6 days in the valleys or 6–8 days in the high mountains. Care is taken during drying to ensure that some moisture (8–10 percent) is left in the seed. This is confirmed by crushing the seed with the teeth. If it produces a mild sound, it is considered fit for storage.

Traditionally, seed is stored in small vessels like the tumdi and the kulna. As per popular belief, Tuesdays, Thursdays and Saturdays are auspicious days for storing seed and Mondays, Wednesdays and Fridays for removing it.

While selecting seed, the cultivator usually chooses seed produced at a relatively higher altitude as seed from higher altitudes germinates faster at lower altitudes.

Early germination has twin advantages as the crop can compete effectively with the weeds and the early ripening of the crop protects it from birds and pests

Seed rate

Seed is sown @ 4–5 kg/acre in the case of single cropping and 2–3 kg/acre in mixed cropping. In general, seed rate between 4–5 kg/ha is considered optimum. Ideal spacing is 45 cm row-to-row and 15 cm plant to plant. Closer spacing of 30 x 15 mm is also adopted in some areas.

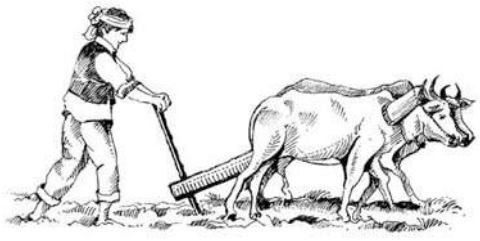
Recommendations

Seed treatment with *trichoderma* can help in controlling root rot, fusarium and wilt diseases that affect the mustard crop.

Before sowing, seed of mustard can also be treated overnight with *jeevamrut*. This increases the pest and disease resistance capacity of the crop.

CULTIVATION

For single crop cultivation of mustard, the field is tilled twice before sowing. During the first tilling, the weeds are uprooted and the field is left in that state for the next 10–12 days. The weeds, thus exposed to the sun, are transformed into manure. The field is then tilled again and the seed is spread over it, after which a *pata* (plank) is applied for levelling and covering it. This also helps to retain moisture in the soil for quick germination of the seed and protects it from birds, pests and from rotting. Sowing just after tilling also ensures that the seeds do not settle very deep in the soil.



Field preparation

In the highlands, in place of the *pata*, bunches of shrubs are used as a broom for uniformly spreading and covering the seeds. As the cultivation takes place in the rainy season, there is wetness in the soil and use of the *pata* is likely to increase spoilage of the seeds. Hence a broom of shrubs.

Cow dung manure (generally stored and processed near the house or the field) and compost is spread during tilling of the field. But in highlands, with the possibility of snowfall, the field is fully covered with cow dung manure and a compost of green leaves in the last week of July or the first week of December.

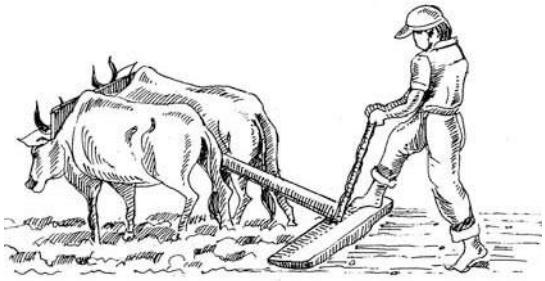
Covering the field with leaves and manure ensures that the crop is protected from the cold.

Weeds

Weeds likely to be found in mustard fields are: *bathua* (*Chenopodium album*); *genhusa* (*Phalaris minor*); *doob* (*Cynodon dactylon*); *tipatia* (*Oxalis latifolia*); *sanwa* (*Echinochloa colonum*); *malkoni* (*Setaria glauca*), etc. Weeds likely to appear in the *kharif* season are *kondo*, *doob*, *tipatia* and *motha* (*Cyperus rotundus*).

In general, weeding (*nirai*) is done 45–50 days after sowing. Generally weeding is done by hand but if the weeds are in excess, a danyala (a comb like wooden or iron instrument) is used for weeding. The harrowing of the *kharif* crop is done after 25–30 days, when the mustard plants have grown 4–5 inches. Weeding is done in September, just before the budding. Harrowing is done with a hand harrow (a small sharp edged semi curved tool).

Application of plank (pata) for covering seeds



CULTIVATION

Mustard has small seed size and therefore, for good germination and stand, a fine tilth is required. In rain-fed areas, harrowing has to be done after every effective shower of rain. For the *rabi* crop, the first tilling of the field, after the harvesting of the *kharif* crop (generally mixed), is done with the traditional indigenous plough. The levelling of the field and crushing of the hard soil pieces with a hammer-like instrument follows the first tilling. Then the field is cleared of stones, wood, and leftovers of the preceding crop with the help of a hand harrow (*kudal*). The *pata* is applied to level the field, which is then left for 7–10 days and then tilled again. In the period between the two tillings, dung manure is applied to the field. Sowing begins in early October (Navratri).

In the case of mixed cropping with wheat, after the sowing of the wheat, the mustard seeds are spread over the field in adequate proportions. This is done to ensure that the mustard seeds do not go deep into the soil and have their growth impeded. The soil is then levelled with the kudal before applying the *pata* to it.

For the *kharif* crop, in the high mountain regions, the field preparations begin from the first week of July when the soil is tilled. The field is then left as it is for 10–12 days during which time the weeds, exposed to sun, air and water, decompose. After that, the field is tilled a second time and the seed is sown.

For the *rabi* crop in Uttaranchal, the manure of green leaves is also used in the first fortnight of December. To make green manure, green leaves from local trees such as *banj* (*Quercus incana*), *buransh* (*Rhododendron sp.*), *pati* (*Artemisia spp.*), poplar (*Populas spp.*) etc., are collected from the forest and stored near the house. These leaves are used as bedding for the bullocks, cows and other domesticated animals. Subsequently this is used as manure in the fields. Owing to some properties in these leaves, this manure is also useful to control pests.

In fields on the mountain slopes tilling is done upwardly which creates little impediments along the slopes and protects the soil and manure from erosion, so that the fertility of the soil is retained.

MANAGING SOIL FERTILITY

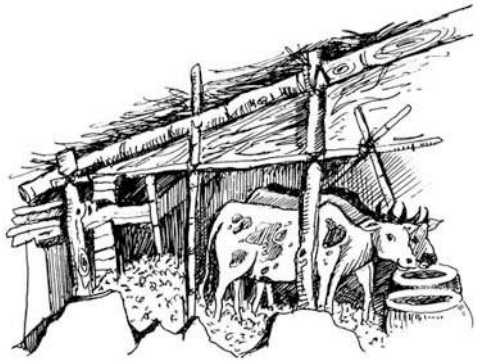
In general, a mustard crop depletes the soil to the extent of 33 kg N, 42 kg K, 17 kg S, 42 kg Ca and 9 kg Mg per tonne of produce. In organic production, efforts are made to meet these requirements through organic inputs.

In the rice-mustard sequence, incorporation of sesbania green manure is useful to reduce nitrogen requirement of the succeeding mustard crop to the extent of 30–40 kg/ha.

Seed treatment with azospirillum can enhance the yield of mustard to the extent of 4–5 percent.

Use of FYM as a nutrient for the crop is common in all the regions of Uttaranchal and in other regions too. Farmers incorporate 10 tonnes/ha or 4–5 tonnes/ha of vermi/BD compost. In the Bhabhar region of Uttaranchal, prior to the cultivation of mustard, the field is kept fallow for some time. In some areas sun hemp or sesbania are grown in the fields at the commencement of the rains, then the field is tilled after 40–50 days and the vegetation is ploughed back. This not only enhances the supply of nitrogen, phosphorus and other organic nutrients in the field but also increases the quantity of microorganisms in the soil, which improve the health of the soil and increase productivity.

Preparation of green manure inside the cattle shed



WATER REQUIREMENTS

Mustard is cultivated in both arid and irrigated lands. It does not require much irrigation. The *kharif* crop does not need any irrigation whereas the *rabi* crop needs irrigation once, in the first fortnight of December. In the plains, two irrigations are recommended, the first at rosette stage (20–30 days) and the second at the siliqua formation stage (50–60 days). Furrow, flood and now, particularly in Rajasthan, sprinkler irrigation is becoming very common.

Water conservation techniques

In hilly regions, formerly *khals* (earthen pond-like structures) were constructed for rain water storage. The water stored in these structures would gradually seep into the soil, enabling it to retain wetness for a long time. Thus, mustard farming in the mountainous region was not completely dependent on rain. But these structures are now rare.

Recommendations

In case of scarce irrigation resources, mulching of the field should be done to retain the moisture. Mulching is also helpful to control weeds.

Water sources

Other major sources of irrigation are *sadabahar* (perennial), *gadhere* or small mountain streams, ponds, *guhls* or traditional canals in mountain regions. The irrigation water is the normal water with a pH of 7.

PROBLEM INSECTS AND DISEASES

There are at least 38 insects associated with the *Brassica* species of crop. Among them, the mustard aphid is the main pest, followed by the white mustard fly, painted bug, leaf minor and the Bihar hairy caterpillar.

Mustard aphid (*Lipaphis erysimi*)

The mustard aphid is called *mahu* in the local language.

It damages the crop at vegetative/flowering and pod formation stages. It is 2–3 mm long, green in colour. It starts infesting the crop in December and by February the number of insects has multiplied manifold.

This pest causes maximum harm to the crop in February–March.

The mustard aphid takes away the nutrients of the plant from the latter's delicate parts, e.g., leaves and stems – and obstructs its growth.

Parts of the infested plant start drying, leading to the eventual death of the plant. The leaves become black and thus photosynthesis is obstructed. Eventually the leaves become yellow, mutilated and fall.

Management

- Early sowing is practised so that before the menace of the pest peaks, the crop is already ripe for harvesting.
- To control the pest in its initial stages, ash is sprinkled in the field @ 25–30 kg per *nali*.
- If the field is irrigated within 45 days of sowing, it also helps in controlling the pest.

Recommendations

- A mixture of garlic (250 gm), tobacco (400 gm), and *shikakai* (200 gm) is crushed, soaked in water and kept for a day. The following day, it is to be mixed in 100–200 litres of water and sprayed per acre of the crop.
- Two foliar sprays of BD 501 at the stage of flowering and fruiting can protect the crop from this pest. One gram of this preparation should be mixed with 13.5 litres of water at sunrise, when the lunar position is northwards and opposite to Saturn, and sprayed in the morning. This quantity is sufficient for one acre of land.
- Use of light traps from the flowering period onwards is also effective.

Painted bug (*Bagrada hilaris*)

This bug is known locally as *jhanga keet*. It is black in colour with yellow and red spots. Its shining pink larva is very small. It attacks the plant in the initial stages of its growth. The eggs of this pest are transformed into pupae in 3–7 days. This bug affects the leaves, flowers and other soft organs of the plant which dry up leaving the plant destroyed.

Management

- The infected plant is removed from the field.
- Ash @ 4–5 quintals/acre is sprinkled on the field.

Recommendations

- The crop should be threshed immediately after harvesting so that the effect of the pest on the ripe crop can be checked.
- Extract of *tipati* (*Roylea cinerea*) leaves may be sprayed on the standing crop.
- If *jeevamrut* is sprinkled at the initial stage, the plant develops better resistance to the pest.

Mustard sawfly (*Athalia proxima*)

This insect is known as *sarson ki illi* or *sarson ki makkhi* in the local language. In its initial stage it is green and gray with no hair on it. On maturing, its colour becomes dark and five stripes appear on its back. The pest survives on the plant from germination till the crop is harvested. The pest causes maximum harm at the larva stage. It generally makes holes in the leaves, thereby weakening the plant's growth. The pest generally attacks the plant in the mornings and evenings. Most of the infested plants get destroyed.

Management

The bugs are removed from the leaves and killed.

Recommendations

- Spray ten percent NIBOLI (neem seed) solution on the crop to reduce the damage.
- Light traps control the population of these flies.
- Liquid pest control agents should be sprayed on the land.

Alternaria blight (*Alternaria brassicae*)

Round brown spots appear on the infested parts and gradually spread over the whole plant. The infested plants fade and fall.

Management

- Before sowing, the field is subjected to 2–3 deep tillings.
- The crop cycle is adhered to.
- Before sowing, the seeds are treated with cow urine.

Recommendations

- Ten gm of *trichoderma* culture mixed with one litre of water may be sprayed on the crop.
- Treating the seed overnight with *jeevamrut* helps it to develop resistance to diseases.

White rust *(Albugo candida)*

This disease is caused by a fungus and infests all parts of the plant except the roots. White or light yellow spots of various shapes appear on the leaves, stems and flowers of the infested plants.

Management

- Before sowing, the field is subjected to 2–3 deep tillings.
- The crop cycle is strictly adhered.
- Treatment of the seed with cow urine before sowing increases its disease resistance.

Recommendations

- A solution of 100 gm of garlic and 30 gm of khadi soap in 0.5 litres of water is mixed in five litres of water and sprayed on the crop. This quantity will suffice for one acre.
- Vermiwash mixed with water in the ratio 1: 13.5 protects the crop from fungal infestations.
- Treatment of seed using 10 gm *trichoderma* per kg of seed is highly recommended.

Miscellaneous pests

Rats, small animals and birds can also cause harm to the crop.

Crop protection

To protect the crop from birds, scarecrows are erected in the fields.

Beneficial creatures

Honeybee, *myna*, snakes, butterflies, *bhaunras* (black bees), are useful for the mustard crop. Snakes eat the rats, birds eat the worms and honeybees, butterflies and *bhaunras* (black bees) help in pollination, resulting in net increase in the yield.

POST HARVEST MANAGEMENT

Cleaning

Cleaning equipment: Winnowing basket

After harvesting, the plants are dried in the sun for 4–5 days. In order to protect them from dew and rain, the crop is arranged in heaps. Threshing is done after 10–12 days. The threshed crop is winnowed and the straw is separated. If there is not enough natural wind for winnowing, an artificial wind is created by using a *phatela* (an indigenous process in which two people hold a 2–3 metre long cloth and create an artificial draught by its movement). The threshed mustard is gradually dropped from a *supa* (winnowing basket) to the ground. The straw flies further away while the grain falls at the feet. By repeating the process 2–3 times the produce gets cleaned.

Drying

After cleaning, the produce is dried in the sun for 4–8 days. The drying periods in the valleys and on the high hills differ. While drying the produce in the sun, care has to be taken to ensure that some amount of moisture is left so that the oil can be easily extracted. Tarred canvas and local fibre mats are used for drying.

Grading

The *supa* is used for grading the mustard. Women are very well skilled and adroit in its use.

STORAGE

Storage equipment

The produce is stored mainly in:

- Jute or cotton sacks
- Wooden boxes (*kothar*) plastered with soil and cow dung paste
- Tin containers
- *Kulna* – a cylindrical basket made of ringal bamboo
- *Chinda* (*tumdi*)
- Glass bottles

Storage vessels were earlier made from *malu* leaves and paddy straw. Now they are made from the wood of *cedrus deodar* and *Toona ciliata*. Small vessels of *tumdi*, paddy straw containers, baskets of malu leaves and small *kulnas* are used for storing the seed. *Kothar*, tin containers, sacks, etc., are used to store produce for self-consumption. The *kothar* and *kulna* are plastered with soil and cow dung paste before being used

Storage equipment: Tumdi

to store mustard. This reduces spillage of the produce and makes the storage pest resistant.

After storing the produce in any one of the above vessels, it is closed with a lid to prevent moisture and air from entering into it. To protect the storage from moisture, the vessel is normally kept on wooden or stone bricks 2–3 inches above the ground.

The stored produce may also be re-dried in the sun, if necessary, from time to time.

REFERENCES

Anon 2002, *Integrated Nutrient Management for Oilseed Crops*, Directorate of Oilseed Research, Rajendra Nagar, Hyderabad 500 030

Anon 2002, *IPM in Oilseed Crops*, Directorate of Oilseed Research, Rajendra Nagar, Hyderabad 500 030

INSTITUTIONS ENGAGED IN RESEARCH AND DEVELOPMENT

Directorate of Oilseed Research, Rajendranagar, Hyderabad 500030.

National Research Centre for Rapeseed and Mustard, Bharatpur 321303.

State Agriculture Universities and KVKs.

POTATO

BACKGROUND TO THE CROP

The potato (*Solanum tuberosum*) is an important vegetable belonging to the family *Solanaceae*. It is believed to have been introduced in India from Europe in the early seventeenth century. China, Russia, Ukraine and India are the leading potato growing countries of the world. India stands at fifth position, both in terms of area and production of potato. The potato is rich in protein, fat, carbohydrates and minerals. In fact, it is considered to be a complete, nutritious staple.

Distribution

In India, the potato is grown in almost all the states. Nearly 80 percent of the crop is grown in the Indo-Gangetic plains comprising Punjab, Haryana, Uttar Pradesh, Bihar and West Bengal. Potatoes amount to about 1.23 percent of the gross agricultural produce in India. The potato is generally cultivated in winter but in a few areas it is also cultivated during the summer and rainy seasons. Of the country's total potato production, 81 percent occurs in the winter season, thirteen percent in summer and six percent during the rainy season.

Area and production

According to 2003–04 data, the potato is cultivated in 1.28 million hectares in India with a production of 23.27 million metric tonnes. In Uttaranchal, potato is cultivated in 19,000 hectares with a yearly production of about 3,40,000 metric tonnes.

There are five main potato growing zones in India. They are classified on the basis of soil and climate. These are:

The western Himalayan zone

Covering Himachal Pradesh, Jammu and Kashmir and Uttaranchal. This zone is further sub-divided into three sub-zones, i.e., higher Himalayan ranges, mid-hills and plains.

The north-western plains

Covering Punjab, Haryana, Rajasthan and some parts of neighbouring states.

The north-central plains

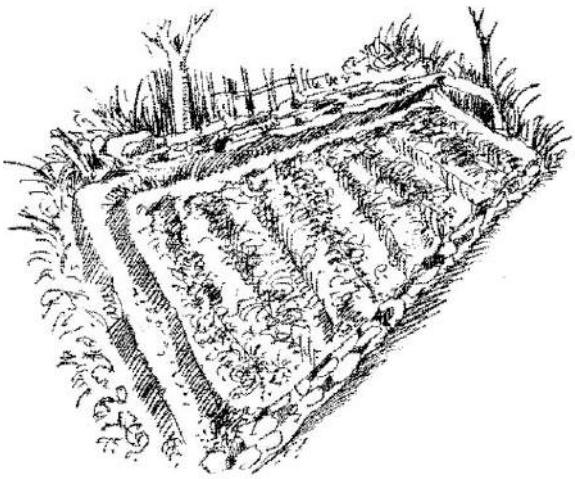
Comprising western Uttar Pradesh and Madhya Pradesh.

The north-eastern hills

Comprising the hilly areas of West Bengal, Assam, Meghalaya, Manipur, Tripura, Nagaland, Arunachal Pradesh and Mizoram.

Low hills and plateau zones

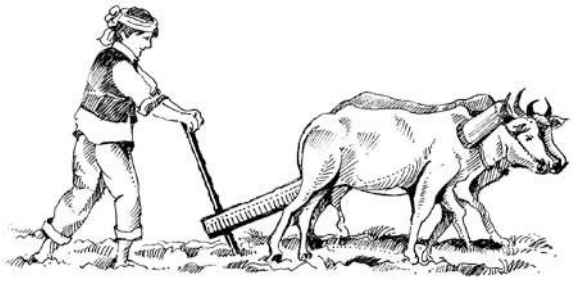
Comprising central and peninsular India, covering Gujarat, Maharashtra, Madhya Pradesh, Karnataka, Orissa and the Nilgiri and Kodaikanal hills in Tamil Nadu.



Burning of trash material

Climate

A cold climate is most suitable for potato cultivation, although it can be grown in a wide range of climatic zones. In the plains, the potato is grown in winter whereas in the hills it is cultivated in summer. Optimum temperatures for potato growth and development range from 15 °C and 25 °C. Minimum night temperature is of great importance for tuberisation and yield. Temperature below 21 °C is favourable for tuber formation. At temperatures above 21 °C, there is a sharp fall in tuberisation. At low temperatures, the vegetative growth of the plants is restricted and when the temperature is near freezing point, permanent injury is caused to the plant.



Pre sowing deep ploughing

Cropping system and the crop pattern

The potato is grown as a single as well as a mixed crop. The *rabi* potato crop is generally cultivated as a mixed crop. It is mixed with radish (*mooli*) and spinach (*palak*). The *kharif* crop is generally cultivated as a single crop. But in some high mountain regions, after the crop is ready in July, it is left inside the ground, and mustard is cultivated as a mixed crop in the field. In October, along with the harvesting of the mustard, the potatoes are dug out while tilling the field. This pattern is prevalent in the Urgam valley of Garhwal in Uttaranchal.

Before cultivation of the *rabi* potato crop, paddy or a mixed crop of soybean and ragi is grown in the same field. After harvesting the potato crop, the field is kept fallow for some time and is then used for paddy cultivation in June–July. In those regions which do not have adequate irrigation facilities, instead of paddy, soybean and ragi are cultivated in the fields after the harvesting of the potatoes.

As a *kharif* crop, before potato is sown, the field is kept fallow for a minimum of three months (December–February). In some areas, sowing of French bean or soybean prior to sowing of potato is also a well established practice.

For better yield of potato, and also to protect it from pests, annual rotation of the field is considered to be a healthy practice.

Kharif	***Rabi***	**Period**
Rajma/potato + mustard	**Potato**	**1 year**
Paddy	**Potato**	**1 year**
Soybean + ragi	**Potato**	**1 year**
Maize/soybean	**Potato**	**1 year**

As a summer crop, the fields are ploughed during May and June to reduce the incidence of soil-borne diseases and control perennial weeds.

In some areas, green manure crops like *dhaincha* and sunhemp are also sown before the onset of the monsoon. The crop is ploughed and buried in soil after 7–8 weeks. This practice supplements the nutrient requirement of the crop by 20–30 percent and improves potato yields.

At the time of final field preparation, 5–6 tonnes/acre of FYM are used. After one to one and a half months of sowing, another 2–3 tonnes/acre of FYM are applied near the roots. Alternatively, 4–5 tonnes of vermi/BD compost can be ploughed into the soil before planting. After deep ploughing and good pulverisation of the soil, when the seed bed is ready, the tubers are planted in lines. The first line is drawn with a rope and subsequent lines are marked at distances of 60 cm, row to row, with the help of a marker. Planting is done in the morning or in the evenings to avoid the midday heat.

Soil

The potato can be grown in all the types of soils, but light, well-drained, sandy loam soils are ideal. With adequate nutrition, the potato grows well even in sandy soils. Heavy types of soils are not well suited for potato cultivation. Potato plants grow better in acidic soil but can also grow in the neutral range (pH 5.5–7.5). Black soils are prone to cracking and drying, and will expose the tubers to sun and hence are not suitable.

Duration

In hilly areas, the average crop duration is 5–6 months, though in a few regions farmers start digging out the potato earlier, by July itself. However, the crop is generally left in the field till October, after which it is harvested. The late-harvested potato is considered to be fully ripened and most suitable as seed. In the plains, the crop duration varies from 90–120 days, depending upon the varieties sown. In the valleys, the duration for the *rabi* crop is 4–5 months and 3–4 months for the *kharif*.

Growing season

The planting and harvesting schedule in different regions needs to be carefully timed in order to provide favourable temperature for crop

growth and tuberisation for the longest possible period. In the hills, planting is undertaken when the chances of ground frost occurrence are over or are remote. In the plains, the main planting commences when the temperature does not impair emergence of the bulb and the normal growth pattern of the plant. Planting time in mid-hills is in January, in high hills in March–April and in very high hills, in May–June. In general, for every rise of about 200 metres of elevation, the planting and harvesting times are delayed by about a month. Planting in the northern plains starts from October and extends to November.

In the mid-hill regions of Uttaranchal, sowing begins in the first week of April and is completed by the end of the month. Harvesting begins in October. In the valleys, the potato is a *rabi* as well as a *kharif* crop. As a *rabi* crop, its sowing begins in the first week of November and the crop is ready for harvesting by the first week of March. As a *kharif* crop, its sowing begins in the month of April and the crop is harvested in July.

VARIETIES

The traditional varieties of potato are as follows :

Traditional varieties

Gol Aaloo – A red coloured, round, very tasty potato. Its seed is easily available in the local markets.

Lamba Aaloo – It is elliptical in shape and has 5–6 budding points so that 5–6 seeds are cut from one potato. It gives very good yield.

Tumadi Aaloo – Very tasty and high yielding.

High yield varieties

In recent years, a number of potato varieties have been developed by the Central Potato Research Institute, Shimla, to suit different climate and soil conditions. The following are some of the main varieties:

Kufri Anand: This variety is recommended for Uttar Pradesh and its neighbouring states. The plants are tall, strong and stand straight. The leaves are brown-green and the flowers are light purple in colour. The tubers are white, long and elliptical. The crop takes 100–110 days to be ready for harvesting and the average yield is 35–40 tonnes/ha.

Kufri Badshah: This variety is recommended for U.P., Gujarat, Haryana, Jammu & Kashmir and Madhya Pradesh. The plant is tall, strong and has plenty of branches. The leaves are brown-green and the flower is white. The tubers are big and elliptical in shape. The colour of the fresh potato is white, but it becomes yellow after drying in the sun. Its growth period is 100–110 days and the yield is approximately 50 tonnes/ha. This variety is resistant to early blight (*ageti jhulsa*) disease.

Kufri Swarna: This variety is recommended for the hilly regions of south India. The plants are straight, erect, strong and tall with abundance of dark green leaves. The flowers are white and the tubers are of medium size, white in colour, and turn yellowish after drying. The crop duration in summer is 130–135 days and in winter, 100–110 days. Its yield is approximately 48 tonnes/ha. This variety is resistant to early blight (*ageti jhulsa*) and late blight (*pacheti jhulsa*) diseases and nematodes.

Kufri Sinduri: This is a variety recommended for Bihar, Uttar Pradesh, Gujarat, Punjab, Karnataka and the mountainous regions. The plants are tall, straight and erect with abundance of branches. The leaves are light green in colour and the flowers are red with white spots on the petals. The medium sized tubers are red coloured and round/elliptical in shape. The crop duration is 110–120 days. Yield is around 40 tonnes/ha. This variety is resistant to *ageti jhulsa* or early blight and leaf rot diseases and can be grown even in high temperature regions, with minimal irrigation.

The other varieties developed are Kufri Chandramukhi, Kufri Jyoti, Kufri Muthu, Kufri Lauvkar, Kufri Dewa, Kufri Bahar, Kufri Lalima, Kufri Megha, Kufri Ashoka, Kufri Jawahar, Kufri Sutlej, Kufri Pukhraj, Kufri Giriraj, Chip Sona-1 and Chip Sona-2.

SEED

Selection

In Uttaranchal, during the harvesting of the crop, disease-free, well-shaped, big sized and healthy potatoes with good germination possibilities are selected and stored as seed for the next crop.

These seed potatoes are stored in a 1.5 metre deep pit, covered with soil and grass above ground level to avoid seepage of water.

Treatment

The potato seed is not subjected to any special treatment. Before sowing, the seed is dried in the sun for a day.

Recommendation

For obtaining higher yield and preventing infestation of pests and diseases, it may be useful to treat the seed by soaking it overnight in *jeevamrut*.

Seed size and spacing

All sizes of tubers can be utilized as seed but medium sized (25–55 mm or 25–75 g) tubers are better than other grades. Tubers of 35–40 mm or 45–50g are considered to be ideal. The potato yield increases with increase in seed rate. The optimum seed rate for getting high yield is 20–25 or 30–35 quintals/ha depending upon the tuber size. In recent years, true potato seed (TPS) is being promoted in certain regions for avoiding or reducing the incidence of viral and other diseases.

TPS seedlings are first raised in a nursery and then transplanted after 30 days (3–4 leaf stage) in the field at 50 cm x 10 cm spacing.

Recommendation

Before transplanting, the seedlings can be treated with *jeevamrut* to protect the crop from pathogenic infections.

Propagation

The potato is generally grown vegetatively, using tubers as planting material. Each tuber has several eyes distributed over its surface with each eye having 3–5 buds, which develop into sprouts. When planted, the sprouted tuber establishes itself as a plant. Each sprout, on emergence above the ground, develops a stem, bearing leaves and branches.

The quality of seed is most important to ensure good crop production. This is because seed tubers account for about 40–50 percent of the input cost. Extensive research has led to the development of a 'seed plot technique' for healthy seed in the north Indian plains.

Using this technique, Punjab, Haryana and Uttar Pradesh have emerged as important potato seed producing states in the plains.

In general, the potato tuber is not subjected to any special treatment. Before sowing, the tuber is dried in the sun for a day. The tuber is stored in a wooden box (*bhakhar*) or jute sacks or in ditches under the ground. The bottom and the walls of the ditch are plated with dry grass. This protects the tubers from moisture. Tuber treatment with cow pat pit, *beejamrut*, *jeevamrut* or *panchagavya* needs to be assessed. This treatment could be helpful in minimizing the incidence of pathogenic infection and also ensure better plant stand.

CULTIVATION

For potato cultivation, the following practices are adopted in the hilly tracts of Uttaranchal:

Burning of leaves and other weeded out vegetation and trash, to protect the crop from soil-borne diseases.

Use of green leaves as manure, to increase pest resistance and improve soil.

Before sowing, the field is subjected to 3–4 deep tillings to expose the eggs and larvae of pests and other harmful worms to the sun.

At the time of the second harrowing, the soil is heaped around the stem to prevent pest infection of the underground growth of the potato.

Dry grasses and organic wastes are burnt in the field identified for potato cultivation. The ash is evenly spread over in the field followed by the use of dung manure (FYM). The field is then covered with green leaves collected from the forest. For green manure, generally the leaves of oak (*Qurecus incana*), *burans* (*Rhododendron sp*), *pati* (*Artemisia spp.*), poplar (*Populus spp.*), etc., are used. The manure of these leaves also has pest control qualities. The field is then tilled using a local indigenous plough and a wooden plank (*pata*) is applied to it to level the soil. Then the field is left for 10–15 days so that the manure and the leaves are assimilated in the soil. The well-crushed FYM is again spread over the field before it is once again tilled. The last tilling takes place 5–6 days

later. Now the field is ready for planting the tuber. The drains along the straight lines are made by a pickaxe or a spade. The seeds are sown at appropriate distances in the heaps between the drains. These are then covered with soil from both sides with a spade.

Sometimes, heavy rainfall after a month of sowing hardens the upper layer of the soil and there is a possibility of the seed rotting. In such a situation, the hard layer is lightly harrowed with a *kudal* to facilitate quick germination.

In order to protect the crop from pests and diseases, the crop cycle is strictly adhered to.

Recommendations

Burning of crop residues and other vegetative material in the field is not an eco-friendly practice. It affects the soil health by also destroying beneficial microbes. Instead, farmers should be encouraged to follow any of the following practices:

- Ploughing of the field to uproot the residues of the previous crop and weeds and then composting them.
- Mulching of the field with vegetation or with the previous crop residues.
- Removing the residues from the field and burning them in a heap outside the farm area, if necessary.

MANAGING SOIL FERTILITY

In order to maintain the fertility of the soil, the field is left fallow from time to time so that it can rejuvenate itself.

For retaining the fertility of the soil, the extra growth of any vegetation and the weeds are pulled out during the first tilling of the field. FYM is normally provided during field preparation and after one to one and half months of sowing. The manure is directly applied near the roots of the plants.

Recommendations

Besides green manure and compost application, further enrichment of the soil may be ensured through application of cow pat pit followed by a

spray of BD 500, *amrut pani* or *jeevamrut* or vermiwash or *panchagavya* as per convenience. Besides, inclusion of legumes in the system as inter or cover or companion crop also helps to supplement nutrient requirements.

Biofertilisers, namely azotobacter and phosphobactrium provide nitrogen and phosphate to the soil.

Interculture

Interculture is confined to weeding and earthing-up. Earthing-up and weeding of potato fields are done as soon as weeds emerge, but preferably when potato plants are about 8–10 cm high. After around one month of planting, light harrowing is done with the *kudal*. The weeds, thus tilted and exposed, are left *in situ* to be transformed into manure. The second harrowing is done 10–15 days after the first one. The first harrowing is done with a very pointed *kudal*, whereas the second harrowing is done with a less pointed *kudal*. During the second harrowing, apart from weeding, soil is heaped around the roots of the potato plants. This process is called *uker* (earthing) in local parlance. *Uker* helps to increase the yield and protect the crop from pests.

WATER REQUIREMENTS

Adequate and regular water supply is needed for sustained growth. The crop in the high hills and plateau regions in the *kharif* season is rain-fed, whereas in the plains it is grown under irrigated conditions. First irrigation is given immediately after planting, particularly if the soil is dry. Second irrigation may be given after 12–15 days. Subsequent irrigations may be given at intervals of 6–10 days, depending upon the nature of the soil and the availability of water. Deficiency of water reduces tuber yield. Mulching helps to get higher yield and economises on water. The *rabi* potato crop in the mountains generally depends upon rainfall for irrigation. But whenever there is insufficient rain, the crop is irrigated as needed. To save the crop from excessive rain at the time of harvesting, a drainage system is created in between the rows.

Water sources

The rainfall in the hills is much higher than the evapo-transpiration rate. The excess water can be stored in farm reservoirs and used in the form of supplementary irrigation when required.

Even a single irrigation at the critical tuber initiation stage can increase the yield considerably.

In the absence of timely rain, the following irrigation sources are used in accordance with their availability in the hilly areas:

- Perennial streams
- Traditional irrigation channels
- Pond/*khal* (seepage tank)
- Drinking water sources

In the plains, the potato is grown under assured irrigation because the winter rainfall is very little. In general, three methods, i.e., furrow, sprinkler and drip are adopted in different areas as per availability.

PLANT DISEASES

Late blight (*Phytopthora infestans*)

Late blight disease, in the local language, is known as *jhulsa rog*. It is caused by a fungus which affects the leaves, stems and roots.

Its symptoms appear in the form of green spots on the leaves, which gradually change into black and brown spots. Some cotton-like growth appears on the underside of the infected leaves. A 2–3 cm long, purple scratch appears on the stem of the infected plant and the plant looks thin and weak. The infested potato has brown spots on it and is pink inside.

Management

- The yearly crop cycle is adhered to.
- The field is subjected to 3–4 deep tillings before sowing so that the soil gets treated by the heat of the sun.
- Uker (soil heap uniformly constructed along the rows) is created to ensure that the potatoes are not left uncovered.
- The infected plant is taken out and burnt somewhere else and not in the field.

Recommendations

- Pest-resistant seed should be used. Advisable varieties of seeds for the plains of north India are Kufri Jyoti, Kufri Badshah, Kujri Sinduri and Chipsona I & II.

Advisable for the mountainous regions are: *Kukri Jyoti*, *Kufri Swarna* and *Kufri Kanchan*.

- To reduce the chances of fungal diseases, two foliar sprays of BD 501 are recommended during the flowering and fruiting stage.
- 10 gm of *trichoderma* culture mixed in one litre of water should be sprayed on the crop.

Early blight (*Alternaria solani*)

Locally known as *ageti jhulsa rog*, this disease infects the leaves. It is caused by the periodic summer. The fungus is produced in the air due to excessive wetness in the soil and favourable temperatures.

Big dark-brown spots appear on the infected leaves. If preventive measures are not taken, the infection spreads to other plants, which are weakened. Gradually the entire crop dies.

Management

- Before cultivating, the field is subjected to 3–4 deep tillings so that the soil is treated by the heat of the sun. The wild growth in the field is converted into green manure which enhances the immunity of the soil and reduces the chances of infection.
- Strict adherence to the crop cycle decreases the possibilities of this disease.

Recommendation

- 35 gm of BD 500 diluted with 13.5 litres of water should be sprayed before sowing the seed.
- Spraying of vermiwash mixed with water in a ratio of 1 : 13.5 litres protects the crop from fungal infestation.
- Ten grams of *trichoderma* culture mixed in one litre of water may be sprayed on the crop.

Black scurf (*Rhizctonia solani*)

This disease is caused by a soil borne fungus. It infects different organs of the plant including the eyes of the germinated seed, the stem and the flowers. The leaves of the infected plants become red and brown. Tubers of the infected plants have brown spots on them.

Management

- Crop cycle is adhered to.
- *Sesbania* or corn is cultivated in the field before cultivating potato in it.

Recommendations

- 35 gm of BD 500 diluted with 13.5 litres of water should be sprayed before sowing the seed.
- Sprinkle *jeevamrut* and *trichoderma* on the standing crop.

Brown rot (*Pseudomonas solancearum*)

Brown rot is an organically caused disease and generally occurs in the central Himalayan region. The stem of the infested plant turns brown. The plant bends and falls. The leaves also gradually turn brown and eventually the plant dies. This disease generally spreads through infected seeds. It enters the plant through the roots and destroys the tissues of the plant; consequently the flow of water from the roots to the upper parts of the plant is blocked and the plant withers away. This disease generally occurs in the summer and increases with a rise in heat and humidity.

Management

- Infected potatoes are not used for seed.
- The seed is not cut in order to prevent pathogens from entering and affecting other seeds as well.
- Sowing is completed by February and the crop harvested before the beginning of the rains.

Recommendations

- Before sowing, treat the seed with cow pat pit or *jeevamrut* or *beejamrut*.

PROBLEM INSECTS

Aphids (*Myzus persicae*)

In its fully-grown stage, this is a green, yellow-green or light pink coloured insect. During this stage, these insects do not have wings. They suck the juice from the leaves due to which the leaves are mutilated. With excessive infection, the leaves dry up and fall. Aphid attacks come usually in the month of August.

Management

- Manure from the leaves of the basing (*Adhatoda vasica*) plant reduces the damage caused by aphids.

Recommendations

- 250 grams of tobacco mixed with four litres of water should be boiled for 30 minutes. One litre of the extract should be mixed with four litres of water, and the solution should be sprayed on one twentieth part of an acre.
- Cow urine and verticillium organic regulator may be applied in the field.
- Spray a solution of 100 grams of crushed garlic mixed with 50 litres of water.

Potato tuber moth (*Pthorimaea operculella*)

This is the most harmful pest the potato crop faces. It penetrates the potato and slowly eats it up. The brown coloured pest is 1.5–2 cm. long and has green-brown spots on its wings. In the hills it damages the crop throughout the year. The female lays eggs on the buds of the tuber and on dissected parts of the seed. A female lays 100–200 eggs at a time, which grow to full size insects in 20–25 days which start attacking the crop. The infestation starts at the roots and gradually reaches the stem and the leaves. In local parlance, the moth is known as *bareek keeda*.

Management

- During the second harrowing, the soil is heaped around the plants (uker).
- The crop is regularly irrigated to cover any ruptures in the soil.
- Salt is sprayed in the field before sowing at the rate of 1 kg salt in 50 litres of water per *nali*.

In non-irrigated areas, 250 grams of salt per *nali* is sprayed 3–4 days before sowing.

Recommendations

- Spray cow urine and *bicchu ghas*/*lantana*/*rambans* mixture at intervals of 15 days.
- Use BD 501 at the stage of 3–4 leaves.
- Treat the seed with *jeevamrut* and azospirillum.
- After harvesting, the potatoes should be covered with leaves. This prevents the female from laying eggs on the potatoes.

Leaf caterpillars (*Spodoptera exigua*)

This is a major pest that damages the crop in the field. It generally attacks the crop in the months of May–June and causes maximum damage in June. It infests the leaves of the plant, cuts its stem at the surface level and eats the leaves during the night. The entire infected plant is slowly destroyed.

Management

- The field is tilled deep 3–4 times before sowing so that the eggs, pupa and larvae are exposed and eaten by birds or killed by the heat of the sun.
- The caterpillar is physically removed and fed to birds or killed.

Recommendations

- NPV (nucleo polyvinyl virus) solution can be sprayed on the field @ 100 litres/acre.
- A solution of 50 gm of tobacco boiled in four litres of water for 30 minutes can be sprayed on the field.
- BD 501 is to be used at the stage of 3–4 leaves.
- Spray ash on the field.

White grub (*Anomela dimidiata*)

This is a major pest in the mountain regions and damages the crop when it is ripe. The white and grey coloured worm is 1–2 cm long in its initial stage and grows to 5–6 cm when it matures. It is called *gubarela* or *kurmula* in the local language.

It is very common in the mountains and infects the potato when it is ripening by boring into it.

Management

- Physically remove the pest by digging near the root of the infected plant.
- 3–4 deep tillings before sowing also help in controlling this pest.
- 200–240 *akarkara* (*Spilanthes acmella*) plants planted in and around the field cause the grub to disappear.

Recommendations

- Do not use raw dung as manure. Only composted dung manure should be used.
- Salt solution should be sprayed in the field before sowing. In irrigated areas, the solution of one kilo salt mixed with 50 litres of water per *nali* is to be used. In non-irrigated areas, the salt is reduced to 250 gm of salt per *nali*.
- Apply 80–100 kg *khali* of neem (deoiled neem cake) per acre before sowing.

Miscellaneous pests

Wild pig, monkeys, porcupines and other animals are also attracted to potato fields.

Management

To protect the crop from these animals, scarecrows are erected in the field. For protection from porcupines, parallel barbed-wire fencing with a gap of 15–20 cm is erected around the field. The first wire is erected not more than 5 cm from the ground to prevent direct entry and attempts at burrowing through.

POST HARVEST MANAGEMENT

Harvesting of the potato crop is usually by manual digging of the field. However, sometimes the field may be ploughed or a potato digger may also be used.

Potato tubers are harvested as soon they mature. In loam or heavy loam soils, tubers are not allowed to remain in the wet soil after

maturity because the lenticels on their surface may proliferate and impart an undesirable look to the tubers.

Drying and cleaning

The potato is first dried for 1–2 days in the sun to destroy the possible presence of the eggs of any pest. A few farmers dry the harvested potato in the field itself while others do so at home.

This allows the soil around it to dry so that it can thereafter be easily cleaned by hand.

Recommendations

Drying of potato in the field itself should be avoided. This practice can enhance the chances of pathogenic infestation of the tubers.

Grading

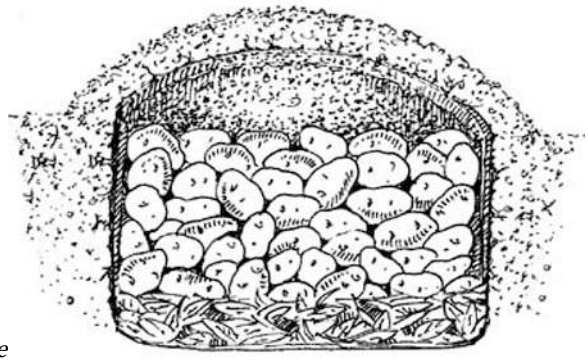
The crop is manually graded. Infected potatoes are separated at the time of harvesting itself. Thereafter, the produce is minutely graded during the process of drying.

STORAGE

The potato is stored in underground pits/ditches, or spread on the floor of the house or filled in jute sacks.

Making underground storage pits/ditches

The most common method of storing potato in the mountains is by the use of underground storage ditches. As the temperature in the ditches is low, the produce can be protected from rotting and from pests. Potatoes stored in the ditch are first layered with grass, then covered with soil and finally once again covered with grass.



Underground storage

In-house storage

In the house, *bajari* or a layer of small pebbles is spread on the floor and the potatoes are spread over it. The storage area is kept free from moisture and smoke.

STORAGE INSECTS AND DISEASES

Aaloo ki sundi (*Phthorimae operculella*)

This grey coloured pest is around 1 cm long and causes rotting of the infested potatoes.

Soft rot

The insect infects the potato in the store through *Erwinia sp.*, *Pseudomonas sp.* and *Bacillus sp.* The potatoes acquire a light pink colour as a result of moisture in the storage area.

Prevention

- To prevent attacks from this pest, the potato should be stored in storage pits/ditches and not in the house.
- There should be no moisture in the storage place.
- The bottom of the ditch should be layered with dry grass.

REFERENCES

Chadha, K. L. 2001, *Handbook of Horticulture*, ICAR, New Delhi.

Chadha, K. L. and Grewal, J. S. 1993, *Advances in Horticulture* Vol.7 Malhotra Publishing House, New Delhi.

Gaur, P. C, and Pandey, S. K. 1992, *A Decade of Potato Research in All-India Coordinated Potato Improvement Project*, CPRI Technical Bulletin, 31

Sharma, R.C. Potato, pp.719–768, *Textbook of Field Crops Production*, Tech. Editor, Prasad R., ICAR, New Delhi

INSTITUTIONS ENGAGED IN RESEARCH AND EXTENSION WORK

Central Potato Research Institute, Shimla 171001, Himachal Pradesh and its various stations.

State Agricultural Universities and KVKs.

SOYBEAN

Bhatt, bhatban, bhatmas, ramkulthi, kalitur

BACKGROUND TO THE CROP

The soybean *(Glycine max L)* is a member of the family *Leguminosae*, sub family, *Papilionoideae*. It is a major source of protein. It has twin uses – as an edible oil and also as a pulse. The protein in soybean is at least three times higher than any other foodgrain. Besides protein, soybean also contains appreciable amounts of vitamins and mineral salt.

Origin and distribution

Soybean farming originated around 100 BC in the eastern parts of north China. Presently, the USA is the largest soybean producer in the world. Soybean cultivation enjoys a prominent position in the world's total oilseed production. In 1965, soybean's share in world oilseed production was 32 percent. It rose to 50 percent in 1980 and continues to be on the fast upward move. Soybean cultivation came to India from China through Himalayan routes and also through Myanmar.

Cultivation area and yield

In India, in 1990, soybean was cultivated on 2.2 million hectares of land, with a net output of over 2.4 million metric tonnes. This has now increased to 7.46 million ha with production of 7.51 million metric tonnes.

Climate

Soybean is a short duration plant and different cultivars differ in the length of time required for crop growth. A hot and humid climate is most appropriate for soybean cultivation. The optimum temperature for rapid germination of soybean is 30 ^{0}C, (minimum is 50 ^{0}C and maximum is 40 ^{0}C). Temperature of 18 ^{0}C or less does not permit pod set. Seed size is largest when plants are grown at 27 ^{0}C and the number of pods per plant is highest at 30 ^{0}C. With good irrigation facilities, soybean can be cultivated even in areas with little rainfall.

Cropping pattern

In hilly regions, soybean is generally cultivated as a mixed crop, mainly with *ragi*. The crop cycle generally adopted is:

Kharif	*Rabi*	Period
Ragi + soybean	Mustard	1 year
Soybean	Wheat + mustard	1 year
Soybean	Fallow	1 year
Soybean	Sugarcane	2 years

Growing season

Soybean is a *kharif* crop. In the hilly regions, sowing begins in the second week of May and is completed by the first week of June. In *bhabhar, tarai* and in the plains, the crop is sown between the last week of June and the first week of July.

Sowing and harvesting period of different regions

Region	Sowing period	Harvesting period
Hills	May–June	October–November
Tarai, bhabhar and plains	June–July	From second week October onwards

Excess of rainfall immediately after sowing hampers the germination of the seed. Therefore, sowing in the third week of June is advised. If soybean is sown in the first week of June, the crop duration gets longer, but sowing after the middle of July affects the growth, quality and productivity of the crop. Recommended time of planting for soybean in the *kharif* season in different parts of India is as follows:

Northern hill zone

Last week of May to mid June

Northern plains and central zone

Last week of June to first week of July

Southern zone

Second week of July

Dharwad region

Third week of June

Soil

Sandy loam soil (*domat),* having adequate drainage, is considered most suitable for soybean cultivation while alkaline soil is considered unsuitable. Soil with a pH range of 6 to 7.5 is favoured for cultivation.

Duration

In the hills, soybean takes 5–6 months to grow, while in the *tarai, bhabhar* and plains, the crop duration is 4–5 months.

VARIETIES

Taking into consideration climatic and soil conditions, the different regions of India are grouped into five soybean zones, and varieties of soybean are accordingly recommended for cultivation. The main soybean varieties are: *Bragg, Lee, PK*-262, *PK*-308, *PK*-327, *Pusa* 16, *Pusa* 20, *Pusa* 24, *Shilajeet, Shivalik, Alankar, Anku, Durga, Gaurav*, *Gujarat Soybean*, *CO* 1, *Davis, Hardee*, etc. Besides these, there are a number of local varieties that are traditionally used in some areas.

Traditional varieties and their significance

- *Kali* (black) soybean: Chances of pest infection are least in this black, round/elliptical variety.
- *Peeli* (yellow) soybean: This light yellow coloured soybean is commercially more useful.
- *Hari* (green) soybean: Its seeds are smaller in size. It is cultivated on a small scale at very few places.

New varieties

- Stem fly resistant varieties – UPSL2773, UPSL586, UPSL80, PLSO77B, PLSD66, IC18736, etc.
- Caterpillar resistant varieties – JS-72-44 (Gaurav)
- Maggot sensitive varieties – Clark-63, Adelphia, Harosoy 63.
- Varieties sensitive to leaf minor – PK-672, PK74-262, VL7, MACS100.

SEED

Selection

For selecting seed, healthy plants are first located from the standing crop in the field itself. The selected plants are separately harvested. If the entire crop is healthy and disease free, there is no need for separate harvesting.

Seed from plants grown at high altitudes is preferred as it germinates quicker at lower altitudes. This also helps in controlling diseases that can affect the crop as the plants attain early maturity.

Treatment

Generally, there is no need for any pre-sowing treatment as the oil content in the seed reduces the danger of pests. Nevertheless, to be on the safe side, the seed is sun-dried from time-to-time during the storage period. The seed is also treated using cow urine, cow pat pit, *beejamrut, jeevamrut, panchagavya*, etc. For controlling seed-borne diseases including root rot and wilt, the seed of soybean should be treated with *trichoderma* @ 10 g *trichoderma* for one kg of soybean seed.

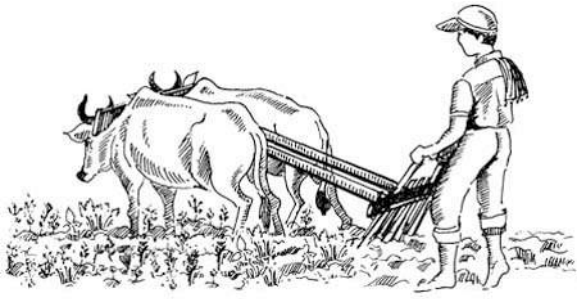
Seed rate

Generally, seed rate of 75–80 kg seed/ha is recommended for the *kharif* crop and 100 kg/ ha for the *rabi* crop. Seed is broadcast in the field. Under conditions of optimum moisture, in heavy soils, the crop is sown at 2–3 cm depth, whereas in medium to light textured soils, it is sown at 3–4 cm depth.

CULTIVATION

Field preparation and tillage practices adopted for soybean cultivation depend upon the type of soil and the region where it is grown. For the seed to establish well, there should be sufficient moisture in the soil. If there is less moisture, then pre-sowing irrigation is required. Being a leguminous crop, soya requires a fine seedbed with the least amount of clods. One deep ploughing or disking followed by two harrowings or two ploughings with a *desi* plough is sufficient.

In Uttaranchal, soybean is generally cultivated as a mixed *kharif* crop along with *ragi*, maize or amaranth, to reduce the possibilities of pest infection and to maximize productivity. During the first tilling, the remains of the wheat crop are exposed to the sun so that they decompose into manure for the soybean crop. In many areas, the remains of the harvested wheat crop are burnt in the field as a pest control measure. In some areas, after harvesting the soybean, the field is kept fallow and is used as a grazing ground. This retains the fertility of the land as during grazing the animals deposit dung and urine in the field.



Mixed cropping of soybean with ragi

Recommendations

Burning of crop residue and other undesirable vegetation in the field itself is not an eco friendly practice. It affects the soil health by destroying beneficial microbes as well. So instead of burning this material in the field, the farmer should be encouraged to follow any of the following practices:

- Plough the field to uproot weeds and the residue of the previous crop and compost the material
- Mulch the field with the vegetation.
- Remove the unwanted vegetation from the field and burn it outside the field area.

Weeds

Weeds in soybean fields reduce the quantity of the produce as they compete with the crop for water, nutrients and light. The major weeds found in soybean crops are *doob* (*Cynodon dactylon*), *tipatia* (*Oxalis latifolia*), *kondo* (*Elusine*), *malkauni* (*Setaria glauca*), *bandara-bandari* (*Setaria glauca)* and *crab* grass (*Digitaria sanguinalis).*

A *danyala* (wooden comb-hoe) is applied to the field 25–30 days after sowing, either by hand or with the help of bullocks. This helps in controlling the weeds at the initial stage itself. It also helps in regulating the growth density of the soybean and the other mixed crops being cultivated along with it and in maintaining the stipulated distance between the plants to ensure their proper growth. The *danyala* is a two feet long wooden strip with six holes, fitted with 8–10 inch long, pointed, sharp studs at a distance of 8 cm from each other and an 8–9 feet long wooden axle in the centre with which it can be pulled, either by

hand or by using a bullock. To maintain uniformity of the distance between plants and to eradicate weeds which have once again emerged, the field is harrowed with a *kutla* 10–15 days after the *danyala* is used.

In a single cropping of soybean, the harrow is not needed, as undesired plants can be manually weeded out 25–30 days after sowing. To keep the crop weed-free, the following preventive measures are to be adopted at the time of sowing:

- Acquire weed-free seed from certified agencies;
- Clean uncertified or home produced seeds before sowing;
- Pick up all rhizomes, bulbs, tubers and stubbles of weed and burn them after they are collected;
- Clean all agricultural implements and tools before and after their use;
- Existing weeds, if any, should be uprooted before they reach maturity and drop their seed in the field.
- Rotate the crop.

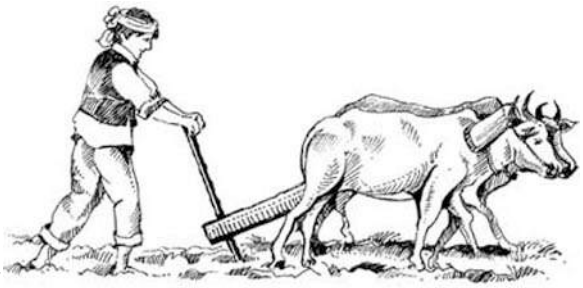
Other crop-specific agronomic practices

In Garhwal, after the plants germinate, instead of using the *danyala*, the field is ploughed into six inch wide furrows. This decreases the density of the plants, facilitates their proper growth and thus enhances the yield.

After threshing and winnowing, the seeds are separated according to their colour, size and shape. The healthy and well-shaped ones are preserved as seed for the next crop.

MANAGING SOIL FERTILITY

In the hills no special effort is made to enhance the fertility of the soil except the use of farmyard manure (FYM). The first deep tilling transforms the remains and roots of the previous crop into manure. Crop rotation is another means by which farmers maintain health of the soil.



Deep tilling of the field

Nutrients

The main nutrients for soybean are nitrogen, phosphorus and potash. Nitrogen and phosphorus are needed when the beans ripen. They are not required during budding and during transformation of the buds into beans. Potash is required in the initial stages of the crop and need for it decreases as the plant grows.

Recommendations

- Apply FYM @ 15 tonnes/ha or poultry manure @ 5 tonnes/ha or biogas slurry @ 12.5 tonnes/ha.
- Dual inoculation of seed with *Bradyrhizobium japonicum* @ 5 gm/kg of seed and phosphate solubilising bacteria (PSB) @ 5 gm/kg seed is very effective.
- In clay loam irrigated areas, co-inoculate B*radyrhizobium* along with PGPRs (azospirillum or pseudomonas) on the soybean to get higher grain yield.
- *Rhizobium* inoculation saves starter dose of nitrogen to the extent of 20 kg/ha.

WATER REQUIREMENTS

Soybean is a *kharif* crop and hence is largely dependent on rains but in the absence of adequate rains, the field must be irrigated before sowing by alternative means. At the same time, there should be no excess water in the field as extra moisture adversely affects germination and growth. Irrigation is also needed during budding – around a month after sowing – which is generally taken care of by timely monsoon rains.

Sources of irrigation

The following are the main sources of irrigation:

- canals
- *gadhere* (perennial streams and water springs)

- tube-wells (only in *tarai* and *bhabhar* regions)

Water conservation techniques

Traditionally, in the hills, the villagers used to collectively construct *khals* (water ponds) for harvesting rainwater from the entire region through gravity flow. *Khals* are a very effective way of irrigating farmlands in these areas.

Unfortunately, as *khals* are no longer being maintained and are gradually drying up, they may soon become a relic of the past.

PROBLEM INSECTS AND DISEASES

Stem fly (*Mdanagro myza sujae*)

As its name suggests, this insect causes maximum damage to the stems of the plant. At mature stage, this fly is brown in colour and acquires a dark colour as it grows older.

As soon as the plant begins to grow, the female pest lays her eggs on the underside of the leaves. The eggs are generally white and cylindrical. After 2–5 days, maggots are formed and they enter the main stem. This causes the leaves to turn yellow and the stem develops spots and slowly turns hollow. This finally destroys the crop.

Management

- Adhere to the crop cycle
- Ploughing in summer, after harvesting the rabi crop, must be deep.
- Sow resistant/tolerant varieties
- Spray cow urine
- Leaves sighted with eggs of the stem fly should be removed and destroyed.

Recommendations

- Two foliar sprays of BD 501, one at the stage of 4–6 leaves and the second at fruiting time @ 1 gm/acre will protect the crop from stem fly infestation.
- Spray organic pest controller at a ratio of 1 : 8 per acre.
- At the stage of 2–3 leaves, spray a mixture of ash and cow urine.

Hairy caterpillar (*Spilisoma obliqua*)

This is a light-brown coloured fly with black spots on its front wings. It acquires a length of 5–6 cm at maturity. The female flies are longer than

their male counter parts. They live in groups and lay eggs on the underside of leaves.

The insects perforate the leaves and also eat them. When the crop matures, the grains of the infected plants are small in size and appear unhealthy.

Thus, the caterpillars adversely affect both the quality and the quantity of the yield.

Management

- Infected plants are not selected for seed.
- Adhere to the crop cycle.
- Seeds are treated with wood ash before storage.
- Two kilos of ash in a cloth or jute packing are added to 25 kg of seed for protection.

Recommendation

- Spray liquid manure at a ratio of 1 : 8 on the standing crop.
- Spray chili-garlic solution @ 75 gm/litre.

Girdle beetle (*Oberia brevis*)

This beetle is 1 cm long and dark yellow or orange in colour. It makes round circles on the stems and in the centre of the leaf. It always makes two parallel holes and lays eggs in one of them. The stem becomes hollow, the leaves fade and fall and eventually the plant dies.

Management

- Use healthy seeds only.
- Bury the remains of the previous crop in the soil during the first tilling of the field.
- Adhere to the crop cycle.

Recommendations

- Use light traps in the field.
- Spray cattle urine and dung.
- Spray organic pest control at the ratio of 1 : 8 on the standing crop.

Bacterial blight (*Pseudomonas glycinea*)

This is a bacterial disease and generally found in the *bhabhar* (foothills), *tarai* and the plains. Plants affected by blight develop yellow spots on the leaves. These spots slowly get bigger and the leaves begin to fall off.

Management

- Before sowing, the remains of the previous crop should be well covered under the soil.
- Adhere to the crop cycle.

Recommendation

- 3.2 kg of *trichoderma* powder should be mixed with 25 kg cow dung manure for one week and then applied per acre, before sowing.
- Apply one kg *trichoderma* mixed with compost per acre during field preparation.
- Before sowing, treat the seed with *trichoderma* @ 10 gm/per kg of seed.
- Apply BD 500 and two foliar sprays of BD 501 at the time of field preparation.

Yellow mosaic virus

This disease is generally found in the *tarai, bhabhar* and the plains. It affects the leaves of the plants. First, yellow spots appear on the leaf, then the entire leaf becomes yellow and finally the leaf falls.

Management

- Burn the remains of the previous crop and other undesirable biomass before sowing.
- Adhere to the crop cycle.

Recommendations

- 3.2 kg of *trichoderma* powder should be mixed with 25 kg cow dung manure for one week and then applied per acre, before sowing.
- In order to conserve naturally occurring bio-control agents like Coccinellid beetles, *Chrysoperla*, etc., biodiversity should be encouraged on the farm through inter-cropping. In rain-fed areas,

inter-cropping of soybean with maize, sorghum or a short duration crop of pigeon pea is advised.

In the mountains, apart from the above insects and pests, *ghughuti* and *chokor* (species of Himalayan dove), monkeys and wild pig also harm the soybean crop. To prevent monkey attacks, dogs are used. Scarecrows are erected to ward off the pigs. *Ghughuti* and *chokor* relish the newly germinated plants. To protect the crop from them, sowing must be completed in the month of May itself so that the plants grow big enough before the birds arrive.

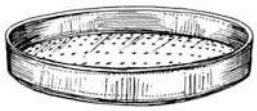
POST HARVEST MANAGEMENT

After harvesting and winnowing, the straw is separated from the grain with the help of a *supa*. Winnowing is done by pouring the grain in the wind from a height of about 5–6 ft. In the absence of natural wind, artificial wind is created by two persons waving a long piece of cloth, holding it from each side.

Cleaning

Winnowing

Drying



Grading sieve

Before storage, soybean seeds are dried for 5–8 days in the sun. The drying period in *tarai* and *bhabhar* regions is 5–6 days while in the mountains it is 6–8 days. To ward off the possibility of infection during storage, no moisture must remain in the produce. Before storage, the soybean is generally dried on a *mosta* (local fibre mat) *tirpa* or canvas sheet or a bedsheet.

Grading

After drying, grading is done with a *chalani* (sieve). The small and weak seeds are separated and used as supplementary feed for domestic animals.

STORAGE

Soybean is generally stored in the house in warm places. The following equipment is used for its storage:

Kulna

Tumbdi

- Jute sacks
- *Kulna* (large ringal bamboo basket, locally produced)
- Any large container

The following precautions are to be taken during storage:

- To protect the seed from moisture, the container should be placed above the ground on a piece of wood.
- The storage container must be kept away from the wall.
- The sacks containing the stored seeds should not be subjected to excessive pressure.
- To keep the temperature of the stored grains high, the storeroom should be in a warm place.

Managing storage insects

Soybean that is well dried in the sun develops immunity to pest infection. If necessary, it may be once again dried in the sun, 6–8 months after storage. Being a pest resistant crop, soybean does not need much attention during storage.

REFERENCES

Chandel A. S. 2002, *Soybean* pp. 372–396 in *Textbook of Field Crops Production*, Ed. by ICAR, New Delhi.

Anon 2002, *Integrated Nutrient Management for Oilseed C*rops, Directorate of Oilseeds Research, Hyderabad.

Anon 2002, *IPM in Oilseed Crops*, Directorate of Oilseeds Research Hyderabad.

Anon 2006, *Soybean Research at Agharkar Research Institute*, Pune.

Pathak, R. K. and R. A. Ram, 2005, *Manual on Jaivik Krishi*, CISH, Lucknow.

INSTITUTIONS ENGAGED IN RESEARCH AND EXTENSION

Directorate of Oil Seed Research, Hyderabad 500030, Andhra Pradesh.

National Research Centre for Soybean, Indore 452017, Madhya Pradesh.

Agharkar Research Institute, Pune 411004, Maharashtra.

ORGANIC INPUTS

This chapter outlines various inputs for nutrient, pest and disease management commonly used in the organic farming of crops. The method of preparation and application is briefly described. For more detailed information, please consult the companion FAO publication, *Current State of Inputs for Organic Agriculture.*

SOIL NUTRIENTS

Nutrient management is fundamental to successful organic farming. Organic management techniques differ considerably from conventional methods. The aim is to create a biologically active soil with good structure and high nutrient and humus levels. In fact, organic agriculture is based on the concept of 'fertilizing the soil' rather than the crops themselves. It relies on organic manure, compost, green manure, leaf manure, crop rotation, biofertilisers, biodynamic preparations and some indigenous methods for enriching the soil. Some of these inputs are briefly described below.

Organic manures

Organic manure is derived principally from substances of plant origin but sometimes may also contain solid and liquid animal wastes. Partially humified and mineralized under the action of soil microflora, organic manure acts on the physical and biophysical components of soil fertility. Farmyard manure (FYM), poultry litter, biogas slurry (described below) are considered to be good organic manures.

Farmyard manure (FYM)

Farmyard manure (FYM) refers to the decomposed mixture of cow dung and urine of farm animals along with the litter (bedding material) and leftover material from roughage or fodder fed to the cattle.

The average composition of well-rotted FYM is 0.78 percent N, 0.72 percent P_2O_5 and 0.65 percent K_2O, depending on the substrate.

The dose of FYM is 10–15 tonnes/ha, depending on the crop and the soil.

Precautions for use

- FYM should be allowed to decay before it is used.
- It should be ploughed into the soil on the same day that it is applied to the field.
- During the rainy season, it should be properly stored, to avoid loss of nutrients.
- Use of FYM as fuel should be restricted.

Poultry manure

Poultry manure is collected from chicken, hen and other household, domesticated poultry.

It is a rich organic manure, since liquid and solid excreta are excreted together resulting in no urine loss.

The average composition of poultry manure is 1.47 percent N, 1.15 percent P_2O_5 and 0.48 percent K_2O.

Application dose

3–5 tonnes/ha. It can be applied directly on the soil.

Precaution

Poultry waste should be decomposed before application. Otherwise, it may be toxic to the plant.

Biogas slurry

The residual end product of a biogas plant is known as biogas slurry. The anaerobic decomposition of cattle dung to form methane yields a slurry which can be used as organic manure.

The manure composition of biogas slurry is 1.4–1.8 percent N, 1.1–1.7 percent P_2O_5 and 0.8–1.3 percent K_2O.

COMPOST AND COMPOSTING

Compost is organic manure or fertilizer produced as a result of aerobic/anaerobic decomposition of a wide variety of plant, animal, human and various other biodegradable wastes. It is obtained from the decomposition of these wastes through a process involving microorganisms.

It is conveniently categorized as rural or urban (town) compost, according to the type and location of wastes used for composting.

A typical composition of rural compost is 0.5 percent N, 0.2 percent P_2O_5 and 0.5 percent K_2O while that of urban compost is 1.5 percent N, one percent P_2O_5 and 1.5 percent K_2O.

Compost also contains on an average 10 ppm zinc, 6 ppm boron and 12 ppm manganese.

The nutrient status of compost depends largely on the nutrient content of the wastes which are composted.

Compost is usually ready in 3–6 months, depending on the methodology adopted for preparing compost.

Aerobic composting

The aerobic method of composting was developed in 1924, at the Institute of Plant Industry, Indore, by Dr. Albert Howard and Dr. Y. D. Vad. It is known as the Indore Method.

In this method, a pit is dug near the cattle shed, on a site free from waterlogging. First, a wet bed, consisting of shredded crop residue is spread at the bottom of the pit. Cattle dung is then spread over this layer and is sprinkled with water to maintain optimum moisture. The process is repeated until layers of these residues reach 30 cm above ground level. A shed is erected over the pit to prevent the contents from getting soaked by rain. The material is turned every fortnight and good quality compost is ready in 16 weeks.

The width of the pit may be 2 to 2.5 m and its depth may be 0.9 m. Depending on the quantity of wastes to be composted, the length may vary from 3 to 10 m.

Precautions

- Care must be taken to keep the dry carbon material moist.
- Avoid composting in pits during the rainy season as it will lead to accumulation of water.

Anaerobic composting

The anaerobic method of composting was developed by Dr. L. N. Acharya at the Indian Institute of Science, Bangalore in 1939.

The Bangalore method attempts to conserve larger quantities of nutrients. Heaps are prepared as in the Indore method after which each heap is sealed with a plaster of mud, which increases its temperature due to the anaerobic fermentation process. By this method, nitrogen rich compost is formed in 32 weeks. The compost is ready when the temperature in the pile approaches that of the ambient air.

The final product is dark in colour, finely divided, rich in humus and has a C/N ratio of 10 : 1 to 20 : 1.

Vermicomposting

Organic manure produced as a result of the activity of earthworms is commonly referred to as vermicompost and the process is called vermicomposting.

The commonly used earthworm species are Eisenia fetida, Eudrillus eugeniae, Perionix excavatus, etc.

The raw material used is dried dung of cattle, sheep, pig or droppings of poultry and small shredded pieces of vegetable waste.

Partially decomposed organic wastes are filled in a specially constructed 2 m x 1 m x 0.5 m bin which is located in a cool

and elevated place. Red worms (*Eisenia fetida*) are preferred for vermicomposting. Between 100–200 earthworms are released in the middle of the bed, to which is added 2–4 kg, one week old, fermented dung. Water is sprayed everyday to keep the earthworms active. In 75–120 days, depending upon the weather conditions, the heap of organic waste gets converted into fine compost.

Precautions:

- Avoid overloading of organic wastes.
- Do not cover the waste with a plastic sheet during the process.
- Vermicompost units should always have a shade for protection from sun and rain.

The unit's contents should always be moist.

Vermiwash

Vermiwash is prepared from populations of earthworms reared in earthen pots or plastic drums.

The extract contains important micronutrients, vitamins (such as B12) and hormones (gibberellins) secreted by earthworms.

Earthworms produce bacteriostatic substances and so the use of vermiwash can prevent bacterial infection.

Vermiwash is sprayed on crops and trees for better growth, yield and quality of produce.

Precautions

- Water should be allowed to fall, drop by drop, into the pot/drum continuously.
- The organic waste in the pot/drum should be changed after it been converted into compost.

Mulching

Mulching is a system of on-site composting in which the organic residues are not ploughed into the ground but are left as a cover on the surface.

Mulch is simply a protective layer of a material that is spread on the top of the soil.

Any material – such as straw, plant residues, leaves, stubble, loose soil or plastic film – may be used as mulch and placed on the soil surface to reduce evaporation and erosion, protect or suppress weeds and protect plant roots from extremely low or high temperature.

Mulching increases infiltration of water, improves soil and moisture conservation, regulates soil temperature, improves root growth, and, over time, enhances the water holding capacity of the soil and enriches it with organic matter.

For straw mulching, crop residues can be applied @ 5–8 tonnes/ha. After emergence and establishment of crops, straw may be spread in between crop rows.

Precautions

- Mulch should not be in direct contact with the plant; 10–15 cm space should be left between the trunk of the plant and the mulch.
- Weeds should be removed before spreading mulch.
- Optimum moisture should be ensured before mulching.

Green manure

Green manure consists of fresh green plant matter which is ploughed into or turned into the soil to serve as a source of organic matter and plant nutrients.

Green manuring with leguminous crops is a well-accepted practice for augmenting nutrient supply, particularly nitrogen and organic matter.

The most commonly grown leguminous crops used as green manure are:

- *Dhaincha* (*Sesbania aculeata*)
- Sunhemp (*Crotalaria juncea*)
- *Moong* (*Vigna radiata*)
- Cowpea (*Vigna unguiculata*)
- *Senji* (*Melilotus alba*)

Some non-leguminous green manure crops are:

- *Bhang* (*Cannabis sativa*)
- Jowar (*Sorghum vulgare*)
- Maize (*Zea mays*)
- *Kodogira* (*Vernonia cineria*)
- Sunflower (*Helianthus annus*)
- Azolla

Green manure can provide 4–5 t/ha of dry biomass and 80–100 kg of N/ha within 50–60 days of plant growth.

Green manuring with leguminous crops 40 days after sowing will ensure a steady supply of nitrogen during growth and flowering periods when demand for it peaks in the crop.

Green manuring hastens microbial activity in the soil, reduces weed growth and improves the plant's resistance to disease.

Precautions

- The time gap between ploughing the green manure and sowing the next crop should not be longer than 2–3 weeks in order to prevent nutrient losses from the decomposing green manure.
- Green manure should not be ploughed very deep into the soil.

Crop residues

The bulk of the crop biomass left after the harvest of the produce (grain, fruit etc.) is called crop residue.

Most crops produce a voluminous amount of residue e.g., straw, stalk, husk, etc.

The NPK content of the residue of different crops varies from 1.75 percent to 3.30 percent.

Mature crop residue being rich in lingo cellulose materials will help maintain soil organic carbon (SOC) when incorporated into the soil.

The addition of crop residues to the soil improves productivity, nutrient supply, microbial and enzymatic activity, organic matter content, physical properties, etc. Decomposition of crop residue in the soil lowers the C/N ratio, which in turn increases the mineralization of nutrients thus making them available to the plant.

In cereals and millets, the grain-straw ratio is usually 1 : 1.5; in pulses it is 1 : 1 and in oilseeds it is 1 : 2.

Crop residue requires to be chopped into smaller pieces for quicker absorption and microbial decomposition.

The quantity of crop residue to be applied varies from 2.5–5.0 tonnes/ha.

Precautions

- Crop residues should not be burnt or used as fuel.
- Crop residues collected from conventional farming need to be tested before they are incorporated in an organic farm as they may contain traces of chemicals.

Green leaf manuring

Green leaf manuring is a process of collection of leaves and tender twigs from shrubs and trees grown on bunds, waste land and nearby forest areas and incorporating them into the soil of the farm.

This is an ideal practice for hilly areas where cultivable land is scarce and non-cultivable green area is in plenty.

The common shrubs and trees used for green leaf manure are *Gliricidia sepium*, *Sesbania specicosa*, *Pongamia glabra* (*Karanj*), *Leucaenea leucocephala*, etc.

Liquid manures

A large variety of liquid manures can be made on the farm from locally available plant materials mixed with cow dung and BD 502/507 preparations and kept to ferment for 8 to 12 weeks.

A 200–litre food grade, plastic drum can be used to hold the liquid manure.

Plant material such as nettles, gliricidia leaves, erythrina leaves, casuarina or any other green crops may be used.

Phospho compost

Phospho compost is phosphorus-enriched compost.

It is prepared by composting decomposable wastes along with 15–25 percent suitable rock phosphate for 3–4 months.

Preparation of one type of phospho compost includes crop waste 60 percent, animal dung fifteen percent, FYM 2 percent, soil two percent, rock phosphate fifteen percent, iron pyrites five percent.

BIOFERTILISERS

Biofertiliser is a product containing carrier based (solid or liquid) living microorganisms which are useful in agriculture in terms of nitrogen fixation, phosphorous solubilisation/ mobilisation, growth hormone production, cellulose degradation, etc., so as to increase the productivity of the soil and/or crop production.

There are mainly three types of biofertilisers, namely, nitrogen biofertilisers, phosphorus biofertilisers and compost accelerating biofertilisers.

Nitrogen biofertilisers

These include *rhizobium*, azotobacter, azospirillum, blue green algae and azolla.

a) *Rhizobium*

It is an aerobic, soil bacterium which fixes atmospheric N2 in symbiotic association with legumes whose root nodules act as the site of N-fixation.

It can fix 20–200 kg N/ha/year depending on the crop and growth conditions.

Its inoculation is recommended for legumes (pulses, oilseeds and forage legumes).

Application of *rhizobium* @ 1.0–2.0 kg/ha as seed treatment for chickpea, pea, pigeon pea, groundnut, soybean and @ 0.4–0.6 kg/ha for lentil, lucerne, berseem, green gram, blackgram, cowpea, etc., is recommended. Seed treatment should be done immediately prior to sowing.

Precautions

- *Rhizobium* should only be used for certain crops.
- It should not be mixed with any chemical fertiliser or pesticides.

b) Azotobacter

Azotobacter is a non-symbiotic, aerobic, free-living, nitrogen fixing, soil bacteria.

It fixes 20–40 kg nitrogen/ha. It also produces growth promoting substances like Indole, acetic acid, gibberellins, etc.

Its use is recommended for cereals and horticultural crops including flowers and vegetables.

Usage is by seed treatment, seedling treatment or soil application, depending on the crop.

Normal dose recommended is @ 200 gm/10 kg of seed as seed treatment during sowing time; 1.5–3.0 kg/ha as seedling treatment during transplantation; and @ 4–5 kg/ha mixed with 30–40 kg well-decomposed cattle manure as soil application.

Precautions

- It should not be mixed with any chemicals.

c) Azospirillum

Azospirillum is an associative, micro-aerophilic, spiral shaped, nitrogen fixing bacteria.

It can fix nitrogen @ 20–40 kg/ha in association with its roots. It also produces hormones like IAA, GA, citokinins and vitamins.

It is recommended as a biofertiliser especially for C-4 plants such as maize, pearl millet, finger millet, etc.

Application, dose and precaution is similar to those recommended for azotobacter.

d) Blue-green algae (BGA)

Blue-green algae is a prokaryotic, unicellular, photosynthetic, N-fixing, aerobic organism.

Commonly occurring BGA are nostoc, anabaena, aulosira, tolypothrix, calolhrix, etc. Generally, heterocyst is believed to be the site of N-fixation.

Its use is recommended for wetland rice (paddy) and it can provide 25–30 kg N/ha; it secretes hormones like IAA, GA, etc. It improves soil structure by producing polysaccharide which helps in binding of soil particles.

BGA can be produced by farmers themselves in a tray trough (6' x 2½' x 9"). First spread 10 kg soil, fill the trough with water upto 5–15 cm and add starter culture. Algal root is produced in 10 days. It is dried and flakes collected for use.

Dose: 25 kg/ha for paddy.

e) Azolla

Azolla is a floating, fresh water fern, triangular or polygonal in shape and fixes nitrogen in association with BGA *Anabaena azollae*. Azolla has many species like *A. pinnata*, *A. nilotica*, etc.

Azolla inoculation can fix 25–40 kg N/ha/crop. It is excellent food for fish, pigs, cows, ducks, etc.

Azolla is also a good manure. It contains 2.08 percent N, 0.61 percent P_2O_5, 2.05 percent K_2O. It can concentrate potassium from the surrounding environment.

Azolla is recommended for paddy, both as biofertiliser and green manure.

The doubling time of Azolla is 1–3 days under optimum conditions, 5–7 days in the field and 20 hours for anabaena azollae. The production process involves preparation of plots measuring 20 m x 2 m with bunds and irrigation channel, flooding upto 10 cm depth, addition of cow dung, azolla inoculation @ 8 kg per plot. After 15 days, 40–50 kg azolla can be harvested per plot of 40 sq. metre.

Dose: Application @ 3–4 tonnes/ha.

Phosphorous biofertilisers

a) Phosphorous solubilising biofertiliser (PSB)

PSB is a preparation of bacteria or fungi which can solubilise 20–30 percent of insoluble phosphate. The phosphorous solubilising bacteria includes *Bacillus megatharium var. phosphaticum*, *B. polymyxa*, *Pseudomonas striata*, etc.

The P-solubilising fungi include Aspergillus awamori, Penicillin digitatum, etc.

Its use is recommended for all crops. Usage is by seed treatment, seedling treatment or soil application. The process is same like Azotobacter.

b) Phosphorous mobilising biofertiliser (PMB)

Vesicular-arbuscular mycorrhizal (VAM) fungi are known as phosphorous mobilizing biofertiliser.

VAMs are obligate parasites. *Gigaspora*, *glomus*, etc., are some members of VAM.

Mycorrhizae in association with the host plant contribute to mobilize phosphates from the soil which are required by a large number of crops like wheat, maize, millets, soybeans, tomato, grapes, citrus, apple, banana, etc.

By using sterile soil-based as well as vermi-culture-based colonisation technology, large scale inoculums of mycorrhizae can be produced and made available for fast growing crops.

At least twelve percent of the root system of most crop plants should be colonised by VAM to obtain minimum desired benefits.

Mycorrhizae can supply 15–30 kg phosphate/ha/season by mobilizing P from the soil.

Compost accelerating biofertilisers

These are microbial cultures, employed to hasten the decomposition of organic materials during composting so as to reduce the time needed for the production of the end product, namely, compost. Examples of these cellulolytic and lignolytic microorganisms are *Trichurous spiralis, Paeciliomyces fusisporus, Trichoderma viride, Aspergillus sp.,* etc.

Trichoderma viride **(T.V)**

Trichoderma viride (TV) is a fungus with multi purpose uses in agriculture. As a biological pesticide it is useful in fungal attacks like wilt, rusting of leaves, root rot disease, etc. It helps in germination of seed. It can enhance the growth of plants and partly satisfies their nutrient requirements.

Seed treatment

- The seed must first be washed to get rid of any chemical fertilizers and pesticides.
- TV culture @10 gm/kg of seed is used.
- Culture is mixed with starch to make it sticky.
- Seeds are coated with the paste and dried in the shade.
- The dried seeds are sown in the evening.

Seedling treatment

- 20 gram of TV is mixed in one litre of water.

- Seedlings of brinjal, chili, tomato, cabbage, etc., are immersed in this mixture for five minutes before transplantation.
- For nurseries, 50 gm of TV culture is mixed with 500 gm of vermicompost or compost and applied to 64.8 m2 of land.

BIODYNAMIC PREPARATIONS

Biodynamic preparations are a part of biodynamic farming (BD) which was introduced by Rudolf Steiner in 1924. The term is taken from the Greek word 'bios' meaning life and 'dynamics' meaning energy.

BD uses special biodynamic sprays and composts. These are prepared using organic wastes like cow dung and herbs which have special properties, exploiting the life energy stored in them. Energy, as per this concept, comes from earth, water, air, fire and the cosmos.

Biodynamic preparations include preparations BD 500 (cowhorn manure), 501 (horn silica), 502 (yarrow, *Achillea milligolium*), 503 (herb, *chamomilia officinalis*), 504 (Stinging nettle, *Utrica dioca*), 505 (Oak, *Quereus robur*), 506 (flowers of dandelion, *Taraxacum officinale*) and 507 (flowers of valerian, *Valeriana officinalis*). The methods used to make some of these preparations are listed below:

Preparation 500 (Cow horn manure)

- About 500 gm cow dung is packed in a horn and fermented for 6 months in the soil (Sept–October to Feb–March).
- Spraying of BD 500 is done at the time of field preparation, in the evenings, during the descending period of moon.
- 25 gm of BD 500 is dissolved in 13.5 litres of water and is sprayed.

- BD 500 increases humus in soil.

Preparation 501

- Finely powdered silica (500–600 gm) is packed in a horn and buried in a pit during the ascending period of the moon during March–April.
- Incubation is allowed for 6 months (till October–November).
- BD 501 should be applied on the leaves at the four-leaf stage.
- BD 501 enhances photosynthetic activity.

Cow pat pit (CPP)

- Cow pat pit (CPP) is a strong soil conditioner. It improves seed germination, promotes rooting in cutting and grafting, improves soil texture, provides the plants with resistance against pests and diseases, etc.
- CPP is used in seed treatment and foliar application as well.
- 60 kg cow dung mixed with 250 gm each of eggshell powder and bentonite/basalt powder is filled in a 60 x 90 x 45 cm size pit dug in the shade. Two sets of BD preparations (502–507) are inoculated into the mixture which is covered with a gunny sack. Compost gets ready in 75–90 days, depending upon the temperature.

PEST AND DISEASE MANAGEMENT

A number of options such as crop rotation, summer ploughing, solarisation, inclusion of cover, companion, inter, green manure, trap crops, use of local seeds/varieties, pheromone traps, predators, parasites, botanicals, biopesticides, etc. are available for need-based management of pests and diseases.

Some of the cultural practices that help reduce pest and disease infestation are noted below:

Adjust the time of sowing to regulate the growth of the crop.

Plant to plant and row to row spacing is similarly used to alter the microclimate and reduce risks. There are no standard prescriptions for these and they are generally based on the knowledge and experience of the farming community.

Crop rotation: Rotating the crop belonging to one family with one of a different family helps to reduce pests and weeds to a large extent.

Trap crops: Pests are strongly attracted by certain plants and when these are sown in the field or along the border, the pests will gather on them rather than on the main crop. The pests can then be easily destroyed. African marigold, mustard, maize, etc., can be grown as trap crops in Cole crops, cotton and vegetables.

Intercropping: Inter cropping generally has a positive effect in terms of reducing the occurrence of pests. Insects find it difficult to locate host plants as the visual and chemical stimuli from the hosts are not strong and the aromatic odour of other plants can disrupt host-finding behavior.

Use of resistant/tolerant varieties: Genotypes showing tolerance or resistance to pest and diseases are preferred in organic cultivation. A series of resistant varieties of different crops have been developed in recent years to suit most climate conditions.

BIOLOGICAL APPROACHES

Botanicals

Neem-based products

Neem has been used from time immemorial as a bio pesticide. Various parts of the neem tree are exploited to make commonly used botanical preparations.

Neem seed kernel extract

Good quality neem seeds should be collected and pounded to remove the outer seed coat. The stripped seed should then be immersed in water (50 gm of kernel in one litre of water). After 12 hours, the solution should be filtered through a fine cloth

and sufficient water added to make a solution of one litre. The solution can be used for direct spraying. About 350–450 litres of the solution are required for one hectare. Khadi soap solution @ 10 ml/litre (100 ml/tank) should be added as an emulsifier to help uniform spraying. The concentration of the extract can be increased or decreased depending on the intensity of the pest.

The extract can be stored for a period of a month. The seeds used for preparing the extract should be at least three months old. If they are less than three months – or more than eight months – old, the azadirachtin content in the seeds will be lower and the seeds will be less effective. The extract prepared should be milky white in colour. If it is prepared from aged seeds, the extract will be brownish in colour.

NSKE is effective in controlling a variety of leaf eating insects and can also be used as a prophylactic.

Neem leaf extract

To prepare leaf extract, one kilo of neem leaves is crushed and soaked overnight in five litres of water. Before spraying, the solution is strained and one ml of soft soap solution is mixed per litre of extract. This solution is effective as a foliar spray against sucking and chewing insects. It can also be applied directly on the soil to control nematodes, especially in *solanaceous* crops, in which case the concentration of the solution needs to be doubled, i.e., 2–2.5 litres of crushed leaves to be soaked per litre of water.

Neem cake extract

A 100 gm of de-oiled neem cake is used to make one litre of aqueous solution. The cake should be kept in a cloth bag and hot water poured over it. The solution should be kept overnight in a covered container. The extract made in this way is very effective against all plant boring insects.

Neem oil

About 25 to 30 ml of neem oil is mixed with soap water to make an emulsion that is sprayed for the control of fungal disease such as downy mildew. Neem oil solution is also effective against a wide range of insects such as beetles, plant hoppers, caterpillars, etc., but it can also harm some beneficial insects. Neem oil is mainly used to protect seeds during storage. Between 5–10 ml of oil is mixed well with 500 ml of seeds, before the latter are stored in an airtight container.

Bordeaux mixture

Bordeaux mixture is copper sulphate mixed with hydrated lime. It is an outstanding fungicide and bactericide that has been used for decades to control diseases of tree fruits and nut, wine fruit and ornamentals. It is promoted under integrated pest management programs and is accepted in organic farming as a restricted input by Codex standards.

Tree paste

Take equal portions of CPP manure, sand, cow dung, rock dust and fine clay. Make a paste using one percent equisetum tea and BD 500. Smear this on the stems of pruned trees. It has been observed at CISH, Lucknow, that cow dung is rich in actinomycetes population, hence a paste prepared from cow dung, urine and neem powder is also effective in management of gummosis, dieback and pests.

Other local formulations for pest management

- In a copper container, mix 3 kg of crushed neem leaves and 1 kg neem seed kernel powder with 10 litres cow urine and ferment for 10 days. Boil the suspension to half and filter.

- Suspend 500 gm garlic paste and 250 gm chili paste in one litre of water separately and keep overnight. Next day mix the solutions and filter.
- Mix 5 kg neem seed kernel powder, one kilo *karanj* (*Pongamia pinnata*) seed powder, 5 kg chopped leaves of neem and 5 kg chopped leaves of besharam (*Ipomea* spp) with 10–12 litres of cow urine in a 200-litre drum and fill with water. Ferment for ten days. Distill the suspension. Distillate can be used as a pesticide.

Microbial pesticides or bio-pesticides

The use of microorganisms as biocontrol agents has gained in importance in recent years. Biopesticides are living organisms – or their derived parts – which are used as bio-control agents to protect crops against insect attacks. Entomopathogenic viruses of the baculovirus group, bacterial insecticides, particularly *Bacillus thuringiensis,* entomo-fungal pathogens, protozoans and insect parasitic nematodes have been found to control important pests that attack crops. These biopesticides are commercially available and are quite difficult to formulate in field conditions.

Types of microbial biopesticides

- Bacterial biopesticides
- Fungal biopesticides
- Viral biopesticides

Method of application of biopesticides

- Seed treatment: 10 gm/kg of seed
- Nursery bed: 1 kg/100 kg soil mix
- Soil drenching: 10 gm/litre of water
- Seedling dip (30 min): 10 gm/litre of water
- Soil application: 5 kg/acre with FYM
- Foliar spray: 1 kg/acre

Biorationals

Biorationals include the use of pheromones (sticky traps) in pest management. Pheromones can be used to assist in the control of pests in three ways:

- through traps
- by disrupting mating
- for survey and monitoring

Biocontrol by insects

Beneficial insects either prey on pest insects or damage the different stages of insect development, e.g., egg, larva, pupa. Accordingly, these biocontrol agents are categorized as:

a) Egg parasites

Parasites of this group damage the egg stage of the harmful insect. Some of the commonly used egg parasites are *Trichogramma spp. Telenomus spp.* and *Testrastichus sp.* They control top shoot borer in sugarcane, internode borer in sugarcane, cotton bollworms, paddy stem borer, etc.

b) Larval parasites

These parasites destroy the larval stages of harmful pests. A classic example is *Bracon spp.* which is used to control the black headed caterpillar in coconut and *Goppniozus nephantidi* which is used against the coconut leaf eating caterpillar.

c) Pupal parasites

These parasites destroy the pupae of harmful insects. *Testrastichus sp* is widely used to control pests like American boll worm, paddy leaf rollers, black headed caterpillars, etc. in their pupal stages.

d) Predators

Predators like *Chrysopa sp, Menochilus spp.* are highly useful in controlling a wide variety of pests such as aphids, white flies, cotton boll worms, leaf insects, etc.

The eggs of these parasitoids are commercially available in the form of egg cards. Each egg card (e.g., *trichogramma*) contains 20,000 live parasitised eggs which have 90–96 percent hatching rate within 7–10 days of parasitisation. These are applied @ 3–5 cards/ha. Each egg card costs between Rs.20 to Rs.50. *Chrysopa sp.* is available in vials containing 1000–5000 live eggs or larvae. The standard recommendation for crops like cotton, sunflower, tobacco, groundnut, mustard and vegetables is 5000–10,000 eggs or larvae/ha. Each vial costs between Rs.150 to Rs.200.

Sex pheromones

Adult females of target insect pests that are ready for mating emit species-specific chemical odours to attract males. This method of utilising the pheromones produced by insects for their procreation as a tool for their elimination is known as a pheromone trap. The mass trapping of males using this type of sex pheromone lure ensures that a majority of the females present in the field remain unmated. As a result they lay infertile eggs. In this way the pest population is checked.

There is also another type of pheromone called the aggregation pheromone in which the signals that insects produce to call others to a location, (e.g., whenever a food source is located) are effectively used to trap both males and females since both sexes respond to these chemical messages.

Installation of traps with suitable pheromone lures @ 2–3 per acre can also provide information on pest incidence and their intensity in agricultural fields.

Types of traps

There are different types of traps. The funnel trap is mostly used against larger moths. Another trap is in the form of reusable sun-board casing with replaceable sticky liners. It is

recommended for use against smaller moths, fruit flies, etc. For mass trapping pests of field crops such as sugarcane borers, a trap that consists of an adapter, a basin to hold water (mixed with kerosene/detergent) and a lure holder with a canopy is in vogue.

Table 4. Commercially important microbial bio-pesticides and biorationals used in India

S.No	Category	Products	Target pest	Major crops
1.	Bacteria	*Bacillus thuringiensis* *Bacillus sphaericus* *Bacillus subtilis* *Pseudomonas fluorescens*	Lepidoptera Mosquitoes, flies Fungal pathogens Fungal pathogens	Cotton, maize, vegetables, soybean, groundnut, wheat, peas, oilseeds, rice
2.	Fungi	*Trichoderma viride* *Trichoderma harzianum* *Trichoderma hamatum*	Fungal pathogens	Wheat, rice, pulses, vegetables, plantations, spices and sugarcane
		Beauveria bassiana *Verticillium lecanii* *Metarhizium anisopliae* *Paecilomyces lilacinus* *Nomuraea rileyi*	Insect pests such as bollworms, white flies, root grubs, tea mosquito bugs	Cotton, pulses, oilseeds, plantation crops, spices and vegetables
3.	Viruses	Nuclear Polyhedrosis Virus (NPV) of *Helicoverpa armigera, Spodoptera sp.* and *Chilo infescatellus*	American Boll worm, tobacco caterpillar and shoot borer	Cotton, sunflower, tobacco and sugarcane
4.	Biorationals	Pheromone traps Pheromone lures, sticky traps and mating disruptants	*Bactocera sp.* *Chilo sp.* *Dacus sp.* *Earias vittella* *Helicoverpa armigera* *Leucinodes orbonalis* *Pectinophora gossypiella* *Plutella xylostella*	Cotton, sugarcane, vegetables, fruit crops

Source: A Thimmaiah, *Current State of Inputs for Organic Agriculture.*

Other indigenously developed special formulations with wide acceptance in organic farming systems prevalent in India

Panchagavya

Panchagavya is a special preparation made from five by-products obtained from the cow, namely, milk, curd, ghee, dung and urine. These ingredients are mixed in a certain order. The process is described below:

Mix 7 kg of cow dung with 1 kg of cow ghee and keep in a pot with a wide mouth. Stir this mixture for three days once every day in the morning and in the evening. After three days, add the cow urine and water and keep for 15 days, stirring the mixture once every morning and evening. After that, add three litres of cow milk, two litres of cow curd, three litres of tender coconut water, three kilos of jaggery and twelve well ripened bananas.

The above mixture may be poured now into a wide mouth mud pot/concrete tank/plastic container. The container should be kept open, but under shade. The contents should be stirred twice a day, once in the morning and once in the evening. The *panchagavya* stock solution will be ready after 30 days. It should continue to be kept in the shade and covered with wire mesh or plastic mosquito net to prevent houseflies from laying their eggs.

This preparation is rich in nutrients, auxins, gibberellins, and microbial fauna and acts as a tonic to enrich the soil and induce plant vigour. For application, 3–4 percent solution is prepared by diluting the stock solution with water. This can be used for seed/ seedling treatment, through irrigation water (flow, drip, and sprinkler) or as foliar spray. Use of *panchagavya* has been found very effective in the growth of vegetables, cereals, pulses, sugarcane, turmeric, ornamental plants and fruit trees.

Amrut pani

Amrut pani is a special bio-inoculant prepared from cow dung, cow ghee and honey. Mix 10 kg cow dung with 250 gm cow ghee and stir thoroughly to form a creamy paste. Add 500 gm of jaggery and stir at high speed. Dilute with 200 litres of water.

Sprinkle this solution over one acre of soil either directly or with irrigation water. After 30 days, apply a second dose in between the rows of plants either directly or through irrigation water.

Amrut pani revitalizes the soil and enriches it. A peculiar practice in some places is for the farmers to dig up the rhizosphere soil from beneath a banyan tree (*Ficus Bengalensis*) as it is considered rich in microbial population. This soil is sprinkled on the soil surface before the application of *amrut pani.*

Beejamrut

Beejamrut is a local preparation to treat seeds for better germination, enhance growth and give higher yields. It is prepared with the following ingredients:

Cow dung	=	5 kg
Cow urine	=	5 litres
Cow milk	=	1 litre
Lime	=	250 gm
Water	=	100 litres

Mix all the ingredients and keep overnight. Sprinkle this solution on seeds to be sown. Dry in the shade before sowing.

Jeevamrut

Jeevamrut is another local preparation which has been found very effective as it is rich in microorganisms. It is prepared with the following ingredients:

Cow dung	=	10 kg
Cow urine	=	10 litres
Jaggery (old)	=	2 kg
Flour of gram, pigeon pea moong, cowpea or urad	=	2 kg
Live soil	=	1 kg
Water	=	200 litres

In an earthen pot or plastic drum, mix 10 kg cow dung and 10 litres of cow urine well with the help of a wooden stick. Add 2 kg jaggery and 2 kg flour. Again, mix well. Keep this solution

to ferment for 2 to 7 days. Shake the solution regularly three times a day.

This stock solution can be diluted 5–7 times with water and used for seed/seedling treatment or incorporated in the field with irrigation water.

Crop rotation

Crop rotation is a planned sequence of growing different crops in the same field.

The crops may be annual, biennial or perennial. Annual crops are rotated by choosing crops in accordance with the prevailing climatic and seasonal conditions.

Rotations such as rice-wheat and maize-wheat-*moong* are examples of annual crop rotation with seasonal crops that will enhance the productivity of the land.

Legumes (alfalfa, clover, hairy vetch) alone, or in combination with small grains (wheat, oats, barley), must be rotated with row crops (corn, soybean, amaranth, vegetables) to ensure healthy crops.

Crop rotation results in control of soil borne pests and other restricted-feeding insects, by creating a break between susceptible crops.

Physico-chemical and biological properties of the soil are found to be far superior in cereal-legume rotation fields when compared with mono-cropping or cereal-cereal rotation fields.

Precautions

- The decision on which combination of crops is to be adopted should be taken based on the area, climate and availability of water.
- Land preparation should match the requirements of the crop.