SUGARCANE

Economic importance

Sugarcane is the main source of producing sugar in our country and in neighbouring countries. Globally 60% of the world's white crystal sugar comes from sugarcane and 40% from sugarbeet.

In the developing tropical and subtropical countries of Asia, Africa and America where ration is poor in protein, sugarcane serves as one of the good sources of nutrition for the local population.

Per capita consumption of sugar in the United States since 1970 exceeds 100lb (45kg) annually. Sugar supplies one-seventh of energy in the diet. It is an economical source of energy.

In Nepal chewing of sugarcane starts from Mangsir and continues up to Chaitra. It is very useful source of food in Jandice. As juice contains sugars, people quench their hunger by chewing sugarcane stalk.

In India percapita consumption of sugar is 14kg per a year. It is around 6kg per capita per year in Nepal.

The main byproducts of sugarcane industry are bagasse and molasses. Bagasse is mainly used for fuel whereas molasses is used in distilleries for the manufacture of alcohol (ethyl, butyl). The bagasse ash serves as fertilizer rich in P and K. The fibrous material left over after crossing of canes is the chief source of power in the sugar mills. Excess bagasse is now being used as raw material in the paper industry.

Green top which constitutes 25-30% of the cane weight is used as feed (fodder) for livestock.

2930 Ethanol is produced from molasses which is later blended with petrol to make an excellent biofuel. Brazil produces 11.7 billion litres of ethanol per anum to run about 6.5 million vehicles. Ten percent ethanol is mixed with petrol. In 2061 a committee was formed to decide the price of ethanol. The producers demanded 51 Rs/litre of ethanol when the price of 1 litre petrol was Rs.67 Production of ethanol can save 40 crore rupees in terms of foreign currency as well as provide 12 crore rupees as revenue to the government. Ethanol plant is established in Rauthat at the cost of 4 crore rupees. (2061-12-10, Radio). The sugarcane industry is the second largest agro-based industry next to textile in India. The sugar factories (mills) utilize 40-50% of the cane produced. Jaggary and Khandsari industries utilize 50-55% of the total cane produced.

Sugarcane plays a vital role in the Indian economy. About 35 million farmers grow and depend on sugarcane for their livelihood. And an equal number of agricultural labourers earn their living by working in sugarcane farms. About 5 lakh workmen are directly employed by the industry. The sugar industries contribute over Rs.1000 crore to the Central Exchequer as an excise duty and taxes annually.

Presently sugar industry is one of the well organized agro-based industries in Nepal due to which in recent year approximately 150000 farm families are engaged in sugarcane cultivation.
It plays a key role in poverty alleviation in rural areas by providing 6 to 8 months seasonal works to the poorer section of the society.

Nepalese cane growers earned approximately NRs 276 crores from sugarcane during 1998/99 and 20% of that money distributed to the weaker section of the society for seasonal works in sugarcane.

In 1996/97 the production of sugar was 95000 mt & approximately 10 crore rupees of revenue was earned in the form of sale tax. In 1998/99 sugar production was 145000mt.

Sugar factories, being located in the rural areas, support huge economic activities in the rural India. In addition to improving the economic condition of the farmers and agricultural labourers engaged in the sugarcane farming, they also support several others like transport operators, agro-service agencies, input dealers, petty businessmen and financial institutions. Most of the workers are drawn from the surrounding areas. Therefore, the sugar cane factory generates rural employment.

Many sugarcane factories also promote education and co-operative movement in their areas of operation.

**Ecology**

Sugarcane is essentially a tropical plant. Temperature, light and moisture are the principal climatic factors that control the growth. Sugarcane thrives best in the tropical hot sunny areas. A long summer growing season with adequate rainfall, a fairly dry sunny and cool but frost free ripening period and free from cyclones (typhoons and hurricanes) are characteristic ideal climatic condition for the production of sugar from sugarcane.

**Relation to temperature**

Sugarcane is a tropical crop but it is widely distributed in sub tropics too. (E.g. Nepal, North India).

The minimum threshold temperature for cane growth is 16°C (18°C). A check in vegetative growth occurs when the daily mean air temperature drops below 210c. Thus, low temperatures are most effective in inducing ripening and lead to better juice quality. The diurnal temperature range, a month prior to harvest strongly correlates with cane sucrose percentage. A mean day temperature of 12-14°C would be highly desirable for proper ripening. At high temperatures reversion of sucrose into fructose and glucose may occur besides enhancement in photo respiration, thus leading to less accumulation of sugars.

In the range of 21-32°C, a close relation between temperature and volume of cane growth exists. The growth is not stopped at high temperature under sufficient soil moisture supply. Under deficit moisture, temperatures above 32°C may exert a retarding effect on growth. Though, temperatures up to 43°C (soil temp) are tolerated under high soil moisture status, the weather condition is conducive for borer pest attack, and sprouts suffer extensive damage under these conditions.
The minimum soil temperature for the germination of sugarcane sett is in the range of 19-21°C. The optimum range is from 27-38°C. (While temperatures above 38°C are not conducive. Temperatures above 38°C reduce the rate of photosynthesis and increase respiration).

No root development occurs below 12°C. It is best at soil temperature of 30°C.

**Relation to moisture**

Generally in sugarcane growing areas the annual rainfall is distributed in such a way that about 30% of the total rainfall coincides with dry season and the remaining 70% with humid season.

Planting time should be selected in such a way that the intensive growth of the sugarcane could take place during rainy season.

The transpiration coefficient of sugarcane is 400. This means 400 m3 water is required to produce one 1 tonne of dry mater.

Sugarcane grows under varying rainfall situation from nil in certain part of Peru (where it depends fully on irrigation) to over 350 cm per yr in some parts of Hawaii.

Even in India it is grown in rainfall of about 600-3000mm/yr. The crop can survive normal variation around of mean of 1200mm/yr.

For obtaining high yield a rainfall of 2000 to 25000 mm per annum evenly distributed is considered ideal. Therefore: in tropics-30-36 and in sub tropics 8-10 irrigations are provided.

Water requirement of a 12 month sugarcane is as follows: Germination- 0-45 days 300mm Tillering 45-120 days 550 mm Grand growth 120-270 days 1000mm (The highest demand for water) Ripening 270-360 day 650mm.

During the active growth period rainfall encourages rapid cane growth, cane elongation and internode formation. But during the ripening phase it is not desirable as it leads to poor juice quality, encourages vegetative growth, formation of water shoots & increase in the tissue moisture. Its effect becomes more deleterious if accompanied by low sunshine hrs.

**Relation to light**

Light is the most important external factor influencing tillering. Adequate light reaching the base of the sugarcane plant during tillering period is of paramount importance.

Light exerts its influence throw two factors: intensity & duration.

**Light intensity**

Under high light intensity, the elongation of stem slows down, but the tillers develop actively. This is because the growth regulating substances which are produced in the apical bud, do not stream down effectively under high light intensity.

When the light intensity is low, the flow down of growth regulating substances from the apical bud increases resulting in the active elongation of the stem and inhibition of the growth of tillers.
Under bright sunlight conditions, the stems are thicker but shorter, the leaves are broader and greener, while under low sunshine with lighter light intensity the stems are slender, and long having thinner, narrower and yellowish leaves.

**Duration**

The duration of light period or day length influences tillering. Short day length decreases number of tillers per plant and ultimately the tonnage yield.

Plants grown under long day produce more dry matter and have a low moisture content than those grown under short day.

Day length is largely responsible for flowering or harrowing in cane.

**Relation to soil**

Sugarcane can be grown on a variety of soil with texture ranging from sand or heavy clay soil to organic soils. There was not difference in yield/sugar percent when it was grown on clay, clay loam and sandy clay loam soils.

The ideal sugarcane soils are deep aerated, well structured sandy looms to clay loams with an adequate supply of organic matter.

Sugarcane is sensitive to soil oxygen deficiency. The critical limit is about 3.4% and value less than this impairs root development and nutrient uptake.

The optimum soil pH for sugarcane is about 6.5, but it grows on a wide range between 4 & 8.5.

**Planting material**

Sugarcane is propagated vegetatively by stem cuttings of immature canes which are variously known as setts, seeds, seed cane or seed pieces. While the cane is still growing, the terminal meristem provides apical dominance which prevents the growth of the lower buds (below). This may be removed by topping the canes a week before taking the cutting, which causes the buds to swell and sprout quickly. This effect of terminal growing top in inhibiting the growth of the lateral buds is also known as the top dominance. The top dominance is considered to be due to the growth regulating substances produced in the apical growing region. When the top bud of a stem grows, it is stimulated by hormone like substance (auxin) which at the same time retard the growth of the lower buds in increasing order from top to bottom, so much that the lower ones remain dormant. That's why the whole stem is not used directly in planting. It is cut into pieces to remove the inhibiting effect of terminal bud and allow the other lower buds to sprout under favourable condition. As a rule each piece consists of three buds.

The fact that the highest bud on the stem germinates more readily than those of lower portion is related not only to top dominance, but to the age of the bud and moisture status of the portion of the stem to which it is attached. The upper buds are protected by leaf sheaths which conserve their germinating power. Those beneath the soil are similarly protected and also germinate readily, a character which is of high importance in the production of good ratoon crops.
For sugarcane cultivation different kinds of planting materials can be used.

Top one-third portion of a cane. Rayungans Immature canes or short crop Water shoots or suckers.

**Top one third portion of a cane**

In general sugarcane is propagated by setts taken from the upper third of the cane. These top setts are formed by a length of about 60 cm or more of the cane at the growing end after the leaf top has been cut away. The internodes which make such setts remain almost enveloped by leaf sheaths which conserve the germinating power of the buds inside them. This portion of the stem is not useful for milling because its juice is too rich in glucose and non-sugar. On the other hand, they serve as an excellent planting material due to young buds which are less liable to be dried out and sprout readily. Bottom portion of the cane consists much sugar and has hard buds which do not sprout quickly. Moreover, bottom buds are over aged & may be damaged & infested with pest or diseases. Therefore, to use ripe portion for milling and growing top portion for seed purpose is an ideal way of making best use of sugarcane.

In practice the whole cane may be is used for setts, but their sprouting percentage decreases considerably from top to bottom. The germinating percentage of setts obtained from top, middle and bottom portions of the cane is found to be equal to 100, 40 and 19, respectively. Due to these reasons the top one third portion of the canes is generally used for planting material.

**Rayungans**

It is an Indonesian term meaning a developed cane shoot. When standing crops are topped, some of the auxiliary buds sprout due to elimination of apical dominance. When the sprouts are four to six weeks old, they harden and are fit for removal from the stem and planting in field. Planting of such developed shoots instead of cane setts helps to fill the gap, but there should be sufficient moisture and fertilizer in the soil for the establishment of Rayungans at the initial stage. Since the cane setts planted in the field take four to six weeks to sprout the rayungans planted to fill up gaps do not appreciably lay behind set planted crop.

**Immature cane or short crop**

A sugarcane crop raised exclusively for seed purpose is known as short crop. The short crop is usually harvested at around 8 months (6months). In the case of short crop, entire crop can be used for preparing setts, discarding only the bottom most buds.

The short crop or seed crops may be given additional fertilizers about six weeks prior to harvest. The practice is known as pre fertilizing, improves seed quality by enhancing sett nutrient status and sett moisture.

Thus, the seedlings emerging from such setts establish quickly and grow vigorously. A good seed is one which is free from pests & diseases, high in moisture content, rich in invert sugar and soluble N compounds. Hence a young cane of 8-9 (6) months well manured and irrigated is ideal seed material.
**Water shoots**

Water shoots are late formed tillers or side shoots which are robust and fast growing. They originate mainly due to plentiful supply of water, inadequate earthing up and late manuring. These watershoots as name indicates, contain lot of water, very less sucrose and more reducing sugar. Therefore, can be used effectively as planting material. Watershoot affects the growth of the adjacent stalks. They harbour insect pests and when they are harvested and sent to mill for crushing with main shoots lead to reduced juice quality and affect sugar recovery. Therefore, it is advisable to remove water shoots as and when they arise.

**Methods of planting Flat planting**

Flat system of planting is mainly followed in the subtropical states of the India. It involves repeated ploughing using wooden plough and compacting by planking to conserve moisture. For planting shallow furrows (8-10cm) are opened with a local plough at a distance of 75-90 cm. The cuttings are placed end to end (but to bud in Nepal) in the bottom of the furrow. After planting the setts are covered with 5-7 cm layers of soil followed by leveling with planking. Irrigation doses not follow immediately. The field should have adequate moisture at the time of planting. Manuring and cultural operations are done after receiving the monsoon in June. The entire crop receives 6-8 irrigation

**Furrow method**

Furrows of 15-20 cm depth are made with local plough or ridgers or spade at a distance of 90 cm apart from each other. Before planting setts, the bottom of the furrow is dug and mixed with basal dose of fertilizers after placing the setts in the furrows they are covered with 5-7 cm layers of the soil leaving upper portion of the furrows unfilled. Immediately after covering of the setts water is let into the furrow.

**Ridge and furrow method of planting sugarcane**

This is the most common method of planting sugarcane adopted by the south Indian farmers, North Indian farmers and progressive farmers of Nepal where irrigation water is available. In the finely of prepared field, ridges and furrows are formed using tractor drawn or bullock drawn ridgers. Some small farmers open furrow manually also. But for obtaining proper depth, tractor drawn implement is desirable. The spacing followed ranges from 60-135cm between the rows. The most common spacing is 90 cm. Closer spacing of 60-75 cm in desirable for early varieties, short duration varieties and shy tillering varieties and under poor soil fertility status (adverse growing conditions like moisture stress, limited irrigation, soil and water salinity, excess moisture or water logging) and in late (summer) planting wider row spacing (100-120cm) is advisable under high fertility conditions with good irrigation facility and for long duration and high tillering varieties. Depth of furrow should be 25 cm. A furrow length of 10-25 meters is ideal when guided irrigation is followed. The bottom of the furrow should be loosened to 10 cm depth. The ridges and furrows is the most ideal system of planting under highly irrigated sugarcane cultivation. The system facilitates easy irrigation, provides good soil aeration and solid support to the plant when a proper earthing up is done.
In this system first basal manures is placed in the furrow bottom and mixed slightly with the soil. The treated setts are placed either in end to end or in an over lapping fashion. End to end placement of setts is followed when the seed rate is lower and the internodal length of the variety is shorter. The over lapping type of the sett placement is followed if the setts have longer internode and the seed rates are higher. Then the setts are covered with soil and irrigated. This type of planting is known as dry planting. This is followed in light soils.

In heavy clay soils, the furrows are irrigated first and the furrows bottom soil is brought to more or less puddled condition and the setts are pressed down the soil. This method is known as wet method.

At the time of planting care should be taken to plant the setts in such a way that the buds are facing the sides. Otherwise, the buds facing down wards finds it difficult to emerge and the one facing upward may be exposed by washing away of soil while irrigating and thus may dry out.

**IISR 8626 method of planting**

Several basic studies initiated during early phase of the establishment of Indian Institute of Sugarcane Research led to the evolution of a new planting system by which cane yields in subtropical India could be doubled. The system involves basic concepts of plants internal factor (i.e. auxin action) and edaphic factor (i.e. soil compaction). Auxins which emanate from growing points of sugarcane control the activity and growth of bud while soil compaction hinders root growth and proliferation. These two points along with another aspect-lengthening of growth period, have combinely been used to develop a new method of cane planting called IISR 8626 method of planting.

**Concept**

In the evolution process of this technique the approach has been a little different than the usual one. Earlier, the emphasis had been on the quantity of inputs used, variety grown, seed-rate or seed-size i.e. 2-bud setts as in Punjab or 3-bud setts as in Uttar Pradesh etc.

However, in the new technique efforts have been make to increase the efficiency of utilized inputs and to enhance the overall productivity of cane so that it could fully exploit the soil and sunshine resources within a given period of time. Finally the technique is intended to exploit to the fullest extent the sub-soil moisture and native soil fertility of Indo-Gangetic plain. Due to these approaches, the technique has been made profitable one.

Collectively the technique has been referred to as "CAEGUS" system. This word stands for "consociation of Auxin Action" "Extension of Growth" and "Unhindered Utilisation of Soil", the three basic principal components of the system.

Thus the essence of the technique is: to plant tailed rayungans other than horizontally in fully fertilised and irrigated deep trenches.
Seed preparation

About two months before planting, the crop standing in the field for seed purposes is topped i.e. the green leafy top is cut off to remove the youngest tender tip of the cane stalk. This topping has to be done at such a time that by the time cane is planted, the side-shoots grow out and have about 3-4 leaves. This takes anything from 2 to 12 weeks. If the weather has warmed up, say as in March, the topping needs to be done only about a month before the proposed planting date. If there is still a month or so of cold weather to go before planting, the topping has to be done 10 to 12 weeks before the proposed date of planting. While topping, it is a good idea to touch the cut end of the cane with a rod soaked in a 0.5 per cent solution of Aretan: Thus is not very necessary, but it may help in some ways.

Trench making

The next step is to dig trenches. No ploughing or seed-bed preparation is to be done. If the field is too dry and hard, it may be irrigated lightly to facilitate digging. The trenches are made at intervals of 90 cm from centre to centre. The width of each trench should preferably be not more than 20 cm and the sides should be vertical. Such trenches can be dug by means of a spade but its width should be produced by sawing off about 4 cm from each side of the blade so as to leave a width of about 18 cm.

To economise on labour requirement, the trenches may be first dug to a depth of 30 cm and the dug up soil may be piled up on the inter-spaces. One third of the fertilizer dose should then be applied in the trench. The bed of the trench is then dug up another 15 cm so as to break up and loosen the bottom soil and also to mix up the fertilizer with it. The soil piled up on the inter-space is then put back into the trenches and while doing so the remaining fertilizer gets mixed with the soil of the entire depth of the trench, from top to bottom. If all the soil up to 45 cm depth is lifted out of the trench and fertilizer is sprinkled while putting it back, it is the best. The trenches may be dug at any time but the fertilizer should be added and the trenches filled up just before planting.

Planting

Seed is collected by cutting from each cane what we now call a long rayungan or a tailed rayungan. Rayungan is a word of Japanese origin used by the former Dutch planters to mean a single node piece of cane whose only bud has been made to grow into a shoot. A tailed or long rayungan is several nodded 40 cm top sett having side-shoots at the top. The tail is important because it is that which gives a boost to the plant. It does not matter whether the "tail" has or has not any buds or sprouts. But it should be there. As soon as these rayungans are out from the stalks, the greens leaves of the shoots should be trimmed. The material may then be dipped or soaked in a 0.25 percent solution of Aretan, if so desired. The first lot of seed is now ready. The water is then allowed to flow in trenches. The quantity of water should be such that it is just enough to be soaked into the soil. The interspaces should be kept dry. The tailed rayungans are then pressed vertically into the wet soil and kept erect. The spacing between rayungans should be about 50-75 cm, closer in late plantings and wider in early plantings. The bases of the side shoots
should be about 5-10 cm below the original soil surface. If they are left without soil cover more soil may be added to the trench.

Irrigation

A crop planted by the IISR 8626 method in March in the loam soils of the central areas of north India would require only 7-8 irrigations in the summer and 3-4 in the post monsoon season. In north-western areas, which are drier, the number of hot weather irrigations required may be about 8--10 and 3-4 respectively. The usual number recommended in eastern areas is 6-7 and 2.

Fertilizers

The N-fertilizer dose required is 120-150 kg N/ha. this is enough to give about 150 tonnes cane per hectare.

In addition, it is desirable to apply about 100 kg of P2O5 also alongside. The two can be mixed together along with gamma-BHC at 1 kg (a.i./ha), and incorporated into the trench soil.

Seed rate

The number of tailed rayungans needed is about 20,000 per hectare. By weight or number of setts, this is about half of what is recommended in the flat planting system. In early planting, the seed rate can be as low as 10,000 per hectare.

Cost and benefit

Cost varies from location to location. However, it is higher than in flat planting. Trench making costs about Rs.1000-1500 per hectare, but this should be discounted by the cost of seed-bed preparations. There are also savings on seed and many manual operations like gap-filling, top dressing, inter cultivation etc.

Advantages of IISR 8626 technique (1) Remarkably high yield(2) Moderate requirement of fertilizers and irrigations, (3) Suited to canal areas as well as tubewell areas. (4) Adaptable for short-season crops and intensive rotations (5) Greater efficiency of inputs, (6) Larger turnover of soil and other capital (7) Fewer cultural operations and no frequent attention to the crop. (8) Manual labour intensive: provides very remunerative employment for manual labour during the off-season, (9) Within reach of the smallest farmer, (10) The cost of production per tonne of cane likely to be reduced by 30 percent and net profit per hectare doubled.

Differences between trench and IISR 8626 methods of planting

There are several important differences of IISR 8626 technique from the usual "trench" method of planting. In IISR 8626 technique (i) the trenches are deeper (ii) they are filled up nearly to the brim before planting is done and not left open with the cane at the bottom. (iii) all the fertilizer is applied in a single dose (iv) not merely rayungans but tailed rayungans are used as seed and (v) the material is planted vertically.
**Spaced transplanting technique**

Nearly ten to fifteen percent of the cane yield is utilized as planting material in conventional planting method. At the same time, the method does not provide opportunities to the crop to fully express its genetic potential for tillering. Inter-plant competition and unevenly distributed solar radiation in conventionally raised crop tend to reduce tillering and also result in higher shoot mortality, thereby adversely affecting stalk density.

Although sugarcane is one of the most efficient converters of solar energy to chemical energy, conventionally planted crop is unable to harvest solar radiation at its optimum capacity. Improved crop geometry through proper spacing of plants is thus crucial for upgrading productivity.

With this consideration in view, an amelioration technology, "Spaced transplantation technique" (STP) for sugarcane crop has been developed at Indian Institute of Sugarcane Research and tested in the field. Field trials were conducted during 1974-78 at the Institute and many other locations in tropical and sub-tropical sugarcane growing belts. Trials conducted in the tropics included northern Karnataka and those in the sub-tropics included Haryana, Uttar Pradesh and Bihar. This technique minimizes the input levels and is suited to farmers with relatively small holdings. STP technique is a more scientific crop management procedure, cultural aspects of which are discussed below.

**Raising of Settling Nursery**

Settling nursery is raised in a small area a month before actual planting, preferably close to the field in which these will be transplanted. Approximately 50 sq meters (5m x 10 m) of the area is well prepared to a depth of about 15 cm and within this block, small plots of approximately 1m² are made. Before dibbling setts in the nursery beds, gamma-BHC at 1 kg (a. i.) per hectare is applied to the soil. In each small plot nearly 600 to 800 single bud setts are accommodated, depending upon the thickness of variety. About two tonnes of seed cane raised in the above manner will be sufficient for transplanting in one hectare of the field. Single but setts are drawn from the upper half of the cane stalks by cuttings just above the growth ring and leaving 8-10 cm of the internode below the bud.

The setts are soaked in 0.1 percent Aretan solution for 10 minutes. The nursery beds are irrigated adequately and the setts are dibbled vertically, keeping the bud and the root bands just above the soil surface. Trash or paddy straw is spread over the setts and then mulched with dry pulverised soil. Nursery is irrigated frequently so as to maintain optimum moisture level. Water stagnation inside the nursery beds should be avoided. Eighty-five to ninety-five per cent of the buds sprout within 3 to 4 weeks time and are ready for transplantation. Three to four green leaves should have appeared in most of the settlings by this time. It has been observed that this material is most suitable for survival and better tillering.

**Transplantation of settling Land preparation**

All preparatory soil operations have to be performed in the same way as recommended for conventional methods of planting in order to have good tilth and weed-free conditions.
Preparation of settlings

Settlings are carefully removed from the nursery and de-topped with a sharp knife. The detopped settlings are dipped in Aretan solution (0.1 per cent) and taken out immediately. A portion of the settling nursery (about 2,000 to 2,500) should be retained, to be used in gap filling, if any.

Transplantation

The transplantation of settling can be done for both the methods of planting, that is trench or flat system. Transplanting settlings at a distance of 90 cm between rows and 60 cm within the rows is recommended. In case of moderate tillering varieties, or in late planting, the spacing between rows and within the rows may be reduced to 75 cm and 45 cm respectively. Under 90 x 60 cm spacing, the number of settlings required per hectare would be about 19,000 and for 75 x 45 cm spacing the number of settlings required would be about 29,000. Cane rows are opened and settlings are transplanted within them. The settlings are dibbled and covered with soil, leaving about 5 cm position of the shoot above the ground and given life irrigation.

After about 10 days of transplantation, the gaps, if any, due to mortality of transplants, are replaced by the settlings from the nursery kept in reserve, and irrigated immediately. With normal management practices 5 to 10 percent mortality could take place i.e. about 1,000 to 2,000 transplants per hectare. The properly transplanted sprouted setts grow vigorously with a higher early tillering.

Fertilizer application and intercultural operations

Fertilizer dose and irrigation schedules are the same as recommended for conventional cultivation i.e. 150 kg N/ha and hoeing after each irrigation when soil conditions become workable. Single or split application of nitrogenous fertilizer can be made as per practice. Spot application of nitrogen fertilizer is preferred in this method of planting because nitrogen use efficiency increases. Phosphatic and potassic fertilizers can be given as per dose recommended in the area, at the time of transplanting. Inter-cultural operations are done frequently as in practice for conventional cane planting. To attain maximum tillering, plots should be kept weed free as far as possible.

Crop management during growth period

Integrated plant protection measures should be adopted during elongation phase as per requirement and recommendation of the area. Removal of dry leaves during grand growth period should be done to minimize the incidence of pests and diseases and to protect the crop from lodging. Timely earthing up of the crop should be done to save the cost of propping which is otherwise required in good crop stand.

Raising cane crop by STP system increases stalk population by 20-25 percent over conventional method of planting. A net saving of Rs.900 per hectare by this technique till transplantation only is computed. The technique described here has yielded about 180 tonnes per hectare on farmer's field as against 100 tonnes per hectare in conventional planting in 12 month crop of northern Karnataka. Similarly the mean yield under this technique rose to over 80 tonnes per hectare as
against 40 tonnes per hectare in north Bihar in commercial tests covering about 40 hectares. In Haryana and Uttar Pradesh STP system gave an average of 115 tonnes per hectares as against 60 and 70 tonnes per hectare respectively with the same level of inputs.

Advantages

STP method of planting is superior to the conventional method of planting in the following ways: Saving of nearly 4 tonnes in seed cane per hectare: Higher stalk population exceeding 1.2 lakh canes per hectare Uniform crop stand, with higher unit stalk weight. Late-shoot production is considerably reduced Lower incidence of pests and diseases Reduced lodging of cane Increase in seed multiplication ration (1:40) over conventional method (1:10) Yield jumps of 20-25 percent in tropical and about 40-50 percent in subtropical cane growing regions of the country.

Ring-planting system

Recently at Indian Institute of Sugarcane Research, Singh et al. (1984) have developed a new planting technique called “Ring planting system” where growth of mother shoot is encouraged and tillers suppressed. The techniques has following conceptual basis.

Conceptual basis

Plants of the gramineae family of which sugarcane is a member start sprouting tillers soon after germination. Tillers emerge from the buds present on the underground portion of the first emerged shoot, the "mother shoot". In a favourable environment "mother shoot may produce as many as 50 tillers. Tillers are weak and "parasite" on the mother shoot because their initial growth and development i.e. until their own root formation, entirely depend upon the food material stored by the mother shoot. As a result of this, mother shoot gets initial setback in its development.

If tiller emergence could be prevented somehow, then the mother shoots will grow freely without sharing nutrients with their off-shoots and thus might produce more yields. This could be achieved by inducing initial competition among plants through the use of heavy seed rate.

However, in the conventional row planting, high seed rates have not produced the desired results.

Agro-technology

The success of eliminating tillers naturally has been achieved by modifying the planting technique with altered crop geometry and soil manipulation as has been done in ring planting system where pits are dug to accommodate high seed rate in certain new placements.

Relative contribution of mother shoot (M) and tiller (T) under different ratios to total cane yield. Shoots Per cane weight (kg) Yield(t/ha) Percent contribution of M M T M T Total Only M 1.00 - 100.0 - 100.0 100.0 IM+IT 0.95 0.70 47.5 35.0 82.5 57.6 IM+2T 0.725 0.80 25.4 50.5 77.4 32.9

Contribution of mother shoot (M) and tiller (T) to cane yield in the population of one lakh millable canes per hectare. Population type Required seed rate Yield obtained Net gain IM+2T 6 t/ha 77.4 t/ha 71.4 t/ha IM+1T 9 t/ha 82.5 t/ha 73.5 t/ha Only M 15 t/ha 100.0 t/ha 85.0 t/ha
Methods of preparing rings

The field, at first, is marked at a regular distance of 120 cm leaving 60 cm space in the beginning both length and width wise. Then with the help of a long rope, straight lines are made both-ways. At a point where both the lines cut each other, a circular ring of 90 cm diameter and 45 cm depth is made (Fig.2.5). The soil from the ring (now pit) is dug out and kept on the periphery of the pits in 30 cm space left in between two pits. This way nearly 6,900 rings could be made in a one hectare field.

Fertilizer application

In every pit, 5-8 kilogram farmyard manure (FYM) or compost/or press-mud cake whichever is available easily is mixed uniformly before sett placement during planting. FYM can fill 10 cm bottom of the pit. To guard against termite attack it is necessary that 5 g Aldrin 5% or 10% BHC dust be mixed with FYM or compost. In addition to this manure, 10 g of urea and 10 g each of phosphorus and potassium are also added in the pit. Thirty days after germination 20 g urea must be top dressed. At the time of earthing up further 20 g urea is top dressed uniformly over every pit.

Seed material and planting

The seed material must be obtained from the nurseries raised from moist hot air treated plant material. It should be dipped in a solution of Agallol or Arean for at least 10 minutes before planting. Twenty three-bud setts then are placed horizontally in each pit. After spraying gamma-BHC over the setts these are covered by 2.5 cm thick soil cover. After germination when plants grow, pits are filled up gradually with the dug soil. The filling is completed by the end of May.

Inter culture

Since plants grow vigorously in this method of planting, to sustain their aerial growth, earthing up operation must be done in first week of July. The crop must be tied up in the first week of August. If necessary second tying is done in September. At the time of second tying, the node of first tying is cut open. Dry leaves are removed in September.

Yield

As sixty buds are planted in each pit and considering normal germination rate, 25-30 millable canes are obtained in each pit. Because of high shoot density and over-crowding in ring, the scope of tiller emergence and their survival is minimum. Hence millable canes are mainly the mother shoots, which are thicker in size and heavier in weight. Thus, nearly 150-180 tonnes cane yield could easily be obtained by this method of planting.

Trench method

In some coastal areas (A.P. India) as well as in other areas where the crop grows tall and the strong wind during rainy season causes lodging of cane, trench method is adopted to save the crop from lodging. Trenches at a distance of 90cm are dug with the help of ridger or by manual labour. In this system U shaped furrows or trenches of 35 cm deep are made. The width of the
trenches is 20cm. After this already prepared mixture of NPK fertilizers should be spread uniformly in the trenches and mixed thoroughly in the soil. The setts are placed end to end in the trenches. Immediately after this trenches are filled with loose soil as in case of flat sowing (5-7 cm of soil layer). In due course of time when the shoots have well developed the trenches are filled by soils while giving earthing up (85 to 100 days after planting).

**Deep trench system**

In this system deep trenches of depth 30-45 cm and width 60 cm are dug out at a spacing of 120cm between the centers of two adjacent trenches. That is the gap between the trenches is 60 cm. Sugarcane setts are planted on either side of the trench bottom and covered with soil slightly. As the cane grows, the trench is filled with soil with each manuring. Finally a small trench is formed between the setts of paired rows which serves as drainage channel to remove excess water during the north east monsoon rains.

The system is found ideal for early drought and late water logging conditions of coastal Tamil Nadu. In the initial stage, because the setts are planted deep in the moist soil zone, they get adequate soil moisture and thus give good germination and a good initial crop stand is established. The trenches formed later on are useful to drain out excess water during the ripening phase of the crop.

The system is highly labour intensive. But the system gives higher yield. Besides more number of productive ratoons can be raised. Therefore, if labour is available. This system can be followed with advantage in the regions where early drought and late water logging problems are present.

**Fertilizer**

Sugarcane is a giant crop producing huge quantity of biomass and therefore nutrients needs are high. On an average, 1 tonne of sugarcane removes 1.0 kg N, 0.6 kg P2O5 and 2.25 kg K2O. Thus a 100 tonnes of sugarcane crop removes 100: 60: 225 kg N, P2O5 and K2O from soil, respectively.

An average of 100:60:225 kg N, P2O5 & K2O per hectare is actually used up by the crop to produce 100 tonnes of cane yield. This means a larger cane yield demands greater amount of nutrient elements, or an adequate fertilization is the key of good yield of sugarcane.

Of the nutrient elements (N, P & K), nitrogen is the most important. Nitrogen increases the uptake of Ca and water and hence is important in maintaining plant turgidity which is the minimum for physiological and biological processes to occur. It influences cane yield through its effect on leaf area, leaf area duration, LAI and rate of photosynthesis. Increased yield following N addition is due to improved yield attributes like number of millable canes, stalk length and girth.

Nitrogen is the key nutrient element influencing sugarcane yield and quality. It is required for vegetative growth i.e. tillering, foliage formation, stalk formation, stalk growth (internode formation, internode elongation, increase in stalk girth and weight) and root growth.
Since vegetative growth is directly related to yield in sugarcane, the role of nitrogen is paramount to build yield in other words.

Yield increments due to nitrogen fertilizer application are two times that of phosphatic and three times of potassic fertilizers. With each kg of nitrogen application the sugar yield increases by 10-30 (max 40) kg per hectare.

At the optimum level of nitrogen (N), the responses was 0.5-1.2 tonne of sugarcane per kg applied N. P= 0.05-.25 tonne/kg P2O5 applied K= 0.02-0.15 tonne/kg K2O applied

**Nitrogen**

It is most essential during the early growth of the plant and immediately after harvesting in the ratoon crop.

Application of nitrogen at the time of planting helps in germination while its presence in soil promotes tillering and growth of the cane.

Nitrogen is transported from roots to the leaves, wherein the process of assimilation takes place and it is transformed into protein substances, which constitute an important part of protoplasm. So, with an abundance of carbohydrate and nitrogenous compound the growth of the cane is usually rapid.

Basal dose of N applied near the sett may be absorbed by sett roots and early formed shoot roots & may help give initial vigour to the germinants.

Maximum uptake of nitrogen (50-60% of the total utilized during vegetation takes place at the end of teillering.

When rows contact, the tillering phase almost stops and its uptake gradually declines.

Deficiency of nitrogen causes paleness of foliage early leaf senescence, thinner and shorter stalk, longer but thinner roots. Deficiency of nitrogen is most favourable at the end of vegetation because in its deficiency plants growth gets retarded and as a result of which accumulation of sugar in stalk takes place.

Excess nitrogen is also harmful. It prolongs vegetative growth, delays maturity and ripening, increases reducing sugar content in juice and thus decreases juice purity and increases soluble nitrogen in juice affecting clarification. Moreover due to increased succulence the crop becomes susceptible to lodging and pest and disease attack.

Amino acids like glutamin, asparagin and thirosine can not be removed. Their presence in the juice prevents the crystallization of part of the sugar (to the extent of 25 to 30 molecules of sugar for each molecule of amino acid). Hence the collective name of Noxious nitrogen for all the nitrogen compounds that can not be eliminated from the juice.

Thus, a progressive depression in juice sucrose associated with increase nitrogen fertilization is caused by immature sucker, continued growth and bonding of sugars with nitrogenous
compounds usually known as undesirable nitrogen in cane. So, management of nitrogen in sugarcane production is, therefore, most critical.

**Potassium**

Intensive utilization of potassium by cane occurs in the first 6 months of vegetation and before harvesting. The crop response to potassium application is higher in light soil and in the region with high rainfall. It is essential for the normal synthesis of carbohydrates, and for the production of sucrose and its translocation to the storage tissue.

Deficiency of potassium in soil leads to a reduction in juice quality with low sucrose content which is exaggerated by higher amount of nitrogen application.

Moreover deficiency of potassium produces thin & soft canes with a tendency to lodge. The older leaves become yellow and brown spots with necrotic centers appear on them. In stead of it red spots appear on the mid rib of leaves.

The requirement of potassium by sugarcane crop in general is greater than nitrogen or phosphorus even though it does not form a part of the plant structure unlike N & P. However, it is required for several plant activities such as carbon assimilation, photosynthesis, protein synthesis, translocation of protein and sugar (carbohydrates), the entry of water into plants and normal root development. It is involved in various enzymatic activities. Thus for sugar synthesis and it translocation to the storage tissue potassium is highly important.

It helps sugarcane under moisture stress by maintaining cell turgidity, (Potassium application also promotes turgidity in the plant cell and thereby maintains the internal pressure of the plant tissues). High potassium in plants helps to maintain higher plant moisture for a long period under adverse conditions. It also promotes higher sugar recovery. Potassium gives resistance to sugarcane against pest and disease attack and lodging.

**Deficiency**

Its deficiency leads to a reduction in juice quality with low sucrose content which is exaggerated by higher amount of nitrogen application. Apical dominance might be lacking or weak under potassium deficient conditions, as apical buds are damaged during potassium deficiency.

**Excess**

However very high potassium in juice is adversely affects the crystalization of sugar and leads to higher sugar losses in molasses.

The best response of potassium application is observed in soils with 7-9 mg of K2O per 100 g of soil. It is deficiency considerably declines in soils with medium (9-15 mg/100 g of soil) and especially high (15 to 25 mg/100g of soil) potassium content.

Moreover the optimum rate of potassium application is evaluated on the basis of nitrogen potash ratio in fertilizers, because the favourable effect of nitrogen on yields of cane and sugar is dependent on ample supply of potassium. The average amount of potash applied for cane cultivation ranges from 100-150 kg/ha. In drought condition its rate is increased by 25%.
**Phosphorus**

Phosphorus requirement is less than N and K. However it plays a very significant role in sugarcane production. Phosphorus is essential for the formation of protein and thus for yield build up. Phosphorus is essential for cell division and thus it is indispensable for stalk and root elongation or crop growth.

Phosphorus promotes early ripening and vigorous tillering. It affects favourably juice quality because it is involved in sugar synthesis and storage.

In ripening simple sugar (monosacharides viz glucose and fructose) are converted into cane sugar (sucrose as disacharides).

Sucrose synthesized in leaves and translocated to stalk through leaf sheath for which required energy is obtained through ATP.

Ripening in cane i.e. deposition of sucrose starts from base and extends to top. Each tiller develops its own roots system. Phosphorus is involved in root formation and therefore assists in tillering.

Sucrose: UDPG+ fructose 6 phosphate---sucrose phosphate+ UDP. Sucrose phosphate- Sucrose + inorganic P.

It interacts with N and thus influences ripening. Juice quality is adversely affected due to high amount nitrogen (content) when phosphorus supply is poor.

Phosphorus uptake in sugarcane is more evenly distributed than nitrogen. During the first months of vegetation sugarcane accumulated up to 20% of the total consumed phosphorus and in the next 3 to 6 months up to 50%. It equals to 72% in nine (9) months.

**Deficiency**

Phosphorus deficiency results in the reduction of length and diameter of cane. It leads to reduced tillering, delay in canopy closer and thus leads greater weed infestation.

The leaves become narrow and bluish green in colour with drying and dying at the tips and margins of the leaves. Application of excess phosphorus is wasteful in most soils due to fixation problems.

Adequate present of phosphorus is cane juice (300-500 mg per litre of juice) is necessary for proper clarification.

Clarification is done for two purposes

Removal of impurities and bleaching effect. The juice is dark green in colour and acidic. It is heated just in excess of boiling point. (approximately 105°C) and milk of lime is added in two stages: before and after heating. The purpose of adding milk of lime is twofold:
To prevent the inversion of sucrose which takes place in acidic conditions, and to coagulate and precipitate impurities.

The treated juice then enters from boiling house to the clarifiers in which organic substances such chlorophyll, anthocyanin, polyphenol, wax, gums, albumins and pectins as well as calcium phosphate (formed by milk of time) coagulate to form flocs and are precipitated as mud. This residue is known as filtré cane or filtré press mud.

The phosphate present in the mixed juice is in the form of soluble phosphate has practical significance. The particular reaction involved relates to the formation of a heavy flocculent precipitate of tricalcium phosphate which not only removes the colloids and other impurities but also absorbs much of the colouring matter and diminishes the calcium content of the clear juice.

Excess % of phosphate (600-800 mg P\textsubscript{2}O\textsubscript{5}/ litre of juice) is not desirable as it forms greater amount of precipitate which creates additional load in clarifiers and filtrers.

The raw juice extracted from sugarcane contains sugar and some other dissolved and suspended impurities in solution.

The dissolved impurities are reducing sugar and other mineral matter present in case as normal continents.

The suspended impurities include particles of soil, waxes, fats, proteins, gums, pectins, soil tannin, starch colouring matters which are compounds of high molecular weight, and dispersed as colloids in juice, which cannot be removed by simple filtration.

The reason being that the collected particles in raw juice bear a negative electrical charge. This charge causes the particles to repel each other and thus prevent their coalescence.

Precipitation may occur when ionic charge of the colloids is neutralized or reversed. In order to neutralize or reverse the change, however, the positively charged particles must be introduced.

The addition of milk of lime introduces an electrolyte calcium to the suspension. The positively charged calcium particles are attracted towards the negatively charged colloidal impurities. If the amount of calcium is sufficient the negative charge of colloidal matter is neutralized and flocculation occurs i.e. the particles get together & do not remain in a state of suspension so that they must settle down.

With heat: albumin, gelatin present in juice as dehydrated, denatured and coagulated by heat alone & precipitated out.

Pectins: are decomposed by the action of lime and heat and are precipitated as calcium pectate and thus eliminated.

SO\textsubscript{2}, CO\textsubscript{2} P\textsubscript{2}O\textsubscript{5}: form thick precipitate of calcium sulphite, calcium carbonate and calcium phosphate, which by surface attraction carry much of the impurities remaining in colloidal dispersion.
Dose of Fertilizer

Sugarcane responds to nitrogen application in all types of soil but more under irrigation than when the crop is rainfed. So depending upon water supply duration of the variety, region of cultivation the dose (Adsali 400kgN/ha) of nitrogen may range from 100-300kg/ha. The average rate of phosphorus application is 50-100 kg P2O5/ha. The crop response to potassium is more related with quality of the stem than its growth.

Nepal   Dose 120:60:40 kg/ha    At present Spring planting Autumn planting  60 kg N/ha at planting 40kg N/ha at planting 150:60:40 kg NPK/ha 60 kg N/ha after 2 months planting 40 kg N/ha at 3-4 months age 1st earthing up  40 kg N/ha at 6 months aged, 2nd earthing up 75:60:40 at planting 75 kg N/ha in two installments at 90 and 120 (irrigated condition) days Rainfed condition -80:60: 40: at planting -40 kg N/ha before onset of monsoon -In direr areas it is recommended to increase the dose of potassium by 25-50% This is to save nitrogen loss through leaching. Sugarcane is frequently irrigated (6-8 in sub tropics). Mainly spring planting is done in Nepal.

Time and method of fertilizer application

It is important that a sufficient amount of nitrogen should be available in soil during early vegetation, when metabolism and tillering in the sugarcane plant is most intensive. (Particularly in the 2nd and 3rd months of vegetation, tillering, 45-120 days).

Moreover, it is well known that incomplete assimilation of the nitrogen causes depression in juice quality (>glucose <sucrose, bonding of sucrose, clarification) of sugarcane at harvest and a period of 4-6 months is required for complete assimilation of the nitrogen, taken up during the boom (peak) period. That's why all nitrogen should be applied at least 5 months before the cane will be harvested.

The time of fertilizer application should take into consideration the crop need at different growth phases (phases) & best use of the applied nutrients without much wastage.

Nitrogen requirement of sugarcane is greatest during the tillering and early grand growth phase. Experiments have proved that most of the N uptake by the crop takes place within the first 6(six) months.

During germination external nitrogen supply is not required

The germinating bud develops with the food material already present in the sett. Also there will not be adequate root system to absorb nutrients from the soil. Therefore any nitrogen applied during this stage will be of less practical use. In stead there could be loss of nitrogen through leaching and other meant.

Therefore basal application of nitrogen at planting is not required in most cases. However, 10% of the total dosage is given as basal (Karnataka). This quantity is placed near the sett and may be absorbed by sett roots and early formed shoot roots and may help give initial vigor to the germination.
In the tillering phase the crop needs high amount for nitrogen for tiller formation and their
growth. Very high amount of nitrogen uptake has been recorded by around 90 and 120 days. i.e. 
the end of tillering phase. Tillering phase commences in a field grown sugarcane by around 30-
45 days. Therefore the first application of nitrogen should be at the start of tillering phase.

In the tropical belt for an Eksali crop, application of N is done at 45 days of planting. In case of 
early maturing & short duration varieties, first application is found best at 30 days of planting.

Regarding of the from and method of nitrogen application, the entire dose needs to be applied 
within 100 days, irrespective of duration/ variety. Normally 2-3 splits are made at critical growth 
stages. viz tillering (35-60 days) formative phase (60-75 days) & grand growth phase (75-100 
days).

Tillering is a physiological process of repeated underground branching from compact nodal 
jointis of the primary shoots. Usually early formed tillers give rise to thicker and heavier stalks. 
Late formed tillers either die or remain short or immature. Maximum tiller population reaches 
around 90-120 days of the crop. By about 150-180 days, at least 50% of the shoots die and a 
stable population is established.

Further the crop requirement for nitrogen is higher at the beginning of grand growth phase or end 
of the tillering phase. This facilitates cane formation, checks tiller mortality and promotes cane 
growth. Therefore, second application for an eksali crop is done at 90-120 days.

Late application of nitrogen beyond 120 days in a 12 month crop will have adverse effect on 
juice quality. there will be continued vegetative growth, late tiller formation, reduced pol% in 
juice, increase in soluble N in juice, water shoot formation and such other problems affecting 
sugar recovery. Much of the later applied nitrogen goes for late tillers and water shoot formation, 
besides attracting pests and loses through leaching. Because, by the 6 months stage, the crop 
itslself would have accumulated in its tissue almost of N required. Therefore late application leads 
to overall productivity decline and loss to the farmers and millers. This time of N application can 
be extended up to 6 months stage in adsali sugarcane.

Potassium

Potassium applications are usually done along with nitrogen application. This is because of better 
utilization of nitrogen by the cane in the presence of potassium (Uptake of N & protein synthesis 
decreases at K deficiency). Therefore potassium is applied along with nitrogen at 45 to 90 days. 
However, potassium is also applied basally in several sugarcane growing regions.

Since potassium is also subjected to losses by fixation (clay colloids 2:1 ellite) and leaching (in 
less base saturation sandy soil) it is a advisable to go for split application along with nitrogen.

In sugarcane late application of potassium at around 6 months has been found to improve sugar 
recovery, particularly under drought or moisture stress condition.

Experiments have proved that phosphorus application should be done before planting right below 
the setts in the root zone. Because phosphorus is highly immobile nutrient unlike N & K. It 
should be available right near the roots for its effective uptake. Also, it gets fixed in the soil
quickly and therefore there is limit for losses other than fixation. The fixed phosphorus is not lost, but will be available slowly over the period of time.

Phosphorus need is greater in the formative phase of crop. Tillering is seriously affected when phosphorus is limiting. Thus the optimum time of soil application of phosphorus is just before planting below the setts.

For efficient uptake and use of the nutrient elements sufficient soil moisture is essential. Therefore, fertilizers application should always be followed by irrigation.

In subtropics a portion of the fertilizer is applied as basal and the remaining after the onset of monsoon rain in June. Irrigation given after fertilizer application should not be excessive, because it will cause leaching of considerable quantities of the applied fertilizer.

**CULTURAL OPERATIONS/PLANT MANAGEMENT**

**Hoeing**

After 10-15 days of planting hoeing should be conducted which loosens the soils and creates suitable environment for setts germination. It also controls small weeds. Hoeing is compulsory after 1st top dressing and irrigation and there after 1-2 hoeings are done according to need.

**Gap filling**

After 20-30 days of planting the field is checked to see the sprouting of setts. The place without sprouts should be filled with new setts. For this purpose, it will be better to use cuttings from the top part of the stem. To promote rapid growth the cuttings should be immediately planted and soil should be sufficiently supplied with water.

**Weed control**

To achieve high cane yield, weeds must be controlled at a proper stage. If weeds are not controlled at a proper stage they directly reduce cane and sugar yields and indirectly add to the loss of the crop by providing favourable atmosphere for the development of insects and diseases. The loss in cane yield may go up to 60-80 per cent, depending upon the type of weed flora present and their intensity in an area.

Autumn sugarcane planted in October takes about three to four weeks for germination. During this period, weeds of winter season germinate and grow profusely even before the emergence of sugarcane seedlings because of enough space and nutrients available in the absence of any competition with the crop. The major weeds in this crop belong to annual broad leaf group like Chenopodium album (bathua), Lathyrus sativa (matri); Vicia spp. (ankari); Angallis arvensis (Krishna neel), Fumaria parviflra (gajri or soya) Solanum nigrum (mkoya), etc. A second flush of weeds emerges with the onset of summer season. Most of these weeds are grassy in nature.

Spring planted crops of sugarcane takes about four to five weeks to germinate. In this crop, weeds start emerging from the very beginning after the planting and continue to emerge till the onset of monsoon. Thus this crop faces a problem of two types of weeds. The weeds emerging
before the start of monsoon are generally broad leaf annuals of winter season and some perennials like Cyperus rotundus (motha); Cynodan dactylon (Doob) and Sorghum helepense (ban chari). Weeds which emerge during rainy season are mostly annual grasses. Their intensity is very high and rate of growth is also very fast. The major weeds of rainy season are Echinochloa colonom and E. crusgalli (Sama, grass) Dactyloctanum aegyptium (makra); Amaranthus viridis (jangil cholai); Celosia argentia (Safed murg) etc.

Weed control in sugarcane is accomplished by adopting mechanical or chemical methods. Mechanical methods can be practised effectively during the pre-monsoon period but their use during monsoon period is not very effective. Several herbicides have been tested for weed control in sugarcane. Some of them are very effective. 2, 4-D is very effective against broadleaf weeds which generally grow in autumn cane. It should be applied 25-30 days after planting or before the weeds attain three to four leaf stage. The rate of application would be 1 kg active ingredient per hectare in 500-600 litres of water. To control weeds in spring cane, spray 2 kg active ingredient of Simazine or Atrazine in 500-600 litres of water per hectare just after planting. Efficiency of these herbicides is increased when there is sufficient moisture in the upper soil surface. Light irrigation immediately after the germination of sugarcane helps in increasing the efficiency of these herbicides.

**Earthing-up**

Earthing-up operation is also known as 'hilling up'. This practice is most commonly followed in the tropical states where furrow irrigation is common. In the sub-tropics also its usefulness has been demonstrated; but it is not very common, particularly because of the flat method of cultivation practices.

Under the tropical sugarcane cultivation practice, earthing up operations are done in two three stages. The first earthing-up is known as 'partial earthing-up' and the second operation is 'full earthing-up'.

The partial earthing up is done after first top dressing essentially to cover the manure and to provide anchorage to the freshly developing shoots roots. In this case, soil from either side of the furrow is slightly taken and placed over the fertilizer band when done manually. This could be carried out also by using a bullock-drawn implement or a narrow wooden plough. While doing partial earthing up, the furrow in which cane row is present gets partially filled. Irrigation is continued to be given in the furrow itself, i.e., on the cane row. Full earthing-up is done after the final manuring, which is usually done at 90-120 days coinciding with the peak tiller population stage. During full earthing-up the soil from the ridge in between is fully removed and placed near the cane on either side. This operation could be done either manually or by using a bullock-drawn ridger. If the area is small, and labour is available, manual operation is preferable as there will be a good earthing-up. This operation converts the furrows into ridges and the ridges into furrow. The furrows thus formed are used for irrigation. Thus irrigations are given in the side furrows, not in the cane row. A tractor drawn ridger can also be used for this purpose. In Gujarat fertilizer application and earthing-up are done by tractor-drawn ridgers having attachment to apply fertilizers also. Thus a single pass of the tractor a accomplishes the job quite efficiently.
Earthing up at 3-4 month stage checks further tillering, provides sufficient soil volume for further root growth, promotes better soil aeration and provides a sound support or anchorage to the crop and thus preventing lodging.

One more earthing-up is done at around 6 months when a stable cane population has been established. This is helpful to prevent lodging, improve soil aeration and help prevent late shoot or water shoot formation. Earthing-up operation in general helps control weeds by mechanically destroying them.

**Detrashing**

Sugarcane produces large number of leaves—equal to the number of internodes. A normal stalk bears, on an average, 30-35 leaves, under good growing conditions. All these are not useful. For optimum photosynthesis only the top 8 to 10 leaves are required. Most of the bottom leaves dry out as the crop ages. In fact the bottom green leaves drain out the food material which otherwise could be used for stalk growth. Therefore it is important to remove the dry and the lower green leaves. This operation is known as detrashing.

Detrashing should be done once the cane formation takes place, around 150 days after planting. There after it could be done at bimonthly interval depending upon the labour availability. In many of the sugarcane growing areas, detrashing is not done mainly due to labour shortage.

Detrashing is done manually. A hand tool can also be used for detrashing which could be locally made. Certain sugarcane varieties have spines on their leaf seaths. In such varieties it is difficult to carry out this operation by hand. Therefore a hand tool (detrasher) may be highly useful.

**Advantages of detrashing**

Detrashing helps in maintaining a clean field. It provides easy movement of air within the crop canopy. Thus provides an ideal micro-climatic condition for unrestricted growth of cane. As already mentioned, removal of green leaves makes more food material available for stalk growth. Detrashing is an important operation recommended to reduce the problem several insect pests like scales, mealy bug, white fly, etc. In some varieties bud sprouting occurs as a result of accumulation of water in side the sheath bud sprouting is not desirable as it would reduce main stalk growth and affect sugar accumulation. By detrashing, the bud sprouting problem could be overcome. Detrashing also facilitates easy entry into the field, particularly to guide irrigation water, application of pesticides, etc. Further, a clean field discourages reptiles in the field. And finally, a detrashed crop is easier to harvest. Thus economy in harvest will result, besides clean canes for milling.

The detrashed trash can be mulched by keeping them in the furrows as a moisture conservation technique. Or, it can be removed and used for composting. However, if there is any incidence of pests, it is advisable to burn the trash after taking it away from the field.

**Wrapping & propping**

Wrapping is the process which consists in bending down one or more lower leaves of the cane and wrapping it around and close to the cane stem. At the same time the canes in the clump, after
they are wrapped, are tied together. The wrapping begins when the cane is 5 months old and is repeated four times at monthly intervals. During the later wrapping two or more cane clumps are tied together for additional strength and to prevent their lodging. Wrapping is an excessive operation and requires considerable labour which has to be done by hand. An acre may require 20 men for each of 1st and 2nd wrapping and 15 men for each third and fourth wrappings.

Usually the tying together of the canes in a clump and of two or more clumps is sufficient to prevent serious lodging, but in certain trates lodging is completely prevented by the use of strong bamboo props. For this purpose the tops the two adjacent rows are brought near each other and tied to a long lather rope running the full length of the rows and fastened at either end by strong bamboo supports.

Inter-Cropping in Autumn Sugarcane Autumn Sugarcane + Potato

Intercropping of sugarcane and potato has been very remunerative. For raising sugarcane and potato together, it is necessary to plant cane at 90 centimetre distance in the first week of October with 75 kg nitrogen per hectare in furrows at planting. The levelling is done and one row of potato in the centre of the sugarcane rows is planted. The distance between potato plants within rows is kept 15cm. An extra dose of 60 kg N per hectare is applied to potato crop at planting. Sugarcane crop is irrigated according to the needs of potato crop. The potato crop will be ready for harvesting in January. Potato yield from mixed cropping ranges from 120-130 quintals per hectare which is about 50 per cent of the yield obtained from pure crop of potato while yield of cane is not affected adversely as compared to pure crop of sugarcane. A dose of 75 kg nitrogen per hectare is applied to sugarcane crop after harvesting the potato.

Sugarcane+ Wheat

Wheat can also be sown in sugarcane. Sugarcane is planted in October. Let the sugarcane crop germinate. It will take about 40 days for complete germination. Irrigate the crop in the second week of November and do hoeing on field condition. Before hoeing, mix urea at the rate of 65 kg (30kg N per hectare) per hectare between two rows of sugarcane. Two lines of wheat (Sonalika or U.P.-115) should be sown at a distance of 20 centimetre (between them). The seed rate of wheat would be about 65-70 kg per hectare. The distance between sugarcane and wheat row will be 35 centimeter. A second dose of nitrogen at the rate of 30 kg per hectare should be applied to wheat 20-22 days after sowing followed by irrigations as generally done in case of wheat second and subsequent irrigations could be given as and when needed by wheat crop. Wheat will be ready for harvesting in April. After harvest of wheat second dose of nitrogen at the rate of 75 kg per hectare should be applied to sugarcane. This system of intercropping produces 35-40 quintals of wheat and is more remunerative than wheat and sugarcane sown separately in rotation.

Sugarcane+Lahi (toria)

Sugarcane is planted in the first week of October. One line of lahi Type-9 or any other short duration variety of toria is sown in the centre of two rows of cane just after planting sugarcane. A dose of 30 kg nitrogen per hectare is applied to lahi 20-25 days after sowing and field irrigated. Plant protection measures are taken as per need. Lahi (toria) crop will be ready for harvesting in
January. After harvesting lahi crop, fertilize the sugarcane crop at the rate of 75 kg nitrogen per hectare and irrigate the crop 24 hours after fertilizer application. In this system, the yield of lahi would be 10-12 quintals per hectare and will have hardly any adverse effect on cane yield. This system is more paying as compared to lahi and sugarcane grown in succession.

**Sugarcane+ Lentil**

Plant sugarcane in the first week of October. Two lines of lentil may be sown 30 centimeter apart in the centre of two sugarcane rows. The distance between cane and lentil rows will also be 30 centimeter. Since lentil is a legume crop, there is no need for applying nitrogenous fertilizer for this crop. The lentil crop will be ready for harvest by the end of March or first week of April. Second dose of fertilizer in sugarcane is applied after harvesting lentil. This system will produce 15-16 quintals of lentil per hectare with no adverse effect on cane yield.

**Inter-cropping in spring sugarcane**

In this system, sugarcane is planted in rows 90 centimeter apart, in the month of February. A dose of 75 kg nitrogen per hectare is applied at planting. In case phosphorus and potassium are also required, these are also applied at planting time. Two rows of short duration moong (Pusa Baisakhi or Type-44), 30 centimeter apart in the centre of sugarcane rows leaving 30 centimeter distance between cane and moong rows are sown. A seed rate of 7-8 kg per hectare is sufficient for sowing moong in sugarcane. No fertilizer is required for moong crop. Irrigate the crop as per need of sugarcane. One picking of moong is necessary and finally the crop may be harvested in the month of May. After harvest of moong, a second dose of nitrogen (75 kg per hectare) should be given to sugarcane crop. In this system moong produces about 5-7 quintals of grain per hectare with no loss of cane yield.

**Sugarcane + Urd**

In this system, sugarcane is planted and cared for as in the case of sugarcane+moong intercropping. Instead of moong, short duration variety of urd like Type-9 is sown in lines between sugarcane rows. In this case three rows of urd, 20 centimeter apart are sown. The distance between sugarcane and urd rows would be 25 centimeter. Urd crop will be ready for harvest in the end of May. There is no need of picking the pods, the entire crop may be harvested at one time. The yield of urd would be 6-7 quintals per hectare with no loss of cane yield.

Similarly other crops like cowpea can also be grown in spring sugarcane.

**RATTOON MANAGEMENT**

Ratooning or stubble cropping is an integral part of sugarcane cultivation practiced in almost all the sugarcane growing countries of the world. The word ratoon seems to have originated either from Latin words retonus-cut down or mown; the spanish reteno-tomean fresh root or sprout; or the French-rejeton, meaning sucker or shoot, scion, descendent, offspring or sprout. Basically ratoon cropping implies (a) more than one harvest from a single planting; (b) regrowth from basal buds on the stem or crown which is situated at the surface of the ground; and (c) harvesting the aerial portion of the plant. In simple terms ratooning is raising a fresh crop of sugarcane from
the preceding plant crop stubble regrowth without fresh planting of setts. This is first ratoon. When a ratoon is raised from the stubble regrowth of the first ratoon, it is second ratoon and so on. The sugar factory cane staff many a time refer first ratoon as R-one, the second ratoon as R-two and so on. The first crop raised by planting setts is referred to as plant crop.

**Extent of ratooning**

In India, almost 50 percent of the cane area is always under ratoons. The percentage of ratoon area is relatively greater in the sub tropics than in the tropics. In Mauritius, 85 percent of the cane milled each year is derived from ratoons; and in Queensland, Australia, it is around 70 percent.

In India, raising one to two ratoons is most common, though there are instances of many ratoons or multiratoons in certain pockets of Tamil Nadu, Andhra Pradesh and Karnataka. A national award winning farmer by name Prafulla Chandra of Shimoga district of Karnataka has raised more than 25 ratoons of variety Co 419. The 25th ratoon was seen by this author. In commercial planting, as already stated, one or two ratoons are most common in India, Many sugarcane growing countries raise several ratoons. In Muritius 5-8 ratoons are raised. So also in Cuba and many other countries" Why not we take many ratoons? is a questions often heard in India.

**Ratoon yields**

Cane yield decline in successive ratoons is a common prenomenon in most of the sugarcane growing countries of the world. A 10 percent yield decline is considered quite normal. In several countries ratoon yields are either same as plant crops or sometimes higher than the plant crops if managed properly. Average yield gap between plant and the ratoon crop in the country is 20-25 percent. The gap is higher in the subtropical states. Because of the lower yields, even though ratoons occupy about 50 percent of the cane area, their contribution to the total cane production is only around 30 percent. Low ratoon yield is one the reasons for the low average yield of the country.

The major causes for yield decline in ratoons are

Free- or gift crop attitude of the farmers towards ratoons and therefore poor ratoon crop management. Reduced initial population because of reduced stubble sprouting Decline in the soil nutrient status. Soil compaction and poor soil physical status. More incidence of pests and diseases. Adverse weather conditions at the time of plant crop harvest, mostly in the sub tropics.

Because of the free crop attitude, most farmers neglect ratoons in all aspects of crop management, particularly all monetary inputs are either not given or given in less quantities. They are content with whatever the cane yield they get. They consider it as a bonus. But when we consider productivity in terms of output per unit area per unit time, poor ratooons means a colossal waste of four land resources.

**Poor sprouting**

Stubble deterioration is a common cause for inadequate sprouting. In the subtropics, winter harvested crops do not give good ratoons because of lack of sprouting due to low temperatures.
Late harvested canes also cause stubble failure due to high temperature. Under wet soil conditions, sprouting fails. Low sprouting may also be due to certain pests and diseases.

**Decline in soil nutrient status**

The plant crop stands in the field for a minimum of one year. During the period it experiences at least one monsoon rainy season. Also, large quantities of irrigation water would have passed through its root zone. Therefore, by the time the plant crop is harvested, the soil gets depleted of nutrients due to crop uptake and losses of applied and native nutrients through leaching and other means.

**Soil compaction**

Soil compaction occurs due to irrigation, movement of animals and humans as well as machinery. Of course, compaction due to machines is practically nil or insignificant in our country as almost all operations are manually carried out. Soil compaction (increase in bulk density) leads to poor soil aeration and reduced water holding capacity. It affects root growth severely. This is why ratoon root system is always less extensive than the plant crop, particularly under inadequate crop management.

**Pests and diseases**

Ratoons in general are more prone to pest and disease attack as they are generally weak and less vigorous in most situations. Three diseases, viz, the RSD, GSD and smut are more severe in ratoons than the plant crops. Several insect pests are also more in ratoons.

**Advantages of ratoons**

Even though ratoons are poor in yield, they are essential for overall economy of sugarcane cultivation. They offer several advantages and hence managing they scientifically could help derive full benefits of the ratoons. The specific advantages are as follows:

Ratoons are economically by about 25-30 percent in the operational cost because of saving in the cost of setts and initial preparatory cultivation.

Ratoons save time as they establish early and in general mature early. Therefore they can be harvested early. Farmers will get time to other crops or enterprises in the farm.

Ratoons stabilise the cane area of a factory. Each year, the factory will have assure cane area to the extent of ratooning, which is around 40-50 percent in most areas; therefore every year the effort for planting is limited to the fifty percent of the total cane area required.

Ratoons often give better quality cane. Therefore they may help improve sugar recovery at the start of the crushing season.

From well maintained productive ratoons cost of production per tonne of cane will be less than the plant crop. Besides, a poor farmer who cannot spend on inputs for raising good ratoons, still can have a bonus crop to sustain himself without much investment. This is one of the reasons
why even poor ratios are welcome to most farmers; even though from overall point of view poor ratoons are not desirable.

**Ratoon management practices**

Variety with good ratooning potential and good plant crop are the essential prerequisites for good ratoons. This has to be combined with basic ratooning operations, viz, stubble shaving, off-barring and gap filling, and proper crop management practices like early manuring, control of chlorosis and management of pests and diseases to get higher ratoon yields.

**Variety**

Sugarcane varieties differ in their ratooning ability. Success of a variety depends on its ability to give better ratoons since varietals adoption by most farmers depends on this factor, besides plant crop yield. Most of the present day sugarcane varieties have good ratooning ability. Generally early maturing varieties are poor ratooners than middle or late varieties. Thin or medium thin varieties give better ratoons than thick varieties. Varieties giving high yields as plant crops give better ratoon yields in most cases. However, this is not always true. Some varieties give higher ratoon yields than plant crops. Co 6304 variety grown widely in Tamil Nadu is a good ratooner while another popular variety CoC 671 is a poor ratooner. However, CoC 671 has been found to give good ratoon yields in some parts of Northern Karnataka, Maharashtra and Gujarat. Thus ratooning ability of variety differs from region to region also. Co 740 the popular variety of Maharashtra, Co 1148, the most popular variety of the subtropics are excellent ratooners, Co7314, Co 8013, Co8018, Co 8021, Co 8121, Co 8122, Co 81222, Co 8134, Co 8145, Co 8208, Co8362, Co 86010 and Co 86011 etc. released from the Sugarcane Breeding Institute have been found to posses excellent ratooning potential.

**Plant crop and its harvest**

Good ratoons result from healthy plant crops. The plant crop should be raised under optimum input levels, particularly nutrients and irrigation. Poorly grown plant crops due to reasons like moisture stress, lack of sufficient nutrients or due to certain pests, cannot give satisfactory ratoons. Plant population in the ratoons can be maintained if there were adequate stubbles in the field. Thus for any reason, if the plant crop has too low cane population at harvest, it is desirable to avoid ratooning. Pest and disease infected plant crops also should not be ratooned, particularly if there is the danger of such disease or pest being carried forward through stubbles to the ratoon crops.

**Time of harvest**

Harvesting the plant crop when weather conditions are conducive for stubble sprouting is important. Low as well as high temperatures are harmful. Optimum temperature for sprouting ranges between 25 and 30°C. When the crop is harvested in winter, as usually happens in the northern part of our country, bud sprouting does not occur because of low temperature. When cane harvesting is done in the hot summer months, again, sprouting is affected due to drying up of the buds and stubbles. Sprouted buds also die. Thus plant population becomes inadequate. Incidence of certain pests like shoot borer becomes heavy. Both these extremes of weather
conditions require special management to obtain better ratoon crops. As extremes of weather conditions are not much in the southern tropical states, harvesting of cane any time excepting very hot summer months (April-June) would result in satisfactory ratoons. However, December to February harvested crops would give best ratoons in the tropical states. In general, early harvested crops always give better ratoons. Autumn planted (early planted during October-November) sugarcane in the tropical states when harvested early in the crushing season would give better ratoons since the weather conditions are quite favourable for better sprouting and early growth. Besides, the ratoons would have grown up sufficiently by the time hot summer when moisture stress is felt sets in and thus would be able to overcome the ill-effects of moisture stress. Autumn planting also helps in overcoming certain insect pests like the early shoot borers both in the plant and ratoon crops.

**Duration of harvest**

For ensuring uniformity of the sprouts and further to promote uniform growth of the ratoon crop, it is essential that the duration of harvesting of a field is not extended beyond a week. Jaggery farmers and some registered growers harvest in piece meal and then ratoon which leads to heterogenous ratoon population. This should be avoided as far as possible.

**Method of harvest**

 Harvesting the plant crop close to the ground levels very important not only to add a few more tonnes to the yield, but also to get a better ratoon crop. This is particularly important in places where stubbles shaving operation cannot be carried out due to either labor scarcity or unfavourable soil conditions like either excess moisture or lack of it.

**Trash disposal**

Trash disposal is an important task soon after the harvest of the plant crop before ay other ratooning operations could be taken up. Green tops are mostly removed for feeding cattle and some are used for tying the cane bundle. Still as much as 8-10 t of trash per hectare is left in the field which must be disposed off.

Most of the farmers burn the trash. Scientifically, trash must be conserved and returned to the soil since it contributes towards organic matter and nutrient status of the soil. Average nutrient content in the sugarcane trash has been estimated to be around 0.35% N, 0.13% P2O5 and 0.6% K2O. When incorporated with soil, trash helps in improving the soil physical condition.

**Conserving trash**

For carrying out ratooning operations, the field has to be cleaned. Trash can be removed to the bunds and then applied to the fields after the initial ratooning operations are completed. Trash mulching is particularly useful in extremes of weather conditions.

Mulching also suppresses weed growth besides conserving moisture. Wherever water is scarce, number of irrigations can be reduced by trash mulching and thus water can be saved. Experiments have shown that irrigation interval can be extended to 15-20 days by trash mulching.
compared to the usual 8-10 days interval in medium textured soils. Mulched trash can be incorporated later into the soil while earthing up after manuring.

Trenches can be dug in the field at regular intervals. Alternate furrows can be used for this purpose. Trash may be put in these trenches. Composting of trash is another way of conserving it.

**In situ trash composting**

In the case of ratoons, the trash can be aligned in situ in the furrows with the help of rakes and compressed either by stamping or any other means. Over this, soil removed while stubble shaving and off baring operations is put and microbial culture is added to facilitate decomposition and then irrigation water is applied. This method of in situ trash composting was developed in Maharashtra. The method was experimented at Coimbatore and there was improvement in ratoon yield. The furrows formed by the usual row spacing of 90 cm (or less), do not accommodate all the trash produced. Therefore only a part of the trash may be used for in situ composting. In Maharashtra the technique was feasible under wide row spacing of 120 cm.

Distinct advantage of trash mulching over trash burning was demonstrated at Sugarcane Research Station, Anakapalle (Andhra Pradesh). About 5 to 10 tonne or more cane yield was obtained in the trash mulched plots.

Trash burning is essential under the following conditions: Plant crop infected by pests and diseases like scales, mealy bugs etc. In areas prone to heavy termite attack. Areas prone to rodent attack. Excess moisture affecting sprouting In soils where sub soil drainage is poor, and In areas where fire hazard exists.

**Stubble shaving**

After harvest of the standing crop and cleaning the field, an indispensable operation that has to be carried out is stubble shaving. The stubbles protruding out of the field are cut below ground level using sharp spade. This is done to facilitate healthy underground buds to sprout and establish a deeper root system in the ratoon crop.

Generally, buds above ground get damaged during harvesting and subsequent cleaning of the field. Besides, buds would be dry and would have been infected with disease causing organisms. Thus, if the above ground buds are allowed to germinate, sprouting would be inadequate to establish a good crop stand. Besides, the fresh shoot-roots also would not be able to enter the hard soil thus affecting absorption of nutrients and water. This is why many a time, drying up of shoots occur inspite of having fairly adequate.

Successive ratoons originate from a higher point. Thus, the root system in the successive ratoons is progressively raised which is undesirable. By deep stubble shaving, the lower buds are forced to germinate and thus have root system at lower level. Deep root system thus obtained would help utilise nutrients and moisture from the lower soil layers. Deep root system is also necessary to give good anchorage to the ratoon crop.
For stubble shaving, sharp implement, preferably a spade should be used so that stubbles are cut with minimum damage to the buds and stubbles are not uprooted. If the soil has become hard and dry and it is difficult to carry out these operations, the field should be irrigated lightly and stubble shaving may be done when field conditions are ideal for working with implements.

In some varieties, as in the case of CoC 671, the root system is shallow and there is problem of uprooting of stubbles. In such cases instead of a spade, it is better to use a sharp knife to cut stubbles to the ground level. Tractor drawn stubble shaver

At the Indian Institute of Sugarcane Research, Lucknow, a tractor draw stubble shave (Fig. 13.3) has been developed and satisfactorily tested for shaving the stumps close to the ground level. Drive for the cutter unit is taken from the P.T.O of the tractor and is transmitted through universal joint and bevel gear, arrangements. The implement gives an out-turn of 2 ha per day and brings down the cost of stubble shaving by 50 percent.

**Off barring 'or' shoulder breaking' and loosening the inter-spaces**

Soil compaction is one of the major causes for the poor growth of ratoon cane. Compaction occurs due to long duration of the crop during which as many as 30 irrigations are given in the tropical belt. These irrigations and also movement of labourers for various field operations lead to soil compaction. Because of this problem movement of air and moisture within soil is affected. This in turn affects development of root system and finally the absorption of nutrients and water. Hence, besides obtaining a better crop stand, it is important to improve the soil physical conditions for the success of the ratoons. "Off barring is an operation wherein the ridges are broken or cut on either side. This operation is also called as "shoulder breaking." To loosen the soil, the inter spaces between the rows are dug. Shoulder breaking can also be carried out by bullock drawn implements like wooden plough, or small ridger like implement. Sub soilers may also be used for breaking the compacted soil. But for passing a sub-solier, a heavy duty tractor is required. These operations reduce soil compaction and facilitate quicker development of fresh root system and help in vigorous growth of the young crops.

**Gap filling**

One serious problem in ratoons is the occurrence of gaps, which when exceed 20 percent cause considerable yield losses. Gaps occur because of poor sprouting owing to the several reasons: cold or hot weather conditions, poor plant crops, attack of fungal disease, insect pests etc. A spot in a row can be considered as a gap if for distance of about 60 cm there is not cane clump. Otherwise there is no need for gap filling.

For gap filling it is better to use per-germinated single bud sett. For this purpose, a month prior to harvest of the plant crop,, nursery may be planted with single bud setts and seedlings of required age can be obtained and planted in the gap. Material for gap filling can also be obtained from spots where excess sprouting is seen. Clumps can be uprooted and cut into quarters an planted in the gaps. Gap filled seedlings or quartered clumps require more attention. Pot watering may have to be ensured for better establishment. In delta region, quartered clump transplanting in the gaps has been found quite effective in the wetland soils.
Polybag seedlings for gap filling

Another recent technique is to raise polybag seedlings and use them for gap filling. For this purpose, single bud setts are planted in polythene bags (measuring 12 x 8 cm having a few punch holes for aeration filled with soil, sand and FYM in the ratio 1:1:1. A month old seedlings can be used for gap tilling. While gap filling, the leaves of the seedlings should be clipped off. Then after removing the polythene bag, the seedlings along with the soil mass should be placed in a small pit made in the gap. A small quantity of super phosphate placed in the pit helps better growth of the seedling. In this method 100% of the seedlings gap filled will survive.

Fertilizer application

As sugarcane removes huge quantities of nutrients from the soil, when a plant crop is harvested, the soil would have become depleted of nutrients. Besides due to impoverished soil physical condition and relatively poor root system development, absorption of nutrients by the ratoon cane is affected. Another problem in the ratoons is the temporary "immobilization" of the available nutrients, particularly nitrogen due to micro-organisms acting upon decaying old root system and other crop residues. These factors necessitate suitable fertilizer management techniques for ratoons.

Early growth in ratoons is relatively quicker. Hence there is need to apply fertilizers early. Several experiments have proved the essentiality of early manuring to ratoons. Entire dose of phosphorus, one-third each of nitrogen and potassium may be applied soon after stubble shaving and off-barring on either side of the ridge and covered with soil. This has to be followed by top dressing of remaining nitrogen and potassium around 30 and 60 days after, in equal splits.

In coastal Andhra Pradesh doubling the nitrogen dosage has been suggested for ratoons. From several studies on nitrogen application to ratoons, it has been established that the dosage can be 25 percent more than the plant crop. In several states however, same dose as that of plant crop is used. But, it is the timing of nitrogen application that is most important. Initial application of nitrogen is important to facilitate quicker decomposition of the old root system and other crop residues.

Incorporation of leguminous crop residues in ratoon cane improves nitrogen use efficiency. Intercrops suitable are sunhemp, French beans and green gram. In one experiment at Mandya (Southern Karnataka), it was proved that incorporation of legume residue of sunnhemp or French bean or green gram along with 200 kg N per hectare was equivalent to 250 kg N per hectare.

Ratoons have also been found to respond to foliar application of urea.

Water management

Ratoons are more susceptible to moisture stress due to their shallow root system. Therefore irrigations are required at frequent intervals, particularly in the early stage. Under moisture stress conditions trash mulching is useful.

Drainage
In some of the canal irrigated tracts, very poor ratoons are seen mainly because of excess irrigation coupled with poor drainage. This situation has also led to varietal degeneration. Avoiding excess irrigation and improving drainage are essential steps to improve the ratoon productivity in these areas.
JUTE

Corchorus capsularis and Corchorus olitorius

1 Economic importance

Jute is an important fiber crop next to cotton. It is a leading crop among all stem fiber crops. As a cash crop it occupies a highly important position in the agricultural economy of Bangladesh and India. In Nepal it was second cash crop after sugarcane before 20 years ago but its cultivation has been decreasing now a day. Its estimated area and production is 10540 ha and 14424 tons respectively with the average productivity of 1369 ton per hectare. The present production only fulfill around the 15% of total demand of the raw jute in the country and the reaming meet by the importing form the B’desh and India.

Raw jute and jute manufactures together form one of the main source of earning foreign exchange. Jute fibers are very strong, hygroscopic and resistant to rot. That is why they are regarded as a valuable material for making sacks of sugar and other food products. The jute is used for manufacturing hessians, sacking and carpet backing. It is used for storing and transporting grains pulses, spices, cement, fertilizer, minerals, cotton and wool all over the world. Mats, tarpaulins, rope and twines, decorative cloth are also prepared by using jute fiber. They can be used for making ropes, carpets, rugs etc. The jute stalks left after extraction of fibers are used as fuel and also for making coarse paper. Newer uses are in blended yarns, soft luggage, furniture molded products and automobile panels.

Leaves of both species (Corchorus capsularis and Corchorus olitorius) are use for culinary purpose but the species capsularis is bitter due to presence of bitter glucoside corchorin. It is called Tita Pat or bitter jute while C olitorious is known as Mitha Pat or sweet jute. The leaves are an important source of beta-carotene; a precursor of vitamin A. Leaves contains 18-22% protein and 5-7 mg/100 g of niacin.

The economical effect of jute production is indirectly related with that of rice. It is due to the fact that they are both grown on the same type of soil. When rice prices are high, less jute is planted and when jute prices are high, less rice is planted. The recent development of high yielding rice and wheat varieties has caused a further decline in jute production.

Jute is a typical plant of humid tropics and subtropics. The largest crop areas (over 95%) under jute are concentrated in Asia (1.804 million hectares out of 1.883 million hectares of world). Jute is mainly grown in India, and Bangladesh. Area occupied by jute equals to 0.94 million hectares.
in India and 0.56 million hectares is Bangladesh. It is 0.145 million hectares in China and in Nepal about 10.5 thousand hectares are occupied by jute.

2. Origin

The primary center of origin of *Corchous olitorius* is Africa. *C. capsularis* is considered to have its origin in Indo-Burma region, as wild types of this species have been found in this region.

3. Ecological requirement

Temperature

Jute is a typical plant of humid tropics and sub-tropics. It is highly demanding in temperature and grows well in the regions with daily mean temperature during vegetation never below 16-18°C. Temperature of 25 to 35°C are found to be best for growth and formation of reproductive organs as well as for blossoming of jute plants.

Moisture

The jute crop is highly demanding in moisture. Therefore, it is raised in the regions of humid tropics and subtropics with 1300 to 1800 millimeters of annual rainfall. The minimum rainfall required for jute cultivation is 1000 mm per year. The crop can be cultivated in the dry tropic and subtropics only under irrigation. The jute plants are sensitive to high moisture levels during intensive growth and maturation.

Light

*C. Capsularis* and *C. olitoritus* are typical short day plant. The transition from the vegetative to reproductive phase in jute is influenced by the available day light period. Long photoperiods prolong the vegetative period and the plants flower with the approach of short day of late August and September, irrespective of the sowing period. For the visible flower bud to be initiated the critical light period seems to be about 12 and 12.5 hours, above which the flowering is retarded. *C. olitorius* is more responsive to short light period than *C. capsularis*. 
Edaphic requirement

Jute can be cultivated on all kinds of soil from clay to sandy loam but, loamy alluvial soils are most favourable for it. Usually sandy and heavy clay soils are not suitable for jute cultivation. Jute can tolerate a pH ranging from 5.0 to 8.6, but thrives best in the normal soil reaction i.e. pH 6 to 7.5. Below or above this pH the crop yield suffers.

4. Varieties

The principal requirements of the jute varieties are as follows: high yield, good fibre quality and resistance to disease and pests. The popular varieties of the species *C. capsularis* are Itahari 1, JRC-212 (Sabuj sona) and JRC 321 (Sonali) while Itahari 2, JRO-632 (Baisakhi tossa) and JRO-7835 (Basudev) were the popular varieties of *olitorius*.

5. Crop rotation

As a rule jute raised in tropics and subtropics for its fibre grows in the field for about 4 to 5 months. This permits to grow a second crop and sometimes a third crop on the same land, with ample rainfall or irrigation facilities. Therefore, after jute the field is sown with other crops such as rice, wheat, potato, legumes, vegetables and mustard. When cultivated on low land subjected to flooding the round pod Jute (*C. capsularis*) grown in the humid season is followed by rice and then by legumes for example chickpea (India, China). Uplands are sown with this crop (generally *C. olitorius* or *C. capsularis*) at the beginning of the rainy season and then in the dry season they are sown with mustard, potato or cereal grains such as wheat, barley and oat.

Thus in the areas with irrigation facilities the following intensive crop rotations may be followed:

1. Jute- Paddy- Wheat
2. Jute- Paddy- Potato
3. Jute- Paddy- Mustard
4. Jute- Paddy- Gram

In the rainfed areas the following crop rotations may be followed with advantage:

1. Jute- Paddy
2. Jute- Wheat
3. Jute - Mustard

6. Field preparation

The jute seeds are small in size and are sown (embebed) at a small depth. Due to this reason it requires a clean, clod free field with fine tilth for its successful establishment. To fulfill this requirement of jute of the field is ploughed and cross harrowed five to six times followed by planking until a seed-bed with good tilth is obtained. In Nepal the field is ploughed 3-4 times with local plough and then leveled for sowing.

7. Sowing

The sowing time in the regions cultivating jute depends on the rainfall season and the resistance of the crop to over moistening. It is desirable that by the beginning of heavy rains the jute plants are well rooted and have reached 80-100 cm in height. That is why in India and other countries (Pakistan) jute is sown in valleys 45 to 60 days prior to the onset of heavy rains. Moreover, as most jute varieties are sensitive to photoperiod, the earlier planting gives higher yield.

The optimum time (period) of sowing for *C. capsularis* is March-April and for *C. olitorius* April-May. April sowing gives the best result in both types of jute.

The sowing of jute in line is done with seed drill. The row to row distance of sowing for *C. olitorius* and *C. capsularis* is 20 and 30 cm, respectively. The distance between the plants within the row ranges from 5 to 7 cm. for both species. The seed should be shown not deeper than 2-3 cm.

For broadcasting method of sowing, the seeds are first mixed with loose soil and sowing is carried out in cross-wise direction in order to ensure even distribution of seeds and uniform stand. After sowing, the field is planked in-order to cover the seeds and bring them in close contact with moist soil which promotes germination.

For line sowing the seed rate is 6 to 8 kg/ha for *C. capsularis* (7.5 kg in Nepal) and 4 to 5 kg/ha for *C. olitorius*. (4.5, kg in Nepal). For broadcast method of sowing the seed rate is increased by 25 to 40 per cent.
8. Nutrient management

Of the plant nutrients, nitrogen is the most important and has been found to give the best response in increasing the vegetative growth as well as fibre yield of jute. Therefore, most references to jute fertilization are concerned with nitrogen. Phosphorus helps to prevent lodging, improves fibre quality and increases efficiency of nitrogen utilization. Excess of nitrogen sometimes lowers the fibre quality, but presence of phosphorus in proper ratio assists to depress its content in fibre and maintain good quality. It increases length of the fibres and decrease their width, assists to improve spinning quality.

Generally in addition to organic manure the dose of nitrogen application ranges from 20 to 60 kg/ha for *C. olitorius* and 40 to 80 kg/ha for *C. capsularis*. Depending on soil requirement 20 to 40 kg of P₂O₅ and 20 to 60 kg of K₂O per hectare are applied. In Nepal the recommended doses of fertilizers for *C. olitorius* and *C. capsularis* are 30:15:30 and 40:20:40 kg N, P₂O₅ and K₂O per hectare, respectively.

The total dose of nitrogen is divided into two equal parts and applied as basal and top or side dressings. Top dressing or side dressing with nitrogen is carried out in one or two installments at four to six weeks of crop age. Nitrogen is generally top-dressed after weeding and thinning. As jute is a monsoon crop, often nitrogenous fertilizers are leached out during the heavy rains. So, it is desirable to apply ammonium sulphate as a source of nitrogen during top-dressing.

Phosphatic and potassic fertilizers are applied before sowing or at sowing. Compost or farm-yard manure is applied at the rate of 5 to 8 tons per hectare and incorporated into the soil at least one month before sowing.

9. Plant management practices

Plant management involves various techniques contributing to good growth of the jute plants. After sprouting (emergence of shoots) *gap filling* and *hoeing* operation are conducted. As jute plants grow slowly for the first 40-45 days they require frequent and timely hoeing during that period. Generally the number of hoeing which ranges from 3 to 6 depends on the development of weeds. The weed infestation in jute is maximum up to 6 weeks crop age. The first weeding is done after 2-3 weeks of sowing.
The critical period of *weed control* is 20 to 35 days after sowing. The loss of yield due to weeds ranges from 30 to 70% (50-55% is common in India). Generally weeding time in jute fields coincides with the transplantation of rice. Therefore, for weed control in jute field, herbicide like Dalapon can be used. Dalapon at the rate of 7.5 kg/ha has been found to be most effective for the control of annual grasses.

**Thinning** is carried out in two steps: first thinning is done along with the first weeding, leaving a distance of 3-4 cm between the plants. The second thinning is carried out at five to six weeks crop age maintaining 5-7 cm distance between the plants. During thinning all diseased, weak and dead plants are removed.

Jute is generally grown under rainfed condition. The crop receives great setback when there are no timely rains or there are excessive rains causing water logging condition. Therefore, during rainy season it is necessary to *drain off* excess water. High yields of jute are obtained under the condition of *irrigation*. One pre-sowing irrigation and three post sowing irrigations before the onset of monsoon have been found to be optimum for higher yield of early sown jute. In the dry tropics and subtropics the number of irrigation may range from 5 to 6.

10. **Harvesting**

Jute can be harvested at any time from 90 days of sowing to the maturation of seeds. However, the early harvest provides low yield with immature fibres. Delay in harvesting, when the seeds are matured, results in high yield of coarse and poor quality fibres which require a prolong period of retting (the difficulty of stripping also increases). Therefore, the ideal stage of harvest in when the plants are either in flowering or in under capsule stage (small pod stage). In most cases jute is harvested at this stage, when both quality yields are found to be good. Under flooded condition it is harvested relatively early for timely transplanting of rice seedling.

The plants are cut close to the soil surface with sickle. If the stems are to be water retted, it is almost universal practice to leave the plants in the field for two to four days. In the field the stems are left in untied bundles with the basal portion of one bundle overlapping the top portion of another bundle. This method facilitates heating and causes the leaves to defoliate readily. After this the stems are tied into bundles of 15-20 cm diameter. At the time of bundling the plants are shaken so that most of the leaves shed on the ground. It is indispensable because of the fact that the leaves contain 35 to 65% of NPK and Ca removed from the soil. So, it helps to reduce loss of nutrients from the soil.
During the defoliation period (2-4 days in the field) the tissues of the stem shrink and cells rupture. This facilitates the entry of microorganisms into the stem when steeped in water and at the same time assists to increase the rate and uniformity of retting.

11. Steeping

After two to four days of harvesting, the bundles of jute are steeped in water. To produce uniform and top quality fibre the basal part of the bundles should be kept in water for three to four days before the entire bundle is submerged. The lower part of the stem, which is thicker, takes longer time for retting as the lignified and suberized tissues resist disintegration. When upper and middle portions are retted the basal portion remains underretted due to which the fibre bundles come out with portions of cortex and periderm during the process of extraction. This portion is termed as "cutting" in the fibre. The presence of cutting in fibre lowers its grade.

After keeping the basal part of the stems in water for 3 to 4 days the bundles should be left flat side by side in water and tied to form a sort of platform called "Jak" which is then submerged in water. To keep the bundles under water farmers often use clods of earth, or banana plants or logs of mango wood.

This should be avoided because the earth by itself imparts dirty color to the fibre and tannin of banana and mango coming in contact with iron of retting water discolors the finished fibre. Therefore, in general, the Jak is covered with aquatic weeds and then submerged into water with the help of cement concrete slab or stones. [The Jak can also be submerged into water using bamboo frame. For this wooden pillars with 3-4 holes are buried at a distance 1.5 m in two rows. The bamboos are fixed in the wooden piller by passing them through holes so that 2-3 tiers of bamboos are formed. The stems are placed between the bamboos and left for retting.]

12. Retting

Retting is a process by which the fibres in the bark get loosened and separated from the woody stalk due to removal of pectin, gums and other mucilaginous substances. This is usually affected by the combined action of water and various aerobic and anaerobic microorganisms. Two types of bacteria and fungus are observed which decompose both pectin and hemicellulose.

*Asparagillus niger*—Fungus.
*Bacillus subtilis*- aerobic bacterium

*Bacillus polymyxa*- facultative bacterium

The microorganisms first invade the top then the middle and finally the basal region of the stem. The microorganisms break down the organic material through the action of enzymes which they secrete.

Disintegration of tissues starts from the cambium and extends to the ray cells, phloem and cortex. As a result of it the fibres are liberated from the wood. Thus, retting is considered to be completed when all the soft tissues are dissolved and the fibres bundles get separated.

1. The retting process is completed in 8 to 30 days.
2. The time required for retting mainly depends upon the maturity of the plants and temperature.
3. Early harvested plants where the tissues are tender take shorter time for retting than the more matured plants.
4. Retting is best done at 32 to 34°C. In such condition the process may take 8 to 10 days (at the end of July)

If the fibre slips out easily from the wood on pressure from the thumb and finger, retting is considered to be completed. When the plants are approaching the right stage for extraction i.e. 10-15 days after submerging, the Jak under water should be examined at least once a day and fibre must be extracted at the right stage. Over retting i.e. delay in extraction results in "dazed" weak fibre.

**Ribbon retting**: The main principle of this method of retting is to separate barks from the stems before steeping in water. The separated barks are then tied into bundles and submerged into water for retting. In order to accelerate the retting process 1 kg of urea is added for each 4 quintal of green barks. Checking about the completeness of retting should be started after 7-8 days of submerging bundles of barks in to water.

13. **Extraction**
Fibre is extracted from the stalks of retted jute by hand. The extraction of the fibre should be carried out gently by keeping the stalks in water. Beating stalks of fibre with wood sticks or against the stone is avoided as it spoils the fibre quality. Usually 8-10 retted stems are held in hand and about 15-20 cm of their bottom portion is broken. After that fibres are carefully separated from the broken stalks. Further to separate fibres from the sticks, the separated fibres are held in hand and the remaining portions of stems are jerked forwards and backwards in water. The extracted fibres are dried in the mild sun over a bamboo frame for two or three days.

14. Jute fibre

Jute belongs to bast fibre plants where fibre is obtained (produced) from phloem by a process of retting. In general the fibre cells of jute are much shorter than those of cotton, hemp and flax.

<table>
<thead>
<tr>
<th>Fibre</th>
<th>Length, mm</th>
<th>Width, micron</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flax</td>
<td>16-30</td>
<td>7-20</td>
</tr>
<tr>
<td>Hemp</td>
<td>15-25</td>
<td>14-30</td>
</tr>
<tr>
<td>Jute</td>
<td>2-6</td>
<td>10-20</td>
</tr>
</tbody>
</table>

Individual fibre cells vary from 2 to 6 mm in length. Fibre cells between 4 to 6 mm in length are common in the longer internodes. The longest fibre cells occur in the stems of the longest internodes.

For spinning by ordinary methods, the ultimate fibres should be fairly long and the length, breadth ratio should be of the order of 1,000 to 2,000. In jute this ratio is, on the average, only about 98 to 119, hence its use is limited to coarse fabrics only. In cotton this ratio is of the order of 1500-2000.

The structure of an individual fibre cell resembles to that of cotton, however, upon drying the fibre cells do not collapse as they do in cotton.

All retted fibres of an entire plant, when properly retted, together form a fibre strand or reed, which is more compact and firmer towards the base and finer towards the other end. The fibre strand consists of loose network, composed of many smaller strands (fibre bundles) each of which contains 20 to 40 fibre cells rigidly glued with pectin substances.
The fiber bundles surround the stem periphery as a ring and joining with one another they form a band of technical fibre.

Both species, *C. capsularis* and *C. olitorius*, have two types of fibre. **Primary fibres**: They develop from proto phloem and form a single layer of outermost fibrous bundle. **Secondary fibres**: They are commercially most important and develop from secondary phloem by the activity of the cambium. The fibres derived from the protophloem do not exceed ten per cent by weight of the total fibre content of the plant.

The development of fibres takes place in two stages: **Primary wall phase**: In this phase the fibres elongate without layer deposition. **The phase of cell wall thickening**: This phase is associated with the deposition (in layers) of the secondary wall. Deposition of the secondary wall only occurs in the stem after elongation has ceased.

**15. Defects of jute fibres**

1. **Cutting**: It is due to the incomplete retting of lower portion of the stems. In Nepal, on the basis of cutting percentage, jute fibres are divided into three categories i.e. high, medium and low. Thus the percentage of cutting for high medium and low quality fibres equals to 15, 20 and 30 in *C. capsularis* and 10, 15 and 20 for *C. olitorius*, respectively.

2. **Dazed fibre**: Such fibres are inferior in strength and poor in spinning. It is caused by over retting of jute stems or delay in the extraction of the fibres. It is also caused by the storage of fibres in the damp stage.

3. **Stiff fibre**: It occurs due to incomplete retting of stems. In such case dark strip of periderm are found to be sticking to almost entire length of the fibre making it very hard and coarse.

   Stiff: not easily bent or changed in shape.

**16. Fibre quality**
The fibre quality of the jute is judged by its suitability for the production of various types of yarns. The fibres which spine into the fine yarn are considered to be of very good quality. Grading of jute is based on the following characteristics.

1. Length
2. Strength
3. Color
4. Luster
5. Percentage of cutting and freedom from extraneous matter.

Of the above characters color, luster and strength are usually considered as very important characters by the mills. Thus a fibre with good length and strength, fine color and luster and smallest percentage of cuttings is called good quality fibre.

Mention the practical on the following headings

Practical 1: Study of the classification and morphological characteristics of Jute

Practical 2: Study of the differences between two species of Jute
TOBACCO

Economic importance

Tobacco is an important cash crop. The world output is mainly rising because of the developing countries where this crop has been very important in export. In the developing countries tobacco is extremely popular in Nigeria, Tanzania, Argentina, Brazil, Pakistan, India, Nepal, Turkey and Thailand.

About 67% of the total world production of tobacco was obtained from Asia. The production of tobacco in China equaled to 47% of the total world production, where as it was only 9.2% in USA. After China and India, USA ranked third in the world tobacco production. In Nepal it is grown in 773.23 ha with the average productivity of 1293 kg ha\(^{-1}\).

Tobacco is mainly grown for its leaves which are used to produce cigarettes, cigars and other products. An industrial product of considerable importance is nicotine sulphate, which is prepared from tobacco for use as an insecticide. It is also used as a source of nicotinic acid (a component of vitamin B complex).

Nicotine: It is an alkaloid, oily liquid soluble in water and has considerable volatility at ordinary temperatures. It is poisonous to mammals. The alkaloid nicotine only occurs in genus \textit{Nicotiana}. Its chemical formula is \(\text{C}_{10}\text{N}_{14}\text{N}_{2}\). Nicotine is produced in the roots of the tobacco plant from simple compound made in leaf and nitrogen from the soil. After synthesis it is carried to leaves and is present in all parts of the plant except in seeds. Strength of the tobacco and its smoke is primarily dependent on nicotine content. Nicotine accumulation is directly related to the level of N. Heavy nitrogenous manuring increases the nicotine content.

Origin

\textit{Nicotiana tabacum} is originated in North-west Argentina, and adjacent Bolivia, whereas \textit{N. rustica} in highlands of Peru, Equador and Bolivia.

Ecological requirement
Although tobacco is a tropical plant, it is cultivated in subtropics, and even in the temperate regions.

**Temperature**

The tobacco plants can be successfully cultivated only in regions where the daily mean temperature never goes below 18-20°C for five months. Tobacco seeds require about 21°C temperature for germination. Temperatures between 27 and 32°C are for rapid and uniform seed germination. Approximately on the third day the seeds begin to germinate at these temperatures. Tobacco plants grow and mature rapidly when average temperatures are about 25-26°C. To obtain top quality smoking tobacco, the leaves should mature at temperatures never below 20°C.

**Moisture**

Tobacco is a moisture loving plant. Its transpiration coefficient ranges from 500 to 600. The critical periods of moisture requirement are observed during seedling formation, rooting and rapid stem growth. During these periods droughts do not only hinder budding and growth of the flowers, but also affect plant productivity and raw tobacco quality.

Tobacco requires 1000-1150 mm of annual precipitation for its successful production. Continual rain during the growing season leads to disease and thin light weight leaves. A low rainfall increases the content of nitrogen, nicotine and Ca but decreases that of potash and carbohydrates in tobacco which affect its quality.

**Light**

Tobacco plants are neutral to day length. Some strains such as Maryland Mammoth belong to short day plant.

**Relative humidity**

RH also influences the quality of leaf and also the yield and curing of the leaves. Droughty conditions along with low humidity affects the quality and yield adversely. RH may vary from 70-80% in the morning and 50-60% at midday. It is observed that RH of 85-95% is an optimum
humidity for the crop because at this level, the leaves are easily used and they do not become very brittle. Drier weather is required for harvesting and ripening of tobacco.

**Relation to soil**

Tobacco has high soil requirements and them very according to the class of tobacco grown, but in general the crop requires adequate drainage, moisture retention and aeration.

Light sandy and sandy loams, because of the low water holding capacity and low soluble mineral matters, tend to produce a leaf of relatively large size, light in color and body, fine in texture and weak in aroma. Heavier soils that contain more silt and clay tend to produce a leaf of smaller size, dark color, heavy body and strong aroma. Thus, it is obvious that physical and chemical properties of the soil influence the quality of tobacco leaves and therefore soils should be selected according to the purpose for which the crop is considered to be cultivated. Tobacco grows well on acid (pH 4.5-4.8) and alkaline (pH 8.5) soils.

<table>
<thead>
<tr>
<th>S.N</th>
<th>Finished products</th>
<th>Suitable soil types</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bidi</td>
<td>Light to medium loams of old alluvium origin</td>
</tr>
<tr>
<td>2</td>
<td>Cigar (binder)</td>
<td>Heavy soils</td>
</tr>
<tr>
<td>3</td>
<td>Cigar (filler)</td>
<td>Light sandy soils</td>
</tr>
<tr>
<td>4</td>
<td>Cigar (wrapper)</td>
<td>Distinctly heavy soils</td>
</tr>
<tr>
<td>5</td>
<td>Cigarette</td>
<td>Light sandy soils</td>
</tr>
<tr>
<td>6</td>
<td>Hookah (chewing and snuff)</td>
<td>Sandy to silt loam alluvial soils</td>
</tr>
</tbody>
</table>

**Classification**

On the basis of botanical features, type and quality of raw tobacco and the origin of ecotypes, the *N. tabacum* is divided into five classes.

1. **Oriental:** It includes two types of varieties i.e. Macedonian, without leaf petiole and Turkish with leaf petioles. Representatives of this class (sub species) have high quality raw tobacco with low nicotine content (up to 1-1.5%), higher content of aromatic substances and sugars and good burning quality. Oriental tobacco is widely distributed in Turkey, Italy, Lebanon,
Greece and former USSR. Most popular strains are Basma, Dubec (Macedonian variety) Samsun and Trabzon (Turkish variety).

2. **American (Maryland and Virginia varieties) Tobacco:** The strains of this type of varieties are large leafed, light colored with high quality tobacco (1.5-2.0% nicotine 20-22% carbohydrates). The world standard varieties are Virginia, Maryland and Burley. In world tobacco production, half of all raw tobacco is obtained from raising Virginia (40%) and Burley (10%). The principal producer of Virginia and Burley are USA and India.

3. **Southern tobacco:** It includes two varieties Argentina and Brazil. The raw tobacco is rich in nicotine (up to 3-4%) and nitrogenous substances but poor in sugars. The raw tobacco is dark colored and is used for the manufacture of low quality cigarettes. These tobaccos are distributed in Brazil, China, Pakistan, India and Argentina.

4. **Island tobacco:** This type of tobacco is grown for the manufacture of top quality cigar raw tobacco. Cigar tobaccos contain much nicotine (up to 3%) and many aromatic substances and have good burning quality. Cigar tobacco production is concentrated in South and Central America and also in the island of South-East Asia (Indonesia).

5. **Asian tobacco:** The plants of this type of tobacco contain high percentage of nicotine (3 to 7%). It includes chewing tobaccos such as Vairam, Sona (India).

**Cigar Tobacco (air cured):**

Cigar tobacco is classified as Cigar filler, Cigar binder and Cigar wrapper.

1. **Cigar filler:** It is used to form the core of the cigar. The cigar filler strains are strong, aromatic (possess pleasant flavor) and burn evenly with firm white ash (good burning quality). Popular cultivars of this type of tobacco are Spanish, Dutch.

2. **Cigar binder:** It is used to hold the filler in shape. Havana is the principal variety. The strains of this tobacco have strong leaves with good burning quality. Cigar filler is heavy but binder is not heavy as filler.

3. **Cigar wrapper:** It is used for the final wrapping of the cigar. The leaves of the cigar wrapper strains are free from flavor, thin and elastic with very fine veins and uniform quality. It must possess a pleasure luster and finish which would appeal to the trader and smoker. Sumatra, and Cuban are the popular varieties of this tobacco.

**Classification on the basis of curing methods**

Tobacco cultivars are divided into different classes according to the method of curing.
1. **Flue-cured**: Orinoco is the basis type of cultivar from which most of the other cultivars have arisen. They include Virginia gold, Harrison special, Virginia Bright, and Oxford. The flue-cured tobaccos are chiefly used in the manufacture of cigarettes. It is also used for pipe and chewing tobaccos. The bright yellow color is due mainly to the soil on which it is grown and to the method of curing.

2. **Fire-cured**: 'Pryor' is the principal type of cultivar and originated from Orinoco. Their principal characteristics are dark color, heavy body and distinctive flavor imparted by the smoke of the open five, used in curing. They are chiefly used for snuff and plug wrapper. Chewing types of tobacco are also fire-cured. They include Vairam, Sona.

3. **Air-cured**: Burley and Maryland are the principal cultivar of the air-cured tobacco. Burley is used for cigarettes, pipes and chewing tobacco, but Maryland is used only for cigarettes.

**Crop rotation**

The chief consideration in determining a crop rotation system for tobacco growing is the effect of previous crop on the yield and quality of tobacco as well as on the incidence of tobacco diseases.

Nematode susceptible crop such as cowpeas, soybean and sweet potatoes should not be included in the rotation. Variation in the crops used in rotation with tobacco generally gives better disease and nematode control than if only one other crop is used in rotation. When tobacco plants are grown without rotation for a long period they become easily infected by mosaic and broom-rape (*Orobanche minor*). Tobacco should not be cultivated after tomatoes, sunflower and other crops which have disease and pests in common.

Crops with which tobacco is more successful include corn, cotton, and small grains. Flue-cured tobacco that follows corn, cotton and small grain is of excellent leaf quality. When grown after legumes the tobacco ranges from poor to good. For tobacco following legumes an appreciable increase in quality is obtained when nitrogen fertilization is reduced or heavy applications of potash are made to balance the deleterious effect of the excess nitrogen left over from legumes. The best type of crop rotation is to plant tobacco is the dry season and maize in the humid season.

**Promising varieties in Nepal**

*Flue cured virginia tobacco*: Bright yellow-103, Hema, Mc-Nair-12
Sun cured tobacco: 2-409, Natu (WAF)

Air cured tobacco: B: K-21

Field preparation

A clean and well pulverized field of good tilth is needed for transplanting tobacco seedlings. The field is ploughed two or three months before the seedlings are transplanted. As a rule deep ploughing with mould board plough and three four cross harrowings are practiced. Each harrowing is followed by planking to make the soil pulverized and leveled.

In Nepal, the field is ploughed several times with local plough followed by planking until a fine seedbed with good tilth is obtained. Field preparation starts a month before the seedlings are transplanted.

Sowing

Tobacco seeds are very small and are not sown directly in the field, but are sown in nursery. While the main field is being prepared tobacco seedling are raised in specially prepared see beds.

Raising seedlings

The seedling period lasts from the time of seed sowing into the soil until the formation of seedlings with 5-6 leaves.

Open nurseries should be situated on the plots with good water drainage (in case of heavy rain) and close to tobacco plantation and source of water. The seeds are sown either on raised beds (10-15cm height) or flat bed of 10 m length and 1 m width with channels of 50 cm width between the beds. The seeds are very small, therefore, they require very fine tilth. The beds must be free from stubbles, weeds and soil borne diseases for which the beds must be sterilized before sowing the seeds. There are mostly two methods of sterilization of nursery bed are popular.
a) **Rabbing method:** It is the process of burning of trashes, weeds or any organic refuse on the soil surface. For rabbing 15-20 cm thick layer of paddy straw, leaves or weeds is uniformly spread over the bed and then it is burnt 7-10 days before the seeding.

b) **Chemical method:** In this method different types of chemicals are used to sterilize the soil. Formaline solution of 2% concentration in water or formaldehyde takes care of damping off. Sometimes Bordeaux mixture, Methyl bromide and calcium cyanamide are also used as fumigants about 2-3 month before the seeding in nursery bed.

The seed-bed area for the transplantation in one acre of land depends upon the type of tobacco. Usually seedlings are raised in an area of 150 -200 m² for transplanting in one hectare of land.

Before sowing, if needed, the beds are irrigated. A seed rate of 2 kg is quite sufficient for nursery bed of one hectare. The shed dried water soaked and pre-treated seeds (seed treatment with agrimycin or Agrosan GN at 5 g per kg of seed) are sown broadcasted on the surface of the beds and later they are mixed in the soil up to a depth of 1.5 to 2.0 cm with the help of a rake. Before sowing the seeds are mixed with ash or fine sand in 1:15 or 1:20 ratio for their uniform distribution on the beds.

During soil tillage the plots are applied with compost at the rate of 30-50 t/ha. In Nepal it is applied @ 25-30 t/ha at least a month before sowing and incorporated into soil. Basal fertilization consist of 10 kg N, 50 Kg P₂O₅, 50 kg K₂O and 16 kg MgO/ha. Top dress at 20-40 kg N/ha depending on the soil type.

Tobacco is usually seeded in beds six to twelve weeks before transplantation (In Nepal seedling preparation takes 50 to 60 days). In Nepal the sowing time of seed bed ranges from 3rd week of July to 2nd week of August and that of seedlings transplantation from 3rd week of September to 2nd week of October.

Watering of nursery bed should be done carefully. Before formation of 1st pair of leaves the plants are watered several times a day at small rates, so as to keep the surface layer constantly moist, but to avoid any excess of water. When the 2nd and 3rd pairs of leaves begin to develop the watering is less frequent, once to twice a day, but the irrigation rates are higher. In Nepal nursery beds are irrigated twice a day. First in the morning and second in the evening. Watering is limited 2-3 days before transplantation.
Usually six to eight weeks are required to obtain transplantable seedlings of *N. tabacum*. In case of *N. rustica* seedlings are transplanted after 5-6 weeks.

**Transplanting**

The field for transplanting tobacco should be well prepared. A few hours before transplanting the nursery bed should be watered for easy removal of seedlings. Seedlings for transplanting are uprooted early in the morning or even at night when air is cool. As far as possible the seedlings should be transplanted immediately after uprooting.

Generally seedlings with good root system and 5-6 leaves are planted. The ready to transplant seedlings of oriental tobacco should be 12 to 15 cm in height, and that of cigar type 10-12 cm. The seedlings of Virginia strains should be 20-22 cm high with more developed root system. In Nepal it is recommended that the seedlings for transplanting should be at least 15 cm in height.

According to the type of tobacco the row to row distance ranges from 50 to 100 cm and that of plant to plant from 10-60 cm. It is because of the fact that different types of tobacco are planted at different populations. For example, the oriental strains with small leaves (Dubec, Samsum) are grown at the plant density of 150 to 200 thousands per hectare, whereas with medium sized at 80-90 thousand/ha. The broad leafed strains (Virginia type) are grown with 25 to 40 thousand plants per hectare.

**Fertilizer**

In tobacco crop it is well known fact that the economic returns are mainly dependent on the right combination of yield and quality rather than on the yield alone. Quality in the tobacco, particularly in the smoking types, depends on the balance of the nutrients in the leaf. Of the nutrient elements nitrogen is necessary for good growth and high yield of tobacco. It forms 13% of the compound which gives tobacco strength, nicotine. Excess of nitrogen either in total or at wrong time spoils the leaf quality. Moreover, it increases vegetative growth and delays maturity as a result of which the cured leaves become dark lacking texture and smoking quality. With excess of nitrogen supply the carbohydrate nitrogen ratios gets reduced which affects tobacco quality. Shortage in nitrogen results in late flowering, low nicotine content and reduced size of the leaves. It has been found that in case of chewing, bidi and hookah tobacco yield is very important factor and abundant supply of nitrogen is essential but incase of flue-cured tobacco nitrogen is not needed in large quantity as light green leaves of good quality are to be produced. In the condition of very fertile soil as well as heavy manuring, particularly with nitrogen, flue cured tobaccos produce heavy leaves which
will not give bright yellow color on curing. So, a delicate balance of nutrients optimum both for yield and quality is of great importance.

Nitrogen is usually applied at the rate of 10 to 40 kg per hectare for flue-cured, up to 100 kg/ha for air cured and fire-cured and 10-20 kg/ha for Turkish tobacco.

Phosphorus is a very important element for tobacco crop. It accelerates the growth of the tobacco roots and ripening of the plant. It improves the quality of tobacco.

With the shortage of phosphorus the plants produce narrow and small leaves of dark green color, the rate of growth slows down and the maturity delays. On curing the leaves become dull and loss luster. Excess (too much) of phosphorus reduces yield owing to the ripening of leaves before they are fully developed.

Depending upon the availability of phosphorus in soil the rate of its application may vary from 40 to 120 kg/ha. In case of flue-cured tobacco, the plants require 50 to 75 kg P₂O₅ per hectare.

Potash is important for normal and healthy growth of the plant. It is needed for good burning quality of smoking tobacco. In case of its shortage, the tobacco leaves turn brown in color, and the fire holding capacity of the tobacco sharply declines. The tobacco burning quality is a function of the coefficient [K/(Ca+Mg)]. When potassium is applied the denominator decreases with the improvement in burning quality.

Source of potassium is also an important factor in tobacco cultivation. It is not recommended to use excess of muriate of potash as excessive chlorine is detrimental to the quality of the cured tobacco. Depending upon the soil requirements and the type of the tobacco the rate of potassium application may be increased up to 100-150 kg/ha.

In Nepal Virginia type (FCV) of tobacco is fertilized at the rate of 40-60 kg of N, 60-80 kg of P₂O₅ and 60-80 kg of K₂O per hectare and Natu tobacco as well as Belachapi 1 @ 40-50:60-65:60 kg N, P₂O₅ and K₂O per hectare, respectively.
Usually the whole dose of phosphorus and potash is applied before transplantation. Whereas that of nitrogen is split into two parts and applied as basal and top-dressings (after 4-5 weeks of transplantation).

In addition to the inorganic fertilizers, application of organic matter in the form of well rotten farm yard manure or compost is also recommended at the rate 6-7 t/ha for heavy soils and 10-12 t/ha for light soils, to improve physical condition of the soil. It may be applied one month in advance and ploughed.

**Plant management**

Plant management of the tobacco includes soil loosening, weeding, top dressing, irrigation, topping and de-suckering.

Tobacco being a quick growing crop requires good aeration for the growing roots. It is very susceptible to poor aeration and water logging conditions. Therefore soil loosening are performed immediately after seedling are rooted which is about a week after transplanting and are terminated before the tobacco plants cover the space between the rows. There may be 3-8 loosening followed by weeding.

Broom rape (*Orobanche minor*) is a very important weed of tobacco which is found towards the end of the season attached to roots and growing up through the soil round the tobacco plants. It is a root parasite and derives all nourishment from tobacco plant. The way of controlling this weed is to collect and destroy it before seed formation. EPTC@ 6kg/ha or DMTT @ 1-2 kg a.i./ha is applied before planting into the soil (30-40 days before transplanting) for its control.

Water requirement of tobacco crop depends upon its type and the region where it is grown. Too much irrigation produces slick leaf with dirty color whereas insufficient irrigation restricts crop growth and curing of the leaves becomes difficult. So, right amount of water should be given through irrigation for successful production of tobacco. In light soils six to seven irrigations are required for the flue cured tobacco. In case of cigar tobaccos more frequent irrigations are required.

The requirement of tobacco plants in water after a month of transplanting rises to maximum and gradually declines after flower budding. The optimum soil moisture before blossoming in the tobacco plants should be 70% of the field capacity and 45-50% during blossoming. In Nepal two
light irrigations are given after 30 and 50 days of transplanting depending upon the requirements of the crop.

**Topping**

It is most important operation for quality of tobacco leaf. It gives a uniform quality product and prevents excessive coarseness in the leaves. It prevents the plants from producing seeds and allows carbohydrates and nutrients to go towards vegetative part instead of reproductive. It causes thickening of the leaves and increases their body. It helps in the increment of sugar and nicotine content especially in the upper leaves.

Topping begins in burley tobaccos when about 50% of the plants show flower heads, in wrapper and cigar filler tobaccos before flower opening and in flue-cured tobaccos when plants have 10-15 leaves (with the beginning of flower opening).

In topping the top portion of the plant which constitutes 15-20 cm in length from the upper most leaves is removed. A topped plant yields more high quality leaves and ripens more uniformly.

**De-suckering**

Because of the topping, the dormant buds in the axil of leaves become active and develop in to shoots known as sucker. Removal of these suckers or lateral branches is called desuckering. Suckers should be removed as soon as they are large enough to be pulled out (3-5 cm in Nepal). De-suckering is conducted 5-6 times at an interval of a week.

The main objective of topping and de-suckering operations is to divert carbohydrate and nutrients of the plant towards the leaves which influences yield and quality of tobacco.

**Piercing**

Piercing is the process of puncturing of stem with the help of 20-25 cm needle just after topping to increase the yield of tobacco leaves.
Harvesting

In tobacco the leaves do not ripe uniformly. The first to ripe are the lower old leaves then the middle ones follow and after that the upper leaves. So, when the leaves are ready to harvest they turn into lighter shade of green to slightly yellow color and becomes thick and so brittle that when a section of the leaf is folded between fingers it snaps easily. Usually harvesting starts after 55-60 days of transplanting. Generally two methods of harvesting are practiced:

1. Priming

In some classes of tobacco such as flue-cured, cigar-wrapper and oriental harvesting is done by picking each leaf as it matures. This method of harvesting is called priming and begins after 14-21 days of topping. Priming starts with lower 2 to 4 leaves (of commercial size) followed by 5 or 6 successive picking of 2 to 4 leaves at intervals of 5-10 days.

After harvesting, the leaves are strung on stick or lath of about 1.2 to 1.5 m length and taken to the barn for curing. A string is attached to one end of the stick, after which the leaves are strung by needle. When the string is full, it is tied to the other end of the stick. A stick holds 60 to 80 or more leaves.

2. Stalk cutting

Air cured, fire-cured and most of cigar tobaccos (except cigar wrapper) are harvested by cutting the entire plant near the soil surface when the middle leaves show first tinge of yellow or when the middle leaves are ripen. Usually it takes place after 40-55 days of topping.

The stalk is then hung upon a lath or stick. It is done by piercing the stalk near its base with a removable metal "Spearhead" placed on the end of the stick or lath and sliding along the lath. A lath or stick holds 6 to 8 salts. Plants are allowed to wilt for a period of few hours to 4-5 days. Wilted plants are easier to handle without damage. The leaves are not removed from the stalk until curing is finished.

Curing
It is the most important operation in the production of tobacco. It is done in order to impart the required color, texture and aroma to the final product. Curing involves the process of drying, decomposition of chlorophyll until the green color disappears from the leaf, changes in the nitrogen compounds including release of ammonia, hydrolysis of starch into sugars and respiration or fermentation of the sugars.

**Flue Curing**

The main objective of the flue-curing is to keep the leaf alive until almost all starch have been converted into sugar and to ill it before any appreciable amount of these sugars have been oxidized to carbon dioxide and water.

Flue curing is usually done in brick barns. The distinctive feature of flue-curing barn is that it is provided with a system of large pipes or flues that carry off fuel gases so that the smoke does not come in contact with the tobacco. There is absolute control over temperature and humidity in the barn.

To sizes of the barns appear to be most common: about 6m x 6m x 6m which commands 8 ha of tobacco and 4.8m x 4.8m x 5.4 m commanding 6.0 ha of tobacco crop. In Nepal they are of 4.9m x 4.5m x 4.9m and 7.3m x 4.9m x 3.2m with the capacity of 700 and 800 sticks, respectively.

After the furnace starts working the curing process consists of three main stages: yellowing of leaf, fixing the color and drying the leaves.

1. **Yellowing of the leaf:** For yellowing of the leaf, a temperature ranging from 26 to 28.3°C is kept during the first 12 hours and then raised to 36.6°C for the next 6-7 ours. After that temperatures of 36.6 to 37.7°C are used for 12-15 hours when the leaves become yellow. Thus it is a slow starving process. The main objective is to give optimum humidity (85%) and retain as much moisture as possible to keep the leaves alive for 30-36hrs.

2. **Fixing the color:** Ventilation is gradually increased to decrease the humidity, but the temperature is increased from 37.7°C to 48.8°C in order to kill the leaf, destroy the enzymes and dry out the web of the leaf. The moisture coming out of the leaves is allowed to escape by opening the ventilators half at first and full afterwards. At this stage the leaves become dry but the midrib and the vein still contain some moisture. So fixing is a critical process and should be carried out with great care. About 80% of the moisture should be driven off. It takes about 12 to 24 hrs.

3. **Drying of the leaf:** It lasts from 28 to 50 hrs. The ventilators are closed and the temperature is raised up to 74°C in order to dry the veins and midrib. This completes the process.
After this process, ventilators are opened to cool down the barn. The leaves are left in barn overnight for absorbing moisture and to come to normal condition for handling and storage. Usually full curing takes about 5-6 days.

For flue curing leaves are harvested by priming method. As a result of it translocation of sugars from leaves to stalk does to take place during curing. Because of this reason a good bodied bright lemon yellow leaves rich in sugar and poor in nitrogenous compounds (the most desirable quality of cigarette tobacco) are produced.

**Air curing**

Most of the cigar tobaccos, Burley and Maryland are air cured without the use of artificial heat. This is a natural process and curing is done in a wooden barn under normal atmospheric conditions. The leaf should be yellow before it dries out and after that the rate of drying is gradually increased by increasing the ventilation. The best temperature for early wilting is 21-24°C and it should never exceed 43°C even in the final stage. The time taken for curing is 6 to 8 weeks and more.

Thus, the main objective of air curing is to keep the leaf alive until even the smaller sugar content has been oxidized away. There are two stages in air curing.

1. **Yellowing:** The leaf remains alive and it is cured at 15.5 to 35°C and relative humidity of 70-80%. One of the important changes that occur during this stage is the disappearance of the starch in the leaf. If the leaf is killed too rapidly by drying, starch cannot remove and tobacco leaves become straw colored. The appearance of the yellow color indicates the end of this stage.

2. **Browning:** The most important change during the second stage is the development of brown color. This is due to the oxidation of the substances present in the leaf. The brown colors are formed by the oxidation of polyphenols and tannins. The development of brown color needs oxygen and moisture. It is completed by the fermentation process.

After drying of the leaves they are tied into hands and bulked on raised platform. The bulks are broken and rebuilt frequently with the shaking of hands. This is necessary to remove any ammonia and carbon dioxide formed during bulking by atmospheric oxygen and to prevent excessive rise in temperature. In addition to it the position of the leaves are also changed i.e. the leaves lying on the top and boarder side of the bulk are placed in the middle and that of the middle portion are transferred outside. This result uniform fermentation of all leaves in the bulk.
**Fire curing**

This is usually done in log or grass barns. The usual system of fire curing is to allow the tobacco to yellow and wilt in the barn without fire up to 7 days. Thereafter slow firing starts to maintain the temperature of 32-35°C until yellowing is completed, and finally to raise the temperature to 51-54°C until the leaves become dry. The fires are removed at night. The smoke from the open hard wood fires imparts the characteristic odor and taste to the tobacco desired for chewing, plug and snuff.

After the smoke treatment the leaves are fermented in bulks for three to four weeks. The fermented leaves are then treated with salted water which is considered to contribute peculiar taste to this type of tobacco.

**Sun curing**

The characteristic reactions which occur during sun curing are the considerable loss of starch with concomitant (accompanying) production of sugars and formation of soluble nitrogenous constituents at the expense of protein. There are several modifications in sun curing.

1. Curing whole plants on racks as in cigar and chewing tobacco. After initial wilting in the field the plants are strung on bamboo poles and cured in sun. The entire process takes about 15 to 20 days.
2. Curing leaves with pieces of stems on racks as in Natu tobacco. In this method of curing racks are not exposed to the direct sun, therefore it takes longer period (6-8 weeks).
3. Curing whole plant on the ground as in bidi and hookah tobaccos. In this curing, leaves are allowed to dry in sun on the ground and are turned over twice a day. This process continues for about a week and then heaps are made which are opened on the next day and re-heaped. This process of heaping, opening of heaps, and spreading and re-heaping continues for about 10 to 15 days. By the end of this period leaves become completely cured.

**Practical 3:** Difference between two species of tobacco

**Practical 4:** Classification and morphological characteristics of tobacco

**Practical 5:** Fertilizer rate calculation for raising tobacco nursery beds.
SUGARBEET

(Beta vulgaris L.)

Economic importance

Sugarbeet plant is one of the most efficient converters of the solar energy into stored energy. It provides around 40% of the world sugar requirement and is grown in 45 countries of the world. It is an important sugar crop which has great potentiality of augmenting sugar production at lower cost and will become an important crop in Nepal in the coming days. It produces about 50-70 ton of the roots under better management with sugar content of 15-16% and recovery of the 10-12% on an average. It is a 6-7 month crops and yield nearly as much as sugar of a 12 month sugarcane crop in subtropical and temperate climate. The crop is mature in April-May when the cane crushing season is nearly over. Thus supply of Sugarbeet can extend the working season of the sugar mills nearly by 2 months and reduces the cost of sugar production.

It’s by products provides the nutritive diet for livestock. The tops contain nearly 10% crude protein and 60% total digestible nutrients. Its molasses can be used for the feed and also for a variety of other industrial uses in the manufacture of critic acid yeast, antibiotics and other products of fermentation industries.

Origin

Sugarbeet is originated in Mediterranean region.

Climatic and soil requirement

Sugarbeet is the crop of a temperate regions and cool season. It is highly versatile and can be raised in the any region with the temperature ranging from 12-30°C during the crop season (October to May). It can be grown profitably in all most all parts of the countries, during summer season in mountains and winter season in the hills and terai. The good germination and emergence the soil temperature must be above 15°C. The optimum temperature for plant growth and development is 20 to 22°C. The temperature above 30°C decreases the sugar content that limits the commercial cultivations.
Sugarbeet can be grown in well drained sandy loam to clay loam soil. Heavy clay coils should be avoided. Drained fertile subsoil is most preferable. Sugarbeet can thrive very well in saline alkaline soil with the pH as high as 9.5. The field should have enough slope and drainage to prevent flooding of the bed. Fields containing herbicidal residues especially the 2,4 D from the previous crop should be avoided.

**Cropping system**

Sugarbeet is the winter season crop. It can be sown after the harvest of the summer season crop. Some of the possible rotations are:

- Maize – Sugarbeet
- Rice (early) – Sugarbeet
- Soyabean – Sugarbeet
- Cowpea – Sugarbeet
- Blackgram – Sugarbeet

**Field preparation and sowing**

A clean and well pulverized field of good tilth is needed for sowing of the sugarbeet crops. As a rule deep ploughing with mould board plough and three four cross harrowing are practiced. Each harrowing is followed by planking to make the soil pulverized and leveled.

The crop can be planted continuous in rows on flat or raised bed of 15-20 cm height at a row to row distance of 50 cm. in the unleveled and high rainfall areas the raised bed is practiced. There should have the optimum moisture at the time of crop sowing, which may be maintained by the pre-sowing irrigation. The 8-10 kg seeds per hectare is drilled or dibbled manually at a depth of 2.5 cm. sowing time is crucial for better performance of Sugarbeet. In general, Oct. 15 to Nov. 15 has been found be an ideal for sowing.

**Important varieties**
Nutrient management

Organic manures are applied as broadcasting and incorporated immediately around 20-30 days before crop sowing. For optimum growth and development of Sugarbeet, application of 120 kg N, 80 kg P₂O₅ and 80-100 kg K₂O is required. Half N and full P and K may be applied as basal application before final land preparation. Remaining nitrogen is applied as two equal split (3 in case of light texture soil) after thinning (20-30 DAS) and at the time of earthing up (45-50 DAS) as side dressing.

Plant management practices

Thinning: At the 20-30 days after sowing the thinning operation is conducted and maintained 20 cm between the plants within rows.

Water management: The crop required 7-10 irrigation that depending upon the season and soil in which crop is grown. One or two irrigations are required till thinning and subsequent irrigations are given at an interval of 20-25 days. Care should be taken so that water doses not remain standing in the filed for more than 24 hours. If so, drainage of water must be done immediately.

Earthing up: At the 45-50 days after sowing the earthing up operation is conducted.

Weed management: Sugarbeet crop faces severe competition from the weeds in the early stages of crop growth so field should be kept weed free for initial 35-45 days. The weeds growing up after this period is not able to compete well ad are smothered easily. Around 3-4 weeds including the one at thinning and earthing up are enough to maintain weed free crop for a good yield. Pyramin @3 kg a.i./ha in 600-800 liters of water can be used at pre-emergence application controlling mostly broadleaf weeds. Betanal @2 kg a.i./ha in 600-800 liters of water can be used at post-emergence application at 25-30 DAS.
Harvesting and yield

Harvesting should be done from the March end to May and can be delayed up to mid-June especially when and where the temperature is not so high. Senescence of lower leaves and retarded above ground growth are the maturity indices of the crop. The roots can be loosened by poughing and collected and uprooting then after. After collection, the tops and crown are cut off from the roots and send to the sugar mills. Storage of roots beyond 36 hours at high temperature will hamper the milling and sugar recovery. Under better management, Sugarbeet produces about 500-700 quintals of roots.
Economic importance

_Gossypium_ spp. is one of the most important fibre crops of the world and regarded as the king of the fibre crop. It is cultivated in about 60 countries of the world but the 10 countries like Russia, USA, China, Brazil, Pakistan, turkey, Egypt, Mexico and Sudan account for 85% of the total production. Since the Second World War, radical changes have taken place in the production, processing and commerce of cotton. Many countries that formerly produced insignificant amounts of cotton, such as the Latin American countries, increased their production steeply and have become important suppliers of the fibre to the world market. Other countries, like India, Pakistan and Turkey, which formerly produced for home consumption only, have also become major exporters. The increase in cotton production was due to the expanded areas and improved production methods, resulting in higher yield.

Thus, from the above information it can be mentioned that cotton plays an important role in the economical development of the country. As stated above textile industries of our country also used to import raw material from neighbor countries, but due to extensive cultivation of cotton in different districts (Banke, Bardia, Dang) they get a satisfactory amount of lint from Cotton Development Board. Modern cotton cultivation was initiated in Nepal in 1969/70. In 1976/77 only 50 growers were involved in cotton farming in 8 ha of land which rose to 130.5 ha (Dang 90 ha, Banke 26 ha, Bardiya 15 ha and Mugu 0.5 ha) in 2014.

The economic importance of cotton is based on different properties of its products. Cotton lint is the most important fibre and is woven into fabrics, either alone or combined with other fibres. The seed fuzz is used in the production of mattresses, surgical cotton, photographic films and paper. The cotton seeds contain 20-25% of semi-drying edible oil which is used for cooking food.

Cotton seed-cake which is the waste product of the oil processing industry contains as much as 40% of protein and serves as an important concentrated feed for live-stock. It is good organic manure with 6% nitrogen, 3% phosphorus and 2 percent potash. The cotton stems are used as organic manure or fuel.

Gossypol: On all aerial parts of the cotton there are internal glands called gossypol. These glands secrete oil called gossypol. It is a volatile poisonous phenolic compound of which kernel contains
0.4-2%. It is rendered harmless on crushing and heating in combination with protein. Gossypol is toxic to non-ruminants.

**Cotton fibre:** Cotton fibres are single-cell specialized extension of the epidermal cells of the ovules or seed. The fibers begin to appear on the ovules as soon as the flower opens and their initial development is not dependent on fertilization. Thus, at first some of the epidermal cells bulge outward and the protoplasm of the cells moves towards the outgrowth and later enters into it. The longer outgrowths make lint and the shorter ones make fuzz. It is generally accepted that the fibers which appear during the first two three days are those that develop into lint, while those that are formed later constitute the fuzz. The fuzz consists of short convoluted hairs which are firmly attached to the testa and provides the linters of the commerce. They are much shorter than lint hairs, ranging from 3 to 12 mm. The lint consists of long convoluted hairs which are white in commercial cotton, evenly distributed over the seed-surface and easily removable.

*The development of the fibers takes place in two phases*

In the first phase which takes about 25 days (the first half of the maturation period of boll), the fibers grow to their full length. During this period the cell wall remains very thin, the nucleus persists and the diameter of the cell does not differ from that of matured fibre.

In second phase, which continues until the boll has completed its development (the next 25 days), the fibers thicken as a result of cellulose deposition in the form of spiral rings on the inner surface of the fibre walls. The direction of the spiral rings deposition may be reversed at any point and this, together with the different rates of deposition, produces convolutions (twists) when the lint collapses into ribbons through water loss on drying when the bolls open. This causes locks of seed-cotton to expand and fluff out. The development of convolutions (twists) in the fibers cause them to cling to each other and thus improve their spinning quality. The ideal fibres for spinning purposes are those that are of uniform length, diameter, cell wall thickness, and twist or convolution.

**Ecological requirement**

Successful cotton production requires a frost-free growing-season of at least 180-200 days, ample light, relatively high temperature and favorable moisture regime.

**Temperature**
Cotton is a tropical plant and grows successfully in locations with a mean annual temperature of over 20°C. The mean seasonable temperature for the six warmest months should be at least 22°C.

The minimum and optimum temperatures for seed germination and early growth of cotton are about 16°C and 34°C, respectively. The optimum temperature during vegetative growth and development ranges from 25 to 30°C.

Cotton is very sensitive to low temperatures during the period of flower bud initiation. At this stage temperatures above 21°C are desirable. During flowering and fruiting temperatures of 26-32°C are desirable during the day-time, but the night should be cool. In general temperatures above 35°C are not desirable.

During the maturation of the bolls, which is essentially a drying process relatively high but not more than 35°C temperatures are desirable.

**Moisture**

Cotton is a drought resistant plant. Owing to its well-developed root system, it absorbs moisture from the sub-soil layers and can withstand short period droughts. Its transpiration coefficient varies from 400 to 1000.

In fertile soil with an ample moisture supply, the plants tend to grow vegetative instead of producing flower buds. Moisture stress restrains vegetative growth and encourages early flowering. However, a satisfactory yield of fibre depends on the maintenance of proper balance between leaf area and boll production. Therefore, a planned moisture regime that will restrain vegetative growth without adversely affecting yield is essential.

Before squaring, when the assimilating surface is relatively small, the cotton plants do not consume much water, but during squaring and flowering, their water demand greatly increases, while during ripening declines. For rainfed crop it requires an annual rainfall of at least 500 mm well distributed throughout the growing season.

**Light**
Cotton is a sun loving plant and cannot tolerate shade, particularly, in the seedling stage. So, high light intensities throughout the growing period are essential for satisfactory vegetative development, for minimal shedding of buds and bolls and hence for high yields.

Reduced light intensity as a result of cloudiness and too dense population of cotton retards flowering and fruiting and increases boll shedding. In other words, reduced light intensity reduces the rate of boll-set and causes excessive vegetative growth. Cotton is a short day plant, but this has been lost in upland cottons which are neutral to day-length.

**Soil**

Cotton has a wide range of soil adaptation and is grown on a great variety of soils, but sandy, saline and waterlogged soils are not favorable for its growth and development. It is grown on sandy loam, clay loam, loam and alluvial soils. Heavy clays tend to delay maturity and increase vegetative growth, resulting in more insect and disease problems.

A soil with good moisture holding capacity is favorable for successful growth of cotton. Good drainage and aeration are also essential as the crop cannot withstand excessive moisture and waterlogging condition. The best soil pH for cotton is 5.8-6.5, but it is tolerant of wide pH (5.5-8.5) range.

**Varieties**

The principal requirements of cotton varieties are as follows: high yield, good quality of fibre and resistant to disease and pests.

The popular varieties of upland cottons (*G. hirsutum*) are Cocker 100, Acala-4-42, Acala-44, Deltapine (USA), Tashkent-1, Tashkent-6 and C-4727, 198 F (Former USSR). Long staple cottons are represented by strains like Giza, Sea-Island and Pimas.

In Nepal, Tamcot SP 37, H-777 and F.-1054 were cultivated of which Tamcot SP-37 was popular. At present H.-1098 and H-1054 are in cultivation.
Crop rotation

Cotton is a good preceding crop for most of the other crops. It does not exhaust the soil. It removes small amount of nutrients from the soil, whereas the crop residues add large amount of organic matter which enriches the soil.

Cotton ranks among those crops which produces good yields when raised continuously for some years. However, if grown continuously for a long period the yield decreases. Therefore, in different cotton growing countries this crop is alternated with perennial grasses such as lucerne (USA, former USSR), with annual legumes such as groundnut, soybean (India, Sudan, USA) and with cereal crops such as wheat (India).

In Nepal it is alternated with pigeon pea. In cotton Farm of Kumbher green manure crop (Daincha) is used in rotation which is followed by mustard in winter season. It is managed in such a way that in each plot the cotton is grown only for two years and in the third year it is cultivated with green manure crop (Daincha) in order to maintain soil fertility.

Field preparation

Cotton, being a deep rooted crop, requires well prepared seed-bed. After the harvest of preceding crop, the residues should be chopped and completely buried by ploughing. Crop residues that remain on the surface of the soil cause difficulties in seed-bed preparation, sowing and post emergence cultivation. Thus, the field preparation for cotton cultivation consists of a ploughing at a depth of 15-20 cm with mould board plough followed by 3-4 harrowing.

With local plough the field is ploughed four to five times and each ploughing is followed by planking to make the soil pulverized and leveled.

In the cotton Farm of Bardia district, the field is prepared by ploughing with disc ploughs followed by two harrowing. After ploughing and harrowing the field is leveled and ridged for sowing.

Seed and sowing
The requirements for cotton seeds are very high. They must have high germination capacity. Seeds with germination ability of less than 85 percent should not be used for sowing. Seeds of cotton are usually prepared by ginning and delinting.

**Ginning:** It is a mechanical separation of long fibres from the cotton seeds.

**Delinting:** It is the removal of fuzz from seeds. Delinting can be done mechanically in the cotton gin or by immersing the seeds in concentrated sulphuric acid. The acid delinting has the following advantages:

- Gives quicker and higher germination.
- Facilitates uniform sowing.
- Reduces seed rate.
- Makes easy to treat the seeds with fungicidal powders against seed-borne diseases.
- Helps in killing hibernating larvae in the seed.

**Sowing**

*Seed treatment* with fungicides like agrimycin or Agrosan GN at 2-3 g per kg of seed

**Time of sowing:** Timely sowing of cotton is the main factor to influence its yield. A delay in sowing results in later start of flowering and fruiting and reduction in the number of flowers and bolls produced. Moreover, it increases the maturation period of bolls in the regions where temperatures decline at the time of bolls ripening. Therefore, the sowing should be carried out within the most optimum time. The optimum sowing time should be selected in such a way that during the first half of vegetation the cotton plants could receive sufficient moisture and the ripening coincided with no rainfall or poor rain fall. In Nepal, cotton is a rainfed crop and the optimum time of its sowing starts from the last week of June to 1st week of July.

**Sowing methods:** Sowing is done generally by drilling the seeds in rows. Line sowing with seed drill is recommended in order to ensure uniform germination, better stand and easy inter cultivation. In Nepal it is done manually.
**Sowing depth:** Sowing depth is determined by soil type, moisture, temperature and seed vigour. In humid areas it is 2.5-4.0 cm and in drier areas it may go up to 8.0 cm. In our condition it is sown at a depth of 4-5 cm.

**Seed rate and spacing:** Seed rate varies according to the variety, its growth behavior, soil fertility and production practices. In our condition 20-25 kg of cotton seeds is recommended for sowing in one hectare. The standard distance between the rows in most countries with mechanized production of cotton is 90 cm. The plant to plant distance varies according to the plant population. In our country cotton is cultivated with the plant population of 35-55 thousands/ha at a spacing of 90 cm x 20-30 cm.
Nutrient management

Cotton plants being a heavy feeder needs proper manuring for its successful cultivation. During vegetative period the cotton plants do not absorb soil nutrients evenly. They utilize 3-5% of nitrogen and phosphorus and 2-3% of potash of the total seasonal intake of these nutrients during the period from emergence of seedlings to the formation of squares. With the formation of squares, the aerial parts of the plant grow rapidly and as a result of which the consumption of these nutrients elements increases. Thus, at this stage 20-30% of nitrogen and phosphorus and 15-20% of potash are taken up by the cotton plants. Later on during the period from flowering to the beginning of ripening about 65-70% of nitrogen and phosphorus and 75-80% of potash are utilized by them.

To achieve high yield an abundant supply of nitrogen is essential until maximum growth is obtained and in later stages a reduced supply of it’s provides satisfactory and uniform maturation. Deficiency of nitrogen produces, chlorosis, meager (poor) growth and increases boll shedding. It reduces the number of fruiting branches considerably and as a result, the number of flowers and fruits is also reduced.

The main specific effect of phosphorus application on cotton is in increasing the earliness of the crop. It assists to increase boll weight, number of seeds per boll and percent of matured bolls at the first picking. Phosphorus deficiency produces dark green leaves and causes delayed flowering and fruiting and shedding of bolls.

Potassium assists to increase the boll number, size of the bolls, seed-cotton yield and fineness of the fibre. With potassium deficiency in soil the leaf becomes pale-yellowish green latter on, the entire leaves become reddish brown, dries and fall off. The premature senescence of the leaves prevents normal development and maturation of the bolls, reduces fibre quality and stem becomes weak and lodges easily.

Farmyard manure or compost is applied better conservation of moisture in the soil as per availability around 15-20 days before crop sowing. In Nepal, cotton is cultivated with the application of 60 kg N, 40 kg of P₂O₅ and 20 kg of K₂O per ha.

All quantity of phosphorus and potash is applied at sowing. Usually (rainfed condition) application of major amount of nitrogen at sowing and the remaining at squaring stage results in balanced vegetative growth, better fruiting, bigger bolls and higher yield.
In Nepal, 66% of the total amount of nitrogen and whole dose of phosphorus and potash are applied at the stage of 3-4 true leaves after thinning. The sources of their application are DAP, Urea and MOP. The remaining dose of nitrogen is side-dressed at squaring stage through urea.

The best results are obtained by applying the fertilizers in bands 5 cm wide, 5-7 cm from the seed-row and approximately 5 cm below the seeding level. In Nepal, fertilizers are recommended to apply at a distance of 8-10 cm from the seed-row and at the same depth from the soil surface.

**Plant management**

Plant management in cotton cultivation consists of soil structure maintenance for optimum air admission, regulation of plant stand (thinning, resowing and gap filling), water and nutrition regimes (irrigation and side-dressing) and weed control.

The rain induced crust is destroyed by rotary hoes. The row spacing is loosened immediately after appearance of sprouts on soil surface. Further, the number of row spacing cultivation depends upon the number of irrigation. Each irrigation should be followed by row spacing cultivation. The row spacing cultivation after heavy rainfall is also essential to preserve moisture and provide good aeration.

The gap between the plants should be filled immediately after sprouting with water soaked seeds. In case of excess seedlings, the thinning should be carried out at the stage of two-three true leaves.

For obtaining high yield the soil moisture should be maintained at the level of at least 70% of the field capacity before ripening and 60% during ripening. The crop should not be allowed to suffer from water stress during flowering and fruiting periods, otherwise, excessive shedding of squares and young bolls may occur resulting in loss of yield. During vegetation period the crop is irrigated at different stages: before flowering, during flowering and fruiting and during ripening. The total number of irrigation may vary from 4 to 6 depending upon the region and technology of cotton cultivation.

Cotton is highly sensitive to weed competition especially during the initial stage of growth. Weed-crop competition in cotton in early stages is chiefly for light. Hence control of weeds either by manual labor or by using weedicides in essential to achieve good yields.
The critical period of weed infestation is 20-40 days after sowing. Weed control is done either by manual or by herbicides is essential to get good yields. Dry hoeing with a hand hoe or spade 5-6 weeks after sowing is very effective in controlling the weeds. Herbicide control will be very effective if we used Baseline @ 1 kg a.i/ha or Diuron @ 0.5 kg a.i./ha in 1000 lit of water as a pre planting spray.

**Topping**

The removal of the tip of the main stem, alone or together with tips of other branches, a few weeks before the bolls begin to open is a practice known as topping or pruning. The main purpose of topping is to ensure a redistribution of the nutritive substances in the plants.

Two types of topping are used:
- Ordinary top pruning or topping
- Drastic top pruning.

In the ordinary top pruning the tips of the main-stem and the vegetative branches are removed where as in drastic pruning the tips of the main stem, vegetative branches and all fruiting branches are removed. The latter method causes a sharp reduction in the shedding of buds and bolls, reduces lodging and increases yield.

**Defoliation**

Defoliation induces abscission (separation) of the cells where the leaves are attached to the branches. Most of the leaves drop off within a few days after treatment. Luxuriant foliage at the time of boll ripening causes delayed maturation. Therefore, the use of defoliants at this stage assists to expose bolls and lint to sunshine and air movement and thereby facilitates a uniform and rapid maturation and drying of the lint. Furthermore, at this stage, the leaves make no further contribution to the lint yield and their removal has not adverse effect on lint qualities.

At least 60% of the bolls should be opened when defoliants are applied, because bolls and fibre development are checked when the leaves are removed or killed. The chemicals used for defoliation are Magnesium Chlorate Hexahydrate (8-12 kg/ha, 58-60% a. i.) and Butiphos (0.6-1.8kg/ha, a.i. 70% EC)

**Desiccation**
It causes rapid death of the leaves as a result of which they dry and break off. Thus desiccants are more drastic than defoliants in their effect on plant development and are therefore applied only after 10-12 days of defoliation.

**Harvesting**

The cotton plants take 2-3 months for the maturation of their bolls. Therefore, cotton is picked 3-4 times in case of hand picking and 2-3 times in mechanized harvesting. The first hand picking is recommended when about 30-40% of the total bolls are opened (dehiscent), the second-when 30-40% of the bolls left after 1st picking open and the third after two-three weeks of the second picking.

**Practical 6: Branching and flowering in cotton**

**Practical 7: Characteristics of cotton species**

**Practical 8: Calculation related to seed requirement and yield estimation of cotton**

**Practical 9: Classification and morphological characteristics of cotton**