SCIENTIFIC SUGARCANE CULTIVATION

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(Indian Council of Agricultural Research)
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Preface

Sugarcane is the second important industrial crop in the country occupying about 5 million hectares in area. Over 5 million farmers are involved in the cultivation of sugarcane. Sugar industry contributes significantly to the rural economy as the sugar mills are located in the rural areas and provide large scale employment to rural population. India is the largest consumer and second largest producer of sugar. The sugar requirement is expected to grow substantially in the coming years due to the population growth coupled with increase in per capita consumption. Sugarcane is also emerging as a multi-faceted crop contributing to the production of sugar, ethanol, electricity, paper and other allied products. Consequently, the overall demand for sugarcane for its varied uses will increase significantly. However, the area under the crop is not likely to increase and the increased demand for sugar is to be met only through the vertical growth in sugarcane productivity and sugar recovery. Thus, the sugar sector demands not only increase in sugarcane production but stability as well as for its sustained growth.

The growth in cane area and sugar production in the country during the last eight decades had been spectacular. There had been a nearly fivefold increase in cane area and tenfold increase in sugarcane production during the period. This growth is largely attributable to the development of superior varieties and improved technologies for crop management. Sugarcane productivity limiting factors are biotic and abiotic stresses, declining soil fertility due to continued monocropping of sugarcane for several decades, depletion of natural resources, the high cost of production and climate change. The current average productivity in the country is hardly 25% of the theoretical yield potential of the crop. The challenges in improving productivity include unfavourable climatic conditions under which the crop is grown in subtropical India.

Training programs help in human resource development and ultimately result in transfer of latest technologies from research organizations to the fields. The National Level Training Programmes organized by the Institute, with the assistance from the Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India would be fruitful in achieving its objectives of educating cane development staff of sugar industry about every aspects of sugarcane agriculture.

The book is a collection of chapters written by various scientists. The contributions of each Scientist towards the preparation of this book are gratefully acknowledged. I am sure this book would be a useful reference for cane development personnel.

Coimbatore,
8 December 2014

Bakshi Ram
Director
Production scenario

India is the second largest producer of sugar after Brazil. India’s sugar production during 2013-14 was 24.55 million MT which is expected to increase by 4% to 25.59 million MT in the 2014-15 crushing season. With an estimated opening balance of sugar of around 7.5 million tonnes, as on October 1, 2014 and sugar production as estimated above, there will be sufficient sugar to take care of domestic requirement (ISMA, 2014). India’s share in world sugar production was 15.30% in 2012-13 and 15.20% in 2013-14.

Sugarcane is grown in 3.0% of the total cultivable area of India, contributing 7.5% gross value of agricultural production. Sugarcane acreage during 2013-14 was 5.01 million hectare which is 13,000 hectare lesser than 2012-13 acreage. According to the latest estimates released by the Directorate of Economics & Statistics, Ministry of Agriculture (Oct 2014), sugarcane acreage in 2014-15 season is 4.87 million hectares. Sugarcane production during 2013-14 was 350.02 million tonnes which is projected lower by 2% at 342.8 million tonnes in 2014-15 sugar season (Oct 14-Sept 15) (Source: DAC’s 1st advance estimate dt 19.9.2014). During 2013-14, Uttar Pradesh holds the largest share in acreage (44.14% of India’s cane area), followed by Maharashtra (19.02%) and Karnataka (8.33%). These three States together accounted for 71.49% of the cane area of the country. Sugarcane production was the highest in U.P. (38.56% of India’s production), followed by Maharashtra (21.79%), Tamil Nadu (10.85%) and Karnataka (10.02%). Nonetheless, sugar production was the highest in Maharashtra (32.20% of the total sugar production in the country) than U.P (26.96%) due to high recovery rate in Maharashtra and relatively higher diversion of cane to gur and khandsari production in Uttar Pradesh. Karnataka is the 3rd major contributor of sugar production in India (17.07% of the total sugar output), due to its high recovery and rising profitability of sugarcane in the State.

During the year 2013-14, countries like Philippines, Peru, Ethiopia, Egypt and Guatemala realized >100 tonnes sugarcane yield per hectare. But the average cane yield/ha in India has remained stable at 68.3 t/ha (in 2012-13) to 69.8 t/ha in 2013-14. During 2013-14, sugarcane yield in high productivity zone (>70 t/ha) like Tamil Nadu, Karnataka, Andhra Pradesh, Maharashtra and Gujarat ranged from 72.1 t/ha to 96.9 t/ha with an average of 82.1 t/ha. The range of cane yield in medium productivity zones (50-70 t/ha) like Haryana, Jharkhand, Punjab, Rajasthan, Uttar Pradesh, Odisha, Uttarakhand and Bihar was 56.8 t/ha to 73 t/ha with the mean of 65.4 t/ha. In low productivity zones (< 50 t/ha) like Madhya Pradesh, Assam and Chhatisgarh the yield level was 27.3 t/ha to 42.2 t/ha (average=35.6 t/ha). As in the previous years, the productivity of subtropical States has remained lower (60.3 t/ha) than tropical States (67.9 t/ha). Cane yield in India is higher than our neighbouring countries like Pakistan (46.7 t/ha), Bangladesh (40.5 t/ha), Nepal (45.4 t/ha), Sri Lanka (53.8 t/ha) but lower than Indonesia (74.88 t/ha), Brazil (75.16 t/ha) and Australia (82.4 t/ha).
Countries like Australia has been realizing 12-14% sugar recovery. Brazil, South Africa and United States are obtaining 11-12% recovery as against 10.26% (2013-14) in India. The average recovery percentage in India during the past five years remained static around 10.2 to 10.6. There is a vast difference in the recovery percentage from one State to another and even from factory to factory in a State. The sugar recovery in the high recovery zone (>10%) like Maharashtra, Gujarat, Karnataka and Madhya Pradesh ranged from 10.64 to 11.42, with an average recovery of 11.05%. In the low recovery zone (<9%), the recovery was 8.18% in Rajasthan and 8.34% in West Bengal and 8.48% in Bihar and the average was 8.49%. This is a great concern for the industry. In the medium recovery States (9-10%) like Haryana, Jharkhand, Punjab, Rajasthan, Uttar Pradesh, Odissa, Uttarakhand the recovery was 9.22% to 9.88 with an average of 9.47%. The recovery in the subtropical region during 2013-14 season was as usual low (8.86%) in comparison to tropical region recovery (9.81%).

The cost of sugarcane cultivation in the country is increasing steadily. The total cost of cultivation is worked out to be Rs. 67,396 /ha in Uttarakhand, Rs. 78,549/ha in U.P., Rs. 97,411/ha in Karnataka, Rs. 1.11 lakh/ha in Haryana, Rs. 1.24 lakhs/ha in A.P., 1.347 lakh/ha in Tamil Nadu and Rs. 1.47 lakh/ha in Maharashtra. About 22-25% cost of cultivation goes to harvest and transport alone. The labour cost for harvest has increased from Rs. 225-450 per ton in 2010-11 to Rs. 500 to 650 per ton in 2013-14. Non-availability / scarcity of labour at the time of sugarcane harvesting and planting is a serious problem than labour cost per se. Mechanization is the way forward to reduce the labour cost. High cost of production, low yield of sugarcane, high sugar price and the non-availability of labour for planting, weeding, earthing up, propping and harvest are the major concerns of cane growers in the country.

Industry scenario

There of 702 installed sugar industries in India (43 in public sector, 324 in co-operative sector and 335 in private sector). The number of sugar mills functioned during 2012-13 crushing seasons was 526 but it reduced to 520 during 2013-14 crushing season. Four mills in Maharashtra, two each in A.P. and U.P., one each in Punjab, T.N. and W.B. did not function in 2013-14, but at the same time there were new mill came into operation in Dadra & Nagar Haveli and M.P. (1 each) and Gujar a (2 mills). About 50 million cane growers and 5 lakh workers derive their livelihood from sugar sector. The annual output of India’s sugar industry is estimated to be Rs. 80,000 crores. The domestic requirement of sugar in 2014 was 23 million tonnes and projected requirement in 2030 is 36 million tonnes i.e. 50% higher than the present production. To achieve this target, sugarcane production should reach to 350 million tonnes, productivity should be improved to 90 t/ha and sugar recovery to 11%.

The Govt of India has hiked the Fair and Remunerative Price (FRP) from Rs. 210/q in 2013-14 season to Rs. 220 /q for 2014-15 crushing season linked to a basic recovery rate of 9.5% and premium of Rs. 2.21 per quintal for every 0.1 percentage point increase in recovery above that level. The SAP declared by the State Govt for 2013-14 crushing season varied from Rs. 240/q in Karnataka, Rs. 265/q in Tamil Nadu, Rs. 275 to 290/q in U.P., Rs. 280 to 295/q in Punjab and Uttarakhand and Rs. 290-301/q in Haryana.

The Central Government has considered the recommendations of Dr. C. Rangarajan Committee on de-regulation of sugar sector and decided to do away with levy obligation on
sugar mills for sugar produced after September 2012 and dispense with the regulated release mechanism on open market sale of sugar. The recommendations of the Committee relating to Cane Area Reservation, Minimum Distance Criteria and adoption of the Cane Price Formula have been left to the State Governments for adoption and implementation, as considered appropriate by them.

Diversification of sugar industries by-products is needed to keep the industry vibrant and viable. Govt of India has allowed 5% doping of ethanol with Petrol for running motor vehicle. Molasses is the cheapest feedstock for the distilleries. Presently, 152 ethanol plants are attached to sugar mills, with the capacity to produce 7,306 Kilo Lit alcohol /day. Cogeneration using bagasse is viewed as another option. The installed capacity of cogeneration plants in India is 3200 MW/day but the potential worked out to be around 5,000 MW/day. Sugarcane bagasse has comparable fibre properties as that of wood pulp. About 10% of the bagasse bulb has been used as substitute for wood pulp in paper industry in China, South America, Thailand and also in India but increased R&D efforts are needed in this direction.

**Varietal scenario**

About 30 research stations in India are engaged in sugarcane varietal improvement.
programme. The ICAR-Sugarcane Breeding Institute at Coimbatore and its Regional Centres in different States of India is playing pivotal role in sugarcane improvement in the country since its inception in 1912. During the period from 1918 to 2013, a total of 520 sugarcane varieties were evolved and released by SBI and other research institutions for commercial cultivation in India. This includes 319 varieties for the subtropical region and 201 varieties for the subtropical states. Varietal scenario in different States of India during the year 2013-14 is depicted in Fig 1-8.

Since 2000-01 a number of sugarcane varieties were released by the ICAR institutes and SAUs. A partial list of recently released varieties (after 2000-01) are given below.


b) **New varieties for Subtropical States**: BO 145, BO 146, BO 147, BO 153, Co 0118, Co...
Various trials conducted under the All India Coordinated Research Programme on Sugarcane has shown that the newly evolved varieties showing cane yield improvement in the range of 10.31 to 12.50 per cent over the existing standards and quality improvement in the range of 1.56-1.82 per cent sucrose in comparison to the respective group local standards (Table 1). Therefore, these varieties have to be promoted for commercial cultivation in the respective zone.

| Table 1 | Percent improvement of cane yield, sucrose% and CCS yield of newly released varieties over the standard varieties in AICRP (S) trials |
|-------------------------------|---------------------------------|------------------|------------------|
| **Category**                  | **Cane yield**                  | **Sucrose (%)**  | **CCS yield**    |
| Tropical Varieties            | 10.31                           | 1.82             | 13.33            |
| Sub-tropical Varieties        | 12.50                           | 1.56             | 12.87            |

In low sugar recovery states like Bihar, U.P. and Uttarakhand special attention is to be given to varietal composition. Among other causes, varietal decline and depletion of soil fertility have resulted in yield and low recovery. In Uttarakhund unapproved varieties like Co 1148, CoP 1216, CoP 1215, UP 39, UP 97, CoS 7918, etc have occupied 2.2% of the total cane area. An unpleasant situation in Uttar Pradesh is that a large number of un-approved or rejected varieties are still occupying 15% of the total cane area in the State. Some of the varieties have completed a life span of 20 years and above (Co 1148-completed 51 years in 2013 from its release in 1962, CoS 687 (36 years), BO 91 &CoS 7918 (31 years), CoLk 8102 (22 years) and CoS 91269-completed 20 years). Therefore, there is a need for replacement of such rejected varieties through intensive extension activities, supply of seeds of new varieties, etc.

**Seed cane scenario**

About 11.9% of the total sugarcane production in the country is being utilized for seed and chewing purpose. However, the seed replacement rate either with disease free quality planting materials or with tissue culture materials or with seeds of improved varieties appears to be low. It is another concern today. The normal practice in many parts of the country is to use commercial crop of sugarcane for seed purpose. Sugarcane is a vegetatively propagated crop. It tends to accumulate diseases very quickly during the course of cultivation. Therefore, quality planting materials assumes importance to sustain yield and soil health. Many sugar mills in South are following the three tier seed nursery programme comprising of primary, secondary and commercial nurseries but it has to pick up in large way in North. In the absence of seed nursery programme, the sugar mills can adopt seed village concept, where the entire village is declared as seed village, the quality of seed materials is monitored with the help of scientists from research stations. Sugarcane seed is bulky in nature and different classes of
seeds are not maintained. Once in a cycle of 5-6 years, planting materials for seed crop should be drawn from heat treated setts or tissue culture derived cane. The tissue culture techniques particularly the meristem culture combined with virus indexing can be used for multiplication of newly developed varieties and rejuvenation of old varieties which are under cultivation. At ICAR-SBI, Coimbatore virus indexed tissue culture seedlings and mother culture flask of improved sugarcane varieties are being produced and distributed to farmers and sugar mills. Bud chip technology is another ways of faster multiplication of seed cane.

Productivity related constraints in recent years

Some of the biotic and abiotic factors that caused constraints in improving sugarcane productivity in the recent years are listed below.

(1) Drought: In some cane growing states particularly in Tamil Nadu, Karnataka and Maharashtra, rainfall was either below normal during 2012 and 2013 or the distribution was not even and this coupled with delay in the onset of monsoon during 2014-15 crop season resulted in moderate to severe drought conditions. Five scientific teams from ICAR-SBI, Coimbatore have surveyed the drought affected sugarcane growing areas in Tamil Nadu, Karnataka ad Maharashtra during July-Aug 2014. Mild to severe drought was observed in the surveyed area. The sugarcane area was reduced to 22-30% in Mandya and Chamrajnagar districts (Karnataka) and the estimated yield reduction (during the current crop season) in the drought affected field would be 50-60%. In few places in Northern Karnataka, there was total drying of the crop. In North Tamil Nadu, many farmers were unable to irrigate the crop (even through drip) as the irrigation sources were dried. Plant crop of 4-6 month age ratoon crops of 4-5 month were affected in North, West and South Tamil Nadu. Ratoon crop suffered severe setback than plant crop. This may affect the supply of sugarcane for 2014-15 crushing season. Seed crop supply would also be affected. To mitigate the drought effects on sugarcane, early planting (Nov-Jan), close spacing, higher seed rate, sett treatment in saturated lime solution, drought tolerant varieties such as Co 86032, Co 99004, Co 99006, Co 2001-13, Co 2001-15, Co 0403, Co 91012, Co 96012, Co 96020, Co 97008, CoC 22, CoC 24, CoG5, CoSi 7, CoV 94012, trash mulching, skip or alternate furrow irrigation, surface or subsurface drip, deep trench system of planting, foliar application of urea+potash (twice @ 2.5%) or soil application of additional dose of potash (20 kg/acre) wherever possible, may be adopted. Despite the vagaries of monsoon and deficiency in rains, resulting in lower acreage of sugarcane in 2014-15 crop season, sugar output is estimated to rise by a marginal 4 per cent in the 2014-15 crushing season.

(2) The incidence of pest and diseases: Sugarcane woolly aphid has appeared / re-appeared in parts of Belgaum district, Bhadra canal areas, Cauvery basin in southern Karnataka, parts of Tamil Nadu and Assam. Sporadic incidence of root borer was reported from Punjab and Haryana. White grub problem was found in parts of Haryana, Uttar Pradesh, SouthernKarnataka and Dharmapuri district of Tamil Nadu. The incidence of yellow leaf disease is continue to be a concern in States like Andhra Pradesh, Gujarat, Tamil Nadu and Karnataka although the yield loss could not be ascertained accurately. During 2014-15 crop season, the incidence of Pokkahboeng was observed not only in subtropical states like Haryana, Punjab, U.P. but also in the tropical states like Maharashtra and Tamil Nadu.
(3) **Soil related issues:** Cultivation of sugarcane year after year in the same soil will lead to nutritional imbalance. Decrease in soil organic carbon, microbial activity in rhizosphere were reported from Philippines and Brazil. In India, 4.5 to 7.9% loss in cane yield was reported due to soil degradation. Excess nitrogenization (unbalanced application of N alone) is another concern. Micronutrient deficiency particularly Fe, Zn, Mo were reported from Northern Karnataka and parts of Tamil Nadu. In peninsular zone, sugarcane response to Sulphur nutrition was observed. This matter is being investigated to evolve suitable INM packages. Quality of irrigation water is deteriorating and water table depth is also going down. Water quality will influence soil and crop health. Therefore, wherever poor quality irrigation water is available, its suitability for sugarcane, particularly for drip irrigation, must be assessed prior to cultivation of sugarcane.

(4) **Intercropping:** Several studies have indicated the complementary role of intercropping in sugarcane. Location specific intercrops have been identified by SAUs and ICAR institutes. Vegetable soybean, black gram, cowpea, ground nut, daincha, sunhemp, etc are suitable for tropical states whereas wheat, potato, green gram, garlic, gram, lentil, sarson, cole vegetable, etc are suitable for subtropical states. Intensive extension efforts are needed to create awareness among farmers regarding intercropping.

(5) **Planting methods:** Attention has been paid to promote trench planting system in subtropical States and Sustainable Sugarcane Initiative (SSI) method in tropical States. The coverage of SSI method in Tamil Nadu was 4,299 ha in 2013-14. However, trench planting system in the subtropics requires fine tuning.

(5) **Mechanization:** Several models of sugarcane chopper harvesters have been investigated by research stations and sugar industry both in tropical and subtropical states. The John Deer CH330 and New Holland 4000 plus are working satisfactorily in red or medium black soil with 5’ and 4’ row spacing, respectively in tropical states but may not so in the subtropical States. Wherever, SSI method or wider row spacing is followed, harvester can be engaged on hire basis. The operational cost of mechanical harvest was worked out to be Rs. 115 to 180 per MT in Tamil Nadu, Karnataka and Maharashtra (but vary with locations) and there was a saving of Rs. 20 to 80 per MT as compared to manual harvesting.

**New trend in research**

(1) Field testing of drought resistant GM sugarcane was started in South America and Java. Transgenic sugarcane carrying Cry 1Ab gene, genes coding for aprotinin were produced at ICAR-SBI during 2010-11 for resistance against top borer, ESB. But due to ban on field test, field test could not be done. Recently, drought and salinity tolerant genes was incorporated in sugarcane variety and pot experiment is in progress.

(2) Sugarcane is a water intensive crop. The water requirement varies from 1200-1800 mm in subtropical belt to 1600-2700 mm in tropical belt. On an average 25-30 irrigation is required for 10-12 month duration crop. Surface and sub-surface drip irrigation is recommended but it is not picking up on large scale due to high investment and other reasons. At SBI research has been initiated to identify water use efficient sugarcane clones.
The concept of energy plantation in sugarcane is being investigated at ICAR-SBI Coimbatore. Type I and Type II energy canes evolved at SBI are being tested in sugar mill and paper industries in peninsular zone. Type II energy canes were specifically bred for high biomass yield, with high fibre and low sucrose and will be exclusively used for energy generation and production of cellulosic ethanol. The Type I energy have average sucrose with moderate to high fibre, the juice can be used in distilleries for direct fermentation and fibre for cogeneration.

The ONGC, India has signed an MoU in October 2013 with Chempolis Ltd, a Finland based biorefining technology company, for a biorefinery project in India. Chempolis and ONGC are targeting production of biofuels in India especially from sugarcane.

In Brazil Petrobras, Brazilian Sugarcane Technology Centre CTC and GraalBio have been engaged in the development of second generation cellulosic ethanol from sugarcane bagasse.

Conclusion

The ICAR-Sugarcane Breeding Institute has contributed immensely towards the growth and expansion of sugarcane cultivation and sugar industry by developing sugarcane varieties and production-cum-protection technologies. The varieties developed by the institute and in collaboration with the SAUs through the national hybridization garden are occupying more than 95% of the total sugarcane area in the country. With the availability of OMICS technology in the genomics era of modern plant breeding, sugarcane research has undergone rapid transformation. To harness the benefit of the technology linking modern techniques with the conventional breeding is essential in sugarcane to meet the growing demand of sugar in future. The improved technological intervention, mechanization and agronomic practices for sugarcane cultivation along with R&D support for suitable alternative may facilitate Indian sugar sector with required thrust.
2. **SUGARCANE VARIETIES SUITABLE FOR DIFFERENT STATES**

G. Hemaprabha

Variety is a major input in sugarcane agriculture. The improved sugarcane varieties developed through organized breeding programme, that started a century back, played a major role in increasing the sugarcane productivity in all the cane growing countries. For planning a successful varietal development programme in sugarcane, breeders should be equipped with the information on the species and speciation in *Saccharum*.

**Varietal Improvement Programme of All India Coordinated Research Project on sugarcane - AICRP(s)**

The need for a proper location specific breeding programme was felt by the breeders in order to address these problems and augment outflow of varieties suited to the specific agroclimatic conditions. This new national strategy took place in the form of a breeding programme called Fluff Supply Programme initiated in 1972 under All India Co-ordinated Project on Sugarcane. Coimbatore was chosen for hybridization work due to its geographical location (77° E longitude and 11° N latitude) ideal for natural flowering and satisfactory seed set. Flowering in sugarcane is seasonal and occurs annually during the short days of late autumn and early winter. It is under both genetical and environmental control. A National Hybridization Garden under All India Co-ordinated Programme of Sugarcane was the highlight of this programme in order to house parental clones of sugarcane research centres to serve as parents in hybridization. Ever since the inception of the programme, NHG is

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Zones</th>
<th>Locations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>North West Zone</td>
<td>Faridkot (Punjab), Karnal (Haryana), Kota (Rajasthan), Lucknow (U. P.), Ludhiana (Punjab), Muzaffarnagar (U.P.), Pantnagar (Uttarakhand), Lucknow (U.P.), Shahjahanpur (U.P.), Sriganganagar (Rajasthan), Uchani (Haryana)</td>
</tr>
<tr>
<td>2.</td>
<td>North Central Zone</td>
<td>Bethuadahari (West Bengal), Gorakhpur (U.P.)Motipur (Bihar), Pusa (Bihar), Seorahi (U.P.)</td>
</tr>
<tr>
<td>3.</td>
<td>North Eastern Zone</td>
<td>Burliksion (Assam)</td>
</tr>
<tr>
<td>4.</td>
<td>East Coast Zone</td>
<td>Anakapalle (Andhra Pradesh), Cuddalore (Tamil Nadu), Nellikuppm (Tamil Nadu), Panipoila (Orissa), Perumallapalle (Andhra Pradesh), Vuyyuru (Andhra Pradesh)</td>
</tr>
<tr>
<td>5.</td>
<td>Peninsular Zone</td>
<td>Coimbatore, Sirugamani, Pugalur (Tamil Nadu), Kolhapur, Padegaon, Pune Pravaranagar (Maharashtra), Powarkheda (Madhya Pradesh), Navsari (Gujarat), Rudrur (Andhra Pradesh), Mandya, Sameerwadi, Sankeshwar (Karnataka), Thiruvalla (Kerala)</td>
</tr>
</tbody>
</table>

Table 1. Zones for testing sugarcane under AICRP and the locations of testing
catering to the varietal development programme in a broader perspective. This gene-pool is a reservoir of yield, quality, and resistance to biotic and abiotic stresses. At present a total of 22 research centers located in almost all major sugarcane regions of the country take part in the sugarcane breeding programmes and identify new clones for testing in different locations of five agroclimatic zones under the AICRP(S). These centres are given in Table 1.

**Varieties identified through AICRP testing**

The All India Coordinated Research Project (Sugarcane) plays a role in the identification of location specific and zone specific varieties and release of varieties through Central Varietal Release Committee for different zones cutting across state boundaries. The improved varieties developed through this decentralised breeding programme involving research centres at different parts of the country, with Coimbatore as a pivotal centre for making crosses, compliments the varietal needs of the country and to maintain the profitability of sugarcane cultivators and sugar industry. Varietal testing programme at most of the sugarcane stations has identified several varieties with wider adaptability in the specific zones and have been notified for commercial cultivation by the Central Sub-Committee on Crop Standards, Notification and Release of Varieties for Agricultural Crops, Government of India. Table 1 gives the details of varieties released in different agroclimatic zones for cultivation.

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Variety</th>
<th>Year of identification/notification</th>
<th>Cane yield (t/ha)</th>
<th>Sucrose (%)</th>
<th>Maturity group</th>
<th>Reaction to diseases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peninsular Zone</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Co 85004 (Prabha)</td>
<td>1991/2000</td>
<td>90.5</td>
<td>19.5</td>
<td>Early</td>
<td>R to smut</td>
</tr>
<tr>
<td>2</td>
<td>Co 94008 (Shyama)</td>
<td>2002</td>
<td>119.8</td>
<td>18.3</td>
<td>Early</td>
<td>MR to smut</td>
</tr>
<tr>
<td>3</td>
<td>Co 8371 (Bhima)</td>
<td>1997/2000</td>
<td>117.7</td>
<td>18.6</td>
<td>Midlate</td>
<td>R to smut</td>
</tr>
<tr>
<td>4</td>
<td>Co 86032 (Nayana)</td>
<td>1994/2000</td>
<td>102.0</td>
<td>20.1</td>
<td>Midlate</td>
<td>R to smut</td>
</tr>
<tr>
<td>5</td>
<td>Co 87025 (Kalyani)</td>
<td>1994/2000</td>
<td>98.2</td>
<td>18.3</td>
<td>Midlate</td>
<td>R to smut</td>
</tr>
<tr>
<td>6</td>
<td>Co 87044 (Uttara)</td>
<td>1994/2000</td>
<td>101.0</td>
<td>18.3</td>
<td>Midlate</td>
<td>R to smut</td>
</tr>
<tr>
<td>7</td>
<td>CoM 88121 (Krishna)</td>
<td>1997/2000</td>
<td>88.7</td>
<td>18.6</td>
<td>Midlate</td>
<td>-</td>
</tr>
<tr>
<td>8</td>
<td>Co 91010 (Dhanush)</td>
<td>1999/2000</td>
<td>116.0</td>
<td>19.1</td>
<td>Midlate</td>
<td>R to smut</td>
</tr>
<tr>
<td>9</td>
<td>Co 99004 (Damodar)</td>
<td>2006</td>
<td>115.5</td>
<td>19.54</td>
<td>Midlate</td>
<td>MR to red rot, drought</td>
</tr>
<tr>
<td>10</td>
<td>Co 2001-13 (Sulabh)</td>
<td>2009</td>
<td>108.59</td>
<td>19.03</td>
<td>Midlate</td>
<td>MR to red rot, drought</td>
</tr>
<tr>
<td>11</td>
<td>Co 2001-15</td>
<td>2009</td>
<td>108.18</td>
<td>18.90</td>
<td>Midlate</td>
<td>MR to red rot, drought</td>
</tr>
<tr>
<td>12</td>
<td>Co 0218</td>
<td>2010</td>
<td>104.53</td>
<td>20.63</td>
<td>Midlate</td>
<td>MR to red rot, drought</td>
</tr>
<tr>
<td>Sl. No</td>
<td>Variety</td>
<td>Year of identification/notification</td>
<td>Cane yield (t/ha)</td>
<td>Sucrose (%)</td>
<td>Maturity group</td>
<td>Reaction to diseases</td>
</tr>
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</tr>
<tr>
<td>13</td>
<td>CoM 0265</td>
<td>2010</td>
<td>116.6</td>
<td>18.85</td>
<td>Midlate</td>
<td>Tolerant to drought, salinity</td>
</tr>
<tr>
<td>14</td>
<td>Co 0403</td>
<td>2012</td>
<td>101.5</td>
<td>18.16 at 300 days</td>
<td>Early</td>
<td>MR to red rot, drought</td>
</tr>
<tr>
<td>15</td>
<td>Co 06027</td>
<td>2013</td>
<td>111.3</td>
<td>19.05</td>
<td>Midlate</td>
<td>MR to red rot, drought</td>
</tr>
</tbody>
</table>

**East Coast Zone**

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Variety</th>
<th>Year of identification/notification</th>
<th>Cane yield (t/ha)</th>
<th>Sucrose (%)</th>
<th>Maturity group</th>
<th>Reaction to diseases</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Co 86249 (Bhavani)</td>
<td>1997/2000</td>
<td>104.2</td>
<td>18.7</td>
<td>Midlate</td>
<td>R to Smut and Red rot</td>
</tr>
<tr>
<td>2</td>
<td>CoC 01061</td>
<td>2006</td>
<td>110.8</td>
<td>17.4</td>
<td>Early</td>
<td>Tolerant to drought, MR to red rot, suitable for co-generation</td>
</tr>
<tr>
<td>3</td>
<td>CoA 92081 (Viswamitra)</td>
<td>2009</td>
<td>125.0</td>
<td>19.5</td>
<td>Early</td>
<td>Tolerant to drought, resistant to red rot</td>
</tr>
<tr>
<td>4</td>
<td>Co 06030</td>
<td>2013</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

**North West Zone**

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Variety</th>
<th>Year of identification/notification</th>
<th>Cane yield (t/ha)</th>
<th>Sucrose (%)</th>
<th>Maturity group</th>
<th>Reaction to diseases</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CoPant 90223</td>
<td>2000</td>
<td>73.3</td>
<td>18.5</td>
<td>Midlate</td>
<td>R to smut, MR to red rot, tolerant to drought, cold and waterlogging, excellent ratooner</td>
</tr>
<tr>
<td>2</td>
<td>CoS 01230 (Raseeli)</td>
<td>2000</td>
<td>68.2</td>
<td>18.8</td>
<td>Midlate</td>
<td>MR to red rot, tolerant to Top borer, shoot borer and stalk borer</td>
</tr>
<tr>
<td>3</td>
<td>CoH 92201 (Haryana-92)</td>
<td>2001</td>
<td>70.0</td>
<td>18.2</td>
<td>Early</td>
<td>MR to red rot</td>
</tr>
<tr>
<td>4</td>
<td>CoS 95255 (Rachna)</td>
<td>2004</td>
<td>70.5</td>
<td>17.5</td>
<td>Early</td>
<td>MR to red rot, excellent ratooner</td>
</tr>
<tr>
<td>5</td>
<td>Co 98014 (Karan 1)</td>
<td>2007</td>
<td>76.3</td>
<td>17.6</td>
<td>Early</td>
<td>Tolerant to drought, water logging, MR to red rot</td>
</tr>
<tr>
<td>6</td>
<td>CoS 96268 (Mithas)</td>
<td>2007</td>
<td>69.8</td>
<td>17.9</td>
<td>Early</td>
<td>MR to red rot, good ratooner</td>
</tr>
<tr>
<td>7</td>
<td>CoS 96268 (Mithas)</td>
<td>2007</td>
<td>69.8</td>
<td>17.9</td>
<td>Early</td>
<td>MR to red rot, good ratooner</td>
</tr>
<tr>
<td>8</td>
<td>CoS 94270 (Sweta)</td>
<td>2006</td>
<td>81.5</td>
<td>17.1</td>
<td>Midlate</td>
<td>MR to red rot</td>
</tr>
<tr>
<td>Sl. No</td>
<td>Variety</td>
<td>Year of identification/notification</td>
<td>Cane yield (t/ha)</td>
<td>Sucrose (%)</td>
<td>Maturity group</td>
<td>Reaction to diseases</td>
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<tr>
<td>9</td>
<td>CoPant 97222</td>
<td>2007</td>
<td>88.2</td>
<td>18.2</td>
<td>Midlate</td>
<td>Tolerant to drought, waterlogging, salinity, MR to red rot</td>
</tr>
<tr>
<td>10</td>
<td>CoH 119</td>
<td>2005</td>
<td>82.8</td>
<td>17.5</td>
<td>Midlate</td>
<td>Tolerant to drought</td>
</tr>
<tr>
<td>11</td>
<td>CoJ 20193</td>
<td>2007</td>
<td>75.9</td>
<td>17.9</td>
<td>Midlate</td>
<td>MR to red rot, suitable for late planting</td>
</tr>
<tr>
<td>12</td>
<td>CoS 96275 (Sweety)</td>
<td>2007</td>
<td>80.8</td>
<td>17.3</td>
<td>Midlate</td>
<td>MR to red rot, good ratooner</td>
</tr>
<tr>
<td>13</td>
<td>Co 0118 (Karan 2)</td>
<td>2009</td>
<td>78.2</td>
<td>18.45</td>
<td>Early</td>
<td>MR to red rot and smut, R to wilt, tolerant to water stress and waterlogging</td>
</tr>
<tr>
<td>14</td>
<td>Co 0238 (Karan 4)</td>
<td>2009</td>
<td>81.08</td>
<td>17.99</td>
<td>Early</td>
<td>MR to red rot, R to wilt, tolerant to water stress and waterlogging, tolerant to low temperature, better ratoonability during winter.</td>
</tr>
<tr>
<td>15</td>
<td>Co 0239 (Karan 6)</td>
<td>2010</td>
<td>79.23</td>
<td>18.58</td>
<td>Early</td>
<td>MR to red rot, smut and wilt, tolerant to water stress and waterlogging</td>
</tr>
<tr>
<td>16</td>
<td>Co 0124 (Karan 5)</td>
<td>2010</td>
<td>75.71</td>
<td>18.44</td>
<td>Midlate</td>
<td>MR to red rot, Tolerant to water stress, water logging and low temperature conditions.</td>
</tr>
<tr>
<td>17</td>
<td>Co 0237</td>
<td>2010</td>
<td>71.33</td>
<td>18.78</td>
<td>Early</td>
<td>Performs better at normal and water logging conditions</td>
</tr>
<tr>
<td>18</td>
<td>Co 05009</td>
<td>2013</td>
<td>75.89</td>
<td>17.44</td>
<td>Early</td>
<td>Better ratoonability during winter</td>
</tr>
<tr>
<td>Sl. No</td>
<td>Variety</td>
<td>Year of identification/ notification</td>
<td>Cane yield (t/ha)</td>
<td>Sucrose (%)</td>
<td>Maturity group</td>
<td>Reaction to diseases</td>
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<tr>
<td>19</td>
<td>Co 05011</td>
<td>2012</td>
<td>82.47</td>
<td>18.00</td>
<td>Midlate</td>
<td>Better ratoonability during winter fast growth, high NMC</td>
</tr>
<tr>
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<tr>
<td>North Central Zone</td>
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</tr>
<tr>
<td>1</td>
<td>Co 87263 (Sarayu)</td>
<td>2000</td>
<td>66.3</td>
<td>17.4</td>
<td>Early</td>
<td>R to red rot and smut, early shoot borer, tolerant to drought and waterlogging</td>
</tr>
<tr>
<td>2</td>
<td>Co 87268 (Moti)</td>
<td>2000</td>
<td>78.9</td>
<td>17.5</td>
<td>Early</td>
<td>R to smut, MR to red rot, tolerant to drought and waterlogging</td>
</tr>
<tr>
<td>3</td>
<td>BO 128</td>
<td>2001</td>
<td>69.2</td>
<td>17.6</td>
<td>Midlate</td>
<td>MR to red rot and smut, tolerant to waterlogging and saline sodic soil</td>
</tr>
<tr>
<td>4</td>
<td>Co 89029 (Gandak)</td>
<td>2001</td>
<td>70.6</td>
<td>16.3</td>
<td>Early</td>
<td>MR to red rot, top, borer, and shoot borer, tolerant to drought and waterlogging</td>
</tr>
<tr>
<td>5</td>
<td>CoSe 92423 (Rajbhog)</td>
<td>2001</td>
<td>70.0</td>
<td>17.5</td>
<td>Midlate</td>
<td>MR to red rot</td>
</tr>
<tr>
<td>6</td>
<td>CoSe 95422 (Rasbhari)</td>
<td>2001</td>
<td>67.8</td>
<td>17.7</td>
<td>Early</td>
<td>MR to red rot</td>
</tr>
<tr>
<td>7</td>
<td>CoSe 96234 (Rashmi)</td>
<td>2007</td>
<td>64.1</td>
<td>17.9</td>
<td></td>
<td>MR to red rot, good ratooner</td>
</tr>
<tr>
<td>8</td>
<td>CoSe 96436 (Jalpari)</td>
<td>2004</td>
<td>67.1</td>
<td>17.7</td>
<td></td>
<td>Tolerant to waterlogging, good ratooner</td>
</tr>
<tr>
<td>9</td>
<td>CoLk 94184 (Birendra)</td>
<td>2008</td>
<td>76.0</td>
<td>18.0</td>
<td>Early</td>
<td>MR to red rot, tolerant to drought and waterlogging</td>
</tr>
<tr>
<td>10</td>
<td>Co 0232</td>
<td>2009</td>
<td>67.8</td>
<td>16.51</td>
<td>Early</td>
<td>MR to red rot, tolerant to drought and waterlogging</td>
</tr>
<tr>
<td>11</td>
<td>Co 0233</td>
<td>2009</td>
<td>67.8</td>
<td>17.5</td>
<td>Midlate</td>
<td>MR to red rot and smut, R to wilt, tolerant to waterlogging</td>
</tr>
</tbody>
</table>

R: Resistant          MR: moderately resistant
Performance of promising varieties

Varietal scenario in India is complex with a large number of varieties being introduced from time to time and in tune with growing needs of sugar industry and farmers as given in Table 2. However, only a few varieties have been in cultivation for a longer time span due to the varietal break down, non preference by the farmers/ factories.

Table 2. List of sugarcane varieties under commercial cultivation in different states and the recently released varieties

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>State</th>
<th>Early maturing varieties</th>
<th>Mid late and late maturing varieties</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Andhra Pradesh</td>
<td>Co 6907, Co 8013, Co 8014, 81V48, 83V14, 86V96, 93V110, 93V297, 83R23, CoA 92081, CoA 95081, CoA 96081, CoC (SC) 23, CoC 01-61, CoV 09356</td>
<td>Co 7219, Co7706, Co 7805, Co 8011, Co 8021, Co 87040, CoA 7602, 86A146, 88A162, 87A380, 85R186, CoR 8001, 83V15, 83V288, 89V74, CoT 8201</td>
</tr>
<tr>
<td>2.</td>
<td>Assam</td>
<td>Co 997, Co 1008, Co 6315, CoBln 9101, CoBln 9102, CoBln 9103, CoBln 94063</td>
<td>Co 740, Co 961, 1132, Co 8315, CoJor1, CoJor2, CoBln 90006, CoBln 9104, CoBln 94063, CoBln 9605</td>
</tr>
<tr>
<td>4.</td>
<td>Gujarat</td>
<td>Co 775, Co 975, Co 6806, Co 8338, Co 87263, Co 94008, CoC 671, CoN 95132</td>
<td>Co 740, Co 62175, Co 6304, Co 7527, Co 8011, Co 8021, Co 86032, Co87025, Co 87044, Co 91010, CoA 7602, CoLk 8001, CoN 85134, CoN 91132</td>
</tr>
<tr>
<td>6.</td>
<td>Karnataka</td>
<td>Co 6415, Co 7704, Co 85002, Co 94008, CoC 671</td>
<td>Co 740, Co 62175, Co 7804, Co 8011, Co 8014, Co 8021, Co 8371, Co 85004, Co 86032, Co 91010, Co 92020, Co 2001-15</td>
</tr>
<tr>
<td>7.</td>
<td>Kerala</td>
<td>Co Ti 88322, Madhumathi</td>
<td>Co 7704, Co 8021, Madhuri, Madhurima, Thirumadhuram</td>
</tr>
<tr>
<td>8.</td>
<td>Madhya Pradesh</td>
<td>Co 527, Co 775, Co 1101, Co 1169, Co 1305, Co 7314, CoC 671, CoJn 86141</td>
<td>Co 419, Co 617, Co 678, Co 1148, Co 1305, Co 6304, Co 7318, Co 7807, Co 8304, Co 86032, CoLk 8001, CoS 707</td>
</tr>
<tr>
<td>Sl. No.</td>
<td>State</td>
<td>Early maturing varieties</td>
<td>Mid late and late maturing varieties</td>
</tr>
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</tr>
<tr>
<td>9.</td>
<td>Maharashtra</td>
<td>Co 419, Co 775, Co 7219, Co 8014, CoC 671, Co 94008, Co 94012</td>
<td>Co 740, Co 7219, Co 7527, Co 85004, Co 86032, Co 87025, Co 87044, Co 91010, CoM 7125, CoM 88121, CoM 0265</td>
</tr>
<tr>
<td>10.</td>
<td>Orissa</td>
<td>Co 6907, Co 7508, Co 7704, Co 7805, Co 8041, Co 87037, Co 87263, CoA 89085, CoOr 03151</td>
<td>Co 740, Co 975, Co 62175, Co 6304, Co 6806, Co 7219, Co 7706, Co 8021, Co 8402, Co 86249, Co 87044, CoT 8021</td>
</tr>
<tr>
<td>11.</td>
<td>Punjab</td>
<td>Co 89003, CoS 8436</td>
<td>CoJ 67, CoJ 83, CoJ 84</td>
</tr>
<tr>
<td>12.</td>
<td>Rajasthan</td>
<td>Co 527, Co 997, Co 6617, CoL 29</td>
<td>Co 419, Co 449, Co 527, Co 1007, Co 1253, CoJ 111</td>
</tr>
<tr>
<td>13.</td>
<td>Tamil Nadu</td>
<td>CoC 90063, Co 94008, CoC 671, CoC 801, CoC 85061, CoC (Sc) 23, CoG 94077, CoG 95076, CoSi 95071, CoSi 6, Co 99006</td>
<td>Co 6304, Co 8021, Co 85019, Co 86010, Co 86032, Co 86249, Co 87044, Co 91010, CoG 93076, CoG 776, CoG 86071, CoG 96071, CoG 98071, CoC 22, CoG5</td>
</tr>
<tr>
<td>15.</td>
<td>West Bengal</td>
<td>Co 62010, Co 62197, Co 7218, BO 90, CoJ 64</td>
<td>Co 1148, Co 62033, Co 62207, Co 7202, Co 7224, Co 87263, BO 91, CoS 767</td>
</tr>
</tbody>
</table>

**New Varieties for subtropical India**

In the recent years, several new varieties have been released, which include a few new varieties identified from SBI regional Centre, Karnal viz. Co 0118, Co 0238, Co 05009, Co 05011 which are expected to bring about an appreciable improvement in the sugarcane production and productivity in Northern India. Among these Co 0238 is spreading in large area in North Western zone by virtue of its high cane yield. Salient features of the important new releases are listed below.
**Scientific Sugarcane Cultivation**

**Co 0118: (Karan 2)** (Co 8347 x Co 86011) is identified as a substitute for CoJ 64 by virtue of a combination of high cane yield (15.70% improvement) and better sucrose (3.07% improvement) over CoJ 64. The variety recorded a mean cane yield of 78.2 t/ha, CCS yield of 9.88 t/ha and sucrose of 18.45% at 300 days and performed well under water stress and waterlogging conditions. Evaluation at over 50 sugar mills in Punjab, Haryana, UP, Uttarakhand showed a better performance of the variety.

**Co 0238 (Karan 4)** (CoLk 8102 x Co 775) is also identified as a substitute for CoJ 64 by virtue of its superiority for cane yield (19.96% improvement) and marginal increase in quality (0.50% improvement in sucrose) over CoJ64. Its mean yield was 81.08 t/ha and sucrose of 17.99% at 300 days. It is non-lodging and gives good yield when harvested during winter and performs better than the standard even under water stress and waterlogging conditions. It is also moderately resistant to red rot and resistant to wilt and smut. Adaptability trials have shown that the variety was better than the existing varieties in UP, Haryana and Bihar.

**Co 0124 (Karan 5)** (Co 89003 GC) is a very recent release as a mid-late maturing clone with an improvement of 12.21% in sugar yield, 14.69% improvement in cane yield and 0.89% in sucrose over CoS 8436.

**Co 0237 (Karan 8)** is an early variety with 8.73% improvement for CCS, 5.53% for cane yield and 4.92% for sucrose over the quality check CoJ 64.

**Co 05009 (Karan 10)** (Co 8353 x Co 62198) The variety recorded 9.16 t/ha of CCS, 75.89 t/ha cane yield and 17.44% sucrose at 10 months age. It was better than the standard CoPant 84211 and on par with CoJ 64 for pol % and CCS % and was better than the standards for cane yield. It is a non-lodging and non-flowering early maturing clone with better ratoonability during winter.

**Co 05011 (Karan 9)** (CoS 8436 x Co 89003) is a mid-late maturing variety with 10.24 t/ha CCS, 82.47 t/ha cane yield and 18% sucrose at 12 month crop age. It is a non-lodging and non-flowering clone and performs better than standards when harvested during winter.

**Co 89003** (Co 7314 x Co 775) is an early maturing clone released for cultivation in the states of Punjab and Haryana. This is resistant to red rot but has been affected by wilt.

**CoPant 90223** (BO 91 GC) with an average yield of 80-85 t/ha and 19% sucrose, has wide adaptation in the Tarai regions of UP, Uttarakhand and Bihar.

**CoPant 94211:** (CP 44-101 X Co775) with cane yield of 65-75 t/ha and sucrose of 18-18.5% is suitable for summer planting after the harvest of wheat crop. It is MR to red rot and exhibits fast growth with a tendency to lodge.

**CoPant 96219:** (CoS 767 x CoPant 84211) has an yield of 80-85 t/ha and sucrose of 18-19% Moderately resistant to red rot and grows well in irrigated and Tarai conditions of Uttarakhand and UP.

**CoSe 92423:** (BO 91 X Co 453) is a mid-late maturing high yielding variety recommended for cultivation in UP, Bihar and West Bengal

**CoSe 95422** (Rasbhari) is an early maturing clone with an average yield of 67.8 t/ha and 17.7% sucrose and occupies significant area in UP and Bihar.
Co 0232 (CoLk 8102 x Co87267): is an early maturing variety, notified for cultivation in North Central zone in 2009.

Co 0233 (CoLk 8102 X Co 775): is a midlate variety notified for cultivation in North Central zone in 2009. Better performance under prolonged waterlogging conditions (14.91 % improvement in cane yield and 12.14 % for CCS over BO 91) is an added merit of this variety.

BO 139: (BO109 x BO 43) is an early maturing variety suitable for upland conditions characterized by quick early growth and suitability for early crushing.

BO 147 (BO 110 self): is a mid season maturing variety with good yield in plant and ratoon crops and withstands limited waterlogging.

CoLk 94184 is an early maturing variety with good rationing potential suitable for North Central zone.

CoSe 95436 (BO 91 x Co 62198) is early maturing clone with cane yield of 79.6 t/ha in plant crop and 71.48 t/ha in ratoon crop released for cultivation in UP.

Varieties for tropical India

Peninsular zone

Co 86032 (Nayana) (Co 62198 x CoC 671): The most notable among the releases is Co 86032, the wonder cane, still occupying the major share of sugarcane land in the tropical India has been the major factor that improved sugar recovery in the zone. The variety records on an average 120 t/ha cane yield, 15.09 t/ha CCS and 19.19% sucrose. This is rated as field tolerant to red rot and is resistant to smut disease and is a rare combination of several advantageous characters: it grows well in all soil types, has good yield high quality and multi-ratooning potential, can be grown throughout the year, maintains juice quality upto 14 months and is amenable for wide row spacing. It is suited for commercial cultivation in Maharashtra, Gujarat, Karnataka, Tamil Nadu, Madhya Pradesh and interior Andhra Pradesh. Poor performance to waterlogged situations and susceptibility to internode borer are major limiting factors of this variety.

Co 8371(Bhima) (Co 740 x Co 6806) is a high yielding moderate sucrose midlate maturing variety with 117.7 t/ha cane yield, 15.77 t/ha CCS and 18.62% sucrose. Thick canes, good ratooning potential, suitability to black and red soils tolerance to waterlogging and drought, A1 quality jaggery are the advantages and is released for commercial cultivation in the states of Maharashtra, Gujarat, Karnataka, Tamil Nadu, Madhya Pradesh and interior Andhra Pradesh.

Co 94008 (Shyama) (Co 7201 x Co 775) is another release through AICRP and is suitable Northern Karnataka. In the Zonal Varietal Trials of the Peninsular Zone, this entry recorded
a mean cane yield of 116 tonnes per hectare, when compared to 90.7 tonnes per hectare by Co 6304 and 98.7 tonnes per hectare of Co 7219. Sucrose content was 19.09% and CCS was 15.46 tonnes per hectare. It is found to have field resistance to all pests. It is also moderately resistant to drought and moderately susceptible to salinity.

**Co 99004 (Damodar) (Co 62175 x Co 86250)**: Co 99004 recorded higher sugar yield of 16.09 t/ha, CCS yield of 116.9 t/ha and sucrose of 16.09 %. The variety has additional merits, viz. its resistance to red rot (R by plug and R by nodal) and wilt, tolerance to drought and salinity, tolerance to internode borer, golden yellow A1 quality jaggery and shy flowering. The variety has excellent field habits like erectness, early vigorous growth, dark green foliage, tall canes without spines or splits and 14% mean fibre.

**Co 2001-13 (Sulabh) (7806 PC)**: was notified for release in Peninsular zone during 2009 as a midlate maturing clone with 14.73 t/ha CCS, 108.6 t/ha cane yield and 19.03% sucrose. This is a midlate maturing clone that performed well and superior to the ruling variety Co 86032 for cane yield and sugar yield in AICRP trials. The canes are medium thick, semi erect with cylindrical zigzag internodes and dark purple and wax coated canes. The variety is high tillering with good ratooning potential and is well suited for drought and saline conditions and combines resistance to red rot and smut diseases, internode borer and free from all pests under natural conditions. The clone gives A1 quality jaggery with moderate fibre (13.43%).

**Co 2001-15** (Co 85002 x Co 775): This midlate variety was notified for release in 2009 and showed superiority for cane yield, sugar yield and CCS % in AICRP trials of Peninsular zone (2006-08). This variety is suitable under normal and drought conditions at different centres. Canes are tall and medium thick with a light canopy and more partitioning towards canes. The average cane yield is 108.18 t/ha of cane yield, 14.57 t/ha of CCS yield and 18.90% sucrose. The clone also combines resistance to smut disease and internode borer, tolerance to drought and salinity, A1 quality jaggery quality and 14.70% fibre. This variety is showing promise in South Karnataka.

**Co 0218** (Shreyas) (Co 8353 x Co 86011): This variety is a midlate maturing clone notified in 2010 for Peninsular zone of India. The zonal mean values for cane yield was 104.53 t/ha, with a CCS yield of 15.30 t/ha and high sucrose of 20.63%. It performed well at the sugarcane stations located in Tamilnadu, Karnataka, and Maharashtra, thus exhibiting wide adaptability in the diverse climatic condition of Peninsular zone. Besides, this clone is also moderately resistant to red rot and tolerant to drought and salinity. Co 0218 possesses A1 quality jaggery and 14.70% fibre. It is a good ratooner with excellent field stand, with erect tall and thick canes and dark green foliage with moderate spines. The spread of the variety is restricted due to the occurrence of rust during the months of July to September at Coimbatore.

**Co 0403 (Samriddhi)** is an early maturing variety notified for cultivation in Peninsular zone. Evolved from the cross Co 8371 x Co 86011, this variety was superior in the AICRP trials conducted at eleven centres. Based on plant and ratoon crops, mean cane yield was 101.5 t/ha, sugar yield was 13.29 t/ha and sucrose was 18.16 % at 300 days. This variety figured in top three position in 27 trials for CCS t/ha, 22 trials for cane yield, 25 trials each for CCS % and sucrose % thus exhibiting its superiority in the zone. The clone is a unique combination of earliness, ratoonability, high yield and resistance to red rot, smut and drought. The crop stand is excellent with a high population of non lodging canes without spines and splits with early vigourous growth.
Co 06027(CoC 671 x IG 91-1100): A high yielding, drought and saline tolerant variety notified for Peninsular zone in 2013. The variety is characterized by mean cane yield of 111.3 t/ha, 14.74 t/ha CCS and 19.32 % sucrose. This clone is characterized by less waxy yellowish purple canes, resistance to red rot, good ratooning potential and non lodging canes.

Co 94012(CoC 671 somaclone) is a sucrose rich variety released for the states of Maharashtra and Karnataka and is the first somaclonal variant to be released for cultivation. It is suitable for early planting and early harvesting, and gives better recovery (14.77 % in BMT) Mean cane yield of 92.85 t/ha, sugar yield of 13.04 t/ha and sucrose of 19.82% have been recorded. The clone is resistant to smut, tolerant to salinity, drought and waterlogging and canes have better keeping quality and fibre is about 14.6%.

CoM 0265(Co 87044 GC): is a new midlate variety spreading in the states of Maharashtra and Karnataka. It has high cane tonnage, moderate sucrose content, good ratooning potential, tolerance to salinity/ alkalinity and is suitable for adsali planting. A farmers’ choice variety, CoM 0265 is spreading in larger areas in the two states.

Co 99006[(BO 91 x Co 62175) x Co 775]is a high sucrose clone identified through AICRP testing and is registered as a genetic stock for quality(mean sucrose is 20.41% at 360 days). Cane yield is 110.83 t/ha which was slightly less than that of Co 86032 (116 t/ha) in the AICRP evaluation trials, but was clearly better for CCS yield (15.80 t/ha). It exhibits resistance to waterlogging, drought and red rot (by nodal inoculation) besides being a good ratooner and yielding quality jaggery. Testing the clone in the state of Tamil Nadu under CAE trials has shown its advantage with substantial improvement in cane yield and sugar yield (20.4 t/ha and 17.7 t/ha CCS in plant and ratoon crops respectively) (Parsuraman et al. 2013)

Other varieties include Co 92020 with multiple ratooning ability, low flowering intensity and better keeping quality, Co 8014 released as Mahalakshmi for the state of Maharashtra suitable for early to midlate planting with shy flowering and high cane and sugar yields, Co 88017(Madhumathi) by Thiruvalla (Kerala) a high yielding midlate maturing clone and Co 86010 is released for the state of Tamil Nadu is a high yielding clone with thick and tall canes. Co 92005 is released for the state of Maharashtra for jaggery production by virtue of its superior AI quality jaggery.

East Coast Zone

The varieties viz. Co 86032, CoC 671, Co 6907, Co 7508 and Co 7805 are grown for a longer period At present other /new varieties are under cultivation in the zone and are listed below

Co 8014: a midlate maturing, high yielding high sucrose variety with cane yield of 100t/ha, resistant to red rot and smut and with good ratooning potential.

CoA 7602: is midlate maturing clone, high cane yielding and moderate sucrose variety with resistance to red rot

CoT 8201 is a high cane yielding type (120 t/h) with high sucrose and resistance to red rot

81V48is a variety with high cane yield and very high sucrose, tolerant to red rot 85R186, 83 V15, 83 V23 and 86V 96 are varieties with high cane yield and moderate sucrose and tolerance to red rot
CoA8401 is an early maturing, sugar rich variety, with field tolerance to red rot and early shoot borer.

81 A 99 (Aravinda); with 100-115 t/ha cane yield and 18.5% sucrose is suitable for rainfed, saline and alkaline conditions.

CoA 92081 (87A298, Viswamitra) is an early maturing, high yielding clone (125 t/ha) and 19.5% sucrose, suitable for rainfed conditions, with good ratooning potential and resistant to red rot. At present this variety is occupying sizable area in Andhra Pradesh.

83R23 (Vasudha) is an early maturing clone with 105 t/ha of cane yield and 18.5% sucrose suitable for upland conditions of Andhra Pradesh.

93 A 145 (Saradha) is an early maturing variety, suitable for all situations with resistance to red rot, salinity, alkalinity and tolerance to post harvest deterioration.

CoA 03081 (97A85, Visakha) is an early maturing clone with a cane yield of 115-120 t/ha and sucrose of 17.5% is suitable for irrigated and drought conditions and resistant to red rot.

CoV 92102 (83V15, Kanakadurga): a midlate maturing variety, suitable for problem soil, upland and waterlogging conditions, but prone to lodging, cultivated in Tamil Nadu too in limited area.

CoV 09356 (2003V 46, Bhavani) released for the state of Andhra Pradesh in 2010 is an early maturing clone with high yield (130 t/ha) and quality (19.5% sucrose), resistant to red rot and is spreading fast in the state.

CoA 05322 (98A163, Rohini) is a midlate maturing clone with consistent performance in all the sugarcane tracts of east coastal region.

Co 87044 (Uttara) is the popular variety for the state of Orissa. It is a mid-late maturing clone with high yield potential and is resistant to red rot.

Co 06030 (CoC 671 x IG 91-1100) is a midlate maturing variety released for east coast zone during 2013 and is characterized by 103.3 t/ha cane yield, 11.21 t/ha CCS and sucrose of 16.60%, tolerance to red rot disease and impressive crop stand. The canes are erect, dark purple and medium waxy, devoid of splits and leaves are easily detrashable and without spines.

Varieties for specific purposes

Varieties with specific attributes are required to achieve higher productivity under certain abiotic stress conditions as well as for diversified uses.

Short duration varieties: Short duration varieties which can be harvested at 7-8 months can be used in cropping systems where immediately after harvest of one crop another crop can be cultivated by which three crops are possible in two years. Some of the early varieties so identified are Co 7204, Co 7304, Co 7704, Co 7712, Co 8338, Co 8341, Co 8348, Co 8349, CoA 7601 and CoC 671. Recently a few clones with peak maturity at 240-300 days have been identified at SBI, which are under testing in factory locations/ multiplication.

Drought tolerant varieties: Though sugarcane is rated as a drought tolerant plant, drought can cause significant reduction in cane yield. Several varieties were found to be drought
tolerant: Co 997, Co 1103, Co 1107, CoLk 8003, Co 87263, Co 87016, BO 89, BO 90, BO 99, BO109, BO104, BO109, CoS 767 Co 98014, Co 740, Co 997, CoA 7602, MS 7054, CoM 7125, CoSi 94071, CoSi 94072, Co 94012, CoC 671, Co 91010, Co 92002, Co 92020, Co 93009, Co 97009, Co 99004, Co 8338, Co 91017, Co 200012, Co 0212, Co 0218, Co M 0265, 81A99, CoA 92081, CoA 92081, CoA 03081.

**Tolerance to salinity:** Salinity is another major constraint in sugarcane productivity affecting germination, tillering, growth, yield and quality. Co 453 and CoJ 13 are typically salinity tolerant types. Several saline tolerant varieties have been available such as BO 91, BO99, BO 102, BO 104, BO108, BO109, CoS 767, Co 1148, Co 8347, Co 8371, CoC 671, Co 89010, Co 94008, Co 94012, Co 97008, Co 99004.

**Tolerance to cold/ frost:** Sugarcane in subtropical India suffers from extreme cold and winter sprouting is a major factor that governs substantial growth of canes in winter months. The clones with sprouting in winter months viz. Co 97009, Co 0238, Co 08339 and CoS 93230 were under cultivation in different areas. Recent selections from Karnal centre also tolerate winter temperature.

**Varieties resistant to water logging:** Many sugarcane varieties resistant to water logging such as Bo 99, BO 110, BO 128, Co 8231, Co 8371, Co 98007, Co 99006, Co 0118, Co 0232, Co 0233, Co 0238, CoP 9103, CoP 9104, CoBln 9103, CoS 8118, CoTl 88322, CoSe 96436, UP 9529 and UP 9530 were identified recently.

**Varieties suitable for jaggery:** The subtropical varieties viz. BO 70, BO 90, BO102, BO104, CoS 767, Co 1148 and tropical varieties Co 6907, CoT 8201, CoA 7602, Co 7219, Co 7706, Co 449, Co 62175, Co 99004 and Co99006 are known for giving good jaggery yield and quality. Co 92005 is a variety released exclusively for jaggery making for the Kolhapur region. High fibre, high biomass and high total sugars.

The varieties with high fibre and moderate sugar can be used for cogeneration of electricity from bagasse. The interspecific and intergeneric hybrids of sugarcane with wild S. spontaneum or *E. arundinaceus* have the potential to be used as energy canes due to their ability to produce high biomass. Varieties with high cane yield and high Brix are suited for ethanol production as the total sugars are important than the sucrose content. Promising clones are expected to be evolved in the near future.

Systematic sugarcane agriculture should start with choosing the right variety for the specific track in order to replace old varieties for increasing and sugar production and productivity so as to reach the target of 36 million tonnes of sugar production by 2030 AD. Now a spectrum of varieties is available, thanks to the intense effort in cane breeding in India. In addition to the varieties developed and recommended for normal conditions, suitable stress tolerant varieties are also developed with a view to step up the average sugarcane yield.
3. CANE AGRONOMY - TILLAGE, CROP GEOMETRY, PLANTING SYSTEMS, WEED MANAGEMENT, IRRIGATION AND INTERCROPPING

R. Dhanapal

For maximizing cane yield and efficient utilization of crop production resources such as water, nutrients, sunlight and space, it is necessary to provide optimum environmental conditions through tillage, crop geometry and other agro techniques. In addition to proper land preparation, crop geometry, planting density, cultural operations like earthing up, detrashing, propping, mulching and flowering control should be carried out at the correct time to improve cane and sugar yields. Most of these operations are labour intensive, but are important to provide optimum conditions for the establishment and growth of crops.

Tillage: Land preparation for sugarcane generally involves primary tillage consisting of one or two deep ploughings with mould board or disc plough to uproot the previous crop stubbles and break the soil into clods. In some places, chiseling is also done at periodical intervals to break the hard sub-soil pans. Primary tillage is followed by secondary tillage consisting of two to three harrowings to break the soil clods to bring it to a fine tilth and leveling. The degree of tilth required for proper germination and establishment of sugarcane crop depends on the system of planting adapted. Laser levelers could be used to properly level the fields.

Crop geometry: Crop production aims at efficient harvest of solar energy, which in turn depends upon the efficiency of light interception and its utilization. Higher efficiency of light interception could be achieved through rapid development of leaf area index (LAI) and maintaining the optimum LAI for a longer duration. Plant population and crop geometry play a dominant role on LAI and light interception. Plant population defines the size of area available to individual plants or the number of plants per unit area, whereas crop geometry refers to the shape of area available for individual plants or the pattern of distribution of plants over the ground.

Row spacing for sugarcane: Cane yield is a function of the stalk population per unit area (number of millable canes) and single cane weight. The number of millable canes and cane weight could be improved by providing optimum conditions for plant growth. Closer spacings generate a higher plant population at the initial stages but the tiller mortality is also high as a consequence of within-row shading. However, under closer spacing, there is an increase in the stalk population resulting in higher cane yield. Varieties widely differ in their response to row spacing. Early and short duration varieties generally perform well under closer spacing while late varieties require wider spacing.

Generally optimum inter row distance depends up on the tillering capacity of the variety, time of planting, fertility status of the soil and stress conditions like drought. Closer row spacings are adopted under low soil fertility status, shy tillering varieties, delayed planting, cooler and slower growing conditions and drought. For high biomass yield, narrow row spacing has been found to be advantageous. The drawbacks of narrower spacing are the high cost of seed cane and difficulties in carrying out cultural operations and harvesting. Closer row spacing also results in quicker ‘close in’ of the canopy and may suppress the
production of late tillers. While closer row spacing of 75 - 100 cm is common in India, wider spacing is adopted in countries like Australia, Brazil, Mauritius and South Africa. In areas where mechanized cultivation is practiced, the row spacing is wider (> 1.2 m) while narrower row spacings (0.6 m - 1.2 m) are adopted in countries where human labour is extensively used for the cultivation of sugarcane.

**Paired row planting:** Paired row system of planting is becoming popular in recent years especially under drip irrigation. In this system, the space between a pair of two rows is reduced by bringing them closer and the spacing between adjacent pairs of rows is increased. The drip laterals are usually laid in between the rows within the pair. This helps to reduce the length of laterals required for laying out the drip system to half that under normal spacing and thereby the cost of the drip irrigation system is reduced substantially. Several studies have indicated that cane yield could be maintained under the paired row system. Experiments conducted at Sugarcane Breeding Institute, Coimbatore during 1988 - 90 have shown that the cane yield in 60/120 cm paired row was comparable with that under 90 cm uniform rows. In a study conducted at Sameerwadi (Karnataka) there was no significant difference in cane yield between normal row spacing (90 cm) and paired row spacing which recorded 101.1 and 102.5 t/ha respectively in the variety, CoC 671. This system also provides scope for raising intercrops in the larger space in between pairs of rows. Several modifications of 90 cm row spacing have been studied in India, so as to have a wider inter-row space alternated with a narrow interspace like 60/120, 50/130, 40/140, 30/150 cm etc. to accommodate an intercrop in the wider inter-row space. In such modifications, the row length per unit land area and the requirement of seed cane remains constant and the yields obtained are also comparable.

**Wide row planting:** In India, harvesting of sugarcane is being done using human labour. As this operation involves drudgery, the availability of human labour for harvesting is gradually dwindling. In addition, the labour is also becoming very costly. Therefore, development of a mechanical sugarcane harvester suitable for Indian conditions is the need of the hour. To facilitate the use of harvesters in cane fields, the row spacing needs to be increased to at least 150 cm for the use of larger machines and this is popularly referred to as wide row spacing. For using the smaller harvesters, 120 cm row spacing could be adequate. By adopting appropriate agro techniques, it is possible to sustain higher productivity levels under wide row spacing. The availability of large interspaces between the wide rows will facilitate the use of power tillers and other small machinery for operations like weeding and earthing up. It will be very easy for the human labour to move inside the field for operations like trashing, plant protection, guiding irrigation water etc.

At Sakthi Sugars, Appakudal, Tamil Nadu wide row spacing of 1.5 m was compared with conventional spacing of 75 cm with the variety Co 86032. Though there was a reduction in the number of tillers at 90 days after planting and NMC/ha, the wide row spacing of 150 cm produced significantly more cane yield, because of increased cane height and diameter and higher single cane weight. Experiments conducted at Sugarcane Research Station, PAU, Jalandhar during the seventies and some of the sugar factories in Punjab have shown that wider inter row spacing of 120 – 150 cm could be adopted without any adverse effect on cane yield and that the ratoon yield was higher with wider spacing as compared to 75 and 90 cm spacing.
Management of sugarcane under wide row spacing

It is necessary to adapt the cultivation practices to maintain cane yield under wide row spacing on par with the conventional 90 cm row spacing. Based on the experiments conducted at Sugarcane Breeding Institute, Coimbatore agro techniques for wide row sugarcane have been standardized. High yield levels have been achieved by selection of varieties, manipulation of plant population and planting pattern and by judicious manuring. The studies conducted on fertilizer and irrigation requirements of sugarcane under wide rows and normal rows indicated that these do not change between the two situations as the yields obtained are comparable.

Varieties: Varietal selection plays a pivotal role in the success of wide row spacing. Significant variety x spacing interactions and differences in the response of sugarcane varieties to row spacing has been reported. Among the varietal characters, high tillering capacity, synchrony in tillering, fan shaped growth pattern, non-lodging nature, higher cane number and higher single cane weight are important for wide rows. In an experiment at Coimbatore with three varieties, variety x spacing interaction was found significant for stalk population, cane yield and CCS yield. The variety Co 91010 recorded similar cane yield at 90 cm, 120 cm and 150 cm (dual rows) row spacings, whereas in the other two varieties (Co 94005 and Co 94008) the cane yield was the highest at 90 cm row spacing and decreased with increase in row spacing. The sugarcane variety Co 86032 performs well over a range of row spacings including 150 cm wide rows.

Seed rate: A seed rate of 75,000 two budded setts/ha, which works out to 6.75 setts per metre length of row, is being adopted for sugarcane under the normal row spacing of 90 cm. It has been well established that tiller mortality is substantially lower and a higher percentage of shoots survive to become millable canes under wide rows. Increase in the average weight of cane at wide row spacing has also been observed in several experiments. Hence, it may not be necessary to increase the seed rate to 11.25 setts per metre row to maintain the seed rate of 75,000 setts per hectare. In an experiment conducted at Sugarcane Breeding Institute cane yield in the sugarcane variety Co 86032 under wide row spacing (150 cm row spacing and 60,000 setts/ha) and normal row spacing (90 cm row spacing and 75,000 setts/ha was almost the same, 119.1 t/ha under wide row and 119.8 t/ha under normal row.

Planting pattern: Among the different methods of sett placement, ‘dual row planting’ has been found to be superior. In this method, broad furrows are formed at a spacing of 150 cm and in the middle of the furrows sugarcane setts are planted in two rows adopting a spacing of 25 - 30 cm between them. In a comparative study of two different methods of wide row planting, the dual row system gave higher cane yield compared to the single row system and normal 90 cm row spacing.

Planting systems

Ridges and furrows: Ridges and furrows are formed in a finely prepared field using tractor or bullock drawn implements. Depth of the furrow should be around 25 cm and for obtaining proper depth, tractor drawn implements are preferable. Convenient furrow length depending upon the slope of the land must be followed. The furrow bottom should be loosened to a depth of about 10 cm to facilitate placement and covering of the setts. This system is adopted
under highly intensive irrigated sugarcane cultivation. It facilitates easy irrigation and good soil aeration. At the time of earthing up, the ridges are converted into furrows and the soil from the ridges is placed along the cane rows to provide solid support to the plant.

**Trench system:** Trench planting is practiced in heavy clay soils, where clod formation is frequent. In this system, ‘U’ shaped furrows or trenches of about 25 - 30 cm depth are formed manually using spade or by using machinery. Trench planting helps to conserve and provide adequate sub-soil moisture which facilitates good germination and cane growth. This also prevents lodging. In areas where there is early drought and late waterlogging condition, deep trenches of 30 - 40 cm depth and 60 cm width have been found to perform better. In this system, as the cane grows, the trench is filled with soil in stages during manuring. In the initial stages, the germinating cane crop gets adequate soil moisture from the sub-soil and a good crop stand is established. During later stages, the trenches serve as drainage channels. The deep trench system has also been reported to ensure better ratoon performance.

**Pit method of planting:** In this system, circular pits of 90 cm diameter are dug out to a depth of about 45 cm with a gap of 60 cm between two adjacent pits i.e. the distance from the centre of one pit to the next pit is 150 cm. At this spacing, about 4000 pits could be formed per hectare. The pits are refilled with top soil and FYM / compost mixture to a depth of 15 cm. About 20 setts are planted in each pit in a radial fashion and covered with soil to a depth of about 5 cm. This system requires large amount of manual labour for making the pits and hence was not very popular. In recent years, tractor drawn machinery for making pits has been developed by Indian Institute of Sugarcane Research (IISR), Lucknow, Tamil Nadu Agricultural University (TNAU), Coimbatore and other organizations. As the cost of pit making has been greatly reduced with tractor drawn machinery, the pit system is increasingly becoming popular. In the pit method of planting, tillering is often suppressed and the growth of mother shoots is very vigorous. This results in thicker and taller canes and single cane weight is substantially increased. The number of millable canes is also usually higher in this system resulting in very high yields especially under the subtropical conditions. Many authors have reported very high cane yields, as high as 184.4 t/ha with the pit system of planting, which was 100 % more than the yield obtained in the normal flatbed planting. The pit method is frequently adopted with drip irrigation. The pit system of planting has several other advantages like better ratoon performance and has also been found useful under saline soil and saline water irrigated conditions. However this is not suitable for machine harvesting.

**Planting sugarcane in FIRB:** About 3.0 lakh ha of sugarcane area in India is under wheat - sugarcane - sugarcane ratoon - wheat system. A drastic reduction in sugarcane yield is a common feature when sugarcane is planted late (summer) after the harvest of wheat crop. In order to improve sugarcane productivity in wheat - sugarcane sequential system, the overlapping cropping under Furrow Irrigated Raised Bed (FIRB) system with wheat sowing on raised beds and sugarcane planting in furrows has been developed at Indian Institute of Sugarcane Research, Lucknow. In this system three rows of wheat are sown on each raised bed (48/50 cm top width) at optimum sowing time in November at 17 cm row spacing, keeping the seed rate of 75-80 kg/ha through a tractor drawn Raised Bed Maker-cum-Fertilizer Seed Drill. Immediately after sowing of wheat, irrigation to the height of 3/4th of the furrow is given for proper germination of wheat. Subsequent irrigations are applied in the furrows. Germination, tillering and growth of wheat are better due to better soil tilth on the raised
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beds. Sugarcane is planted in furrows (32/30 cm top width and 22 cm depth) in the month of February (optimum time of sugarcane planting in sub-tropical India) in the standing wheat crop. In this system sugarcane planting is advanced to 50-60 days which otherwise is done in late April/May in wheat - sugarcane sequential system. Sugarcane planting coincides with irrigation at boot leaf stage in wheat. Irrigation is given in furrows preferably in the evening and sugarcane setts are planted next day and pressed into the soil manually when the soil is in muddy condition (wet planting). The technology has been evaluated in sandy loam soil successfully. In order to chisel the furrow, a wheel hoe has also been designed to loosen the soil before irrigation for better placement of setts. After wheat harvest, the furrows are used for irrigating sugarcane till earthing up operation. To make the technology operationally feasible and cost effective, IISR has developed a tractor drawn Raised Bed Maker-cum-Fertilizer Seed Drill. The equipment can be operated by any 35 HP tractor.

The first and foremost benefit of the FIRB technology is that sugarcane is planted at the optimum time i.e. in the month of February. Otherwise, it is delayed by nearly 2 months to April end/May in wheat - sugarcane sequential system and thus system produces 35 percent higher cane yield without reduction in wheat yield. The system increases water use efficiency by saving irrigation water as it is applied only in the furrows requiring less volume of water in wheat, which works out to be 20% water saving as compared to flat method. The technology reduces production cost and increases margin of profit especially for small and marginal farmers with limited resources.

Weed Management

Weed competition in sugarcane is much greater than in other short season row crops, because of the wider row spacing and slow initial growth phase. More than 200 weed species have been reported to infest the sugarcane fields and among them, 30 are of economic importance. The composition of the weed species varies depending upon the climatic conditions, soil type, cropping systems followed and management practices adopted for controlling weeds and cultivation of the crop. Studies have shown that if weeds are not controlled effectively in the initial stages, the loss in cane yield could be anything between 17.2 and 35.4 t/ha.

Pre-emergence weed control: Practices adopted to control weeds after planting of the crop but before its emergence is known as pre-emergence weed control. In this practice, weeds are controlled at the germination stage itself and there is no chance for them to compete with the crop. Only root absorbed selective herbicides, which do not cause any harm to the crop, could be used. Simazine (1.5 – 2.5 kg a.i./ha), atrazine (2.0 – 2.5 kg a.i./ha), metribuzin (1.0 – 2.0 kg a.i./ha), ametryne (2.0 kg a.i./ha), diuron (1.25 – 2.50 kg a.i./ha), oxyfluorfen (0.3 kg a.i./ha), oxadiazon (0.4 kg a.i./ha) and pendimethalin (2.0 kg a.i./ha) have been found to be useful for pre-emergence weed control in sugarcane. Of them, atrazine has been found to be the most suitable in view of its efficacy in wide range of conditions, low cost and easy availability. It has to be applied on the soil surface as a blanket spray on 3rd or 4th day after planting sugarcane using a deflector (flat fan) type of nozzle. The recommended dosage range from 1.5 to 2.0 kg a.i./ha depending upon the type of soil. For the herbicide to be effective, spraying should be followed by irrigation. Atrazine can be used even in standing crop or ratoon crop in situations when the weeds are in emerging or in germination phase.
Overgrown weeds are not affected by atrazine. Atrazine controls both broadleaf weeds and grasses germinating from seeds. It does not control weeds like *Cynodon* and nut grass that emerge from vegetative parts. Atrazine cannot be used in intercropped sugarcane, as many of the common intercrops are susceptible to atrazine. In intercropped sugarcane, metribuzin (0.5 kg a.i./ha) or oxyfluorfen (0.3 kg a.i./ha) or pendimethalin (2.0 kg a.i./ha) or oxadiazon (0.4 kg a.i./ha) can be used as pre-emergence herbicide.

**Post emergence weed control:** Practices adopted to control weeds after the emergence of the crop are known as post emergence weed control. Weeds can be removed manually (hand pulling or hand hoeing or by both) or controlled mechanically by using animal / power tiller / tractor drawn intercultivation implements or by use of post emergence herbicides. Manual hoeing and weeding thrice at 30, 60 and 90 days after planting has been found to be an effective post emergence weed management practice in sugarcane. Use of intercultivation implements is less costly but the weed control efficiency is lower and the weeds along the crop rows are not controlled. At times, it may not be possible to carry out the intercultural operation in time and the only option is the use of post emergence herbicides. Only foliage absorbed selective herbicides could be used. A commonly used post-emergence herbicide in sugarcane is 2,4-D. The recommended dosages vary from 1.0 to 2.5 kg a.i./ha depending on the intensity of weeds. However, it controls only broad-leaved weeds but not grasses. Non-selective contact herbicides like paraquat and foliage absorbed translocated herbicides like glyphosate are useful as directed spray for controlling weeds in the inter-row spaces in sugarcane. This will be of much use even in fields with the problem of perennial weeds like *Cynodon* and nut grass. The directed post emergence application is to be done using a Knapsack or Backpack sprayer with hooded nozzle. As these are non-selective herbicides, extra care must be taken to avoid spray fluid from falling on sugarcane stem and leaves. The weeds present along the rows have to be removed manually.

**Herbicides approved for use in sugarcane:** Though a large number of herbicides have been found to be effective for weed management in sugarcane, only a few of them have been approved for use in sugarcane crop by the Central Insecticides Board. The details of the approved herbicides are given in Table 1.

<table>
<thead>
<tr>
<th>Herbicide name</th>
<th>Dosage/ha)</th>
<th>Waiting period before harvest (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,4-D Dimethyl Amine salt 58% SL</td>
<td>3.5 kg</td>
<td>-</td>
</tr>
<tr>
<td>2,4-D Na salt Technical (having 2,4-D acid 80% w/w) (Earlier Registered as 80%WP)</td>
<td>2.0-2.6 kg</td>
<td>300</td>
</tr>
<tr>
<td>2,4-D Ethyl Ester 38% EC(having 2,4-D acid 34% w/w)</td>
<td>1.2 to 1.8 kg</td>
<td>330 - 330</td>
</tr>
<tr>
<td>Diuron 80% WP</td>
<td>1.6-3.2 kg</td>
<td>-</td>
</tr>
<tr>
<td>Metsulfuron Methyl 20% WP(Add non -ionic surfactant 0.2%v/v)</td>
<td>6 g</td>
<td>346</td>
</tr>
<tr>
<td>Hexazinone 13.2% + Diuron 46.8% WP</td>
<td>1200 g (264+936)</td>
<td>282-306</td>
</tr>
</tbody>
</table>
Management of creeper weeds: With the extension of sugarcane cultivation to rice fields, twining weeds or creeper weeds or binder weeds have become a major problem. These weeds twine around sugarcane clumps, bend the canes, damage the tops and affect cane growth and final yield loss could be as high as 25%. They also interfere with harvesting operations. The major creeper weeds are *Convolvulus, Ipomoea, Coccinia, Passiflora and Cardiospermum*. Management of creeper weeds poses serious problems as they germinate after the earthing up and it is difficult to use mechanical methods are take up spraying operations. At Pantnagar, application of metribuzin 1.25 kg a.i./ha + dicamba @ 350 g. a.i./ha at 70 DAP effectively controlled *Ipomoea* spp. along with other grasses and non grass weeds.

Management of *Cynodon* and *Cyperus*: Digging, collection and destruction of underground vegetative parts of perennial weeds like *Cynodon dactylon* that are capable of multiplying, can be done during the fallow period, to effectively check such perennial weeds. Puddling is also helpful in reducing the infestation of perennial weeds. Pre-planting weed control using ‘glyphosate’ followed by in-crop weed control with ‘pre-emergence atrazine’ and ‘post emergence ethoxysulfuron’ or ‘directed post emergence paraquat’ or ‘directed post emergence glyphosate’ all were found useful to manage weeds including *Cynodon* and nut grass. Pre-emergence application of atrazine at 1.75 kg a.i./ha followed by two post-emergence sequential applications of ethoxysulfuron at 80 g ai./ha at 15 and 30 DAP has been suggested as an effective weed management practice for fields severely infested with nutgrass. After the spray of ethoxy sulfuron, nutgrass is effectively controlled and its re-emergence was very slow. However, ethoxy sulfuron had no effect on *Cynodon* as well as the second flush of weeds germinating from seeds.

Management of *Striga*: *Striga* (commonly known as witch weed) is a serious parasitic weed that invades host plant’s root system for nutrients, water and carbohydrates, eventually stunting growth and killing the host plant. *Striga* are most abundant in dry, infertile, marginal soils in semi-arid tropical grasslands and savannas. When sugarcane cultivation is extended to infertile soils under moisture deficit conditions, *Striga* becomes a problem for sugarcane. In recent years, *Striga* has been reported to be a serious problem in sugarcane in isolated pockets. A multi-pronged approach is needed to manage the *Striga* problem. The soil fertility has to be improved and moisture stress should be avoided. To control the *Striga* after emergence, 2,4-D Na salt has to be applied at 1.0 kg a.i./ha as a directed spray and the spray has to be repeated at 15 days intervals two or three times. This should be done before *Striga* flowers. Application of pendimethalin at 2.0 kg a.i./ha as a directed spray to the soil in the base of the sugarcane clumps just before the second irrigation after full earthing up would control *Striga* at the emergence stage itself. If some escapes are there, they can be controlled by spraying 2,4-D. Pre-emergence application of atrazine 1.0 kg/ha on third day after planting + hand weeding on 45 DAP with an earthing up on 60 DAP combined with post-emergence spraying of 2,4-D sodium salt 5g / litre (0.5%) + urea 20 g/litre (2%) on 90 DAP is recommended for complete control of *Striga asiatica* in sugarcane. The *Striga* control efficiency is 99.3%. Other management options include:

- Grow fodder jowar or maize and after 45 days pull out the plant
- Grow cotton in infested soil which acts as a trap crop
Apply adequate FYM or organic manure to improve soil fertility and retention of soil moisture

Apply extra dosage of nitrogen and apply fertilizers in more splits

Give light but frequent irrigations

**Integrated weed management**  Integrated weed management involves the use of all feasible control methods (including herbicides) to give the most practical and economical results. An integrated approach of weed management, viz., maintaining the fallow fields weed free, thorough field preparation before planting, pre-emergence application of atrazine, ensuring good even germination and avoiding gaps, trash mulching, selective manual weeding before fertilizer application, post emergence application of 2,4-D for broadleaf weeds and need based directed spot application of either glyphosate or paraquat for perennial weeds will considerably reduce the competition of weeds to sugarcane and help in sustaining the cane productivity and production.

**Earthing-up:** Earthing-up operation is generally followed in the tropical states where furrow irrigation is common. In tropical region, earthing up operation is done in two 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 fertilizers. This practice could be carried out either by manual labour or by using a tractor/bullock-drawn implement. While doing partial earthing-up, the furrow in which cane row is present gets partially filled. Irrigation continues to be given in the partially filled up furrow. Full earthing-up is done after the final manuring, i.e. at 90-100 days. During full earthing up, the soil from the ridges is completely removed and placed near the cane on both the sides. This operation converts the furrow into ridges and ridges into furrows. The furrows thus formed are used for irrigation. Earthing up suppresses weeds and provides adequate support to the stalks and discourages the emergence of late shoots, which leads to poor juice quality. In some places one more earthing up is also done around six months when a stable cane population has been established. This is helpful to prevent lodging, minimize soil erosion and to prevent late shoot or water shoot formation. Wet earthing up is also practiced in certain areas. This is usually done when the crop is about 6 months old. The furrows are irrigated and the wet soil removed from the furrow is plastered on the ridges. This gives a firm support to the canes against lodging and also effectively checks late shoot formation. Heavy and high earthing-up is useful especially during floods to drain the excess water quickly. The earthing up operations also help in covering the fertilizers applied and promote better root system development and anchorage.

**Detrashing:** Sugarcane on an average produces 30 – 35 leaves under good growing conditions. As the cane grows the lower leaves gradually dry up. The dried leaves are called trash. The operation of removing loosely adhering dried and drying cane leaves from the cane is known as trashing. For optimum photosynthesis only the top 8 – 10 leaves are required. 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. Detrashing should be done once the cane formation takes place; dry and senescent leaves are stripped at 5th and 7th months and may be applied as mulch in alternate furrows. Detrashing is generally done manually. Detrashing provides easy movement of air within the crop canopy, provides an
ideal micro-climate condition for the growth of cane and also reduces the problem of insect pests like scales and mealy bugs. It also facilitates easy entry into the field, particularly to guide irrigation water, application of pesticides etc.

**Mulching:** In sugarcane, trash mulching is a highly useful technique to conserve soil moisture and to reduce the impact of moisture stress. Besides conserving soil moisture by reducing the evaporation from the soil surface, mulching also moderates soil temperature, helps in improving germination, better tiller survival and checks weed growth. In a multilocation trial in Tamil Nadu, 36% higher germination was observed under trash mulching as compared to control when sugarcane was planted during the hot weather period (March). This ultimately led to about 20% higher stalk population and 10% higher cane yield. At Coimbatore soil temperature was reduced by 2.1°C under trash cover, creating a more favourable environment for crop growth. The mulched trash may be incorporated into the soil while earthing up both in the plant and the ratoon crops. Microbial cultures could also be used for enhancing degradation of the incorporated trash.

Trash mulching at 3 t/ha immediately after ratooning results in conservation of soil moisture resulting in better development of root system and increased cane yields in a ratoon crop. Under trash mulching, there could be termite problem, which could be overcome by taking appropriate control measures. Other farm wastes like leaves, straw etc. could also be used as mulches which will help to conserve the available soil moisture by eliminating direct evaporation of water from the soil surface, which helps to maintain higher soil moisture status, besides improving infiltration of water into the soil. This will favour higher tiller survival and higher cane yield.

**Intercropping in sugarcane**

Adoption of wide rows would facilitate intercropping during the initial stages of sugarcane growth, which will generate additional income for the sugarcane farmers. When sugarcane is grown adopting closer row spacing of about 90 cm, it takes about three months for ‘closing in’ of the canopy while it takes longer time under wide row spacing. The availability of more space and sunlight for a longer duration under wide rows facilitates growing of intercrops without any adverse effect on sugarcane. Under wide rows, as the availability of growth resources like solar radiation and space is more, medium canopied high yielding varieties of crops could be raised as intercrops. The yield and additional returns from intercrops will also be more compared to intercrops grown in closer spaced sugarcane. Growing of legumes as intercrops can also result in improvement of soil fertility. Legumes could fix atmospheric nitrogen under favourable conditions and it may become available to the associated sugarcane crop. A large number of crops have been tested for their compatibility with sugarcane. Generally short duration crops which can be harvested before the final earthing up are recommended. They should be of determinate growth habit and dwarf in nature. Green gram, black gram, soy bean, sunnhemp, daincha, potato and onion could be raised as intercrops in sugarcane.

**Irrigation**

Water is one of the most critical inputs in crop production, but it is rapidly becoming a precious and scarce commodity. According to the United Nations, four out of every ten...
people on the globe now live in areas where water is scarce. The U.N. has predicted that by 2025, as much as two-thirds of the world population i.e. about 5.5 billion people may be living in countries facing serious water shortages. India is a water-starved country and per capita fresh water availability in India is very low compared to countries like Canada and Brazil. Increasing competition for water in agriculture, industry and domestic purposes as well as environmental issues are already manifested in many inter-and intra-sector, river basin, state, district and village level conflicts for water. These will escalate further as India’s annual per capita water availability goes below the water scarce threshold level of 1700 m$^3$ within the next two decades. Hence there is an urgent need to increase the existing water use efficiency in Indian agriculture.

For the normal growth and yield of any crop, it has to be provided with optimum soil moisture conditions, i.e. water content of the root zone soil is neither excess nor deficit (close to the field capacity) throughout its growing period. When such a condition is provided to the crop it does not undergo any stress and it paves the way for the normal functioning of the physiological processes resulting in the optimum growth and yield.

Water is the major constituent of cane, both physiologically and compositionally. The harvested product (cane) comprises about 70% water. It has been worked out that to produce one tonne of cane, 200 to 250 t of water is required. Sugarcane is a crop of about one year duration and it has to pass through all the seasons of the year irrespective of the time of planting. If we consider the different seasons and months of the year, some are moisture deficit, some are with adequate moisture supply and in some there is moisture surplus. The evaporative demand and the water requirement of the crop are generally high during the deficit period compared to the surplus period. Hence providing optimum soil moisture conditions throughout the growing period is necessary to realize high yields.

**Water requirement of sugarcane**

Sugarcane is cultivated in India under widely varying conditions of soil types, rainfall pattern, temperature regimes and water availability. Water requirement of sugarcane varies from 1200 to 3500 mm depending on the yield level, crop duration and the climatic conditions. The water requirement varies from 1200 – 1800 mm in the subtropical zone while it is 1600 – 2700 mm in tropical belt except Maharashtra. The total crop water requirement is about 3500 mm for $adsali$ cane in Maharashtra (Srivastava et al., 2007). Yates and Taylor (1988) in their comprehensive review gave WUE values ranging from 0.7 to 1.45 tonnes of cane/ha/cm in different sugarcane growing regions of the world. In the tropical region, 30 to 40 irrigations are given. In the sub-tropical region, there are places wherein sugarcane is grown under rainfed conditions; there are places where only 3 to 5 protective irrigations are given during summer months and there are places wherein about 15 irrigations are given. In some places, the crop suffers water logging for some period necessitating provision of drainage facilities and moisture deficit in some other period which warrants irrigation.

**Efficient water management**

Irrigation is the artificial application of water to the root zone of the crop which is a supplementary to rainfall, so as to provide optimum soil moisture condition in the root zone of the crop to realize its normal growth and yield. Hunsigi (1993) reported that under furrow
irrigation nearly 90% of soil moisture extraction takes place in the first 60 cm of the soil layer. However, the distribution of roots in the soil is strongly dependent on soil characteristics, cultvars and soil water content (Jones et al., 1990). In most places, rainfall is not uniformly distributed throughout the growing season of the crops. In such a situation, the crops will have to suffer water deficit at some stage or other. The objective of irrigation is to alleviate water deficit in crops at times of insufficient rainfall.

The availability of water at the farm level is not uniform throughout the year. First an estimate of the water availability during different months of the year has to be made, the period of least water availability should be identified and the area that could be commanded with that water should be estimated. The area of a crop like sugarcane in a farm should be limited to that area. In the rest of the area, other crops of shorter duration could be grown in periods of favourable water supply. In periods of less water availability, a part of the land in the farm should be kept fallow.

**When to irrigate?**

Irrigation is given to supply adequate water to the plants so as to obtain optimum yield and quality. It should be given at the optimum time so that the soil could supply water fast enough to meet the local atmospheric demands without placing the plants under any stress that would reduce yield or quality. Sugarcane performs well when the soil moisture is in the upper range, very close to the field capacity. It has been found that for sugarcane irrigation is to be given at 50% depletion of available soil moisture during the vegetative phase (from planting to 270 days after planting [DAP]) and at 75% depletion of available soil moisture during the maturity phase (from 270 DAP to harvest). The time of irrigation is decided based on physiological indications of the plant, soil moisture status or climatological data. Verma (2004) recommended that sugarcane crop during its formative phase should be irrigated once in 10 – 15 days in Punjab; once in 10 – 12 days in Haryana; once in 7 – 15 days in Rajasthan; once in 15 – 20 days in UP and Bihar; once in 15 days in West Bengal and Assam; and once in 10 days in MP. During the maturity phase the irrigation interval should be once in 25 – 30 days in Punjab and Haryana, once in 30 days in UP, Bihar, West Bengal and Assam, and once in 15 days in MP.

**Irrigation based on physiological indications of the plant**

Plant growth is related to the water balance in plant tissues. As soon as the water supply to the plant gets reduced, the physiological processes of the plant are disturbed and growth and yield are subsequently reduced. The physiological and morphological indications of water deficiency in plants which could be used as guide for deciding the time of irrigations are listed below.

- Appearance of the plant
- Indicator plant method (sunflower, *Datura*, maize)
- Plant population or density method
- Measuring the stomatal aperture
- Plant water content (crop logging)
- Leaf water potential
Irrigation based on soil moisture status

Depending on the ability of crop plants to extract water from the soil, the soil moisture status could be used to decide the time of irrigation. For sugarcane, it is necessary to maintain the moisture content of the root zone soil close to field capacity during the vegetative phase. In other words, the crop has to be irrigated before the depletion of 50% of the available soil moisture. The methods available to assess the soil moisture are as follows:

- Feel and appearance method
- Gravimetric method
- Electrical resistance units
- Tensiometers or irrometers
- Neutron scattering
- Time Domain Reflectometry

Irrigation based on climatological data

The irrigation requirement of the crop has a direct relationship with the evaporative demand of the climate which is measured by the pan evaporimeter. The cumulative pan evaporation can be used to decide the time of irrigation. Pan evaporation (PE) data may not be available at all locations and as an approximation, the PE data of the district in which the farm is located / nearest agricultural research station could be taken as pan evaporation and used for deciding the time of irrigation based on IW/CPE ratio. Srivastava et al (2007) while summarizing the results of irrigation experiments conducted in several parts of the country, indicated that IW/CPE ratio of 0.80 was found better than 0.50 ratio at Karnal (sandy loam soil), Sehore (clay loam) and Lucknow (loam).

How much to irrigate?

The quantity of water that is required to be applied during irrigation is the quantity needed to bring back the soil moisture content from its depleted level to field capacity of the soil plus conveyance and application losses. As the active root system of sugarcane extends up to 50 cm depth of soil, irrigation will have to be given to bring the soil moisture back to field capacity in the entire top 50 cm soil layer. The quantity of water required to raise the moisture content of the soil from 50% available soil moisture to field capacity and the conveyance and application losses ranges from 50 to 80 mm depending on the textural class of soil. Sandy soils require less water while clayey soils require more water per irrigation. But depletion of soil moisture is fast in sandy soils while it is slow in clayey soils. Hence, in sandy soils, irrigations are to be given more frequently compared to clayey soils.

Depth-interval-yield approach

In this approach, experiments are conducted by trying different depths and intervals of irrigation without cognizance of soil and water conditions. The depth and interval that produces the best yield is selected and recommended to farmers. It is found that frequent light irrigations are more effective than few heavy irrigations at longer intervals. However,
this approach of deciding the depth and time of irrigation may result in either pre-mature irrigation or delayed irrigation resulting excess water at some stages or lack of water at critical stages affecting crop growth and yield. Studies have shown that the following irrigation schedule with 60 mm of water per irrigation is optimum for sugarcane grown in a loamy type of soil in tropical India.

<table>
<thead>
<tr>
<th>Stage of the crop</th>
<th>Irrigation interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germination (up to 35 days)</td>
<td>7 days</td>
</tr>
<tr>
<td>Tillering (36 to 100 days)</td>
<td>10 days</td>
</tr>
<tr>
<td>Grand growth (101 to 270 days)</td>
<td>7 days</td>
</tr>
<tr>
<td>Maturity (After 271 days onwards)</td>
<td>15 days</td>
</tr>
</tbody>
</table>

In lighter soils, the interval between irrigations has to be reduced slightly while in heavy soils, the same has to be increased. Again, the interval has to be adjusted depending on the quantity of rainfall received during different periods.

**Soil moisture deficit approach**

In this approach, depletion of available moisture in the soil is taken into account for determining the interval between irrigations and the quantity of irrigation water is decided depending upon the available water holding capacity of the soil. This method takes care of the evapotranspiration of the crop and the effective rainfall. The only problem with this method is that it is necessary to monitor the soil moisture continuously. Studies have shown that sugarcane crop needs irrigation at 50 % depletion of available moisture up to 270 days and at 75 % depletion thereafter.

The quantity of water needed per irrigation can be calculated using the following formula:

\[
IW = \frac{(MFP - MRP)}{(100)} \times BD \times D \times \frac{(100)}{(100 - CAL)}
\]

Where,

- **IW** = Quantity of water needed per irrigation in mm
- **MFP** = Soil moisture at full point or field capacity in percentage
- **MRP** = Soil moisture at refill point i.e. at 50 per cent or 25 per cent available soil moisture as the case may be in percentage
- **BD** = Bulk density of soil in g per cc
- **D** = Depth of root zone soil layer in mm
- **CAL** = Conveyance and application losses of irrigation water in percentage

The actual quantity of water required in litres per irrigation for a given area can be arrived at by multiplying the **IW** in mm with area of the field in m².
Climatological approach

In this approach, pan evaporation is taken into account both for determining the interval between irrigations and the quantity of water to be applied per irrigation. This approach is popularly known as IW/CPE ratio. Here the IW represents the depth of water per irrigation while CPE represents the cumulative pan evaporation. The IW is decided depending on the soil characteristics and usually ranges from 50 to 80 mm. The studies carried out by adopting this approach have revealed that sugarcane requires irrigation at IW/CPE ratio of around 0.9. Thompson and Boyce (1971) opined that pan evaporation, with its simple instrumentation and calculation requirements is adequate to estimate potential evapotranspiration of sugarcane for irrigation control. Torres (1998) advocated the use of a visual device in the form of plastic container (calibrated and field tested plastic bucket), which works as an evaporimeter for effective scheduling of irrigation to sugarcane in regions where meteorological data is scarce. A calibrated evaporation minipan has been also suggested as a simple irrigation scheduling tool for sugarcane in Australia.

Conventional methods of irrigation

Surface irrigation: In this method, the irrigation water is conveyed from the source to the field, usually through earthen channels and in the field, water is allowed to flow on the soil surface. This method is simple, cheap and easy to adopt. But a major portion of the water is lost both during conveyance and application. There are different methods of surface irrigation which are described below:

Flood irrigation: This type of irrigation is adopted generally for the crop planted in flat system. In this method, the irrigation water is not regulated in the field and allowed to flow uncontrolled. The irrigation water requirement per irrigation in this method often exceeds 100 mm. As the water stagnates in the field, a lot of the water percolates down beyond the root zone resulting in the wastage of precious irrigation water. Besides the root zone soil remains saturated for a few days every time it is irrigated which affects the soil aeration and consequently the growth of the crop. The only advantage of this system is that it is easy to adopt when the availability of irrigation water is plenty or unlimited. But this results in poor water use efficiency and poor water application uniformity, in addition to potential water logging and salinity problems

Furrow irrigation: This is the most common irrigation method adopted for sugarcane. Water from the irrigation channel is diverted into small furrows along the slope in between small ridges or broad beds. Water in furrows moves both laterally and vertically to moisten the ridges and sub soil. This is a cheap and easy method but there is some application loss. The method could be improved by adopting a proper irrigation schedule based on soil moisture deficit approach or climatological approach or the depth-interval-yield approach and by regulating the quantity of water per irrigation based on the available moisture holding capacity of the soil.

Skip furrow irrigation: It is a modification over furrow irrigation wherein alternate furrows are skipped by bringing two rows in a common furrow, if necessary by suitable adjustment of spaces between the rows. The crop population remains the same whereas the number of furrows irrigated gets reduced. There are reports which show that there could be a saving of
30 to 36 % in the quantity of irrigation water by adopting skip furrow method of irrigation. However, a reduction of 14 % in the cane yield has also been reported. Adoption of 60/90 cm paired rows with irrigation in 60 cm furrows and trash mulching in unirrigated 90 cm furrows resulted in over 10 % saving in irrigation water with higher cane yield compared to normal 90 cm uniform furrow irrigation as shown in the table 3 below:

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Treatment</th>
<th>Cane yield (t/ha)</th>
<th>Water used (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>90 cm uniform rows with irrigation in all furrows</td>
<td>71.7</td>
<td>2308</td>
</tr>
<tr>
<td>2.</td>
<td>60/90 cm paired rows with irrigation in 60 cm furrows and trash mulching in unirrigated 90 cm furrows</td>
<td>77.1</td>
<td>2053</td>
</tr>
</tbody>
</table>

**Alternate furrow irrigation:** Alternate furrow irrigation is another modification of furrow irrigation wherein irrigations are given in cycles to the odd and even numbered furrows. It has been reported that there is a saving of 41 per cent in the quantity of irrigation water by adopting this method. But there was a reduction in the cane yield to the extent of 26 per cent. This method could be adopted during periods of irrigation water scarcity and the normal furrow irrigation could be readopted when the availability of irrigation water improves. Ved Singh (2002) reported the highest water saving of 33% when alternate furrow irrigation was adopted.

**Overhead/Sprinkler irrigation:** In this method, water is transported through easily dismantlable, surface laid pipes under pressure and sprinkled over the canopy by rotating type of nozzles. There are different sizes in sprinklers. The medium sized ones could sprinkle water to a radius of 10 to 15 metres and could be arranged in the field in such a way that sprinkling of water is more or less uniform all over the field. There are larger sized ones known as rain guns which could sprinkle water to a radius of over 30 metres. These could be fixed and operated in semi circles also. Just one rain gun can cover over 0.1 ha at a time. Here the conveyance and application losses are lower and it is easy to regulate the quantity of water to be applied. This is a useful and feasible method when the crop is young. But at later stages, when the height of the crop canopy goes up, shifting of the pipes and sprinklers in the field from one place to the other becomes very difficult and poses practical problems in its adoption. This system of irrigation limits the root system to the surface layer of the soil which leads to lodging of the cane. As the water is sprinkled over the canopy, it wets the canopy, trash and cane before reaching the soil surface. In this process, a small quantity of water is wasted. Sometimes it may induce aerial rooting of the cane which affects the quality. The distribution of water is also not uniform all over the field. The initial cost of the system is very high and the energy requirement for operation of the system is also very high. Of the different sprinkler type systems available, only permanent systems have proved practical in the long run. In clayey soils, sprinkler systems have proved very useful for better germination of the crop and to economise irrigation water as it wets only the surface soil.

**Micro-irrigation**

The term “micro-irrigation” describes a family of irrigation systems that apply water through small devices. These include minisprinklers, microsprinklers, bubbler irrigation...
and drip irrigation. These devices deliver water onto the soil surface very near the plant or below the soil surface directly into the plant root zone facilitating precision water application. Micro-irrigation systems are immensely popular in arid as well as subhumid and humid zones where water supplies are limited or water is expensive. In irrigated agriculture, micro-irrigation is used extensively for row crops, mulched crops, orchards, gardens, greenhouses and nurseries. Of the different micro-irrigation systems, drip irrigation is gradually becoming popular in India mainly in wide spaced horticultural crops and also in sugarcane.

**Drip / Trickle irrigation:** Drip irrigation was introduced in the 1970s in Hawaii, Australia and Mauritius. The main advantage of drip system is that the irrigation water is transported from the source to the root zone of the crop through a network of tubing without any conveyance loss. Besides the quantity of irrigation water can be easily regulated in the drip irrigation system to the actual requirement of the crop. Through drip irrigation, the moisture in the root zone of the crop can be maintained near field capacity almost continuously. As the conveyance loss is practically eliminated and the irrigation water is directly fed into the root zone of the crop at the levels required by the crop, it results in the saving in the quantity of irrigation water.

**Types of drip irrigation systems:** There are two types of drip irrigation systems viz. surface and sub-surface systems. A drip system, whether surface or sub-surface, essentially consists of pump, sand filter, screen filter, venturi, back water arrangement, pressure gauge, water meter, control valves, mains and sub-mains, laterals and drippers/emitters. In the surface system, the laterals are laid on the surface and drippers are fixed at desired intervals on the laterals. This type of drippers is known as online drippers. In this type, again there are ordinary drippers and self flushing and pressure compensating drippers. The drippers are available at varying capacities, say 2, 4, 6 or 8 litres per hour. The distance between the laterals, distance between the drippers and the capacity of the drippers can be varied depending upon the need of the crop and soil characteristics. Here the water drips at the soil surface and there is chance for the loss of water through surface evaporation. In the sub-surface system, the laterals are buried in the soil at desired depth along the crop rows. These laterals have emitters fixed inside and are known as inline drippers. They are fixed at desired intervals which emit the water right in the root zone of the crop and only a little quantity of this water come to the surface. Hence, in this system, the chance for the loss of water through surface evaporation is very less. Different types of sub-surface laterals with emitters are available commercially. Biwall and Typhoon are some of them.

**Field layout of the drip system:** The field layout depends on the area of the field, shape of the field, distance between the water source and the field, and the capacity of the pump available. In most cases, the drip system can be directly connected with the existing pump in the farm. But when the operating pump pressure is too less or very high than that required by the drip system, a new pump has to be installed for the drip system. To facilitate drip irrigation in sugarcane, the planting method needs to be changed to wide row or paired row or trench or pit system. The spacing between the laterals can be from 1.5 to 2.4 m depending upon the planting system and geometry. The drip system is designed for the specific fields by the manufacturers/dealers in consultation with the farmers. The manufacturers/dealers also do the installation as per the requirement of the farmers taking the local conditions into account.
**Scheduling of drip irrigation:** Irrigation water economy could be achieved in drip irrigation only when the actual water requirement is computed on a daily or once in two days basis and only the computed quantity is applied. At planting, the drip system is run continuously so as to bring the moisture in the root zone of the crop to field capacity. Thereafter, the quantity of irrigation water has to be computed based on the crop coefficient (Kc value) and the evaporative demand of the climate (pan evaporation). The Kc values for sugarcane at different ages for a location with moderate humidity and wind velocity are given below.

The quantity of water to be irrigated on a given day can be computed using the formula given below in table 4.

\[
Q = A \times Kc \times PE
\]

Where,
- \(Q\) = Quantity of water to be irrigated on a given day in litres
- \(A\) = Area of the field in \(m^2\)
- \(Kc\) = Crop coefficient value depending on the age of the crop
- \(PE\) = Pan evaporation for the day in mm

It may be difficult to obtain the pan evaporation data daily. As discussed earlier, the average monthly PE values of the district or the nearest agricultural research station can be used. A chart can be prepared indicating the duration for which the system should be operated every day right from planting up to the harvest. Whenever there is rain, the farmer has to use his judgment and can withhold irrigation for a few days. Similarly, there may be situations wherein the farmer may not be in a position to give irrigation on certain days due to reasons like power shut down. Running the system for more time in the subsequent days can compensate this. Hence, at the farmers’ level, the system can be used with some flexibility.

**Experimental results with drip irrigation**

Drip irrigation has been experimented in sugarcane in different parts of the country and the results are presented in the table 5 below:

**Table 4. Stagewise Kc value for sugarcane**

<table>
<thead>
<tr>
<th>Crop age (months)</th>
<th>Kc value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 1</td>
<td>0.55</td>
</tr>
<tr>
<td>1 – 2</td>
<td>0.80</td>
</tr>
<tr>
<td>2 – 2.5</td>
<td>0.90</td>
</tr>
<tr>
<td>2.5 – 4</td>
<td>1.00</td>
</tr>
<tr>
<td>4 – 10</td>
<td>1.05</td>
</tr>
<tr>
<td>10 – 11</td>
<td>0.80</td>
</tr>
<tr>
<td>11 – 12</td>
<td>0.60</td>
</tr>
</tbody>
</table>
The results in general indicate around 30% saving in irrigation water which is compared to conventional furrow irrigation. But with regard to cane yield, there are conflicting reports. In some places, increase in the yield ranging from 10 to 30% has been reported. In some other places, practically there was no increase in the yield of drip irrigated plot compared to conventional furrow irrigation. Lester R Brown (2003) reported that drip irrigation in sugarcane improves yield by 6 to 33%, results in 30 to 65% saving in irrigation water and improves water productivity by 72 to 208%. Magwenzi (2000) from Swaziland reported application efficiencies of 72–89% under drip and centre pivot systems compared to 48–75% for furrow systems. Clancy (1996) reported 90–95% water use efficiency with subsurface drip irrigation in Australia compared to typical values of 70% for overhead and 60% for furrow irrigation systems.

In an earlier experiment conducted (during 90s) at Sugarcane Breeding Institute, Coimbatore (Table 6), surface drip irrigation using self flushing and pressure compensating drippers resulted in about 30 per cent saving in irrigation water with over 20 per cent increase in cane yield compared to conventional furrow irrigation (Ramesh et al, 1994).

### Table 5. Water use under drip irrigation

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Location</th>
<th>Irrigation method</th>
<th>Conventional furrow</th>
<th>Surface drip</th>
<th>Sub-surface drip</th>
<th>Water saving/yield increase in drip (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water requirement (mm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Coimbatore</td>
<td></td>
<td>1990</td>
<td>1112</td>
<td>1112</td>
<td>44</td>
</tr>
<tr>
<td>2.</td>
<td>Coimbatore</td>
<td></td>
<td>1670</td>
<td>1198</td>
<td>1198</td>
<td>28</td>
</tr>
<tr>
<td>3.</td>
<td>Pune</td>
<td></td>
<td>2153</td>
<td>1075</td>
<td>938</td>
<td>50-56</td>
</tr>
<tr>
<td>4.</td>
<td>Rahuri</td>
<td></td>
<td>2160</td>
<td>914</td>
<td>-</td>
<td>57</td>
</tr>
<tr>
<td>5.</td>
<td>Padegaon</td>
<td></td>
<td>2240</td>
<td>1762</td>
<td>1425</td>
<td>21-36</td>
</tr>
<tr>
<td>6.</td>
<td>Akola</td>
<td></td>
<td>1574</td>
<td>1151</td>
<td>-</td>
<td>27</td>
</tr>
<tr>
<td>7.</td>
<td>Bhavanisagar</td>
<td></td>
<td>1462</td>
<td>1177</td>
<td>-</td>
<td>20</td>
</tr>
<tr>
<td>8.</td>
<td>Pune</td>
<td></td>
<td>2741</td>
<td>1376</td>
<td>1273</td>
<td>50-53</td>
</tr>
<tr>
<td>9.</td>
<td>Nasik &amp; Sholapur</td>
<td></td>
<td>2383</td>
<td>1754</td>
<td>1624</td>
<td>26-32</td>
</tr>
<tr>
<td>Cane yield (t/ha)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Coimbatore</td>
<td></td>
<td>94.7</td>
<td>90.1</td>
<td>98.0</td>
<td>4</td>
</tr>
<tr>
<td>2.</td>
<td>Coimbatore</td>
<td></td>
<td>78.7</td>
<td>95.1</td>
<td>80.4</td>
<td>2-17</td>
</tr>
<tr>
<td>3.</td>
<td>Pune</td>
<td></td>
<td>128.1</td>
<td>175.5</td>
<td>143.8</td>
<td>12-36</td>
</tr>
<tr>
<td>4.</td>
<td>Rahuri</td>
<td></td>
<td>114.7</td>
<td>130.6</td>
<td>-</td>
<td>12</td>
</tr>
<tr>
<td>5.</td>
<td>Padegaon</td>
<td></td>
<td>108.9</td>
<td>116.5</td>
<td>112.6</td>
<td>4-6</td>
</tr>
<tr>
<td>6.</td>
<td>Akola</td>
<td></td>
<td>125.3</td>
<td>111.6</td>
<td>-</td>
<td>-11</td>
</tr>
<tr>
<td>7.</td>
<td>Bhavanisagar</td>
<td></td>
<td>102.4</td>
<td>150.2</td>
<td>-</td>
<td>32</td>
</tr>
<tr>
<td>8.</td>
<td>Pune</td>
<td></td>
<td>95.1</td>
<td>107.6</td>
<td>99.5</td>
<td>4-12</td>
</tr>
<tr>
<td>9.</td>
<td>Nasik &amp; Sholapur</td>
<td></td>
<td>104.7</td>
<td>122.9</td>
<td>120.3</td>
<td>13-15</td>
</tr>
</tbody>
</table>

The results in general indicate around 30% saving in irrigation water which is compared to conventional furrow irrigation. But with regard to cane yield, there are conflicting reports. In some places, increase in the yield ranging from 10 to 30% has been reported. In some other places, practically there was no increase in the yield of drip irrigated plot compared to conventional furrow irrigation. Lester R Brown (2003) reported that drip irrigation in sugarcane improves yield by 6 to 33%, results in 30 to 65% saving in irrigation water and improves water productivity by 72 to 208%. Magwenzi (2000) from Swaziland reported application efficiencies of 72–89% under drip and centre pivot systems compared to 48–75% for furrow systems. Clancy (1996) reported 90–95% water use efficiency with subsurface drip irrigation in Australia compared to typical values of 70% for overhead and 60% for furrow irrigation systems.

In an earlier experiment conducted (during 90s) at Sugarcane Breeding Institute, Coimbatore (Table 6), surface drip irrigation using self flushing and pressure compensating drippers resulted in about 30 per cent saving in irrigation water with over 20 per cent increase in cane yield compared to conventional furrow irrigation (Ramesh et al, 1994).
Fertigation: Fertigation can be a more efficient means of applying crop nutrients, particularly N and K, so that nutrient application rates could be reduced. However, only information limited is available on the extent of the possible reduction in N application rate for fertigated sugarcane. Thorburn et al. (2003) studied the response of cane and sugar production to different N rates (0 - 240 kg/ha/year) applied through drip fertigation to one plant and three ratoon crops in Australia. The results indicated that the high soil water contents maintained with daily application of irrigation water through the trickle system promoted mineralisation of soil organic matter and stressed the need to avoid over-application of N in fertigated sugarcane. Raskar and Bhoi (2001) in their studies on the effect of sources and levels of fertigation on yield and quality of sugarcane found that the yield obtained due to application of 75% and 100% of the RDF was on par indicating 25% saving in fertilizer. Cane yield obtained with the use of water soluble fertilizers was on par with that obtained with urea, DAP and MOP.

An experiment on micro irrigation in sugarcane involving a combination of planting methods (paired row planting, trench planting and pit planting) and fertigation levels (100% and 75% RDF) and a control (surface irrigation in sugarcane planted in ridges and furrows at 90 cm row spacing) was conducted at SBI, Coimbatore during 2007 - 2010. Drip irrigation saved 40% of irrigation water as compared to the conventional furrow irrigation. Yield data recorded showed that paired row planting with fertigation performed on par with surface irrigation. Cane yield in paired row planting was on par with surface irrigation. Under all the three methods of planting under drip, fertigation using 75% of the recommended dose of fertilizer was found to perform on par with fertigation using 100% of the recommended dose of fertilizer indicating 25% saving in fertilizers.

Economics of drip system: Assuming that the drip laterals are spaced at 1.8 m and drippers are spaced at 0.6 m along the laterals, about 5600 m length of laterals and 9400 drippers are required to install drip irrigation system for one hectare of sugarcane. These along with other components costs at present between Rs. 70,000 and Rs. 100,000 per hectare depending upon the type of system and size of fields. By replacing the laterals in 6th year, the system could be used for about 10 years. The cost of replacement in the 6th year will be about Rs. 30,000 to Rs. 50,000 per hectare. Therefore, the total investment on drip irrigation system for 10 years ranges from Rs. 100,000 to Rs. 150,000 per hectare. Even assuming that there is about 30% saving in irrigation water and about 15% increase in cane yield, the cost is very much prohibitive. Narayanamoorthy (2002) assessed the impact of drip irrigation for sugarcane in India and estimated that drip irrigation resulted in 44% energy saving, 23% increase in productivity and a saving of 1059 kwh of electricity per hectare and was found to be economically viable even without subsidy.
Advantages of drip irrigation

- Irrigation water is transported from the source to the root zone of the crop without much conveyance and application losses which results in economy of irrigation water.
- The quantity of irrigation water can be regulated so as to wet only the root zone of the crop.
- Soil moisture in the root zone of the crop could be maintained near field capacity throughout the crop duration which leads to better crop growth and higher cane yield.
- Costly inputs like fertilizers and pesticides could be applied through irrigation water and the dose of such inputs could be reduced increasing their efficiency.
- Under situations of acute water shortage, the irrigation interval gets widened beyond the critical limit and the crop often dries up. With drip irrigation it is possible to evenly apply the available irrigation water over the entire cropped area, thereby keeping it alive so that it can be rejuvenated later.
- With drip irrigation as separate space is not allotted for irrigation channels etc., the effective cropped area is more producing additional cane yield.
- Drip irrigation reduces the drudgery of the irrigation labour as well as labour cost.

Constraints in adoption of drip irrigation in sugarcane

- The high cost of the system.
- Operational problems like non-availability of electricity, spare parts, good quality components, trained man power etc.
- Clogging of drippers particularly when poor quality irrigation water is used.
- Shallow rooting is a common feature which results in severe lodging affecting yield and quality.
- Filter maintenance
- Root intrusion
- Damage from farm implements and animals
- Difficulties in designing and installation of the drip irrigation system because of the small size of the holdings.
- The planting geometry of the crop needs to be modified from the conventional uniform rows to paired rows for adoption of drip irrigation
- Components like pressure gauges, filter screens and water meters become non-functional quite often due to salt deposition necessitating replacements or repairs which add to the maintenance cost.
- The power consumption is more compared to conventional irrigation
- There are different grades of drip irrigation system components with wide variation in quality and longevity, which cannot be easily distinguished, and there are chances for the farmers to lose on account of poor quality.
Once a drip irrigation system is installed for sugarcane, one plant and one or two ratoon crops can be successfully taken. After that, most often the system is not suitable for crops coming in rotation like rice, groundnut etc.

**Computer models for irrigation scheduling**

New instruments are being designed to monitor soil moisture and software/models are becoming available for irrigation scheduling. Singles et al (1998) have developed an easy to use, accurate software for irrigation scheduling in South Africa. The software ‘IRRICANE’ consists of three steps, viz. downloading weather data from an automatic weather station; calculation of reference crop ET using Penman–Monteith equation; and calculating daily water balance for each field. Le Mezo et al (2003) used IRRICANE to work out the irrigation schedule for next 10 days based on crop water needs, soil characteristics, climate and irrigation system in Reunion Island. Qureshi et al (2002) used a computer simulation model ‘SWAP 93’ to simulate soil water balance of sugarcane and to predict the impact of irrigation schedules on salinity and waterlogging in Sindh, Pakistan. Other crop growth models like CANEGRO and APSIM have also been used to work out irrigation schedules after incorporating Penman-Monteith equation.

The irrigation water requirement varies widely between the methods of irrigation adopted. The variation arises mainly because of the differences in the amount of conveyance and application losses among the different methods. The conveyance and application losses are very high in the flood irrigation system and very little in the drip irrigation system. They are moderate in controlled furrow irrigation system and sprinkler irrigation system. There is urgent need to improve water use efficiency in sugarcane farming in view of the increasing scarcity of water and frequent droughts and competition from other crops and domestic and industrial users. Micro irrigation systems are a potential means of increasing water use efficiency and productivity of sugarcane and need to be extensively adopted in the years and decades to come. This calls for concerted efforts of system designers, researchers, development workers and farmers to find solutions to various problems observed.

- At the farm level an assessment of the availability of irrigation water in different months of the year should be done and the month in which the availability is lowest should be identified. The sugarcane area in the farm should be restricted to the minimum area that could be commanded during the month of lowest water availability.

- Flood irrigation not only leads to wastage of precious water but also lowers the productivity of the crop. Hence it must be avoided.

- Furrow irrigation is easy to adopt and wastage of the water can be minimised. Planting cane in long furrows and adoption of surge irrigation would be advantageous. Transporting of water from the source to the field head should be done as far as possible only through pipelines.

- At times of water scarcity, alternate furrow irrigation or skip furrow irrigation may be adopted. When water availability becomes favourable the farmer can switch back to normal furrow irrigation from alternate furrow irrigation.
Drought management practices like trash mulching and foliar spray of a solution containing 2.5% urea and 2.5% muriate of potash at fortnightly intervals during the drought period can be done to tide over the ill effects of drought.

In heavy soils, during germination phase, sprinkler irrigation would be advantageous to give light irrigations and to obtain better germination of the crop.

Drip irrigation with fertigation is advantageous to economize irrigation water, save costly chemical fertilizers and increase cane yield.

References


Thorburn, P.J.; Dart, I.K; Biggs, I.M; Baillie, C.P; Smith, M.A; Keating, B.A, 2003. The fate of nitrogen applied to sugarcane by trickle irrigation. Irrigation Science, 2003; 22(3/4); 201-209
Torres, J.S.  A simple visual aid for sugarcane irrigation scheduling. Agricultural Water Management; 38(1): 77-83


Integrated nutrient management (INM) comprises the intelligent use of organic, inorganic and biological resources to sustain optimum yields, improve and maintain soil chemical and physical properties and provide nutrition packages that are technically sound, economically attractive, practically feasible and environmentally safe (Tandon, 1992). INM optimizes all aspects of nutrient cycling, supply, uptake, and loss to the environment to improve food production. It helps to improve soil organic matter, increase available nutrients, increase and sustain crop production, increase the economic potential and minimize environmental pollution.

Nutrient requirement of sugarcane

Sugarcane is a long duration crop having C₄ metabolism. Its huge biomass production potential demand large amounts of water, nutrients and sunlight. An average crop of sugarcane with 100 t ha⁻¹ cane yield removes 208, 53, 280, 30, 3.4, 1.2, 0.6 and 0.2 kg N, P, K, S, Fe, Mn and Cu, respectively, from the soil (Zande, 1990). According to projections, about 450 Mt of sugarcane will be produced from an area of 4.50 Mha during the year 2020 in India and this will remove 0.90, 0.24, 1.26 and 0.135 Mt of N, P, K and S from the soil, which needs to be replenished to maintain the productivity (Singh and Yadav, 1996). About 0.88 Mt of nutrients comprising 0.70 Mt of N, 0.06 Mt of P and 0.12 Mt of K in addition to 55,000 t of S, 10,000 t of Zn and 5,000 t of Fe are required to harvest 450 Mt of cane.

Fertilizer recommendations

Fertilizer is the most important component of integrated nutrient supply system as it is responsible for nearly 50% of yield in sugarcane. Soil nutrient resources will not be able to sustain intensive cropping of sugarcane, which depletes large quantities of NPK along with significant amounts of secondary and micronutrients. Use of fertilizers in balanced proportion and adequate amounts is inevitable to attain the potential production. Fertilizer recommendations for sugarcane in major sugarcane growing states of India are summarized in Table 1. The recommendations vary from state to state depending upon the soil type, crop duration, yield level and irrigation practices. The fertilizer doses are generally higher in tropical states (100 to 450 kg N/ha) compared to subtropical states (100 to 225 kg N/ha).

Integration of organics, chemical fertilizers and biofertilizers

Soil test based fertilizer recommendation approach considers all soil nutrient deficiencies and corrective measures for achieving optimum yield. A combination of organic, inorganic and biofertilizers that are available and affordable are optimized to supply adequate nutrients at right time and right place. Phonde et al. (2005) reported significantly higher cane yield, sugar recovery and relative economic benefit in site specific nutrient management based fertilization than blanket recommendation and farmer’s practice. Combinations of 50% recommended N, P₂O₅ K₂O, S and Zn with pressmud at 20 tonnes and rice mill ash at 10
tonnes per hectare showed the highest net economic benefit and better apparent nutrient balance in soil (Paul et al., 2005). Farm yard manure applied @ 15 t ha$^{-1}$ accompanied with chemical fertilizers (N, P$_2$O$_5$, K$_2$O, S and Zn @ 178, 53, 54, 26 and 2.6 kg ha$^{-1}$) produced 108.4, 96.8, and 73.5 t ha$^{-1}$ cane yield in plant, first, and second ratoon crops, respectively.

Keshaviah et al. (2013) obtained significantly higher sugarcane yield of 170.33 t ha$^{-1}$ when nutrients were applied with 50 per cent N through pressmud and 50 per cent NPK through fertilizers + biofertilizers. Kumar and chand. (2012) found that the yields of both plant and ratoon cane were enhanced by 27.7 and 16.2 per cent, respectively by the application of 100% NPK + 25% N through FYM + biofertilizers (Azotobacter + PSB) in plant cane following 100% NPK + trash incorporation with cellulolytic culture + biofertilizers in ratoon. Venkatakrishnan and Ravichandran (2012) found that basal application of seasoned pressmud @ 25 t ha$^{-1}$ and application of 100% RDF + lignite flyash @ 25 t ha$^{-1}$ + humic acid 50 kg ha$^{-1}$ was the best INM combination for sustained sugarcane productivity and soil fertility on the sandy loam soil.

Table 1. Fertilizer recommendations for sugarcane in major sugarcane growing states of India

<table>
<thead>
<tr>
<th>State</th>
<th>N fertilizer recommendations (kg/ha)</th>
<th>P$_2$O$_5$ fertilizer recommendations (kg/ha)</th>
<th>K$_2$O fertilizer recommendations (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Andhra Pradesh</td>
<td>112 - 400</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Assam</td>
<td>130</td>
<td>26</td>
<td>50</td>
</tr>
<tr>
<td>Bihar</td>
<td>70 - 170</td>
<td>31 - 47</td>
<td>25</td>
</tr>
<tr>
<td>Gujarat</td>
<td>250</td>
<td>5</td>
<td>104</td>
</tr>
<tr>
<td>Haryana</td>
<td>150</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Karnataka</td>
<td>187 - 250</td>
<td>33 - 55</td>
<td>62 - 125</td>
</tr>
<tr>
<td>Madhya Pradesh</td>
<td>300</td>
<td>80</td>
<td>37</td>
</tr>
<tr>
<td>Maharashtra</td>
<td>150 - 400</td>
<td>48 - 74</td>
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<td>Orissa</td>
<td>200</td>
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</tr>
<tr>
<td>Punjab</td>
<td>150 - 225</td>
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<td>-</td>
</tr>
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<td>Rajasthan</td>
<td>150 - 175</td>
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<td>25</td>
</tr>
<tr>
<td>Tamil Nadu</td>
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</tr>
<tr>
<td>Uttar Pradesh</td>
<td>150</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>West Bengal</td>
<td>160</td>
<td>26</td>
<td>50</td>
</tr>
</tbody>
</table>

(Singh and Yadav, 1996)

Ocheuze et al. (2013) observed that keeping the crop residues over soil increased soil N stock and recovery by sugarcane, reaching equilibrium after 40 years with recovery of 40 kg ha$^{-1}$ year$^{-1}$. Of the total nutrients in the trash, 75 % of the K$_2$O (81 kg ha$^{-1}$ year$^{-1}$) and 50 % of the N (31 kg ha$^{-1}$ year$^{-1}$) were in the tops, indicating the importance of maintaining tops in the soil to sustain soil fertility.

Patel et al. (2013) found that for securing higher yield and remuneration in rice - sugarcane cropping sequence, application of 25% N through FYM + 25% N through poultry
manure + 50% N through inorganic fertilizers gave net return and B:C ratio close to that obtained with 100% recommended fertilizers alone and improved the soil health in terms of positive nutrient balance. Kumar and Chand (2013) found that application of NPK fertilizers increased the cane yield of plant and ratoon crops of sugarcane over N and P alone. Farm yard manure with N and $\frac{1}{2}$ P, press-mud, pressmud compost with N and $\frac{1}{2}$P, FYM + N and P, green manure + N and P gave at par cane yields as full NPK fertilizers alone.

Li et al. (2013) found that the dry biomass yield under sugarcane-soybean intercropping increased by 35.44 and 30.57% for sugarcane, and decreased by 16.12 and 9.53% for soybean, respectively. The nitrogenase activity of intercropping soybean nodule was significantly increased by 57.4% as compared with that in monoculture. The urease activity in the intercrop was promoted by 81 to 89% as compared to that of monoculture. The effective nitrogen and phosphorus content of rhizospheric soil increased by 66 to 311.7% as compared to the monoculture system.

**Micro nutrient fertilizers**

Micronutrients *viz.*, Zn, Cu, Fe, Mn, B and Mo are as essential as the macro nutrients. These nutrients do not show any linear response for their fertilization when these nutrients are found in adequate quantities in soil. Crop yields are drastically reduced when the nutrient concentrations fall below the critical limits. Hence, micronutrient fertilization is recommended when the soil nutrient concentration falls below their critical limit or the plant tissue nutrient concentration is below the critical limit or the plants express nutrient deficiency symptoms. To avoid nutrient losses due to hidden hunger, tissue analysis must be performed periodically in areas where widespread nutrient deficiencies are prevalent. When the nutrient concentration falls below the critical limit, fertilization either as soil application or as foliar spray is essential. The critical limits of micro nutrients in the top visible dewlap (TVD) leaf blade are furnished in Table 2.

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Critical levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe (non-calcareous soil)</td>
<td>4.2 ppm</td>
</tr>
<tr>
<td>Fe (calcareous soil)</td>
<td>6.3 ppm</td>
</tr>
<tr>
<td>Zn (Loamy soils)</td>
<td>1.2 ppm</td>
</tr>
<tr>
<td>Zn (Clay soils)</td>
<td>2.0 ppm</td>
</tr>
<tr>
<td>Mn</td>
<td>2.0 ppm</td>
</tr>
<tr>
<td>Cu</td>
<td>1.2 ppm</td>
</tr>
<tr>
<td>Hot water soluble-B</td>
<td>0.44 ppm</td>
</tr>
</tbody>
</table>

Source: (Singh, 2008)

**Micronutrient fertilizer recommendations**

**Zinc**

(a) Zinc deficient soils: Basal application of 37.5 kg ha$^{-1}$ of zinc sulphate.

(b) Sugarcane crop with zinc deficiency symptoms: foliar spray of 0.5% zinc sulphate with 1% urea at 15 days internal till deficiency symptoms disappear.
Iron
(a) Iron deficient soils: Basal application of 100 kg ha\(^{-1}\) of ferrous sulphate.
(b) Sugarcane with Iron deficiency symptoms: foliar spray of 1% ferrous sulphate with 1% urea at 15 days interval till deficiency symptoms disappear.

Micronutrient mixtures

Common Micronutrient mixture: To provide all micronutrients to sugarcane, 50 kg of micronutrient mixture containing 20 kg Ferrous sulphate, 10 kg Manganese sulphate, 10 kg Zinc sulphate, 5 kg of Copper sulphate, 5 kg of Borax mixed with 100 kg of well decomposed FYM, can be recommended as soil application prior to planting.

Amount, time and method of application of chemical fertilizers

Adoption of proper method and time of fertilizer application is essential to minimize the loss of nutrients from the soil and to increase fertilizer use efficiency. Fertilizers should be placed close to the root zone to enable the roots to derive immediate benefits. Placement can be made by making 8-10 cm deep furrows on either side of the cane rows using implements, placing the fertilizers in the furrows and then covering them. Proportion of fertilizer nitrogen recovered in the crop was 33 % when urea was buried in the soil, but it was only 18 % when urea was broadcast.

The timing of nitrogen fertilization is based on two factors, viz., small foraging capacity of the initial sett roots and a major need for nitrogen at the tillering phase. Maximum amount of N is absorbed within 90 days after planting (DAP). Therefore for a 12 - 14 month crop, N should be applied within 60-90 DAP. Delayed N application results in late tiller production and prolongation of the maturity phase with accumulation of reducing sugars and poor juice quality. For a two-year crop, or for areas with two rainy seasons and where tillering takes place in two flushes, a late supplementary N application is beneficial. For ratoon crop, N fertilizers are applied in two or three splits. The first dose of 1/3 to half of N is applied immediately at the time of ratoon initiation to ensure adequate N to overcome the temporary immobilization of N due to decomposition of stubbles. Full dose of phosphorus should be applied at ratoon initiation.

Methods of fertilizer applications

Basal application
i) The entire quantity of phosphorus is applied as basal along the furrows and incorporated.

ii) Zinc sulphate @ 37.5 kg ha\(^{-1}\) and Ferrous sulphate @ 100 kg ha\(^{-1}\) are applied to zinc and iron deficient soils before planting.

iii) 2.4 kg ha\(^{-1}\) of Azospirillum inoculant is mixed with 25 kg of FYM and 25 kg soil and applied near the clumps on 30\(^{th}\) day of planting on one side of the row. The same is repeated on 60\(^{th}\) day and 90\(^{th}\) day on the other side of the row.
Top dressing

Nitrogen and potassium are applied in three equal splits at 30, 60 and 90 days after planting.

Improving fertilizer use efficiency

The use efficiency of applied N fertilizers ranges from 30 - 40 %. The major pathways of N losses are NO$_3$-leaching, NH$_4$-volatilization from soil and crop tops and denitrification as nitrogen oxides. Average recoveries of applied N for different sources of fertilizers was reported to be in the following order: ammonium sulphate (27.3%) > potassium nitrate (23.0) > urea (19.0%) while for soil types the order was loamy sand (25.9%) > loam (20.5%).

a. Neem Cake Blended Urea: For every 68 kg of N, 28 kg of powdered neem cake is mixed and kept for 24 hours and applied on 30, 60 and 90 days after planting. Thus, 75 kg of N ha$^{-1}$ can be saved.

c. Band placement: Deep furrows of 15 cm depth are opened with hand hoes and the fertilisers are placed in the form of band and covered.

d. Subsurface application: Application of N as urea with potash at 15 cm depth by the side of the cane clump will result in a saving of 20 kg N ha$^{-1}$.

Foliar application of fertilizers

Foliar application of nutrients particularly N can be adopted under adverse soil moisture conditions like water logging and limited water supply situations. The use efficiency of foliar applied N could be as high as 90 - 95 % and foliar spray helps to save about 20 - 30% fertilizer N. Best time for foliar application is either morning or evening. Noon hours should be avoided as the stomata close during that time. The optimum concentration for foliar spray of urea is about 2.0 - 2.2 per cent. For spraying a tall crop, a boom sprayer with long handle could be used. Foliar application of urea with potash during the formative phase (2.5 % each of urea and KCl at 60, 90 and 120 days after planting) was found to be beneficial when moisture was limiting and increased cane yield by 18.6 % over control.

Fertigation

Fertigation of N and K to sugarcane enhances their efficiency while saving the cost on fertilizers. The economic benefit from applying the liquid fertilizer to sugarcane was found significant (Tang et al., 2006).

Diagnosis of nutrient status of soil and plant

Deficiency symptoms are the best method of identifying nutrient disorders in the field. But by the time the visual symptoms appear, the crop might have suffered substantial yield loss. A crop may also suffer from hidden hunger, a condition in which a nutrient is deficient yet no symptoms appear. Tissue testing can help forestall hidden hunger. Soil testing is relatively easy and inexpensive method for evaluating the nutrient content available to plants. Based on soil samples reflecting different soil types, geographic conditions, and production histories for each part of a farmer’s field, recommendations are made to the farmer for applying the appropriate quantity and type of fertilizer.
Nutritional Disorders

Nitrogen deficiency: All leaves of sugarcane exhibit a yellow-green colour and retardation of growth. Cane stalks are smaller in diameter and premature drying of older leaves. Roots attain a greater length but are smaller in diameter.

Phosphorus deficiency: Reduction in length of sugarcane stalks, diameters of which taper rapidly at growing points. The colour of the leaves is greenish blue, narrow and somewhat reduced length. Reduced tillering, decreased shoot / root ratio with restricted root development.

Potassium deficiency: Depressed growth, yellowing and marginal drying of older leaves and development of slender stalks. An orange, yellow colour appears in the older lower leaves which develop numerous chlorotic spots that later become brown with dead centre. A reddish discoloration which is confined to the epidermal cells of the upper surfaces and midribs of the leaves. The young leaves appear to have developed from a common point giving a “Bunched top” appearance. Poor root growth with less member of root hairs.

Zinc deficiency: Mild zinc deficiency exhibit a tendency to develop anthocyanin pigments in the leaves. Pronounced bleaching of the green colour along the major veins and also striped effect due to a loss of chlorophyll along the veins. In acute cases of zinc deficiency there is evidences of necrosis and growth ceases at the growing point (meristem).

Iron deficiency: Symptoms of Iron deficiency are generally seen in young leaves where pale stripes with scanty chlorophyll content occur between parallel lines. In advanced stages of deficiency the young leaves turn completely white, even in the veins. Root growth also becomes restricted.

Boron deficiency: Boron deficiency could be seen in the cane by depressed growth, development of distorted and chlorotic leaves and the presence of definite leaf and stalks lesions. In extreme cases of boron deficiency the plant will die.

Organic manures

Legumes

Legumes are grown either in sequence or as intercrops for green manuring, grain or fodder. Sunnhemp and sesbania are the most common green manure crops. Large amount of green biomass of narrow C:N ratio, when incorporated into the soil during green manuring, contributes sizable amounts of plant nutrients, particularly N and brings improvement in soil physical conditions. Integrated use of green manure crops with mineral fertilizers increases the use efficiency of nitrogenous fertilizers and reduces the N requirement of sugarcane by 41-85 kg ha$^{-1}$. The biomass incorporated through intercrops like green gram and cowpea has been estimated to be around 5 t ha$^{-1}$. It has also been estimated that green manure intercrops like daincha and sunnhemp can add 4.8 - 7.6 t of green biomass per hectare. Intercrop also prevents the leaching of nitrate-N due to ramification of roots leading to higher nitrogen utilization.
Scientific Sugarcane Cultivation

Sugarcane trash

Sugarcane trash accounts for about 10-12 per cent of the cane harvested and its availability is about 30 million tonnes per annum. Trash is a useful source of plant nutrients and contains 0.42 per cent N, 0.15 per cent P, 0.57 per cent K, 0.56 per cent Ca, 0.30 per cent Mg and 0.12 per cent S besides 360, 110, 90 and 30 ppm of Fe, Mn, Zn and Cu. At many places, farmers prefer to burn the trash before harvest for convenience and even after harvest due to handling difficulties. During burning of sugarcane trash, large amounts of C, N and S, present in the plant residues are lost via volatilization (Hemwong et al., 2009). The benefits of green cane harvesting in increased soil organic matter and cane yield are well recognized. Basanta et al. (2003) indicated that unburned trash remaining as surface mulch resulted in an average N recycling of 105 kg ha⁻¹ year⁻¹ which may lead to a more efficient recycling of fertilizer N applied to the system and therefore reduce fertilizer needs. It also increases microbial activity and soil enzymes (Graham and Haynes 2005). Recycling high C:N ratio sugarcane trash material may lead to strong N immobilization and thereby affect N cycling processes and N₂ fixation of legumes grown subsequently.

Trash could be recycled as mulch or converted into organic manure by proper composting. Compost making from sugarcane trash is a slow process due to its very high C:N ratio (113:1). Many fungal cultures, viz., Pleurotus and Trichoderma viride have been found to hasten the process of trash decomposition and improve the compost quality. Sprinkling of urea (5 kg t⁻¹) to reduce the C:N ratio and fresh cow dung (50 kg t⁻¹) as a starter quickens the composting process. vericompost can also be produced by utilizing the partially decomposed sugarcane trash and cow dung.

Pressmud

Sugar factories produce about three tonnes of filter pressmud for every 100 tonnes of cane crushed. Sulphitation pressmud contains about 1.0 to 3.1 % N, 0.6 to 3.6 % P and 0.3 to 1.8 % K on oven dry basis in addition to large amounts of secondary and micronutrients. On an average, one tonne of oven-dry sulphitation pressmud contains 17 kg N, 36 kg P, 14 kg K and 23 kg S. Raw pressmud cannot be used directly as organic manure in sugarcane because of the evolution of large amount of heat during its decomposition. It can be composted with sugarcane trash or cow dung, either alone or in combination. It takes about six months for compost making. Inoculation with fungal cultures such as Pleurotus or Trichoderma will hasten the process of decomposition and reduce the time required for compost preparation. The compost has good manurial value containing as much as 1% N, 3% P₂O₅, 1% K₂O and 8% CaO on dry weight basis.

Biofertilizers

Biofertilizers help in increasing biological fixation of atmospheric N and enhancing native P availability to the crops. Use of organics such as trash and pressmud in appreciable quantities, will serve as a source of energy for soil microorganisms and improve the efficiency of N fixation. In addition, phosphobacteria could be used to improve the availability of native phosphorus. Gluconacetobacter diazotrophicus (earlier known as Acetobacter diazotrophicus), a N-fixing bacteria associated with sugarcane as an endophyte, is present in high numbers in the root, shoot and leaves. Field trials conducted in India have shown that inoculation by
G. *diazotrophicus* together with other diazotrophs or vascular arbuscular mycorrhiza can match yield levels equal to the application of 275 kg N ha\(^{-1}\) (Muthukumarasamy *et al*., 2002). Differences among different microbes and their differential behaviour with sugarcane varieties are documented by Hari and Srinivasan (2005). *Azospirillum* improved the cane and sugar yield compared to *Gluconacetobacter* and *Azotobacter*.

**Conclusion**

The following steps have to be adopted to manage the soil fertility for higher cane productivity.

i. Test soil for nutrient status to determine the amounts of additional nutrients needed to obtain optimum cane yield

ii. Derive the fertilizer dose based on soil test results, realistic yield goals, water availability, crop requirements, past fertilization practices and previous cropping history

iii. Time N applications to correspond closely with crop uptake patterns and water availability to increase NUE and minimize leaching and runoff losses

iv. Place fertilizers to increase accessibility of nutrients to plant roots, reduce losses due to volatilization of ammonia, erosion and runoff

v. Foliar application during drought and fertigation with drip irrigation may be followed.

vi. Use animal manures and organic manures to improve soil tilth, water holding capacity, CEC and soil structure and to reduce the need for inorganic fertilizers

vii. Rotate crops and include legumes in the cropping systems to improve total nutrient recovery with different rooting patterns, reduce erosion and runoff

viii. Control nutrient losses in erosion and runoff by using appropriate structural controls, adopting conservation tillage practices, management of crop residues, land leveling etc

**References**


Ratoon cropping is an old system which has been practiced for many years, especially in the tropics. Although the origin of ratooning is probably not known for any particular crop, it may have begun when man first noticed regrowth of new shoots following cutting of certain crops at harvest, thus producing a new crop without replanting. Also, early man’s observations of grassland regrowth following burning might have created an interest in utilizing regrowth of plants as a basis for multiple harvesting from an original root system. The word ratoon seems to have originated either from the Latin words retonsus - cut down or mown; or retono - to thunder back, resound; the Spanish - retono fresh shoot or sprout or even the French rejeton - sucker or shoot, scion, descendant, offspring or sprout. The first harvest of a crop is usually called the “plant crop” and each succeeding harvest is designated “first ratoon,” “second ratoon,” and so on.

Advantages of ratoon cropping

- Reduced cost of production through saving in land preparation and care of the plant during early growth of the clone; such early growth is eliminated because of the presence of a readily formed root system. Ratoons are economical by about 25 – 30 per cent in the operational cost because of saving in the cost of setts and initial preparatory cultivation.
- Better utilization of growing season, especially in monsoonal climates
- Higher yield per unit area in a given period of time.
- Can be used in breeding to maintain the same plant of a clone through several seasons.
- Often uses less irrigation water and fertilizer than main crop because of the shorter growth period.
- Ratoons save time as they establish early and in general mature early. Therefore they can be harvested early. Farmers will get time to grow other crops or have enterprises in the farm.
- Ratoons stabilize the cane area of a factory. Each year, the factory will have assured cane area to the extent of ratooning, which is around 40-50 per cent in most areas and therefore every year the effort for planting is limited to the fifty per cent of the total cane area required.

In 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 ratoons are welcome to most farmers, even though from over-all point of view the ratoons are not desirable.

Sugarcane varieties

Sugarcane is considered to be mature and ready for harvesting if it attains over 18%
(16% in sub-tropical zones) sucrose and 90% purity of cane juice. The varieties, which attain such level at 300 days of age, are considered as early varieties. If these parameters are reached by a variety in 360 days it is considered as mid-late. The main idea of maturity-based classification of varieties is to facilitate harvesting of variety at proper time in order to enhance overall recovery and consequently the sugar production.

**Extent of ratooning**

In India, almost 50 per cent of the cane area is always under ratoons. The percentage of ratoon area is relatively greater in the subtropics than in the tropics. In India, raising one to two ratoons is most common, though there are instances of many ratoons or “multi-ratoons” in certain pockets of Tamil Nadu, Andhra Pradesh and Karnataka. In commercial planting, as already stated, one or two ratoons are most common in India. Many sugarcane growing countries raise several ratoons.

**Ratoon yields**

Cane yield decline in successive ratoons is a common phenomenon in most of the sugarcane growing countries of the world. A 10 per cent 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 per cent. The gap is higher in the subtropical states. Because of the lower yields, even though ratoons occupy about 50 per cent of the cane area, their contribution to the total cane production is only around 30 per cent. Low ratoon yields is one of the reasons for the low average yield of the country. The major causes for yield decline in ratoons in our country 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 ratoons means a colossal waste of our 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. It has been observed that from white woolly aphid affected plant crops, ratoon sprouting is seriously affected, even total failure has been noticed.

**Decline in soil nutrient status**

The plant crop stands in the field for a minimum of one year. During that 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. 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.

**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 varietal adoption by most farmers depends on this factor, besides plant crop yields. Most of the present day sugarcane varieties have good ratooning ability. Generally early maturing varieties are poor ratooners than midlate 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 that was once grown widely in Tamil Nadu is a good ratooner while another popular variety CoC 671 a poor ratooner. However, CoC 671 was found to give good ratoon yields in some parts of Northern Karnataka, Maharashtra and Gujarat. Thus ratooning ability of a variety differs from region to region also. Co 740 the variety of Maharashtra & Co 1148, a variety of the
subtropics are excellent ratooners. Co 7314, Co 8013, Co 8018, Co 8021, Co 8121, Co 8122, Co 8134, Co 8145, Co 8208, Co 8362, Co 86010 and Co 86011 Co 2001 – 13, Co 2001 – 15 etc. released from the Sugarcane Breeding Institute have been found to possess excellent ratooning potential.

**Plant crop and its harvest**

Good ratoons result from healthy plant crop. 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 my 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 the 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 and moisture stress is felt 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 heterogeneous ratoon population. This should be avoided as far as possible.
Method of harvest

Harvesting the plant crop close to the ground level is 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 stubble shaving operation cannot be carried out due to either labour 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 any other ratooning operations could be taken up. Green tops are mostly removed for feeding cattle and some are used for tying the cane bundles. 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 % P$_2$O$_5$ and 0.65 % K$_2$O. When incorporated with soil, trash helps in improving the soil physical conditions.

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 barring operations, is pit and microbial culture is added to facilitate decomposition and then irrigation water is called. This method of *in situ* trash composting was developed in Maharashtra. The method was experimented at Coimbatore (Sundara, 1996) and there was improvement in ratoon yields. 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 tonnes more cane yield was obtained in the trash mulched plots.
Trash burning

Trash burning is essential only under the following conditions:

1. Plant crop infected by pests and diseases like scales, mealy bugs etc.
2. Areas prone to heavy termite attack
3. Areas prone to rodent attack
4. Excess moisture affecting sprouting
5. Soils where sub soil drainage is poor, and
6. 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 times drying up of shoots occur inspite of having fairly adequate sprouting.

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, a 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 ad 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 the stubbles to the ground level.

Tractor drawn stubble shaver

At the Indian Institute of Sugarcane Research, Lucknow, a tractor drawn stubble shaver 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 per cent.
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-soiler, 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 exceeding 20 per cent cause considerable yield losses. Gaps occur because of poor sprouting owing to several reasons: cold or hot weather conditions, poor plant crops, attack of fungal diseases, insect pests etc. A spot in a row can be considered as a gap if for a distance of about 60 cm there is no cane clump. Otherwise there is no need for gap filling.

For gap filling it is better to use pre-germinated single bud setts. For this purpose, a month prior to harvest of the plant crop, nursery may be planted with single bud setts and seedlings if required for gap filling can also be obtained from spots where excess sprouting is seen. Clumps can be operated and cut into quarters and 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 wet land 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. One month old seedlings can be used for gap filling. 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.

Suggested Reading

ICIC.CIID. 2011. 8th International Microirrigation congress. Innovation in Technology and management of microirrigation for crop production environment 21 October 2011 Tehran, Iran ICID New Delhi


6. MANAGEMENT OF SOIL CONSTRAINTS IN SUGARCANE PRODUCTION

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Sugarcane being a long duration C4 plant with high biomass yield utilizes matching quantity of water and nutrients. Its ratooning ability has enabled the growers to retain the crop for 3 to 6 years without replanting and the assured market through buyback arrangement by sugar factories encourages the farmers to cultivate the crop continuously. Improper soil management practices and lack of crop rotation practices has resulted in the overexploitation of the soil resources affecting the soil productivity as evidenced from the stagnating or even declining sugarcane productivity. A good soil should have the following characteristics.

- Optimum organic matter to support macro and micro fauna
- Optimum reaction and salt concentration in soil solution.
- Adequate supply of nutrients
- Good drainage and optimum moisture retention
- Small population of plant pathogens and insects/pests
- Large population of beneficial organisms
- Free of chemicals and toxins that may harm the crop
- Resistance to degradation

Sugarcane prefers well drained, well-structured and aerated loams to clay loams that are more than 1 m deep. Preferably the ground water table should be at a depth below 1.5 m from the surface. An available water content of the soil of >150 mm/m is optimal. Though sugarcane tolerates short spell of water logging (1 - 2 weeks) or flooding, these conditions may enhance the risk for fungal, viral and bacterial diseases. It can also withstand mild drought. Sugarcane can equally be grown on soils with textures other than loam or clay loam with appropriate management practices.

Classification of soil constraints

Physical Constraints
- Slow permeability
- Excessively permeability
- Subsoil hardening
- Surface crusting
- Soil compaction

Chemical constraints
- Acid soils
Scientific Sugarcane Cultivation

- Saline and alkali soils
- Poor fertility
- Calcareous soils

**Biological constraints**
- Poor or low soil organic matter

**Management of soil constraints**

**Physical constraints**

**Slow permeability**

The permeability and drainage is an estimate of the pathway of rainfall/irrigation water movement when it contacts the soil surface. Slow permeable soils are those having infiltration rates <6 cm/day due to high clay content of the soil. Due to low infiltration rates, the amount of water entering the soil profile is reduced thus increasing the run-off. Further, it encourages erosion of surface soil leading to nutrient removal in the running water. Moreover, due to heavy clay content, the capillary porosity is relatively high resulting in impeded drainage and reduced soil conditions. This results in increase of some soil elements to the level of toxicity to the plants. It also induced nutrient fixation in the clay complex thereby making the nutrient becoming unavailable to the crop, eventually causing deficiency of nutrients.

**Management**

1. Provision of drainage facilities either through open or closed sub surface drains
2. Application of river sand or red soil of coarser texture
3. Application of liberal doses of organic manures like farm yard manure, compost, green manure, composted coir pith, sewage waste, press mud etc.

However, if water stagnation is due to high water table, which is the characteristic of the geographical location, growing varieties tolerant to water logging and adopting suitable planting methods along with improving the drainage facilities will help to overcome the yield loss or even total crop loss.

**Excessively permeability**

Excessively permeable soils are those having high amount of sand exceeding 70%. Due to this, the soils are inert and unable to retain nutrients and water. These soils being devoid of finer particles and organic matter, the aggregates are weakly formed and the non-capillary pores dominating with very poor soil structure. Due to low retaining capacity of the soils, the fertilizer nutrients are also lost in the drainage water.

**Management**

1. Compacting the field with 400 kg stone roller (tar drum filled with 400 kg of sand or
stones can also be used) 8-10 times at optimum moisture conditions.

2. Application of clay soil up to a level 100 t ha⁻¹ based on the severity of the problem and availability of clay materials.

3. Application of organic materials like farm yard manure, compost, press mud, sugar factory slurry, composted coir pith, sewage sludge etc.

4. Crop rotation with green manure crops like sunhemp, sesbania, daincha, kolinchi etc.

**Subsoil hardening**

The sub soil hard pan in red soils is due to illuviation of clay to the sub soil horizon coupled with cementing action of oxides of Fe, Al and calcium carbonate, which increases the soils bulk density to more than 1.8 Mg m⁻³. Hard pan can also develop due to continuous cultivation of crops using heavy implements up to certain depth constantly. Besides, the higher exchangeable sodium content in black soils areas also results in compactness. All put together lowered the infiltration and percolation rates, nutrient movement and free air transport within the soils profile. It prevents root proliferation and limits the volume of soils available for nutrients uptake resulting in depleted, less fertile surface soil. Due to this, the contribution of sub soil fertility to crop growth is hampered.

**Management**

1. Chisel ploughing at 0.5m interval crisscross at 0.5m depth once in 2-3 years.

2. Application of organics to improve the aggregation and soil structure so as to prevent further movement of clay to the lower layers.

3. Deep ploughing of the field during summer season to open up the sub soils.

4. Cultivating deep rooted crops like tapioca, cotton so as to encourage natural breaking of the hard pan in crop rotation

5. Raising deep rooted semi perennial crops to open up the sub surface hard pan

**Surface crusting**

Surface crusting is due to presence of colloidal oxides of iron and Aluminium in Alfisols which binds the soil particles under wet regimes. On drying it forms a hard mass on the surface. The ill effects of surface crusting are

1. Obstructs germination

2. Retards/inhibits root growth.

3. Results in poor infiltration.

4. Accelerates surface run off

5. Creates poor aeration in the rhizosphere

6. Affects nodule formation in leguminous crops
Management

1. Plough the soil at optimum moisture
2. Liming@ 2 t ha⁻¹
3. Farm yard manure at 10 t ha⁻¹ or composted coir pith at 12.5 t ha⁻¹ or other organics
4. Scraping surface soil by tooth harrow
5. Sprinkling water at periodical intervals may be done whenever possible.

Soil compaction

Soil compaction is the reduction of soil volume due to external factors. The risk of soil compaction is greater today than in the past due to an increase in the size of farm equipment. Compaction is caused by wheel or foot traffic on the soil and by soil tillage. Soil compaction reduces soil productivity. Besides reducing yields, soil compaction also reduces soil health and environmental quality:

1. Compacted soil is dense and has low porosity. Large pores which are very important for water and air movement in the soil are compressed. Infiltration is reduced and erosion is increased
2. Compaction causes an increase in the soil’s penetration resistance and more energy is expended when tilling compacted soil
3. Compacted soil is a harsher environment for soil organisms, especially earthworms, to live in
4. Compaction affects nutrient uptake. Denitrification rates can increase in compacted soil due to limited aeration. Enhances ammonia volatilization loss and reduces P and K if root growth is inhibited.

An understanding of the causes of soil compaction is necessary to develop management strategies that either avoid or correct its effects. Compaction avoidance is much preferred over compaction alleviation after a problem has been caused because correction strategies can be costly and often may not correct the problem entirely. The aim of compaction management should be to avoid subsoil compaction altogether, and to limit surface compaction as much as possible. Soil compaction is not likely to cause much damage if traffic is limited to dry soil conditions.

Management

1. Reduce axle load to at least below 10 tonnes by reducing load; increasing number of axles
2. Reduce contact pressure by reducing tire pressures to minimal allowable pressures; using flotation tires; using tracks or duals to replace singles; using radial-ply instead of bias-ply tires; installing larger diameter tires to increase length of footprint; properly ballasting tractor for each field operation
3. Reduce the number of passes over the field and limit the area of the field that is impacted
by traffic by increasing swath width of spreading and spraying equipment and reducing width of tracks.

4. To avoid plough pans, do not drive a tractor wheel in the furrow; use no-tillage; use a chisel instead of moldboard plough; use a field cultivator instead of disk harrow.

**Chemical Constraints**

**Acid soils**

Sugarcane is also cultivated in acid soil in some areas of Kerala, Karnataka and Goa. Acid soils are characterised by low pH (less than 6.5), which leads to increased solubility of aluminium, iron and manganese often to levels that are toxic to the plants. Shoot elongation as well as tillering of cane is adversely affected. Application of lime (2.5 to 7.5 t/ha) is recommended to raise the pH to neutrality. The quantity of lime recommended depends on the pH, CEC and buffering capacity of the soil. The common liming materials are burnt lime, pulverised limestone and dolomite. The caustic nature of the burnt lime causes handling difficulties and is also costly. However, pulverised limestone and dolomite are cheaper and safe for handling. Liming materials are to be applied before ploughing. Red and laterite soils benefit largely from regular and adequate liming. Among the phosphatic fertilizers, bone meal and rock phosphates are well suited for acid soils.

**Saline and alkali soils**

The primary cause of accumulation of salts is weathering of parent materials in arid and semi-arid regions where evaporation is greater than precipitation (low rainfall coupled with high temperature). The secondary causes of salt accumulation are continuous use of bad quality irrigation water, rise in groundwater table, impeded drainage, indiscriminate land use pattern and construction of dams, inundation of seawater, etc.

Due to excess salts in soil solution plant has to exert more energy to absorb water. Osmotic potential of soil moisture increases and results in physiological water stress. The excess of salt may have direct or indirect effect on plant metabolism. The soluble salts contain important cations namely calcium, magnesium, sodium and potassium and anions namely sulphate, chloride, carbonate, bicarbonate and borate. Excess of calcium will have only indirect effect rather than direct effect. It causes lime induced iron chlorosis and also zinc deficiency. It may also cause magnesium and potassium deficiency in extreme cases. Excess of magnesium interferes with the uptake of calcium and to some extent potassium. Excess potassium may result in calcium and magnesium deficiency. Excess of sodium may have either direct or indirect effect. pH of cell sap increased and most cells are inactivated. Enzyme activity also reduced and many of the metabolic activities stopped. Causes necrotic symptom and ultimately leads to death of plants.

Indirectly excess of sodium affects physical and chemical properties of soil. Humus dissolved, pore space blocked as a result of deflocculation and destruction of soil structure. Due to water stagnation the root zone are deprived of oxygen. In sodic soil, pH will be more than 8.5 due to hydroxide, carbonate and bicarbonate of sodium. Plant roots are affected by high soil pH. Phosphorus is precipitated and availability reduced. Molybdenum and boron are highly soluble and have toxic effect. Due to anaerobic condition the nitrification is reduced.
In alkaline condition ammonium is converted into gaseous ammonia and lost. Deficiency of calcium and magnesium are noticed.

Chloride toxicity rarely occurs in small patches. It causes necrotic leaf spot and drying of leaf margin. Chlorine generally interferes with quality. Sulphate injury is common in acid soils than in salted soils. It induces the uptake of sodium and potassium and reduces calcium uptake. Carbonate and bicarbonate cause direct injury and are most deleterious anions. They cause iron and zinc deficiency by precipitating them. They also interfere with nitrogen nutrition. Boron at high pH dissolves as borate and causes boron toxicity.

Salinity/sodicity causes reduction and delay in germination in sugarcane. It causes burning of tips of young leaves and edges of older leaves. In extreme cases, the spindle dries up exhibiting a burnt appearance. It retards stem elongation, root development and tiller production resulting in poor yield and juice quality. The canes harvested from salted soils are withered and pithy. Normally sugarcane crop stand is poor in salt affected soils with slick or barren spots in the field. EC of 4 dS m\(^{-1}\) and ESP of 15 are considered as threshold levels.

**Management**

**Saline soil**

Saline soils are characterized by high soluble salts (EC\(_e\)>4.0 \text{ dS/m}). The reclamation process involves leaching of excess soluble salts and avoiding further accumulation of salts. The field should be leveled first and divided into small plots of about 1000 sq. m by providing bunds. Drainage channels of 75 cm depth are to be provided all-around the field. The field is to be irrigated copiously with the best available water and stagnated for two to three days so that the salts in the soil get dissolved. Then the salts are removed by draining the water through drainage channels (vertical drainage) so that the salts are removed from profile at least to a depth of 75 cm. This leaching process has to be repeated till the soil is free of harmful salts. Surface drainage has to be avoided. Leaching and drainage could be improved by applying huge quantities of organic manure and mechanical treatments like deep ploughing, sub-soiling, sanding and profile inversion.

**Sodic soils**

Sodic soils are characterized by high pH\(_e\) (>8.5) and high exchangeable sodium percentage (ESP) (>15) without salinity (EC\(_e\)<4.0). The saline sodic soils are characterized by high EC\(_e\) (>4.0). The physical condition of sodic soils is to be improved by addition of large amount of organic matter in addition to chemical amendments to replace sodium by calcium in the exchange complex and to remove carbonate and bicarbonate with sulphate. Generally gypsum, phosphogypsum, pressmud, sulphur and pyrites are recommended as amendments. Gypsum is the most effective and cheap amendment. The recommended quantity of powdered gypsum (2.5 to 12.5 t/ha depending upon soil pH, ESP and soil buffering capacity) is applied to the soil by broadcasting, irrigated with good quality water and ploughed thoroughly so that the reaction takes place effectively. Reclamation of saline-sodic soil involves the addition of amendments to replace excess of sodium present in exchange complex with calcium ion. Then the excess soluble salts and sodium salts formed are to be
removed as in the case of saline soils. After reclamation, the following points are to be considered while cultivating alkaline soils.

1. Level the land
2. Apply huge quantity of organic manure
3. Use 25 per cent more N than recommended
4. Apply 25 kg FeSO₄ and 12.5 kg ZnSO₄ per hectare
5. Irrigate with less quantity of water at frequent intervals.
6. Improve drainage facilities
7. Grow resistant sugarcane varieties
8. Use physiologically acidic fertilizers
9. Mulching can be practiced. Enriched pressmud may also be applied to improve soil physical conditions
10. Monitor soil pH, EC and ESP and avoid salt accumulation

**Poor fertility**

Indian soils are in general poor in nitrogen and well supplied with phosphorus and potassium. Application of NPK fertilizers based on soil test results will help in improving sugarcane productivity. Iron chlorosis is common mainly due to high lime content in soil. This can be corrected by repeated foliar spray of ferrous sulphate (1.0 to 2.0%) with 0.1% citric acid at weekly intervals till the chlorosis vanishes. In normal soils, soil application of ferrous sulphate (@ 50 kg/ha) will alleviate this malady. Application of 150 kg of ferrous sulphate along with organics is recommended for calcareous soils. Zinc deficiency is also noticed in some soils. This can be corrected by foliar spray (0.5%) coupled with soil application (25 kg/ha) of zinc sulphate.

**Calcareous soils**

More than one-third of the world’s soils are calcareous. In India, sizable sugarcane growing area is occupied by calcareous soils. The calcareousness is a unique property of soil, which affects the physico-chemical properties, nutrient availability and plant growth. Calcereous soils may have CaCO₃ content varying from a small amount in some part of the soil profile to an appreciable amount occurring throughout the profile. Availability of nutrients in the calcareous soils becomes even more complex phenomena due to presence of solid CaCO₃. This is because (i) CaCO₃ serves as a prominent sorbent of nutrition, (ii) its presence increases soil pH and (iii) it supplies Ca, which forms salts of various solubilities. In such soils, the availability of nutrients like, iron, manganese, phosphorus, zinc and boron due to heavy fixation has been limiting and still posing a serious threat to successful crop production. The presence of CaCO₃ also induces loss of nitrogen through volatilization. Application of ferrous sulphate (125 kg/ha) and zinc sulphate (25 kg/ha) fortified organic manure could be applied besides liberal use of organic manures. Soil pH should be corrected towards neutrality by using the amendment gypsum. Sulphur or pyrites could also be
used. Foliar application of ferrous sulphate (0.5 - 2.0 %) with 0.1% citric acid and zinc sulphate (0.25 - 0.50 %) from 45th day after planting at weekly interval till the crop recovers is an effective method to alleviate deficiency of zinc and iron.

**Biological constraints**

**Low soil organic matter**

Soil organic matter content, measured during routine soil testing, is considered as one of the most important indicators of soil health. From an agronomic and environmental point of view, organic matter gives the largest benefits if it is found close to the soil surface. It improves soil aggregation, infiltration, resistance to erosion, workability, and leads to improved seed-to-soil contact when planting. Soil becomes resistant to compaction and facilitates root development. Depleting SOM content in the agricultural soils within the past four decades has been evidenced by reduced soil organic carbon content to the tune of <0.5% from around 1.0% half a century ago. Especially in sugarcane based cropping system, where the bulk of the crop residue is burnt due to handling problems and even the stubbles are removed for fuel after the final harvest (of the ratoon crop) and the soil is tilled several times in a cropping cycle, the carbon input is lower and the loss of SOM through oxidation is also accelerated. SOM inputs can be increased leaving the crop residues in the field, growing cover crops during otherwise bare fallow periods and adding compost and manure.

Soil tillage reduces surface organic matter content, so minimizing tillage will help improve soil health. Recent research suggests that tillage, especially moldboard plough primarily redistributes organic matter to deeper soil layers. With moldboard plowing, soil organic matter content is uniform throughout the plough layer while the chisel plough and disc harrow cause smaller surface organic matter losses. In long-term no-tillage system, soil organic matter content will be high at the soil surface and decrease rapidly below 2 or 3 inches. Sugarcane based cropping system provides ample opportunities to enhance the SOM and soil health. Some of them are as follows:

**Pressmud compost**

Fresh press mud has a wide C : N ratio and evolves a lot of heat during decomposition. Hence it should be applied only after proper decomposition. Fresh press mud composted using *Pleurotus, Trichoderma viride* (1 kg/t of press mud), urea (5 kg/t of press mud), cow dung as a starter (50 kg/t of press mud) and enriched with rock phosphate, ferrous sulphate, zinc sulphate etc. serves as good organic manure. Bio-earth is produced by heaping fresh press mud in windrows sprayed with correct proportion of distillery effluent and mixed thoroughly by using Aero tillers mounted on tractors. Simultaneously the microbial culture is also sprayed and mixed. A distinctive black, loamy, free flowing and dry baggable compost with pleasant earthy smell is produced. The experience with this compost in many countries has shown a reduction in fertilizer inputs by up to 50% with simultaneous rise in production of crops. This is the best way of restoring organic matter to soil and the most practical and profitable method of disposing distillery effluent.
Sugarcane trash compost

In sugarcane about 10 t of trash/ha is available and in most of the locations, it is burnt. By trash burning we not only lose valuable organic matter, but also kill the soil fauna ranging from microscopic bacteria to macroscopic earthworms and microarthropods. Trash contains about 0.35% N, 0.13% P$_2$O$_5$, 0.65% K$_2$O, 0.27% CaO and also appreciable quantities of micronutrients, but with wider C:N ratio (60:1). The lingo-cellulosic nature of the trash combined with its silica content and spiny nature makes its handling a difficult task. Decomposition also takes longer time. Its bulkiness also demands huge labour for transporting out of the field. Burning of trash results in 100% loss of N and a sizable quantity of P and S from it. The rapid trash composting technique similar to that of press mud composting technique using fungal cultures (*Trichoderma viride* and *Pleurotus* – one kg) 7.5 kg of urea + 50 - 75 kg of fresh cow dung for every tonne of trash can be adopted. Trash compost has a nutrient content of 0.8% N, 0.25% P$_2$O$_5$ and 0.7% K$_2$O with C:N ratio of 22:1. Trash can also be composted along with press-mud. This may substitute about 20 - 30% of the nutrient requirement also.
7. INTEGRATED MANAGEMENT OF SUGARCANE DISEASES

R. Viswanathan

Introduction

Sugarcane diseases are constraints to crop production all over the world, and no country is protected to the destructive influences of plant pathogens and pests. More than 125 diseases of sugarcane caused by fungi, bacteria, viruses, phytoplasma and nematodes have been reported from all over the world (Rottet et al., 2000). In spite of all the efforts of breeding for disease resistant varieties, this crop is becoming more and more prone to many diseases and pests. The disease incidence is increasing at an alarming rate and the yield is falling down every year. As per the ISSCT report, every year sugarcane diseases cause the loss of several millions of dollars. About 10-15% of the nations sugar produced are lost due to diseases. Among them red rot, smut, wilt and pineapple disease (sett rot) are the important fungal diseases. Bacterial diseases like leaf scald disease (LSD) and ratoon stunting disease (RSD) are found to cause considerable yield loss in some countries. Also gumming disease and red stripe are known to cause damage in certain regions. Among the viral diseases mosaic is prevalent in almost all the countries however its severity is felt more in American continents. Besides these, grassy shoot caused by phytoplasmas is also a potential disease, which can cause considerable damage to sugarcane production in several Asian and African countries. In addition, newly recorded yellow leaf disease (YLD) has become a major constraint in many countries. Foliar diseases such as yellow spot, brown spot, brown stripe, eye spot, ring spot, rust etc may cause loss to sugarcane depending on the prevailing environmental conditions. Many promising varieties were removed from cultivation in the past since they succumbed to new pathogenic variants with more virulence. Also slow build up of many non-fungal diseases in sugarcane causes decline in varietal performance and results in varietal deterioration. In this lecture important diseases of sugarcane and their management are briefly described for the understanding of the extension workers involved in sugarcane development.

Red rot

It is one of the most widespread sugarcane diseases in the country and it has been a constraint for the past 100 years in India and other South Asian countries. First large-scale destruction of the cane in India by the disease was noticed in Godavari delta of then Madras Presidency on the cultivar Red Mauritius during 1895 to 1899. The disease is responsible for the elimination of many commercial varieties in India in the earlier decades. Epidemics of the disease have been very common ever since its occurrence in India. It was involved in the failure of important commercial varieties like Co 312, Co 419, Co 453, Co 658, Co 997, Co 1148, Co 6304, Co 7805, CoC 671,CoC 85061, CoC 92061,CoJ 64,CoLk 8102, CoS 562, CoS 8436, CoSe 95422 etc. The epiphytotic nature of the disease was noticed in the subtropical regions of the country till 1970s and later the pathogen got a foothold in the tropical region and is presently in a devastating form in many parts of the Peninsular India particularly in Coastal Andhra Pradesh, Orissa and Tami Nadu. Currently the disease occurs in all the sugarcane growing states in India except Karnataka and Maharashtra states.
The disease is caused by the fungal pathogen *Colletotrichum falcatum* Went. Disease infection seriously affect crop productivity since infected stalks become unfit for milling and partial infection also affect the quality of canes due to inversion of sucrose to reducing sugars. In the advanced stages entire stool dries up. When such canes are split open longitudinally they show reddened areas with horizontal white patches. The entire parenchymatous tissues are affected and in later stages they form a hollow cavity with dark grey mycelial growth of the fungal pathogens. On the rind, dark brownish lesions of various sizes can be seen. Similarly necrosis on nodal region is also commonly observed. In such canes cut ends show reddening with white patches.

The disease is primarily transmitted through infected setts. The secondary spread of the disease occurs during monsoon period when high humidity condition prevails. Sporulating conidia at the nodal portion of the susceptible canes are carried through rain splash and irrigation water to the adjoining cane/area resulting in secondary spread. Fresh surviving debris of red rot inoculum also serves as a source for further spread of the disease.

**Smut**

The disease is cosmopolitan in distribution and at one time or another it has been important in all the sugarcane growing countries. The disease caused severe yield loss to sugarcane for long time in Maharashtra and Northern Karnataka regions till Co 740 was under cultivation. Replacement of Co 740 with Co 86032 and Co 94012 reduced the smut severity in these regions. Currently the disease occurrence is noticed in low intensities in Co 7219, Co 7527, Co 8011 etc in these regions. Widespread cultivation of CoA 92081 resulted in severe outbreak of smut in Andhra Pradesh state. Recently introduction of new varieties has resulted in occurrence of the disease in Southern Karnataka also. Similarly severe smut is noticed on Co 86002 and CoSi 95071 in Gujarat in tropical region. The disease also causes severe yield losses in many African countries. Severe smut infection severely affects the cane yield and sugar recovery. The yield loss due to the smut could be up to 50 percent in sugarcane. In addition to loss in cane tonnage due to reduced number of millable canes, the disease infection reduces sugar recovery. The severity will be worse in the ratoons.

The disease is caused by the fungus *Sporisorium scitamineum* (Syd.) M. Piepenbr., M. Stoll & Oberw. 2002 (Syn: *Ustilago scitaminea* H. & P. Sydow). The fungus has no alternate hosts. Disease affected stools give out excessive tillers which are lanky and end up with black whip structures. Affected clumps show profuse tillering with lanky tillers. Occasionally whips are produced from axillary buds also. The infected plants within a field often arise from planting systemically infected setts or from ratoons of infected clumps of previous crop. The disease is very well adapted to aerial dispersal and spread. Smut is generally favoured by hot dry weather conditions. High rainfall reduces the severity of smut development. Disease severity usually increases through ratoon crops. Plant stress increases frequency of whip development; cultivars that normally would not have whips may show symptoms under high stress.

**Wilt**

Wilt has caused significant losses in India where several epidemics have occurred. It is responsible for the elimination of many popular varieties from cultivation. Wilt is very
common in certain locations where conducive environment and susceptible hosts are available (Viswanathan, 2013a). In most of the delta regions endemic nature of the disease prevails. The disease adversely affects germination. Wilt incidence is always higher in ratoon crops compared with the plant crop. Besides yield reduction, wilt disease also causes 14.6-25.8% reduction in juice extraction and 3 to 20 percent in sugar recovery due to deterioration in juice quality. Combined infection of red rot and wilt causes more loss to the crop than their infection alone.

*Fusarium sacchari* (E.J. Butler) W. Gams is the disease causative fungi. The affected stools turn yellowish and finally dry as in the case of red rot. Longitudinal splitting of the affected cane shows dull brownish discolouration of internal tissue with linear pith cavities and desiccation. Wilt fungi are weak soil borne pathogens. Abiotic factors like drought, waterlogging, drought followed by water logging weaken the root system and predisposes the plant for wilt infection. Subterranean soil pests such as white grub, root borer and nematode and insect pests like mealy bug, scale insect, fungal pathogen like red rot weakens the plant and root system paving the way for wilt infection.

**Sett rot (Pineapple disease)**

Sett rot is caused by the fungal pathogen *Cerotocystis paradoxa*. The disease is common in germinating setts. The disease is primarily spread through soil borne inoculum under ill-drained conditions. The fungus infects the setts mainly through the cut ends and slowly spreads to the entire parenchyma tissues. Sett rot infected setts fail to germinate leaving many gaps in the field. In the early stage of rotting stinky odour of pineapple is emitted due to production of ethyl acetate and it helps in identifying the disease.

**Ratoon stunting**

The disease is caused by the xylem limiting bacterium *Leifsonia* (*Clavibacter*) *xyli* subsp. *xyli* (Lxx) (Davis *et al*.). Diseased clumps usually display stunted growth, reduced tillering, thin stalks with shortened internodes and yellowish foliage. The characteristic stunting and unthriftiness associated with RSD are usually greater when there has been a growing period with moisture stress. The sugarcane varieties vary in their tolerance to the pathogen infection. Growth of a disease crop is slower than that of a healthy crop, and ultimately the yield is reduced. The reduction in yield is due to the production of thinner and shorter stalks rather than a reduction in the total number of canes. The affected plants may not show any abnormality in the root system or in the underground buds and portions of the stalk. In general the disease severity is more in older varieties. The term ‘ratoon stunting’ is misnomer since the disease also causes severe damage in plant crops.

Diseased stalks of some varieties may exhibit an internal discolouration of vascular bundles at the lower portion of nodes, but these symptoms are often ephemeral. They appear as yellow to reddish brown dots, commas, or short lines when viewed by slicing longitudinally through nodes. The range of colours includes yellow, orange, pink, red and reddish brown and these colours usually stand out in marked contrast to the light-coloured ground tissue of the node. The discolouration does not extend into the internode unlike similar symptoms due to other diseases. The discoloured strands should be found right through the node, and all nodes in the fully developed part of the stalk should show some
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symptoms. The disease is mainly transmitted through infected setts and survives in the leftover debris/soil.

**Grassy shoot**

The disease is caused by Sugarcane grassy shoot (SCGS) phytoplasmas. It occurs throughout the country and its severity is more in the areas where proper seed nursery programmes are not there. Infected stools show excessive and stunted tillers with narrow leaves. Most of the tillers do not develop into millable canes. In the affected clump, the few canes formed and are stunted with leaves being yellow or white. In some cases, axillary bud sprouting with yellow or paper white leaves may be seen. The whole infected stool appears like a big bunch of grass. The disease is mainly transmitted through infected setts. GSD can cause very heavy yield loss particularly when planting material is obtained from infected sources. The disease severity will be more in ratoon crops and this contributes to poor yield in ratoons.

**Mosaic**

This is one of the oldest diseases recorded in India and is associated with varietal degeneration. *Sugarcane mosaic virus* (SCMV) and *Sugarcane streak mosaic virus* (SCSMV) cause mosaic disease in sugarcane in India. The virus has abundant variation and a single strain can infect sugarcane, maize and sorghum. Symptoms of mosaic may vary in intensity with cultivar, growing conditions, temperature and strain of the virus. The chlorotic areas are most easily seen in young, rapidly growing leaves, particularly near the basal portion of the leaf. The proportion of the leaf that is covered by the chlorotic areas may vary from scattered, short yellowish stripes to chlorotic areas that predominate over the leaf with islands of normal green. On older leaves, the symptoms tend to recover and appear as healthy. The virus causes mild mottling in the leaves with dark and light areas of chlorophyll development. With more virulent strains, stunting, yellowing, chlorosis and sometimes necrosis are also noticed. Recently we found that infection of debilitating strains affects yield and quality in sugarcane (Viswanathan and Balamuralikrishnan, 2005). Generally long chlorotic streaks alternate with the normal green portions of the leaf are observed in different varieties in the country. Primary transmission takes place through infected setts. In the field aphids transmit the virus. Although mild strains of mosaic are reported to prevalent in India the causative virus(es) in combination with other pathogens associated with RSD and YLD cause severe yield loss.

**Yellow leaf disease (YLD)**

This disease is caused by *Sugarcane yellow leaf virus* (SCYLV) and reported in India during 1999 (Viswanathan, 2002). In addition to SCYLV, Sugarcane yellow leaf phytoplasma (ScYP) also reported to be associated with the disease. The symptoms appear initially on matured leaves three through five usually in maturing plant or ratoon crop. The symptoms could be very clear after 5 to 6 months of crop growth. On the leaves, the symptom appears as yellowish midrib on the lower surface. The yellowing may be confined to midrib region or the yellow discoloration may spread laterally to adjoining laminar region parallel to midrib up to a distance of 2.0 cm. Reddish to pinkish discoloration of midrib and laminar region is also noticed in certain varieties. In most susceptible varieties, typical yellowing of midribs...
and laminar region is noticed on upper surface of the leaves. Finally symptoms of necrosis of discoloured laminar region from leaf tip to bottom and subsequent drying of entire leaf is noticed.

In ratoon crop, the intensity of the disease will be much higher than in plant crop. The disease incidence in sugarcane is found aggravated by the poor maintenance of the crop in the field. It is observed that infestation with internode borer, flowering, drought conditions, Striga infestation, and infection with other pathogens such as ratoon stunting, grassy shoot etc favour early expression of the disease. The sugarcane varieties showing mild symptoms usually record normal cane growth. In severely infected clumps cane thickness and stalk height are significantly affected. Severe infection of the disease leads to shortening of internodes in the top. This effect culminates in bunching of leaves at the top. Usually such infection results in drying of entire clumps. Severe infection of SCYLV leads to reduced juice quality and sugar recovery. Combined infection of SCYLV and ratoon stunting bacterium in sugarcane causes severe stunting than their infection alone (Viswanathan, 2002; 2004). The disease occurs in epidemic form on most of the cultivated varieties and it adversely affects cane productivity in the tropical region. The disease infection may result in 25-30 % loss to cane and juice yield in popular varieties (Viswanathan, 2012). Recently assessing impact of the virus infection on physiological parameters viz. photosynthetic rate (A), stomatal conductance (gs) and SPAD meter values revealed significant reduction in sugarcane cultivars. Virus-infected varieties recorded significant reductions in growth/yield parameters, such as stalk height, stalk thickness and number of internodes. Plant growth reductions were found to be 42.9, 42.3 and 38.9% in YLD-susceptible varieties CoPant 84211, Co 86032 and CoC 671, respectively. In addition to reductions in stalk weight, height and girth, YLD also reduced juice yield in the affected canes up to 34.15% (Viswanathan et al. 2014).

Primary transmission of the disease occurs through infected setts. Secondary transmission is achieved through aphid Melanaphis sacchari. Planting of infected setts would result in cent per cent expression of the disease in the field and build up of high virus titre in most susceptible varieties causes severe foliage drying during late maturity stages of the crop.

**Varietal degeneration**

Sugarcane pathogens like SCMV, SCSMV, SCYLV, SCGS-phytoplasmas and ratoon stunting bacterium systemically infect sugarcane and over the years the varieties degenerate due to the systemic colonization of these pathogens (Viswanathan, 2012, 2013b). Decline in varietal performance over the years is mainly due to accumulated pathogens inside the stalk affecting cane growth and photosynthetic efficiency, which directly results in reduced cane yield and sugar yield. Although these viral/ bacterial pathogens cause limited symptoms in the field, continuous vegetative propagation results in enhanced pathogen load that would increase the pathogenic potential to cause disease. Combined infection of two or more viral/bacterial pathogens accelerates the damage to the crop in the field and this is due to infection of one pathogen makes the plant more susceptible to another. In this way, a variety degenerates faster and its potential comes down over the years. Author has witnessed such degeneration in a popular cv Co 419 in Karnataka state due its high susceptibility to mosaic, YLD and RSD. Similarly cvCoC 671 another popular variety of tropical region degenerated
due its high susceptibility to mosaic and YLD in different parts of Karnataka and Maharashtra. The cvCo 86032 was able to replace popular variety CoC 671 in large areas in these states due to the degeneration. However, the cv 86032 also showed decline in performance due to very poor seed nursery programme in many sugar factories in the tropical region. In the subtropical region, the popular variety CoS 767 suffers due to varietal degeneration caused by RSD, YLD and mosaic pathogens.

**Top rot (PokkahBoeng)**

The disease is common during rainy months in the field. Although under normal situations it may not cause significant yield loss it has the potential to arrest the crop growth temporarily. The disease occurs throughout the world and severe forms of the disease are recorded in high humidity areas. *Fusarium verticillioides* is the causative fungus (Teleomorph: *Gibberella fujikuroi* (K. Sawada) H.W. Wollenweber). The disease manifests in two phases viz. pokkahboeng and top rot. The most common symptom is a malformed or twisted top, which gives this disease its name “pokkahboeng” from the Javanese language. Symptoms develop during rainy periods which coincide with grand growth period. Initially, young leaves are chlorotic at their base and patchy elsewhere on the blade. Chlorosis is most obvious on the lower surface of the leaf or in twisted laminar regions, where white mycelium may be seen. Affected leaves tend to be narrow at the base. Development of further symptoms is dependent on the susceptibility of the variety and on environmental conditions conducive to the pathogen. Young leaves may become infected in the spindle, resulting in pronounced wrinkling, twisting and shortening of the leaves. Sometimes the leaves are shortened to few inches without lamina having malformed midrib or growth of the leaves ceased to few inches without malformation giving a de-topped spindle. As the leaves mature, irregular reddish stripes and specks develop within the chlorotic areas. Infection in the spindle may reach the growing point and continue into the stalk (Viswanathan, 2012).

Sometimes the growing point is killed leading to development of top rot. Due to death of spindle, sprouting of the lateral buds occurs. Most of the pokkahboeng-infected canes generally recover from the symptoms but in top rot recovery is not there. Upon recovery we notice the normal whorl with remnants of twisted leaf portions of affected leaves still twisting around the spindle. This disease is favoured by warm, moist growing conditions. Symptom development begins early in the rainy season which normally coincides with rapid and vigorous growth of the canes. The three to seven months-old are most susceptible to the disease. Conidia are air borne and are deposited on plants, then washed by rain into infection sites.

**Foliar diseases**

The foliar diseases such as rust, eye spot, yellow spot, brown stripe and ring spot are air borne and most of them survive on other collateral and weed hosts. None of the foliar pathogens are sett-borne. High moisture or relative humidity following rains accompanied by low or cool temperatures favours their incidence. During this period, excess irrigation and non-stripping off their lower leaves and dry leaves, leading to high relative humidity build up within the crop. Such microclimatic conditions help to build up of the disease to epidemic levels. Among the different foliar diseases, rust has become more severe and occurs...
in epidemic form in Maharashtra and Karnataka during post monsoon season. Almost all the varieties under cultivation such as CoM 0265, CoVSI 9805, Co 86032, Co 92005, CoC 671, Co 94012, etc were affected by rust. The newly introduced variety CoM 0265 shows high susceptibility to brown spot in Maharashtra and Karnataka.

**Integrated disease management**

The various types of diseases on sugarcane determine the quality, quality and stability of crop yield. This long duration cash crop due to its vegetative propagation, high sugar accumulation and practice of ratooning makes it easily susceptible to the diseases in the field. Besides this, wide spread practice of monoculture and heavy wet condition add to its susceptibility. This unfavourable environment in host plant invites large number of pathogens. The pathogens are not only reducing the yield but also cause the deterioration of the variety due to their accumulation in the stalk over the time. This phenomenon is referred to as varietal degeneration and this result in loss of full potential of a variety and subsequently such varieties are withdrawn from cultivation. In the past and even today many high yielding, high sugar and popular cane cultivar like Co 419, Co 740, CoC 671 etc are being withdrawn from cultivation only because of their high susceptibility to red rot, smut, grassy shoot and mosaic. No single method is efficient / available to control sugarcane diseases due to various reasons hence an integrated approach involving cultural, chemical/physical methods, host resistance and legislative measures is suggested for the sustainable management of sugarcane diseases (Viswanathan and Padmanaban, 2008).

**Easily available options**

Infected planting materials are responsible for the primary spread of the disease in the field. Hence, going for the disease-free setts would reduce the risk of disease introduction to disease free areas. Lack of awareness on seed cane health and ignoring quarantine regulations resulted in introduction of diseases, their epidemics and varietal degeneration in the country. To increase sugarcane productivity, supply of healthy seed canes is to be ensured in the field. As vegetative propagation in sugarcane favours harbouring of the pathogens causing red rot, smut, wilt, grassy shoot, leaf scald, YLD and RSD in the setts, adequate care should be taken while selecting seed canes. Since it is difficult to detect incipient infections of C. falcatum in seed-pieces, it is recommended to take the planting material from a disease free crop. Any crop with more than 5% smut or as high as 2% grassy shoot incidence is unsuitable for seed purpose. For red rot, if there is any infected clump in the field the plot is to be rejected for seed. It is advised to select always a disease free area to raise the seed crop.

Next to healthy seed, sanitation is important in preventing healthy cane from becoming infected with pathogens. Left over sugarcane debris is the prime substrate for the survival and spread of pathogen inoculum especially in the case of red rot, wilt and ratoon stunting. Red rot-infected debris is found to readily infect planted setts and cause death of settlings. Destruction of all plant debris such as cut canes, trash and stubble in situ is essential for the reduction of the pathogen inoculum. Further, complete removal of the disease-affected clumps in the field would also ensure disease free field.

Many of the diseases in sugarcane are aggravated by various biotic and abiotic factors. Negligent crop faces different biotic and abiotic factors like different borers, sucking pests,
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drought or water logging etc. Biotic factors such as infestation of internode borer or *Striga* favours early expression of YLD. Hence, all these biotic stresses are needed to be minimized to reduce the severity of YLD. It is well known that root borer infestation favours wilt outbreaks in different regions. Hence, adequate care should be taken to minimize many of these biotic and abiotic factors which predispose the crop for the infection of different pathogens.

**Disease surveillance and Diagnosis of sugarcane diseases**

Taking preventive measures immediately on noticing the disease occurrence is the best way of avoiding any major outbreaks of the diseases. When due attention is not paid during the first infection stage it would lead to its eventual spread and thereafter attaining epidemic proportion.

Many of the diseases do not cause diagnosable symptoms on the seed cane and different factors influence disease expression in the field hence we need to follow certain diagnostic techniques based on serology or molecular biology to detect them in the seed cane before planting in the field. Effort to detect and diagnose sugarcane pathogens using more advanced laboratory techniques has been achieved in the past two decades. Molecular-based diagnostic tests are generally considered to be very sensitive and this is probably their biggest advantage. Research personnel and development workers should be actively involved in creating awareness on supply of healthy seed. In addition to detecting sugarcane pathogens in seed canes, the recent approaches in the disease diagnosis using serological and molecular approaches have applications in the field of developing disease-free seedlings, disease surveillance and integrated disease management in sugarcane.

Since sugarcane is propagated through vegetative cuttings and this favours spread of diseases through planting materials. Primary transmission of different diseases through seed canes poses serious threat to sugarcane growth and performance. There is a need to diagnose of pathogens in sugarcane setts for effective disease management practice. Also diagnosis is important for the identification of pathogens, breeding crops for resistance to pathogens and epidemiological studies. Biological, physico-chemical, protein and nucleic acid based methods are available for detection of different pathogens. Of these, serological (protein) and nucleic acid based methods offer more reliable and sensitive methods for detection. Among serological methods, various forms of enzyme linked immunosorbent assay (ELISA) have become very popular and largely used for routine detection of pathogens in sugarcane. Tissue-blot technique is also equally effective for the detection of ratoon stunting bacterium and SCYLV. Among different nucleic acid hybridization based methods, dot blot is more suitable for large scale testing of samples. Polymerase chain reaction (PCR) is the most sensitive method \((10^{-2} - 10^{5})\) times more than ELISA) available presently for the detection and is important in sugarcane viruses occur at low concentration. PCR technique has the potential to detect more than one pathogen in one reaction and diagnosis is also amenable to automation. Various forms of PCR such as DNA-PCR, RT-PCR, IC-PCR, real time quantitative PCR and multiplex PCR are becoming more popular for detection of pathogens in sugarcane. Studies are in progress to develop diagnostic kits based on tissue blot, dot-blot, ELISA, NASH and RT-PCR for the different non-fungal diseases of sugarcane at this Institute.

Detailed studies conducted over the years at SBI, Coimbatore resulted in standardizing molecular diagnosis of different pathogens infecting sugarcane. Plant Pathology lab at SBI is
an accredited lab for indexing four viruses and one phytoplasmain sugarcane tissue culture seedlings. Currently, PCR technique is used to index sugarcane materials for GSD infection and RT-PCR technique is used to index sugarcane for SCMV, SCSMV and SCYLV infections. These diagnostics tests have become imperative to raise disease-free planting materials. Hence tissue culture production units in the country are utilizing the indexing service from our lab, which is an accredited test laboratory (ATL) for sugarcane virus testing in the country. The molecular tests are highly sensitive to detect very low virus titre in in vitro stock culture or in seedlings. Utilization of these molecular techniques will be a boon to raise disease free planting materials for sugarcane plantations. There is also possibility of maintaining the popular varieties for many years without degeneration to sustain higher productivity.

**Ratoon management**

We notice more damages caused by the diseases in ratoons than plant crop due to different reasons. Inoculum level of systemic pathogens causing smut, GSD, LSD, RSD, mosaic etc. gradually increases and result in severe expression of diseases in ratoon crop. Combined infection of two diseases such as RSD and mosaic or RSD and YLD adversely affect the crop growth and such effect is more pronounced in ratoons. Also establishment of ratoon crop in the field is severely affected by pathogen infection in plant crop. Similarly more accumulation of pathogen in ratoons facilitates acquiring higher virulence in the pathogens. The popular sugarcane variety Co 419 lost its prominence due to its susceptibility to RSD, mosaic and YLD. Higher RSD pathogen load favours YLD and entire foliage become yellowish and slowly crop degenerates and dries. This situation was found more in ratoons, due to high pathogen load/vigour. Since multi-ratooning of sugarcane has several advantages it is being followed in many countries. However to sustain sugarcane productivity and to improve ratoon productivity these points are to be given due consideration.

**Emerging new diseases**

Recently many diseases have emerged as serious ones in different countries. However YLD has as serious disease in different continents. This disease has spread to epidemic form in some varieties. Although mild infections of the disease do not cause much crop loss continuous use of seed from such fields lead to severe disease out break. Similarly, problems of wilt, RSD and GSD have been ignored in certain pockets, as there was no previous history of their severity there. Due to introduction of new varieties or change in cultivation pattern, minor diseases become severe. Hence, we have to keep a constant vigil on the emerging diseases in the region and immediately suitable management practices are to be taken up to avert future losses.

**Chemical control**

Chemical controls are possible for few of the diseases, particularly those caused by fungal pathogens. Sett rot pathogen survives in the soil. As a prophylactic measure, the sets are to be dipped in fungicide solution to protect the cut-ends from the pathogen. Recent studies at the Institute revealed that sett treatment of Thiophanate Methyl fungicide in combination with biocontrol bacterium *Pseudomonas* reduces soil borne infection of red rot pathogen surviving in debris. If rust is severe five to six sprayings of Mancozeb (0.2%) between November and March is recommended to control under our conditions. Similarly to
control eye spot spraying of copper oxychloride or Mancozeb (0.2%) once in 30 days during initiation period is recommended. Whenever the disease is high, fungicidal application should be sprayed at 18-20 day intervals.

**Use of resistant varieties**

The use of resistant varieties is the most important means of managing sugarcane diseases in a sustainable way. Although frequent breakdown of sugarcane varieties is a cause of alarm, new varieties with high to moderate levels of resistance to the disease are introduced time to time. Classical example is the performance of Co 86032 in different parts of the country especially in Tamil Nadu, where it occupies more than 80% of the cane plantation. Though the cultivar is susceptible to red rot under artificial testings by plug method, it showed high levels of field tolerance. The cultivar showed high levels of resistance when tested by nodal method, which was reflected in its field tolerence under endemic location. The variety suitably replaced two important commercial varieties CoC 671 and CoC 92061 and the cultivar performed better than these two in sugar recovery at different locations. The varieties Co 86010, Co 86249, Co 93009, Co 94008, Co 95003, Co 97008, Co 99004, Co 99006, CoV 92102, Co 0118, Co 0238 etc are found to be resistant to red rot (Viswanathan, 2010). Unlike red rot, smut resistance in commercial varieties in the field is quite stable. Most of the ruling varieties are resistant to smut.

While advocating sugarcane varieties to a factory care should be taken that there should be a proper varietal admixture in that region. In case of disease outbreaks, the disease spread will be rapid in case of monocropping as there is no barrier to check the disease. Also cultivating a single variety in more than 75% of the area would result in development of highly virulent strain of the pathogen, which may cause more damage to the crop than the existing pathotypes.

**Three-tier nursery programme**

The scientific principle involved in heat therapy is that the pathogens present in seed materials are inactivated or eliminated at set temperatures not deleterious for the host tissues. Aerated stream therapy (AST) is advocated to eliminate sett borne infections of GSD and RSD. Any fault in the AST unit may adversely affect the sett germination. Hence functioning of the heating unit and temperature control systems, proper volume and circulation of the heating medium and proper loading of the cane within the treatment chamber are to be monitored time to time. Treated setts should always be treated with fungicides (Carbendazim 0.1%) to reduce the entry of soil pathogens through cut ends. Since operations in AST need critical care and handling this treatment is recommended only for raising primary seed in three tier seed nursery programme. The treated setts should always be planted in factory farm for better monitoring. In place of the theromotherapy meristem-culture derived seedlings can be used in three tier seed nursery programme to get disease-free seedlings.

**Virus elimination**

Since many of the viruses are systemically infecting sugarcane virus elimination through meristem-tip culture is being followed in many countries. *In vitro* culture techniques employed for virus elimination involve indirect morphogenesis. However, clonal fidelity is not assured
when plants regenerate via a callus stage. Some viruses can be effectively eliminated from infected plants owing to their mode of replication and their mechanism of movement within the plant. Three methods are currently used to eliminate the virus/phytoplasma from infected planting materials viz., thermotherapy, tissue culture and chemotherapy. Of these methods, meristem tip culture is the most widely used method to eliminate the virus/phytoplasma. This technique takes advantage of the fact that many viruses are unable to replicate in this region. Transfer of the meristem dome, together with one or two leaf primordial, to a culture medium and development into a plantlet may lead to the elimination of a virus. Successful elimination of sugarcane mosaic virus and Fiji disease virus in sugarcane through apex or bud culture has been reported earlier.

Studies conducted to eliminate the SCYLV and SCYP by tissue culture from infected sugarcane plants in Mauritius found that the tissue culture derived regenerated plants were remained free from the respective pathogens over a period of one year in the glasshouse, confirming that the pathogens had been eliminated by tissue culture. Also attempts made from CIRAD, achieved virus elimination of 92 %, however they got only 64 % disease free plantlets. Hence stringent seed indexing methods have to follow while screening of the regenerated plantlets. The potential for eradicating pathogens via rapid regeneration of plants directly from leaf roll discs was explored in South Africa. The technique, NovaCane®, has been used successfully to remove SCYLV from sugarcane. Here leaf roll explants from the stalks were placed on MS0.6 medium (MS salts and vitamins, 20 g/L sucrose, 0.5 g/L casein, 0.6 mg/L 2,4-D, 8 g/L agar pH5.8) for five weeks with fortnightly subculture intervals. Embryo germination occurred on MS0 (MS salts and vitamins, 20 g/L sucrose, 0.5 g/L casein, 8 g/L agar pH 5.8) after a further five weeks. Plantlets were transferred to seedling trays after ten weeks and acclimatized in the glasshouse. Two months later, tests for the presence of the disease causal agents in selected plants were performed by RT-PCR for SCYLV and it was found that the process eliminated SCYLV. In addition, this process enabled elimination of bacterial pathogens from diseased sugarcane plants while simultaneously enabling large-scale micro-propagation. As disease eradication was not 100% effective, they have suggested that donor plants require conventional screening for the presence of known causal agents prior to micro-propagation.

Detailed studies were conducted at SBI, Coimbatore to eliminate Sugarcane yellow leaf virus (SCYLV) from infected sugarcane. Meristem culture combined with viricide Ribavirin has effectively eliminated the virus and reverse transcription polymerase chain reaction (RT-PCR) is being used routinely to index the tissue culture materials (mother plants or seedlings) for the virus. Production of SCYLV-free seedlings has ensured supply of YLD-free planting materials to the growers fields and such fields showed renewed vigour in the crop. Overall, virus elimination through meristem culture combined with molecular diagnosis has been demonstrated as a viable strategy to manage YLD, which occurred in epidemic form in sugarcane in the recent years.

Quarantine

Although quarantine regulations are recommended time-to-time craze for new varieties among the factory authorities resulted in spread of red rot from one region to another in India. Lack of strict seed movement and quarantine laws resulted in the introduction of red rot to states such as Gujarat, Karnataka and Maharashtra, through indiscriminate lifting of...
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seed materials of CoC 671 and CoC 92061 from Tamil Nadu. These states were free from the disease for the past 100 years. Similar situation exists in other countries also. Recently there have been instances of bringing varieties from other countries were noticed in different parts of the country by the sugar industry personnel, especially in private sector. This may lead to introduction of new diseases into the country and cause new problems to the industry. Hence strict seed movement laws are very much required for checking the transport of cane from an infected zone to disease-free regions. Each country should have a crop health map for various diseases and regulated seed movement to different regions accordingly.

Conclusion and future perspectives

The fungal diseases like red rot, smut and wilt were responsible for the elimination of many elite commercial varieties in the past in different epidemics. Additionally many of the non-fungal diseases contribute to decline in their performance due to ‘varietal degeneration’. Lack of awareness on seed cane health and ignoring quarantine regulations resulted in introduction of diseases, their epidemics and varietal degeneration in the country. Hence sugar industry may follow strict quarantine norms when they bring new varieties from unknown sources or destinations. This would prevent introduction of new diseases which are not reported in the region from other zones or countries.

Growing disease resistant varieties is the mainstay in disease management in sugarcane and introduction of disease resistant varieties after red rot or smut epidemics has saved sugar industry during several occasions. However, sugarcane varieties vary in their potential against different diseases and any elite commercial variety may not possess tolerance against all the major diseases. Hence to sustain the productivity in such varieties alternate management strategies need to be followed to contain the disease losses.

Although YLD has created a havoc to sugarcane cultivation in the country and SBI has evolved strategies to manage the disease through meristem culture combined with molecular diagnosis of the virus. Hence, need of the hour is to establish YLD-free nurseries in different sugar mills to reduce disease severity. Wherever appropriate conventional seed nursery programme through aerated steam therapy needs to be followed to reduce severity of GSD and RSD. Disease surveillance programmes in the country need further strengthening including use of remote sensing approach. This would lead to creation of disease maps for various diseases in sugarcane and this would facilitate developing possible forewarning systems and varietal deployment in a region in the future.

Recent outbreak of pokkahboeng and rust in different parts of the country hence there is a need to create awareness about the potential diseases which may seriously affect sugarcane production. Hence the sugar industry should be prepared to tackle minor diseases when they become major diseases in sugarcane.

References


**Further Reading**


8. INTEGRATED PEST MANAGEMENT IN SUGARCANE

R. Jayanthi

The term pest management, as opposed to pest control, in itself contains the inherent suggestion that pests are to be managed and not completely controlled so as to eradicate them. The limitations and inadequacies of a single method such as the chemical control led to the use of different methods in conjunction with one another in the more recent strategy of integrated pest management (IPM). The concept of IPM may be defined as the integrated use of all available methods and strategies to manage the pest populations below the EIL with least ecological or environment disturbance and greatest socio-economic acceptance.

Integrated Pest Management, or “IPM,” is a type of pest management. According to the National Coalition on IPM, 1994, “IPM is a strategy that uses various combinations of pest control methods, biological, cultural, and chemical in a compatible manner to achieve satisfactory control and ensure favourable economic and environmental consequences.” IPM is not one single action, it is a process, a series of steps that must be carefully thought out ahead of time. Each step depends upon the given situation, the given pest and your given ability, both physically and financially, to accomplish all of the steps.

The adoption of IPM involves comprehensive information of the pest biology and ecology to identify the week links and target them with suitable strategies. The series of logical steps or components for developing a viable IPM strategy for the crop can be roughly enumerated as: (i) identification of target pests through monitoring; (ii) establishment of economic thresholds; (iii) understanding the crop-pest-natural enemy ecology; (iv) development of integrated pest management strategy. Although it is desirable to have a perfect IPM strategy as per such protocol, in the absence of the requisite background it is advisable to make a beginning with the available knowledge and improvise upon it as and when new information is acquired.

PEST MANAGEMENT STRATEGIES

IPM uses a combination of compatible techniques which include cultural, biological, mechanical, varietal and chemical methods.

Cultural control envisage modifications of agricultural practices to disrupt or reduce pest populations. Correct fertilization and watering are major cultural practices that influence the health of plants and their susceptibility to pests. Growing healthy plants is one of the best ways to reduce pest problems. Cultural practices like manipulating the dates of planting, trash mulching, detrashing, earthing up, etc. have been found to be useful in suppressing pests like shoot borer, internode borer, mealy bugs, scale insect and whitefly. While some cultural practices are routinely followed, some others may be constrained by non-availability of labour. Mechanical measures are more controlled by consideration of economics.

Biological Control refers to the use of natural enemies to control pests. The actions of parasites, predators or pathogens on a host or prey population is common in nature. Enhancing and preserving biological control agents is an important component of IPM. In
some cases it is advantageous to release commercially reared natural enemies to augment control. The stable sugarcane crop system provides ideal conditions for both natural and applied biological control of various pests. The low insecticide usage incidentally conserves natural enemy complex of pests and keeps them under check. The overall equilibrium is often disturbed by the introduction of new pests like woolly aphid which, by virtue of its rapid multiplication and dispersal rates, has proliferated uncontrollably. Such pests can be managed by deliberately introducing its native natural enemies and colonizing them in the invaded areas. The process can be expedited by devising mass multiplication systems for potential natural enemies. Such redistribution has been successfully practiced or recommended for native pests like pyrilla, whitefly and woolly aphid. Regular pests like internode borer can also be targeted through augmentative approach with efficient natural enemies.

**Mechanical control** refers to using barriers or traps to exclude or catch pests. In sugarcane using pheromone traps for managing key borer pests, *viz.*, shoot, internode and top borers. However, still much remains to be worked out in this aspect. With respect to other mechanical control tactics most relevant to sugarcane pests, the method of collecting and destroying adult beetles of white grubs on a large scale on a campaign basis at the time of their emergence, collecting and destroying egg masses of pyrilla and top borer coinciding with the brood emergence, etc. will contribute to reduction in pest populations both in the long- and short-term. may be cited as distinct instances.

**Chemical control** is the most common technique and includes the use of pesticides. Pesticides are manufactured and formulated in many ways. If applied at the correct rate and time, pesticides are usually safe and effective. Organic insecticides such as insecticidal soap and horticultural oil are readily available. An indispensable, often reliable in emergency situations, tool in pest management, insecticides prevent rapid buildup of pest populations to EILs. Since the crop canopy itself provides the safeguard against their excessive usage, selective use of insecticides safe to natural enemies is not a priority. However, there is a need to educate farmers on the use of appropriate insecticide, formulation, method and time of application for a given pest. In ecological selectivity, the appropriate stage of the insect is targeted as in the case of second stage larvae of white grub which prevents the population from reaching the devastating third stage. In selectivity through improved application, insecticide should be applied to the active site of pest attack. Furrow application of chlorpyriphos or lindane for shoot borer, sett dipping in confidor for termite control, application of sprays instead of granules that too in patches showing woolly aphid attack, treatment of periphery of the field where whitefly begins its attack are some examples.

**Varietal component**

Plant selection and resistance involves the selection and use of plants that are pest resistant and compatible with the existing conditions (shade, soil type, drainage, exposure) of the desired planting location. Commercial hybrids are seldom released with tags of ‘high resistance’ to pests because directional breeding for resistance to pests is an exception than a norm in breeding programs. It is also seen that in occasional focused breeding programs, varieties released as resistant to pests do not find commercial acceptance, because generally they do not show the desirable level of economic traits. However, management of pests can
be envisaged through the management of the available varieties by taking a susceptible variety out of cultivation both in space and time in the context of a specific pest abounding in that location/region. and replacing it with new varieties. This will not only break continuity in proliferation of the pest but also bring in desirable changes in yield and quality. If needed, the old variety can be brought back to cultivation some time later when the pest populations in the area decline either due to climatic factors or due to some inherent resistance in the new variety. An integration of all the above control methods is the best way to get safe, long-term pest management with minimal adverse effect on the surrounding environment.

**Record keeping**

IPM programs rely on records to make field recommendations. As program evaluations and future plans are developed, good field records are essential. The time spent recording information on a ledger or data sheet is often hard to justify as productive. All production inputs must be recorded: date, time, control method and results obtained.

**Integrated management of important sugarcane pests**

**Shoot borer**

The attack of shoot borer begins from the first week after germination and continues until four months with peak activity during summer (April-June). Its attack leads to formation of more tillers than usual in frequently/adequately irrigated crops or results in formation of elimination of young shoots/poor tillering leading to gaps in fields, especially under dry field conditions. The following measures are recommended for its management:

1. Early planting (December-January) should be followed in problem areas to avoid synchrony of the susceptible stage of the crop and the peak activity period (April-June) of the borer.

2. Use of pheromone traps two weeks after planting @ 25/ha with one lure change.

3. Two to three light earthing-up and trash mulching (to be adopted with caution in termite/armyworm prone areas) during the early stages of the crop growth.

4. Frequent irrigation, if possible, will also have the same effect as trash mulching.

5. Insecticidal sprays with chlorpyriphos 20 EC @ 1 kg a.i./ha when the incidence level exceeds about 15%, the currently accepted ETL. This amounts to 5 liters/ha or 2 liters/ac of the formulation which is applied at the dilution of 50ml/10 lit of water for 100 m row length. The approximate quantity of spray fluid will be about 400 liters/acre which should be done with a knapsack sprayer directing the spray fluid on leaf whorls and around the collar region of the plant.

**Internode borer**

The borer attacks sugarcane from 4th month of planting coinciding with the formation of internodes and continues till harvest or flowering. The borer exhibits peak activity during June-December coinciding with monsoon and post-monsoon periods. The borer not only feeds in the internodal regions, but also feed in the region of the apical meristem leading to
dead heart formation. Consequently, crop growth is arrested and axial buds sprout giving a bunchy top appearance. The crop remains stunted and naturally the productivity is adversely affected. The bored stem portion turns reddish within and easily break off. The borer is difficult to manage since it is an internal feeder and occurs virtually throughout the year. Taking up insecticidal sprays in grown up crops is just not practicable and efficient natural enemies against this borer are virtually not available for commercial use. Under this situation, the following are the recommendations for managing this pest.

1. Large scale cultivation of varieties showing high incidence of the pest may be avoided temporarily in problem areas and may be grown in conjunction with other less susceptible types spatially and temporally, in hot spots.

2. Use of pheromone traps at 4th – 5th month of the crop @ 25 per hectare at suitable height with lure changes may be tried.

3. Internode borer pupates outside the cane stalk. Periodical detrashing, preferably at fifth and seventh months, minimises the borer attack by denying the borer suitable place for pupation. Also, the larvae dispersing from one internode to another remain exposed due to want of cover and become prone to predation. Also, detrashing keeps the crop clean and enables a possible early application of insecticide in hot spots.

4. Insecticides application is feasible may be up to the 6th month stage in detrashed and well maintained crops. Spraying monocrotophos 0.1% on top internodes may be useful.

**Top borer**

The attack is characterized by leaf mines, shot holes on opened leaf, atrophied central shoot, stunting of cane and sprouting of axial buds leading to bunchy top. A more serious pest of subtropical India, it shows definite brood patterns during February-September. Here, the control should be envisaged for each brood by monitoring brood emergence. When advanced pupal stages are noticed in the affected cane samples, control measures need to be initiated.

1. Hand collection of prominent top borer egg masses for up to one month from the day of setting the pheromone traps at 4 days intervals so that egg masses could be destroyed before the larvae hatch on 5th day of oviposition. Egg masses collected may be held in 60 mesh nylon bags in the field to facilitate selective emergence of egg parasitoids.

2. *Isotima javensis* is an efficient natural parasitoid in the field. The parasitoid may be multiplied on a small scale for release in problem areas. Similarly, *Trichogramma japonicum* occurs naturally on the borer. Since multiplication techniques for this group of egg parasitoids are available, it may be multiplied and used in problem areas.

3. In severe cases of infestation carbaryl at 1 kg a.i./ha or phorate at 3 kg a.i./ha may be applied in the root zone, covered with soil followed by irrigation. Since the third brood is the most destructive, insecticide application may be resorted to during the last week of June to coincide with the third brood occurrence.
Stalk borer

Nature and extent of damage

One of the most destructive pests of sugarcane in subtropical India, the stalk borer is a major pest in Uttar Pradesh, Haryana, Punjab and Bihar. Soon after hatching, the larvae move on the upper surface of the leaf for about 15 minutes but later move downward and take shelter inside the top leaf sheaths (+4 to +8) or in the central whorl. They feed by scraping the inner surface of these leaf sheaths for about a week where they complete two instars. Usually two to six larvae mine in one leaf sheath due to which the leaf sheath decays and subsequently the entire leaf dries. As a result of feeding by the newly hatched larvae, leaves show distinct longitudinal orange yellow streaks extending from tip to base on both sides of the midrib towards leaf margins. It is the third instar larva which bores into the shoot and internodes of the canes. In the early stages of crop growth, i.e. from March to June, the infested shoot produces a deadheart very similar to that caused by early shoot borer. The grownup cane shows no visual symptoms of infestation unless the leaf sheaths are removed, when the bore holes may be seen clearly on the internodes. An infested cane may harbor three to 15 larvae at a time and the damaged internodes show symptoms of reddening (Fig. 23) which sometimes emit a rancid odor. Often in mature canes, three well marked regions of borer infestation, viz. the lower, middle and top portions may be discerned during August-December indicating the three broods of the pest occurring at different stages of plant growth. However, in epidemic conditions, larvae may be found in all the internodes of the infested cane during November-January. Canes which are severely damaged during July-August may dry up from November onwards. The borer causes losses of 16-29% and 1.7-3.7 units, respectively in cane and sugar yields in the subtropics.

Bioecology

Moths have straw colored forewings with a number of golden spots on the periphery and light straw colored hind wings with silvery fringe. The eggs are laid in masses on the underside of the leaves arranged in two to five parallel rows. The incubation period ranges from 4-10 days. The newly hatched larva is creamy white in color which normally passes through five instars but in summer and winter there can be as many as eight instars. The fully grown larva has five violet stripes along the length of the body. After a normal larval period of 16-51 days, pupation takes place inside the tunnel formed by the larva. Pupal period ranges from 6-10 days during March-October and 20-24 days in January. The borer completes five generations in Haryana, five to six in Uttar Pradesh and seven in Bihar.

Management practices

- Detrashing autumn planted crop during September – October will expose the infested internodes to the activity of natural enemies. This will enhance the effectiveness of insecticides if applied.
- Removal of water and late shoots at 15 days intervals during winter.
- Release of Trichogramma chilonis at 2.5 cc/ha at 10-15 days interval from July reduced the infestation level.
The tachinid parasitoid *Sturniopsis inferens* naturally parasitizes stalk borer up to 43%. Mass multiplication and field releases at low doses of 15 gravid females/ha have been found to control stalk borer in a subtropical sugar factory area. It would be useful to mass multiply the parasitoid for inoculative or augmentative releases.

The braconid parasitoid *Cotesia flavipes* causes up to 14% natural parasitism of the borer. In field studies, the parasitoid at 2000 females/ha released five times reduced stalk borer infestation by 70%. This can be mass multiplied using available techniques and released for the control of the borer.

Detrashing followed by application of systemic insecticides twice during August and September at monthly interval would be useful.

**Root borer**

**Nature and extent of damage**

A common pest in the subtropical sugarcane belt, root borer entered parts of tropical India about two decades back but subsided five years later. It attacks the underground stalk portion of cane and the intensity of damage varies with the stage of the crop. In the early stages, i.e. during May-June, deadhearts are formed which cannot be easily pulled out nor do they emit offensive smell as in the case of shoot borer. Often one or two leaves adjacent to the central whorl also dry-up. In grownup canes the damage symptom is visible in the form of yellowing of leaves. The canes need to be uprooted to detect the damage and the presence of larva. While attack by the first brood affects tiller production, second to fourth broods reduce cane length and weight in the decreasing order of magnitude with the brood number. Yield loss and sucrose reduction have been observed due to borer attack.

**Bioecology**

Moths have straw colored forewings and whitish hind wings. Female lays eggs singly on the upper and lower surfaces of leaves along the midrib. After an incubation period of 5-8 days, the first instar larva crawls to the base of the stem and enters it by making a single hole at or just below the ground level. The larva feeds in an irregular semi-circular pattern and may leave the bored stem and enter into another underground stem of the same clump or adjoining shoots. Larval period varies from 23 to 43 days in summer and longer during rainy season and winter. Larvae hibernate during October to February. The full grown white colored larva cuts an opening at the exterior end prior to pupation and constructs a silky pupal tube up to the surface of soil for easy emergence of the adult. Occasionally, pupation occurs in the silken tube outside the cane. Pupal period lasts for 7-11 days during summer and rainy seasons and 8-14 days during winter. Life cycle is completed in 30-73 days depending on the season and region. The borer is active at high temperatures and moderate humidity levels. Generally ratoon is more prone to its attack. Unirrigated fields and sandy or sandy loam soils harbor high borer incidence.

**Management practices**

Mechanical destruction of affected shoots along with borer larvae in the pre-monsoon period reduces pest inoculum.
Deep harvesting of canes that are to be ratooned should be adopted to expose larvae or pupae.

In endemic areas, avoidance of ratoons minimizes proliferation of the pest. In such areas, digging and destroying stubbles after harvest reduces carryover of the pest to the next crop or season.

In cases of severe infestation, fields should be ploughed up and affected stubbles with larvae should be collected and destroyed.

In spring/summer planted sugarcane, green gram grown as intercrop followed by its incorporation reduces early incidence of the borer.

Collection and destruction of moths using light traps also minimizes perpetuation of the borer.

Release of *Trichogramma chilonis* @ 50,000/ha at 15 days intervals from July to October offers partial protection.

**Gurdaspur borer**

**Nature and extent of damage**

It is an important pest of sugarcane in Punjab, Haryana and western U.P. It is also reported from Sriganganagar in Rajasthan and some parts of Himachal Pradesh. The pest exhibits both gregarious and solitary phases. After hatching, larvae wander about for a few hours in search of a suitable site and enter the cane gregariously through a single hole. The entrance hole is always made on a sheathless internode and never below the third internode from the top. They feed gregariously in galleries in a spiral manner making minute punctures on the rind from within. Externally the tunnel appears as a dark spiral made up of a series of punctures. As many as 35 larvae may feed gregariously in one cane. After feeding two thirds of internode in a spiral manner, the larvae bore deeper and feed upward by making a straight tunnel. Third instar larvae start dispersing to other canes singly or in groups of two to three and in the later stages one caterpillar is found infesting the internodes in each plant. Leaves wither due to larval feeding just below the rind but as the infestation advances and the central tunnel is formed, the entire whorl of leaves turns yellow and dries up. As a result of the attack, canes fail to grow, damaged internodes become weak and infested stalks break off easily. Nodal buds in the remaining portions of canes are stimulated and side shoots are formed. The pest causes 15-25% damage normally but can inflict as high as 40-50% damage in years of severe attack with reported losses of 38-100% in cane weight and 29% in sucrose.

**Bioecology**

The forewings of the moth are pale grey brown in color with several blackish spots along the outer margins; hind wings are white in color. Adult moths lay creamy white eggs in clusters on the upper surface of leaf in and along the grooves of midrib near the leaf sheath. Mature larvae possess four violet stripes, the lateral being comparatively thicker. Before pupation, larvae form a pupal cell in the cane. The pupae are yellowish brown in color with reddish brown stripes and numerous microscopic spines on abdominal segments. The egg, larval and pupal stages last for 4-9, 48-64 and 6-13 days, respectively. After the
completion of two broods during June-September, more than 80% larval population comprising full grown third brood larvae move downwards to the below-ground portion of the cane by November for hibernation. The pest flourishes well under moderate temperature and high humidity conditions. Early monsoon, heavy rains and water logging also favor its multiplication.

Management practices

❖ Affected canes with five to six top internodes harboring borer larvae in the gregarious phase should be cut and removed regularly. The operation should be carried out on a campaign basis from second fortnight of July to the end of September.

❖ Stubbles harboring hibernating larvae, easily identified by the presence of round tunnel holes at the cut ends, should be uprooted and burnt to kill the larvae.

❖ Ratooning of heavily infested crop should be avoided to prevent perpetuation of the pest.

Plassey borer

Nature and extent of damage

The borer derives its name from its occurrence in an epidemic form at Plassey (West Bengal) in 1956. It is an important pest in some parts of West Bengal, Bihar and Assam. The incidence of the borer can be easily recognized by the presence of dried crown of infested sugarcane. Borer attack occurs in two distinct forms. Primary infestation is caused by as many as 156 newly hatched larvae aggregating in the top three to five internodes. Due to such gregarious feeding, fresh red colored frass is seen projecting out of the bore holes and the top leaves of the canes ultimately dry up. Affected internodes break off easily and nodes adjacent to the infested internode develop sett roots which completely envelop the stalk; sprouting of nodal buds also occurs. In the case of secondary infestation, the grownup larvae disperse to either the lower healthy portion of the canes showing primary attack or the neighboring canes. Larvae feed by tunneling the internodes. One larva may bore into one to five internodes in a cane but cane tops do not dry up in this form of damage. Losses are more due to primary than secondary infestation and may vary in the range of 8.2 - 12.6% and 10.7 - 48.6% for yield and sucrose, respectively.

Bioecology

Moths are cinnamon brown with terminal series of black spots broken externally by small silvery white points. Hind wings whitish except for a few light brown scales in the costal area of male moths. Egg masses are deposited on the underside of top one to three leaves in two to four tiers. Occasionally, eggs are also laid on leaf sheath and stalk. Larvae from one egg mass hatch synchronously in seven days and penetrate into one of the tender internodes. After 10 days of primary infestation, the larvae disperse to adjoining canes each one boring into a separate internode. There is a well marked polymorphism and larvae are of four different types. However, a typical larva possesses four broad pinkish stripes present sub-dorsally and laterally in pairs. The egg, larval and pupal stages last for 7, 26-46 and 6-11 days, respectively. The pest remains active from end of February to middle of November.
All stages of this pest are simultaneously met with from April to October showing overlapping generations. However, distinct broods are also reported in different places during June-October. Larvae hibernate from mid November to February. The fourth and fifth broods overlap during February – June. Rainfall appears to favor its multiplication. The incidence is high in heavy soils and under waterlogged or flooded conditions.

**Management practices**

- Collection of moths in light trap to minimize pest proliferation.
- Collection and destruction of egg masses and cane tops showing primary infestation.
- The braconid parasitoid *Cotesia flavipes* causes up to more than 35% mortality. This can be mass multiplied with available techniques and released inoculatively or augmentatively for the control of the borer.
- High natural egg parasitism of *Trichogramma* sp. (30-71%) was observed on the borer. Avoiding indiscriminate use of insecticides conserves the parasitoid and allows them to bring about natural control of the borer.

**Woolly aphid**

The pest that invaded southern states a couple of years ago occurs throughout the year with low populations in summer. The pest can thrive in summer too if a crop of suitable stage is available. The buildup of populations generally begins in June and continues up to November. In a given crop, attack generally begins from third to fourth month onwards but 6-7 months age appears to be the most suitable stage. Populations increase with the growth of crop and foliage resulting in honeydew deposition and sooty mould growth on leaves. The dense colonies of the aphid give a white patchy appearance in the field.

**Preventive management**

Various routine agronomic practices and specific recommendations scrupulously followed will confer several advantages. Some practices help prevent the entry of the pest in new areas while some others ensure a healthy and hygienic crop that allows monitoring and plant protection measures.

1. Complete avoidance of transport of seed material or green tops as fodder from affected areas minimizes the risk of introducing the aphid to a new area.

2. Destruction of affected leaves and priority for harvest of affected cane would prevent extensive spread of the pest in recently invaded areas. Detrashing enhances accessibility for monitoring and spot application of insecticides. It also minimises the strata for the development of sooty mould and prevents the crop from presenting a sickly appearance.

3. It has been a general observation that the aphid colonizes crop with dark green foliage and avoids sickly crop. Excessive and late application of nitrogen, and excess irrigation which predispose the crop to severe attack may be avoided.

4. Wider spacing and paired row planting, and wrapping and propping operations confer the indirect advantage of rendering the crop canopy more amenable to pest monitoring and control operations, particularly spot application of insecticides.
Management of invading phase

Invading phase may be applied to a sugarcane belt that has not yet been invaded by the pest or to individual fields where the incidence has not begun in the current season. Management in either case involves the following schedule:

1. Intensive monitoring of the field is the first and vital step for efficient management of the pest in invading phase. Due to the high multiplication rates and dispersal ability of the aphid, weekly monitoring should be invariably followed. Attention should be given to cooler areas such as the crop under tree-shade where infestation is likely to begin, particularly during summer (March-June) when the aphid populations are generally low.

2. When aphid colonies are noticed they should be destroyed by spraying insecticides. Removal of infested leaves for burning or burying should be not done as it favours the spread of nymphs to other parts of the field while bringing the infested leaves out of the field for destruction.

3. Insecticide should be delivered as spot application in the patches that show aphid colonization giving a thorough coverage of lower surface of leaves. Besides the infested plants in the patch, unattacked plants within 2 m outside the periphery of infested plants should also be treated with insecticide to control the inapparent colonies.

Management of established populations

Management of the pest in areas where it has established and spread extensively involves combined use of insecticides and predators since in such areas, natural enemies would already have established. The following tactics should be used in a multi-pronged approach for long-term suppression of the pest.

1. Upon locating inoculum colonies through weekly monitoring, insecticides are used for quick reduction of aphid populations. This minimizes the intensity of damage and narrows down the ratio of aphid and its predators which appear subsequently. If the incidence is in few patches and intensity is low to moderate, locally available low-cost detergent soap or powder at 2% may be sprayed thoroughly covering the undersurface of entire leaf. If the incidence is more widespread, insecticides should be used. Since the residual effect of currently used insecticides is very short, control achieved is temporary and aphid populations would reappear in a few weeks. This would necessitate the dependence on natural enemies for long-term control.

2. With increase in aphid populations, predators start appearing alongside the pest and there is a need to utilize them for long-term suppression of the pest. Conservation of predators becomes the first step in successful biological control of the pest. To conserve resident predator populations, a few refugia are created in the field by demarcating a few aphid infested patches of 50 sq. m area. Predators collected from other parts of the field are released in these patches which are kept insecticide-free. As pointed above, spraying should be confined to infested patches. If infestation is spread all over the field, spraying can be done in the entire field leaving the refugia.
3. The treated fields should be monitored continuously for reduction and reappearance of the pest. Spot application of insecticides may be continued if predators have not established or predator culture is not available for colonization.

**Insecticide usage**

1. Timely identification through monitoring and destruction of inoculum colonies with insecticides prevent speed of spread and establishment of the aphid. Predators that arrive late are not harmed.

2. Acephate 75SP, monocrotophos 40EC and dimethoate 30EC at 2g or 2ml per lit. water have been found effective against the aphid.

3. Spot applications at the recommended dosage reduce the quantity of insecticide, time and labour spent on plant protection operation in the hostile canopy. Besides, spot application minimizes risk to non-target organisms and environment. It will also retain fodder value of tops from unsprayed patches of the plot.

4. Insecticides should be used in rotation to prevent rapid development of resistance. Similarly, mixing several insecticides should be avoided to prevent development of multiple resistance.

**Biological control**

Insecticide treatment should be avoided in fields where the biological control agents—parasites/predators are observed naturally/ have been released.Among the natural enemies, the parasitoid, *Encarsia flavoscutellum* has shown great potential in controlling the pest. Among the predators, *Dipha aphidivora* is predominant in some southern states like Tamil Nadu. It can be effectively put to use as follows.

1. Collection and redistribution of cocoons from fields with well established cane, aphid and predator populations to fields with young crop and just established pest populations.

2. Mass multiplication of *Dipha* using the tray method and field release of the predator at dosages up to 1,000 cocoons per ha. Leaf bits bearing the cocoon masses can be inserted in leaf axils of the standing cane from which adults emerge and oviposit among the established colonies.

**Scale insect**

Once a severe pest in coastal region of Andhra Pradesh and humid tracts of Tamil Nadu, it appears to be below damaging levels in the recent past. The insect is capable of causing reduction in germination of infested setts, inhibition of cane growth, reduction in yield and quality, and loss in jaggery production. Usually appearing in 5-6 month old crop, heavy infestation is witnessed during June-December.

1. Selection of healthy seed from pest free areas and uninfested fields is important as infested setts affect germination. The measure is not at all important from the point of establishment of scale in the present crop due to the long gap between planting and internode formation. It is significant if the seed material is being imported to an area
where scale has not been recorded earlier. Also in areas where the pest has remained low for a long time use of healthy seed prevents its reentry or reestablishment.

1. Detrashing of crop two or three times at internode formation will expose the colonizing sites as well as the crawlers that move upwards to settle underneath the tightly clasping leaf sheath to the onslaught of weather thereby reducing their build-up.

2. Soaking setts in malathion 0.1% for 15 minutes is once again important when seed material is imported to new areas as discussed in point (1) above.

3. Application of malathion 50 EC at 0.1% or dimethoate 30 EC at 0.1% or acephate 75% SP at 0.15% as sprays. Sprays preceeded by detrashing will enhance the effect of insecticide treatment.

**Pyrilla**

Pyrilla is the most destructive foliage-sucking pest of sugarcane. Heavy rainfall followed by 75-80% humidity, intermittent drought periods, high temperature (26-30°C) and wind movement favour rapid buildup of pyrilla. Other factors favouring pyrilla buildup are dense and luxuriant crop, excess nitrogen application, water logging, lodging of cane and varieties with broad and succulent leaves. Adults and the nymphs suck leaf sap from the under surface of the lower leaves. When the infestation is heavy, leaves turn yellowish white and wither away. Due to continuous desapping by large number of hoppers top leaves in the affected canes dry up and lateral buds germinate. The hoppers exude a sweet sticky fluid known as honeydew, which promotes quick and luxuriant growth of the fungus, capanodium species and as a result the leaves are completely covered by the sooty mould. This affects photosynthesis. The loss in cane yield due to pyrilla has been estimated to be around 28% with about 1.6% unit loss in sugar. The managemement of this pest can be done as follows.

1. Removal and destruction of the white coloured puffy pyrilla egg masses or egg-bearing /nymphs bearing sugarcane leaves at regular intervals. Alternatively, the egg masses may be kept in cloth bags and suspended at different places in the field to facilitate selective emergence of adult egg parasitoids while trapping neonate nymphs.

2. Spraying of Chlorpyrifos 20 EC (1500 mL/ha)or Dichlorvos 76 EC(400 mL/ha) or Monocrotophos 36 SL(500 mL/ha) can be adopted if essential.

3. If the pest reaches a regular or key pest status, a biological control based strategy will give a more lasting solution .Release of 8000-10,000 cocoons or 8-10 lakh eggs of of the parasitoid, *Epiricana melanoleuca* /ha is reported to be very effective in suppressing this pest.

**Whitefly**

It is frequently especially in crops subject to waterlogged conditions, saline soils and poor field hygiene.

Detrashing and destruction of leaves bearing whitefly puparia before the emergence of the adults.
In the initial stages, attack of whitefly would be restricted to border areas where insecticide sprays with malathion 50 EC at 0.1% or dimethoate 30 EC at 0.1% or acephate 75% SP at 0.15% may be resorted to.

Collection and redistribution of the parasitoid *Amitus minervae* from fields where its activity is prevalent.

**Mealy bugs (*Saccharicoccus sacchari, Kiritshenkella sacchari*)**

Infest the canes especially in genotypes with tight leaf sheaths. They are pinkish / yellowish insects. Detrashing, maintaining field hygiene and spraying with Monocrotophos 36 SL @1700 mL/ha may be resorted to for their suppression.

**Black bug**

**Nature and extent of damage**

Of the three species of black bugs infesting sugarcane, *Cavelerius sweeti* is the most predominant pest of ratoons in north India. While *Dimorphopterus gibbus* is of sporadic occurrence, *Spilostethus macilentus* is an occasional pest. The nymphs and adults of *Cavelerius sweeti* are found in the leaf whorls and under the sheathing bases of leaves. The leaves of affected plants turn pale yellow with brown patches. In severe infestation, they become riddled with holes, owing to several bugs puncturing the same spot. The tips and margins of the leaves dry up gradually and the entire plant may wither. The growth of the plant is arrested and the quality of juice is adversely affected. Both nymphs and adults suck the sap resulting in stunting of the ratoon crop.

**Bioecology**

Adult *Cavelerius sweeti* is black in color with legs and antennae being ochraceous (Fig. 56). The longevity of males and females is 112 and 118 days in summer and 210 and 242 days in winter, respectively. Fresh eggs are cigar shaped, smooth and creamy white turning vinaceous brown later. The egg period ranges 9-17 days during May-September and 85-159 days during October-April. First instar head yellow, ochraceous; compound eyes red; antennae four segmented, the fourth being the largest. Fourth segment of the body is amber colored with white spots, fifth and sixth segments reddish brown, last three segments black. Second instar head reddish brown, posteriorly suffused with black; compound eyes scarlet red; pronotum blackish, meso and metanotum suffused with white. Third instar head reddish brown, suffused with black; pronotum dark brown, posteriorly suffused with reddish brown. Mesonotum brown, anterior margin of both pronotum and mesonotum suffused with white; wing pads evident. The durations of first, second and third instar nymphs are 8-15, 3-17 and 4-14 days, respectively. Black bug incidence is heavy in ratoon fields where trash is retained for a long time. Mild weather and large numbers of overwintering individuals are responsible for the outbreak of the pest during the pre-monsoon periods. The loss due to bug damage is severe in unirrigated fields.

**Management practices**

- Burning trash and crop residues after harvest, removing sprouts from stubbles by the end of April and irrigating the fields reduce black bug infestation.
Application of acephate 75SP or dimethoate 30EC or malathion 50 EC at 2g or 2ml per lit directed towards the leaf whorls to target all stages.

Mites (Oligonichus indicus, O. sacchari, Tarsonemus spinips, Aceria sacchari)

They are non insect pests. Nymphs and adults scrape and suck the sap from underside of leaves and form large colonies. The affected leaves show blotching and red spots and give a scorched appearance. To control mites, foliar spraying of monocrotophos 40 SL can be undertaken @ 1 litre/ha / Application of malathion @ 0.05%. Removal and destruction of infested plants is also advocated.

Termites

Termite attacks the planted sugarcane setts as well as plants of all stages until harvest.. Attack in the early stages of the crop result in drying of germinating shoot tip followed by the entire clump. Severely attacked canes will be filled with mud as its contents are foraged by workers. Its attack will be known only when the plants express dried symptoms and once the symptoms are noticed, it is very difficult to save the plant. In termite prone areas the following measures, particularly sett treatment, will be useful.

1. Dipping setts for 2 min in solution of imidachloprid (Confidor) 17.8 SL at 4 ml or chlorpyriphos 20 EC at 50 ml per 10 lit of water prior to planting would protect the setts for up to 30 days from termite damage. In addition, drenching the setts with the above solutions may reinforce protection.

2. In grown up crops, drenching the affected and adjacent healthy clumps and rows around the collar region with chlopyriphos 20EC @ 50ml /10 liter water or confidor 17.8 SL @ 4ml /10 liter water as and when required will protect the crop from termite damage. Pesticides may be applied either a day after irrigating the field or the field may be irrigated after application of the insecticide for better effect.

White grub

White grubs are reportedly expanding their spatial range in the recent times and some of the sugarcane tracts appear to be endemic to the pest. The pest has an annual life cycle with the grubs being active in the soil during July-September causing complete devastation of the crops under conditions of extreme intensity. Extensive root feeding especially by grown-up grubs (third instar) results in yellowing of leaves and drying of clumps. Since the symptoms manifest only after serious damage is done to the crop, it is essential to monitor the presence of grubs early and plan emergency control measures.

1. Large scale mechanical collection of beetles at the time of their mass emergence immediately after first showers during May - June reduces beetle population progressively over a few years. The adult beetles congregate on host trees like neem the same night of emergence. Since the beetles are not attracted to light actively, the trees should be shaken vigorously to dislodge the beetles, which will then be attracted to light sources such as jeep or tractor head lights. The beetles thus collected can be immersed in 0.1% Nuvan and transferred to double layered synthetic cement or fertilizer bags till they are killed. The collection may be continued for a week.
2. Small neem trees may be sprayed with monocrotophos immediately after the first summer rain to kill the adult beetles which congregate on these trees for feeding. Alternatively, big branches of the neem trees sprayed with the insecticides may be planted in the fields to attract and kill the adult beetles. Sprayed trees should be labeled in local language cautioning not to use floral parts or leaves.

3. Repeated deep ploughing at the time of land preparation in February exposes quiescent adults for desiccation and vertebrate predation. This may be particularly useful in farms with neem trees nearby. Ploughing and flooding the field near neem trees will bring grubs to the surface which can be collected and destroyed.

4. Puddling and rotation with paddy eliminates grub population. Rotation with sunflower is also advisable to break the continuous availability of sugarcane.

5. *Beauveria brongniartii* formulated with carrier materials such as press mud, lignite or talc may be applied at $2.5 \times 10^{12}$ spores / ha in June – July coinciding with emergence and oviposition activity of beetles to target young stages of grub. The formulation may be mixed with suitable quantity of farm yard manure or well cured press mud and distributed in the furrows, followed by irrigation of the crop. Repeated application over a few years may be needed to build up the inoculum of the fungus in the soil to enable it to act as a self-perpetuating mortality factor. Pesticides commonly used in sugarcane adversely affect the fungi in culture media but they are less likely to be as toxic in the field. Asynchronous application may prevent such incompatibility problems.

6. It is important to monitor crop of all ages from June - July onwards for slight yellowing of lower leaves followed by the location of grubs near the root zone to decide about chemical application. Insecticide applications will be useful if applied early to target young grubs. Targeting third stage grubs decreases the success of chemical control and disturbs economics.

**Rodents**

Eighteen species of rodents (rats, squirrels) are pests in agriculture, horticulture, forestry, animal and human dwellings and rural and urban storage facilities in India. Of these, rats are common pests of sugarcane. The predominant rat species that inflict damage to sugarcane are *Bandicota bengalensis*, *Rattus mela*da, *Tatera indica* and *Mus musculus*. They begin to damage the canes around 90 days after planting and the damage increases with the age of the crop. Damage is mainly caused by gnawing through the rind of the lower internodes of canes and by damage to the roots during digging of burrows by rats, particularly the highly fossorial *B. bengalensis*. As a result of gnawing of roots and loosening of soil during burrowing, canes may lodge when irrigated or due to wind if not properly wrapped and propped. Lodged canes and ratoon crops are generally known to suffer greater damage. Rats have been reported to partially damage 8.6% - 12.1% canes with most of the damage restricted to lower internodes.

**Management**

The available management options can be grouped into two basic approaches: non-lethal or preventive and lethal or reductional. The non-lethal or preventive measures involve environmental, cultural and biological methods, which produce a more lasting effect.
However, the lethal approach, particularly the use of rodenticides and trapping, which provides an immediate solution to the problem, is often considered the most practical, economical and effective method of combating rats.

An integrated approach incorporating the following methods will ensure long-term prevention and management of both resident and immigrant populations of rats. It is imperative to adopt control measures involving all farmers, on a campaign basis over large areas, for successful rodent management in sugarcane and other crops.

- Removal of wild vegetation or weeds – clean fields
- Reduction in bund thickness and height
- Deep tillage and ploughing of vacant land around fields
- Rotation of paddy with crops like sunflower to reduce immigration to cane
- Wrapping and propping of the standing crop
- Trapping in fields using suitable devices
- Fumigation of burrows with aluminium phosphide tablets
- Use of baits (zinc phosphide/bromadiolone)

Selected references


Indian agriculture had been on traditional lines till the first waves of Green Revolution in the late 60s, which gave a sudden boost to the production and productivity of major crops. Quick dissemination of information from the Agricultural Research System to the farmers and reporting of farmer’s feedback to the research system is one of the critical inputs in transfer of agricultural technology. As a result of extensive research over the last several years, technologies are now available to boost sugarcane production in the country. However, the impact of such massive research efforts could not be fully reflected in terms of cane productivity. In most of the developing countries today, it is not the lack of technology that worries, but it is the rate of transfer of technology from the points of production (research system) to the points of utilization that matters.

Sugarcane scenario

Our country has come a long way in sugarcane cultivation from just 1.19 m. ha area under sugarcane in 1930-31 and a sugarcane production of 36.35 m. tons to 5.15 m. ha area with a record production of 375 m. tons sugarcane during 2013-14. Correspondingly, the productivity has also increased from 30.9 t/ha to 69.0 t/ha during 2013-14. However, there is a wide disparity in productivity between the different cane growing states of the country. This gap has to be bridged so as to maximize the unit productivity and minimize the cost of sugarcane cultivation.

The Indian sugar industry lacks the flexibility of the Brazilian sugar industry, where the processing of cane for sugar or alcohol depends on the prevailing market trends with respect to these commodities, which ensures sustained growth and profitability of the industry. Domestic sugar price of sugar in India is among the lowest in the world. The production cost of Indian sugar is estimated to be in the medium range - costlier than Australia and Brazil but lower than that of USA. In future, we may face stiff competition from African countries, whose production costs are lower than India.

Sugarcane growers in India seem to have their own valid reasons for non-adoption of sugarcane technologies, which could be ignored altogether in ‘top-down’ approaches. The list includes:

- Technology is too complex
- Not easily divisible into manageable parts
- Not compatible with farm and personal objectives
- Not flexible enough
- Not profitable
Too high capital outlay
Too much additional learning is required
Risk and uncertainty is too great
There is conflicting information
Lacking the physical infrastructure and
Lack of a social infrastructure

Technology transfer typically involves a ‘top down’ approach where scientists determine research priorities; generate innovations they believe are good for the farmers and provide results to extension agents. This is sometimes termed the linear adoption or diffusion model (Rogers, 1983). Extension efforts that take farmers into account need to be strengthened and this should form one of the primary tasks towards achieving the sugarcane targets for 2025 AD and beyond.

A systems perspective

The usefulness of a systems approach for understanding and analyzing agricultural technology generation and dissemination is widely acknowledged. Although they are sometimes criticized because they are so abstract, systems analyses offer holistic vantage points for understanding the factors that impede or enhance the two-way flow of technology and information between farmers and the public organizations that constitute the system.

Any agricultural knowledge system consists of four components set in a larger context (Fig. 1). The components are technology generation, technology transfer (knowledge and input transfer), technology utilization, and support system. The organizations that constitute the components, as well as others in the system environment influence each other in complex ways.

![Fig.1. Agricultural Knowledge System](image-url)
Emphasis on a systems perspective in agricultural research requires a complete reversal of the technology generation approach *viz.*, a farmer first or farmer participation approach where farmers are fully involved at all stages of technology development (Chambers, 1983, Van den Ban and Hawkins, 1998). Participatory research is a systematic process involving people in the analysis of their own situations. Farmer participatory research is a term increasingly used in agricultural research and development circles. In the context of shrinking resource base, agriculture in future can be sustained only by producing more food, fuelwood, fibre and other commodities from less land, less water and less energy per unit of output without the accompaniment of ecological harm. The stress on ‘farmer participation’ has arisen from a realization that earlier approaches to on-farm research recognized the importance of farmers, but was not able to effectively incorporate farmers’ skills and experimental practices into the research process.

The Strategic Extension Campaign (SEC) methodology developed by Food and Agriculture Organization also emphasizes the importance of people’s participation in strategic planning, systematic management and field implementation of agricultural extension training programmes.

### Challenges faced

**In sugarcane agriculture**

Sugarcane crop currently faces severe challenges on several fronts in our country. This includes:

- Increasing cane production to meet the ever increasing demand for sugar
- Diminishing interest in agriculture due to decreasing net return from the crops
- Diversion of labour from agriculture to other sectors. The fact here remains that adequate farm labour is unavailable and the available labour is unaffordable
- Sugarcane despite being the singular source for green power and ethanol is often accused as a water guzzler. With growing ecological concerns, cane crop can no longer remain oblivious of the need to conserve water.
- Monocropping and excessive usage of fertilizers and pesticides have horrendously harmed our soil productivity. We hence need to put in place appropriate alternative and ameliorative measures to restore soil productivity for sheer sustainability of cane cultivation.
- As the sugar industry moves from control to competitive era, conflicts of role must necessarily give way to convergence of interests. We need to build in synergies between diverse stakeholders so that we are ready to take on global competition.

**In sugarcane extension**

The dynamic situation in sugarcane farming poses several challenges to the extension system. Some of the challenges with which the extension system has to cope up include:

- How to reach individual farm families involved in the sugarcane cultivation and deal with the Complex, Diverse and Risk prone (CDR) environment?
How to improve the technology standards of the farmers through effective and optimal technology use, especially when the pressure on land is increasing and common property lands are slowly fading out.

How to face the emerging agricultural development situation as a sequel to the technological and development interventions?

How to take cognizance of the changes that are taking place in the society in terms of shift from farming to industry, rural to urban (migration), focus from social to economic issues.

**Way Forward**

Sugarcane agriculture is faced with several challenges, as also uncommon opportunities. Being a crop of a well-organized sector, namely the sugar factories, public private partnership as a governance strategy can very well be utilized to converge the efforts of varied organizations at the grass root level of a community. The sugar industry contributes substantially to the rural economy as the sugar mills are located in rural areas and provides large scale employment to rural population. A SWOT analysis of the extension approaches till late 1980s reveal a lacuna of trickle down approach rather than a democratic one. Change thus became inevitable in all developmental spheres of steering India into a developed country. In this era of globalization, mankind has become assertive and needs a rationalization of any developmental efforts being undertaken. This can include:

**Technology generation:** A critical technology is a technology aimed at solving of a current problem faced by users in their context, and a technology should be developed in terms of the capabilities, resources, opportunities, social and economic considerations that are both internal and external to the technology with emphasis on positive and negative consequences for the users (Gupta, 2009). Involvement of farmers in the planning, operating, monitoring, evaluation and follow-up actions in technology generation and dissemination is of tremendous importance. Nevertheless, the attributes of technology viz., relative advantage, compatibility, complexity, trialability and observability have to be kept in mind when making specific recommendations.

**Public Private Partnership (PPP):** PPP through participatory mode has been recognized as one of the most effective mechanisms to upgrade the country’s infrastructure services. There is a scope to leverage PPPs as a relevant means in the agriculture sector as well. Enhanced yield and productivity is a crucial need, with India still battling food insecurity and poverty. Participatory approaches in agriculture are generally found at the community level where the strengths of the public and private sectors supplement each other in providing information and advisory services that address the needs of farmers and rural communities. The public sector’s obligation for provision of information and services can be best achieved through harnessing the potential of the private sector to add local context in a commercial environment.

**Convergence of Extension Services:** There are many extension service providers in the field, providing different kinds of useful services like information and service support to farmers. They are state, central government agencies, agribusiness companies, agri-preneurs, input dealers, manufacturing firms, NGOs, farmers’ organizations and progressive farmers. There
is duplication of efforts with multiplicity of agents attending extension work without convergence. There should be a coordinated attempt to synergize and converge these efforts at the district level through ATMA and below to improve the performance of various stakeholders.

**Increased role of Extension agents:** In addition to the government efforts in stepping up the allocations for sugarcane development programs, the sugar factories / department of agriculture through their extension agents are expected to play an increasing role in improving the productivity levels in their respective zones. Such programs would enable the farmers in each zone to improve their sugarcane yields simultaneously enabling the sugar factories to get larger quantities of better quality cane at appropriate time, thus ensuring higher sugar recovery levels with a longer crushing duration. The extension agents can use the following ways to help the cane growers to reach their goals:

+ Giving timely advice to make them aware of a problem
+ Increasing the range of alternatives from which they can make a choice
+ Informing them about the expected consequences of each alternative
+ Helping them to decide which goal is most important
+ Helping them to make decisions in a systematic way, either as individuals or as a group
+ Helping them to learn from experience and from experiments and
+ Stimulating them to exchange information with colleagues

**Frontline demonstrations:** The adage ‘Seeing is believing’ holds good even today. Realizing this, the Indian Council of Agricultural Research introduced the concept of ‘Frontline demonstrations’. These are first line demonstrations conducted by the research scientists to demonstrate promising technologies in the farmers’ fields under different agro-climatic regions and farming situations. The purpose is to convince extension functionaries and farmers together about the potentialities of technologies for further wide scale diffusion. These demonstrations are conducted in a block of at least one hectare land in order to have better impact of the demonstrated technologies. The special features of frontline demonstrations are:

+ These are conducted under the close supervision of the scientists.
+ Only newly released technologies or those likely to be released in near future are selected.
+ Only critical inputs and training are provided from the scheme budget, remaining inputs are borne by the farmers themselves.
+ Training of the farmers associated with the frontline demonstration is a pre-requisite for conducting such demonstrations.

Frontline demonstrations are being conducted since 2001-02 in Coimbatore and Tirupur districts in Tamil Nadu state. There was considerable improvement in yield in all the demonstration plots over the farmers’ practice. Since the demonstrations are conducted in farmers’ fields they serve as a motivation for the farmers in the neighbourhood as well.
demonstrating the technologies in the farmers’ fields, the factors contributing to higher crop production and field constraints of production were also studied to get feedback information and discussed in scientific meetings (RajulaShanthy, 2011).

*Pluralistic extension:* Of late, development practitioners have termed an “Integrated, Multi-Disciplinary and Holistic approach to Rural Development (IMDH-RD)”, stressing the need to address both agricultural and rural problems to create effective and environmentally sustainable development (Davidson, 2006). To effectively cope with the challenges posed by a multi-sectoral approach, a pluralistic agricultural extension mechanism is required to coordinate the various stakeholders. Pluralism recognizes both the heterogeneity of the farming community and thus the need for diversity in extension service delivery systems. This approach requires farmers and other rural inhabitants, extension agents, input supply dealers, researchers, policy makers, and so on to focus their efforts, activities, and programs on encouraging a sustainable agriculture that is inclusive rather than exclusive.

*Cooperative Approach:* In states like Uttar Pradesh, and to a limited extent in Andhra Pradesh, Bihar, Haryana, Madhya Pradesh and Punjab sugarcane is purchased by the factory through cooperative societies, whereas, the factories deal directly with the sugarcane growers in all the other major sugarcane producing States including Maharashtra, Gujarat, Tamil Nadu and Karnataka. It is recommended to have a direct link between the factories and the farmers in terms of computerized operations for preparation of cane supply calendars, issuance of supply orders to the farmers, making cane price payment through the banks and maintenance of grower-wise records etc. This in turn creates an opportunity for the farmer to interact with the cane development personnel on scientific crop management. Tri-partite agreement of sugar mills with banks and farmers can be encouraged for procurement of sugarcane to facilitate use of Kisan Credit Cards, availability of loans to farmers and custom hiring of machineries.

*Yield gap analysis:* The untapped reservoir of yield as exhibited by the difference in productivity among research institutions, demonstration plots, crop yield competition plots and the sugarcane growers fields in general form the future source of output growth. To

<table>
<thead>
<tr>
<th>States</th>
<th>Potential yield* (t/ha)</th>
<th>Existing yield*2013-14 (t/ha)</th>
<th>Yield gap (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Andhra Pradesh</td>
<td>169.01</td>
<td>78.0</td>
<td>53.8</td>
</tr>
<tr>
<td>Bihar</td>
<td>127.16</td>
<td>56.8</td>
<td>53.3</td>
</tr>
<tr>
<td>Gujarat</td>
<td>188.37</td>
<td>65.0</td>
<td>65.5</td>
</tr>
<tr>
<td>Haryana</td>
<td>181.27</td>
<td>73.0</td>
<td>60.0</td>
</tr>
<tr>
<td>Karnataka</td>
<td>183.00</td>
<td>84.6</td>
<td>54.0</td>
</tr>
<tr>
<td>Madhya Pradesh</td>
<td>167.25</td>
<td>42.2</td>
<td>74.8</td>
</tr>
<tr>
<td>Maharashtra</td>
<td>192.33</td>
<td>77.4</td>
<td>60.0</td>
</tr>
<tr>
<td>Orissa</td>
<td>158.70</td>
<td>66.3</td>
<td>58.2</td>
</tr>
<tr>
<td>Punjab</td>
<td>182.60</td>
<td>70.0</td>
<td>61.7</td>
</tr>
<tr>
<td>Tamil Nadu</td>
<td>203.70</td>
<td>107.0</td>
<td>47.5</td>
</tr>
<tr>
<td>Utter Pradesh</td>
<td>162.72</td>
<td>62.4</td>
<td>61.7</td>
</tr>
<tr>
<td>West Bengal</td>
<td>165.07</td>
<td>105.0</td>
<td>36.40</td>
</tr>
<tr>
<td>Average</td>
<td>173.43</td>
<td>105.0</td>
<td>57.24</td>
</tr>
</tbody>
</table>
obtain maximum sugarcane production and meet the growing needs, the gap between the potential and actual farm yields should be bridged.

**Extension strategies to bridge the yield gap in sugarcane cultivation include:**

- Need based technological interventions to be introduced in the field level to increase the adoption rate
- Whole farm development and farming system research are ideal extension approaches to bridge the yield gap
- Before initiating the measures to bridge the yield gap one should study the ‘technological gap’ prevailing in the area.
- Participatory technology development programme for inclusive development of sugarcane production system

**Constraint analysis:** Constraints are highly location specific and hence there is a need to identify the farm level constraints that come in the way of realizing the untapped yield reservoir. Constraints may be knowledge and information based, technology related, socio-economic in nature, infrastructure oriented and from a managerial perspective. The effect of the various field level constraints is visualized in the level of adoption. As cane growers are part of sugarcane development, area specific approach should be taken to improve the socio-economic conditions, strengthen infrastructural facilities and credit facilities, and involve the multiple development agencies located in the area.

Thorough analysis of yield gap along with filed level constraint analysis must be done to have a direct bearing on adoption or rejection of recommended technologies and assessment of the impact of related cane development programmes. Participating farmers are to be objectively and effectively involved in such studies. Only by this way, effective strategy formulation and its subsequent operation can be ensured.

**ICT based transfer of technology:** Information technology is unfolding and has very high visibility in this era of communication explosion. ICT based transfer of technology is a tool for communicators of all trades and an effective catalyst for change. The biggest advantage of information technology is that it is far more interactive and personalized that can render services particularly the information as per the needs and requirements of the end users (such a facility makes a favourable impact on adoption and utilization of the improved and innovative techniques in hi-technology farming). The information technology has a convergence of three strands of technologies viz., computers, microelectronics and communication. It encompasses different things as books, print, reprography, telephone network, broadcasting and computers. Information technologies that can be profitably used in transfer of new farm technology are Satellite communication, Geographic Information System, Computer network, Video, Mobile, Internet, Radio and Reprography. The key to future expansion in use of computer based transfer of technology in agriculture lies not with the technology itself, but rather with the way the messages are treated to reach the intended clients. Historians, however testify that technology does not change the world, but the people who adopt and use technology make the changes. In this context its highly essential that the
extension functionaries realize the brain waves of the users, develop suitable communication systems and sensitize the clients towards betterment.

The ICT initiatives at Sugarcane Breeding Institute include

- Databases on sugarcane varieties
- Multimedia module on sugarcane production
- Expert system on sugarcane pests
- User centred website on sugarcane and
- Video films on specific topics

Multimedia

What is multimedia?

The term multimedia describes a woven combination of text, graphic art, sound, animation, and video elements. When you allow an end user - the viewer of a multimedia project - to control what elements are delivered and when, it is interactive multimedia. When you provide a structure of linked elements through which the user can navigate, interactive multimedia becomes hypermedia. The people who weave multimedia are known as multimedia developers.

The integration of multimedia technology into the communication environment has the potential to transform an audience from passive recipients of information to active participants in a media rich learning process.

Where to use multimedia?

Multimedia is appropriate whenever a human interface connects a person to electronic information of any kind. Multimedia enhances traditional text-only, computer interfaces and yields measurable benefit by gaining and holding attention and interest; multimedia improves information retention. When properly woven, multimedia can also be profoundly entertaining.

Studies indicate that if you are stimulated with audio, you will have about 20 per cent retention rate, that of audio visual is up to 30 per cent, and in an interactive multimedia presentations where you are really involved, the retention rate is as high as 60 per cent.

Prerequisites for a multimedia module

Multimedia is often a team effort; artwork is performed by graphic artists, video shoots by video producers, sound editing by audio producers, and programming by programmers. To create multimedia you need to have a real yearning to communicate, because multimedia is creating, essentially, an entirely new syntax for communications. One must have an interest in human psychology because you need to anticipate the brain waves of users. One should adopt a strategy that allows one to prototype and test the interactive design assumptions. The three basic items for preparing a multimedia module are hardware, software and creativity (good ideas to make multimedia).
The Multimedia Production Team

High quality interactive multimedia applications are the product of the efforts of a production team. Several software applications are available that enable the average computer user to develop simple and effective presentations. But the production of fine quality high end multimedia applications is usually the work of a team of specialists. Typically this team consists of The Production Manager, Content specialist(s), Instructional Designer, Script writer, Text Editor, Multimedia Architect or (Program Authoring Specialists), Computer Graphic Artist, Audio and Video specialists and Computer Programmer.

Quality Multimedia production is a result of effective and synergistic teamwork.

Multimedia authoring

Multimedia authoring consists of bringing together different elements of multimedia or the building blocks of multimedia such as text, graphics, sound, animation, video etc. into a comprehensive presentation, and if and when needed, incorporation of interactive elements, such as navigation tools. The application software used for such integration of the elements into a presentation and incorporation of interactivity through navigational controls is called multimedia authoring software or simply authoring tool.

Selection of multimedia authoring tool

Varied multimedia authoring tools are available in the market. The basic considerations are purpose of application, level of expertise available/amenable, time frame for the production, budget and level of cosmetics to be applied. The authoring tools generally used for education purpose includes Macromedia Director, Flash, Authorware, Asymetrix ToolBook, HyperCard, HyperStudio and SuperCard.

Multimedia on sugarcane production

Sugarcane Breeding Institute has pioneered in developing a multimedia module on sugarcane production. It describes and illustrates the several steps involved in the scientific sugarcane procedure and is in the information kiosk format targeted for sugarcane growers, extension personnel and researchers interested in the practicalities of sugarcane production technology. The module envisages the use of different multimedia building blocks such as text, audio, video, graphics and animation. The module contains detailed information from sett planting to harvest with suitable visual clippings allowing the learner to learn at his own pace of learning (Rajula Shanthy and Thiagarajan, 2011).

The various steps in the development of the module is detailed below:

i. Initially the storyboard for the module was finalized and detailed literature on sugarcane cultivation was collected.

ii. The available text matter was organized and generated as text files.

iii. Graphic elements on sugarcane production were collected and the same were scanned and generated as graphic files.
iv. Digital stills relevant to the text matter were generated and stored as graphic files.

v. Relevant video files were created using the available CDs on sugarcane production technologies and suitable video clippings were also generated for the purpose.

vi. The module was integrated using Macromedia Flash as the authorware

The module has three parts viz., sugarcane varieties, crop production (both for plant and ratoon crop) and crop protection technologies (pest, disease and nematodes). The module comes in the form of CD for nearly one-hour duration.

**Expert systems**

Expert Systems, a recent advance in the use of computers is one of the important application oriented branches of Artificial Intelligence. In the past decade, a great deal of expert systems had been developed and applied to many fields such as office automation, science, and medicine including agriculture. Development of expert systems in agriculture has been paid much attention due to the complexity of problems confronting farmers like yield losses, soil erosion, diminishing market prices from international competition, increasing chemical pesticides costs and pest resistance and economic barriers hindering adoption of farming strategies.

The application of expert system technology to agriculture seems natural, considering the widespread use of extension agents in the field. Extension agents may not always be available for consultation or may not be able to optimize economic decisions. Expertise gained in the developed countries could also be distributed to developing countries, although resistance to new technology would have to be overcome.

**Expert System – defined** : An “Expert System” is an intelligent computer program that uses knowledge and inference procedures to solve problems that are difficult enough to require significant human expertise for their solution.

**Components of Expert System**

Although there is no general standard for expert systems, most include:

- a knowledge base of domain facts and associated heuristics
- an inference procedure or control structure for utilizing the knowledge base
- a natural language user interface

**Expert Systems in agriculture**

Computer assisted agriculture through distributed knowledge based expert system is a frontier area in transfer of technology. Generally the expert system is designed to answer questions typed at a keyboard attached to a computer on such diversified topics, for example, in pest control, the need to spray, selection of a chemical to spray, mixing and application, optimal machinery management practices, weather damage recovery such as freeze, frost or drought, etc. Some of the expert systems that have been developed for use in agriculture are Rice-Crop Doctor, AGREX, Farm Advisory System, Sericulture, Grain Marketing Advisor, COMAX, Gossym, Pomme, PLANT d/s
Work done at Sugarcane Breeding Institute

SUGAR-EX

Sugarcane Breeding Institute has developed an expert system to diagnose pests for sugarcane crop, provide details of the identified pest and suggest preventive/curative measures (Rajula Shanthy and Mukunthan, 2009). The SUGAR-EX illustrates the use of expert systems broadly in the area of agriculture and more specifically in the area of sugarcane production through development of a prototype, taking into consideration the major pests limiting sugarcane yield.

This prototype is a result of joint effort by the Scientists of Extension and Entomology Sections of the Institute. The subject matter expert knowledge on sugarcane entomology was obtained from the previous publications of the Institute, reference books and personal experience.

The following pests have been included in the system for identification and suggesting preventive and curative measures - early shoot borer, internode borer, top borer, stalk borer, plassey borer, gurdaspur borer, root borer, white grub, scale insect, mealy bug, white fly, pyrilla, wooly aphid, blister mite, red mite and white mite.

The Logic Flow

The brief logic flow of the expert system is as follows:

i. Basic input: The basic input can be given as
   a. part of the plant where damage symptoms are seen - stem/cane, leaf, root
   b. description of the damage symptom
   c. life stages of the pest - egg, larva, nymph, pupa, adult
   d. description of the life stage

ii. Considering these symptoms/ description of the life stages, the pest is identified

iii. The user then has the option to either exit the window or further reset and proceed with diagnosis for other pests

iv. After diagnosis, the user can directly get hyperlinked to know more about the pest, get management measures as well as get a graphic view of the damage symptom/ life stages of the pest.

All these operations are done using a “mouse”, which helps a new user to get acquainted with the system faster and operate it easily. In this system, computer, graphics, digitized pictures and text are being used following a “Decision Tree”, logic.

Website for cane development personnel

Sugarcane Breeding Institute has developed an interactive and user-centered website that provides a platform for sugarcane growers, cane development personnel, scientists and students to share information and knowledge on sugarcane. It is available at http://caneinfo.nic.in.
**Is there a single extension strategy?**

There is no single extension “magic bullet” that will support demand-driven and/or decentralized extension that also provides better ways to address these changes and challenges. Instead, they are yielding another patchwork of responses that include: Client-focused extension, Privatization of extension, Broadening the role of extension to include other related sectors, Participatory extension, Farmer-to-Farmer extension, Unified delivery of rural and agricultural development services and Demand driven extension.

As the working environment in Extension system is getting increasingly complex, there is a need for the professionals to:

- Work under complex and fluid circumstances with little supervision
- Diagnose farmers’ problems effectively
- Listen to and learn from farmers
- Communicate effectively and work with farmers and farmer groups
- Present options, based on principles of science and sound agricultural practices

Despite criticisms of linear technology transfer (top-down) theories, there is still a need for access to reliable scientific information from the sugarcane research institutes, just as there is a need to provide for active participation by farmers in research and development processes. Face to face contact, one-to-one exchange of information and advice, whether from farmer to farmer or from a change agent to the cane grower (and vice versa), will continue to be important. New information and communication technologies will facilitate training and information exchange. Public extension’s future (such as the state departments of agriculture) depends on our ability to interpret trends and use information technology to deliver programs and teach problem solving for the farmers. But such strategy will need to be supplemented by other extension strategies so as to enhance sugarcane productivity and ensure increased profits for the cane growers.

**Conclusion**

The conclusion is that no single theory, model or strategy is likely to be sufficient by itself. If the possibility of adoption is to be maximized, communication channels must be utilized in an ideal sequence, progressing from mass media to interpersonal channels (Sill, 1958). The production of sugarcane has an impact in rural areas and has served as an effective instrument for carrying progressive trends in the countryside. The development of sugarcane on a holistic sense in the years to come requires mix up of innovative extension approach with technological interventions appropriate for a given situation. It is just the fitness of such blending that demands to formulate and implement a strategic plan for total sugarcane development.

**References**


Scientific Sugarcane Cultivation


10. FARM IMPLEMENTS AND MACHINERY IN SUGARCANE CULTIVATION

T. Arumuganathan, Ravindra Naik, SJK Annamalai and T. Rajula Shanthy

Introduction

Sugarcane is one of the most important agro-industrial crops, which is being cultivated in around 4.50 million hectares area in India. The country has produced more than 355 million tonnes of cane at a national average of 70-80 tonnes per hectare. Sugarcane crop remains in the field for almost a year and right from land preparation to harvesting of the crop and its timely supply to the mill. There is a heavy demand of labour and machinery throughout its crop cycle. Sugarcane accounts for 60–70% of the cost of sugar production and thus has a vital role to make sugar industry a commercially viable venture. The existing level of mechanization is confined to tractorisation only in general and use of land preparation equipments mainly cultivator and harrow in particular (Sharma et al., 2007). The farm mechanization in the context of sugarcane cultivation aims at introducing timeliness of operation, reducing human drudgery and improving overall production efficiency. As regards mechanization in sugarcane, number of useful equipments have been developed by many research institutions and state agricultural universities and the adoption level has not been encouraging. The mechanization of cane planting has been, till recently, confined to the use of tractor drawn ridgers for opening the furrows and the rest of the operations involved in cane planting were done manually. Land preparation is done as in the case of other crops by commonly used tillage implements. Planting, interculture, earthing up and transportation are in semi mechanized stage. Use of improved equipments in accomplishing other cultural operations required in cane cultivation, is almost nonexistent. The major advantages of mechanization are timely completion of operations, labour savings, economical, highly efficient, uniformity and quality of the work. The limitations in mechanization are requirement of larger fields, high initial investment cost of implements and leaving vacant space around the field for the mobility of the machineries like tractor and sugarcane harvester.

A brief description of some of the equipments for sugarcane cultivation has been given and ways and means have been suggested so as to take these useful labour and cost efficient devices to the farmers with a view to sustain sugarcane productivity.

Sugarcane Planting

Sugarcane is planted in the form of cut setts of 2-3 buds. Thus cutting of setts is an important operation prior to planting. Different methods of sugarcane planting are followed in different areas of the country. Some of the methods are flat planting, trench planting, pit planting, staggered row planting and space transplanting. In areas were sugarcane lodging takes place, trench planting is followed. Different row spacings ranging from 90 cm to 150 cm are adapted.

The different operations carried out during sugarcane planting are (i) Making of furrow or trench (ii) Sett cutting (iii) Placement of setts in furrows (iv) Fertilizer application in bands
on either sides of setts (v) Application of fungicidal, anti termites and anti insecticide solution (vi) Covering and pressing of setts. The various machineries and planters involved in sugarcane planting are discussed here.

**Power operated sugarcane sett cutting machine**

Indian Institute of Spices Research (IISR), Lucknow has developed power operated machine to cut sugarcane setts for planting (Singh and Singh, 2006). Fungicidal treatment of setts is also done simultaneously. Electric motor, diesel engine or tractor is used as a prime mover to operate this machine. In this machine, circular saw blades with sharp and finer teeth are used to cut setts.

**TNAU sugarcane sett cutting machine**

An electric motor operated sett cutting machine was developed at TNAU, Coimbatore. It consists of a circular saw directly coupled to a 0.5 hp electric motor. By using this cutter, 3600 setts can be prepared by employing 3 persons within an hour. The cost of the unit is Rs. 3500/-.

**Leveling of land by laser guided leveler**

Traditional methods of land leveling are cumbersome, time consuming as well as expensive. Laser leveling is a user guided precision leveling technique used for achieving very fine leveling with desired grade on the agricultural field using a guided laser beam throughout the field. It maintains the grade by automatically performing the cutting and leveling operations. Both level grade and slope grade (one way or two way) can be achieved with the help of this precision equipment.

**Pit making machine (single row)**

Sugarcane productivity can be increased by adopting pit planting method. For pit planting approximately 10,000 pits have to be made per ha. This is a labour intensive job. A tractor operated pit making machine for this purpose was developed at IISR, Lucknow,
which consists of a rotating auger blade powered by tractor PTO (Sharma and Singh, 2007). Sugarcane setts are then planted manually in these pits. The field capacity of the unit is 50-60 pits per hour.

**Tractor operated pit digger for sugarcane planting (two row)**

A tractor operated two row pit digger was developed at TNAU for digging holes of 90 cm dia at 150 cm row spacing to a depth of 30 cm. The unit consists of two helical blade augers of 90 cm dia fitted to a rectangular frame work. The auger rotates in opposite direction to each other. About 250 to 300 pits can be dug in one hour. The cost of the unit is about Rs. 60,000/-

**Tractor drawn semi-automatic sugarcane planter**

This machine was developed at IISR, Lucknow. It consists of two ridger bodies for making ridges and furrows, mounted on the main frame. A metering funnel is attached in which the operator drops the sugarcane setts. A separate box with metering device meters fertilizer automatically (Singh and Sharma, 2010).

One tank is also attached for application of insecticides/fungicides through nozzles. A covering device is available for covering the furrows. The planter is a two-row unit and it is operated by 35 hp tractor. The field capacity of the unit is 1 ha/day. The cost of the unit is about Rs. 55,000/-

**Tractor operated semi automatic roto drum sugarcane planter**

This planter was developed at PAU, Ludhiania. This is similar to the IISR model. However, the additional feature was placement of setts end to end. For this purpose, in addition to drop attachment, a rotating drum was provided to carry setts along the rotating drum till it was lying in stationery bottom plate underneath the drum. Cut setts were placed in the rotary magazine manually. The field capacity of the unit is 1 ha/day. The cost of the unit is about Rs. 65,000/-
Tractor drawn automatic sugarcane planter

This implement was developed at IISR, Lucknow. In this implement, in addition to other operations, the feeding of setts is carried out mechanically by means of a conveyor chain, which carries the setts from the tray to the funnel (Singh and Sharma, 2008). Other operations such as fertilizer application and spraying of chemicals can also be carried out. The field capacity of the unit is 1 to 1.5 ha/day. The cost of the unit is about Rs. 70,000/-.

Tractor drawn ridger type sugarcane cutter planter

This implement was developed at IISR, Lucknow. This is a semi automatic planter designed for operating with whole cane. In place of sugarcane setts, whole cane is fed. A horizontal blade cuts the sugarcane into setts having 2-3 buds and conveys the setts through a chute behind the two ridger bodies (Srivastava, 2010).

In addition, fertilizer is metered from fertilizer box through fluted roller mechanism. This implement is suitable for ridge and furrow system of planting. Power for set cutting is obtained from tractor PTO. It saves 80% labour cost and 60% cost of operation compared to conventional method. The field capacity of the unit is 1 ha/day. The cost of the unit is about Rs. 65,000/-.

Tractor drawn disc type cutter planter

This implement was also developed at IISR, Lucknow and is similar to tyne type cutter planter except for the fact that disc type furrow opener is used in place of tyne type furrow opener. Like the tyne type cutter planter, this planter also derives power for sett cutting from ground wheel. This implement is suitable for flat planting. In addition to sett cutting, fertilizer and insecticide application are carried out mechanically. Disc type ridger/furrows are suitable for stony, hard soil. The field capacity of the unit is 1 ha/day. The cost of the unit is about Rs. 55,000/-.
## Technical details of sugarcane planters

<table>
<thead>
<tr>
<th>Particular</th>
<th>Ridger type</th>
<th>Disc type with ground wheels</th>
<th>Slit type with ground wheel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tractor power requirement</td>
<td>35 hp</td>
<td>25/35 hp</td>
<td>25/35 hp</td>
</tr>
<tr>
<td>Labour</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Type of furrow opener</td>
<td>Ridger</td>
<td>Disc with furrow guider</td>
<td>Tines with furrow guider</td>
</tr>
<tr>
<td>No. of furrow openers</td>
<td>2&lt;</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Width of the furrow, cm</td>
<td>40-45</td>
<td>40-45</td>
<td>7-10</td>
</tr>
<tr>
<td>Row to row distance, cm</td>
<td>75 or 90</td>
<td>75 or 90</td>
<td>60-90</td>
</tr>
<tr>
<td>Source of power to drive sub units</td>
<td>Tractor pto</td>
<td>Ground wheel</td>
<td>Ground wheel</td>
</tr>
<tr>
<td>Field capacity, ha/h</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td>Field efficiency, %</td>
<td>65</td>
<td>65</td>
<td>65</td>
</tr>
<tr>
<td>Saving over conventional planting, %</td>
<td>40</td>
<td>40</td>
<td>40</td>
</tr>
</tbody>
</table>

### Khalsa PE-430 sugarcane cutter planter

This is a commercial model developed by M/s. Punjab Engineers, Meerut. This model has been sold to many sugarcane farmers in North India. Although initial designs were taken from IISR, Lucknow and the firm has made improvement on the same. The sett cutting design has been changed and cutting knives are mounted on counter rotating rollers. The field capacity of the unit is 1 ha/day. The cost of the unit is about Rs. 55,000/-.

### Khalsa PE-630 whole stalk sugarcane cutter planter

This is an improved version from PE – 430 model. In this model, one tank is fitted near tractor seat and other tank in front side of tractor. This has been done to reduce the problem of front wheel lifting due to weight of machine. In this model, since tank is placed in the front side, some weight is transferred to tractor front wheel. Also two pneumatic wheels are provided so that entire weight is not taken by tractor hydraulic. The field capacity of the unit is 1 ha/day. The cost of the unit is about Rs. 60,000/-.

### VSI – NATP two row sugarcane cutter planter (PTO driven)

This design has force- feeding followed by rotary sett cutting. With the help of these mechanisms, the working system of the machine has become more effective and simple. The field capacity of the unit is 1 ha/day. The cost of the unit is about Rs. 85,000/-.
VSI – NATP two row sugarcane cutter planter (ground wheel driven)

This has force - feeding mechanism followed by cylindrical cutting mechanism for sett. This unit is driven by ground wheel which is more effective and simple. The field capacity of the unit is 1 ha/day. The cost of the unit is about Rs. 85,000/-. 

IISR tractor operated multipurpose equipment (three rows) for sugarcane culture

This implement was recently developed by IISR, Lucknow for performing various operations of sugarcane cultivation. This is a tractor mounted equipment with three point linkage system. This can be lifted or powered by the hydraulic system of the tractor. This equipment can perform the following operations, required for the sugarcane cultivation

i. Land preparation: The equipment can be used as tractor operated nine tine cultivator.

ii. Cane Planting: The equipment can be used as a three row whole cane cutter planter. It does the operations of opening of furrows, cutting cane setts and placing of setts in furrows, placement of fertilizer and chemicals, covering of the setts with soil and providing light compaction.

iii. Interculture: The equipment can be used for interculture operation. Three row spaces are inter cultivated in single pass.

iv. Earthing up: Earthing up operation in three row of cane can be performed by this equipment.

The field capacity of the unit is 2 ha/day. The cost of the unit is about Rs. 75,000/- with all the attachments.

IISR Tractor operated multipurpose equipment (two row) for sugarcane

The planter can be operated by any tractor of 25hp or above. It is a mounted type. It can plant sugarcane in two rows simultaneously. The field capacity of the unit is 1 ha/day. The cost of the unit is about Rs. 60,000/- with all the attachments.

CIAE-SBI planter for seedlings raised from sugarcane bud-chips

A mechanical planter was developed jointly by Central Institute of Agricultural Engineering and Sugarcane Breeding Institute for planting sugarcane seedlings raised from bud-chips in portrays or polybags. The functional components of the equipment viz., metering
mechanism, operator’s seat, furrow openers, soil opener and soil closure are mounted on the main frame which is mounted on standard three-point hitch of a tractor. The bud chip seedlings are dropped by two operators through the indexing tray rotated by metering mechanism. A shoe type furrow opener opens up the soil in which the soil bearing seedlings are dropped. The furrow closure which follows the soil opener closes the soil thereby giving stability to the seedlings. The furrow openers at both sides open up furrows for irrigation. The machine is capable of planting in 1.2 ha in a day.

**Sugarcane bud chipping machine**

Pedal operated model is ideal for scooping bud-chips from sugarcane for settling nursery and it consists of outer frame, bud chipper to chip the buds, cane holder to hold the cane, pedal for operating the bud chipper, collecting basket to collect the chipped buds. A sitting stool is provided so that, if required the operator can sit and operate the bud chipping machine. Capacity of the equipment is 550-600 buds/hour. Saving in labour and cost is found to be 78-80 and 85-88% respectively. Pneumatic model is used for scooping bud-chips from sugarcane for settling nursery. The pneumatically operated sugarcane bud chipping machine consists of outer frame, bud chipper to chip the buds and an air compressor with a pneumatic cylinder. The pressure required to chip the buds varies from 0.60 to 0.70 MPa. Capacity ranges from 900-1000 buds/hour. Saving in labour and cost is found to be 67-68% and 60-62% respectively (Naik et al., 2013).

**Pro-tray filling cum sugarcane bud-chip placing equipment**

Part filling of pro-tray with the nursery soil media for sugarcane bud-chip by the first soil filling unit. Placing of the sugarcane bud-chip in portray is done through the seeding unit by the vibrating mechanism. Checking the proper placement of sugarcane bud-chip in por-trays and rectifying the same (to be carried out
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manually) final filling of the portray with the nursery soil media for sugarcane by second soil filling unit. Provision for the water sprinkling mechanism for the portray filled with sugarcane bud chip and soil media.

**Sugarcane bud-chip settling planter**

The equipment consists of a main-frame, attached to standard three-point hitch of a 35-hp tractor. The metering mechanism, operator’s seat, furrow openers, soil opener and soil closure are mounted on the main frame with necessary supports. The bud chip seedlings from the nursery can be dropped by two operators through the indexing tray rotated by metering mechanism. The field capacity of the machine is about 0.15 ha/hour (Naik et al., 2013). The cost of two row tractor operated sugarcane bud chip seedling planter is Rs. 30,000. The savings in cost was 46.50 %. The breakeven point for the equipment was 41.30 hectare/annum and the payback period was 2.12 years.

**Moist hot air seed cane treatment unit**

The moist hot air seed cane treatment unit is ideal for controlling seed piece transmissible diseases like grassy shoot, ratoon shunting and primary infection of red rot of sugarcane, which otherwise pass from one generation to another. It also helps controlling the insect, pests like scale, mealy bugs etc. Seed cane is treated above 95% humidity at 54±0.5º C for a total duration of 4 hours including initial period of heating. The unit consists of (a) thermally insulated chamber, (b) cylindrical drum with wire mesh tray 8-10 numbers, 1 kW finned air electric heater, (c) 60 cm sweep blower fan steam generating, and (d) instruments for precise control of temperature and humidity. Sugarcane is loaded in the trays, which are kept inside the drum. Doors are closed for a set duration of time. Steam is generated outside the rear panel and is injected inside the chamber. It gradually gets mixed with hot air. Most hot air circulates inside the drum to treat seed cane. Various models have been developed by Indian Institute of sugarcane research, Lucknow and Sugarcane Breeding Institute, Coimbatore.

**Technical details**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Power Requirement</strong></td>
<td>15 kW with 440 volts</td>
</tr>
<tr>
<td><strong>No. of persons required</strong></td>
<td>3</td>
</tr>
<tr>
<td><strong>Treatment temperature</strong></td>
<td>54ºC, 95-98% RH</td>
</tr>
<tr>
<td><strong>Germination % of treated cane</strong></td>
<td>At par with normal untreated cane</td>
</tr>
<tr>
<td><strong>Output</strong></td>
<td>600 kg cane per treatment</td>
</tr>
</tbody>
</table>
Weeding and Interculture

Animal drawn sugarcane earthing up hoe

It is suitable for loosening the soil between the rows and moving it towards the standing plant for earthing up. It can be operated when the row spacing is maintained between 900 to 1200 mm. It consists of three iron bars for loosening of soil and scraper with adjustable wings for earthing up. It saves 78% cost of operation. It is suitable for earthing up operation of sugarcane crop having row spacing of 900 to 1200 mm. Field capacity of the machine is 0.14 ha/h and speed of operation is 2.0 km/h. Weight of unit is 45 kg.

IISR bullock operated weeder mulcher

It consists of a rotating reel on which four blades are attached. It is operated by a pair of bullock. It cuts a 3 cm layer of soil along with weeds and leaves it in layer above soil. Some times if weeds are entangled between the blades, the rotating blades can be lifted with the help of a lever.

Bullock drawn three-tyne cultivator with sweep shovel

This implement was developed at IISR, Lucknow. This implement, after some modifications has also been commercialized. It is used for interculture operations. Three row bullock drawn cultivators are commercially being manufactured in different names in almost all the cities of the country and also by local artisans (Singh et al., 2007).

Serrated blade hoe

This implement was developed by PDKV, Akola. It is an animal drawn equipment consisting of serrated heat treated mild steel blade with V shaped teeth. It is used for weeding, hoeing, and mulching.

Animal drawn sugarcane earthing hoe

It is an animal drawn implement suitable for earthing up operation of sugarcane crop having row spacing of 900 to 1200 mm. It consists of three bars for loosening the soil and scraper with adjustable wings for earthing. This implement was developed at MPKV.

Engine operated interculture equipment

This implement is a single row unit used for weeding and interculture operations in sugarcane crop. The power source is 3.5 hp diesel engine and this operates up to 5-8 cm depth. This implement was developed at IISR, Lucknow (Singh, 2010).
**Rotary power weeder**

This machine was developed at TNAU, Coimbatore under AICRP on Farm Implements and Machinery. The equipment consists of 8.3 hp light weight diesel engine mounted on a frame. Engine power is transmitted to the gear box and then to the ground wheels.

There is provision to adjust wheel settings according to row to row spacing of the crop. Two clutches are provided, one to engage or disengage ground wheel and other for engaging or disengaging power to rotary weeder. Rotary weeder has 3 rows of discs mounted with 6 nos of curved blades fitted in opposite directions alternatively in each disc. These rotating blades enable cutting of the weeds, which is chopped up into the soil. Width of coverage is 350 mm and depth can be adjusted. Rotary weeder unit can be detached from frame and its plate and sweep type blades, junior hoe cultivator or a ridger can be fitted. The field capacity of the unit is 3 ha/day. The cost of the unit is about Rs. 75,000/- with all the attachments.

**Tractor drawn three row rotary weeder**

A three row tractor mounted rotary weeder was developed at Tamil Nadu Agricultural University with an operating width of 600 mm; the spacing between consequent rotary weeding units is 300 mm. Hence the theoretical width of operation is 2400 mm. The depth of operation is 75 to 100 mm. The speed of operation is 1.00 to 2.00 kmh$^{-1}$. The field capacity of the unit is 2 ha/day. The cost of the unit is about Rs. 95,000/-.

**Plant Protection**

**Knapsack, back pack and rocker sprayers and dusters.**

Commercially available knapsack, back pack and rocker sprayers and dusters are used by the farmers. These equipments are either hand operated or engine (power) operated. The common problem is less coverage of area while using these type of sprayers.

**High clearance sprayers and wide swath boom sprayers**

The high clearance sprayers and wide swath boom sprayers are slowly introduced in different crops and they are more economical as compared to other types of plant protection measurers. The high clearance sprayers are self propelled units. The boom sprayers are either tractor operated or power tiller operated, or bullock drawn. The self propelled high clearance sprayer is powered by 20 hp diesel engine. It has 18 hollow cone nozzles. The maximum ground clearance is 120 cm. The boom length is 1080 cm. The width of boom coverage is 1350 cm. The field capacity of the unit is 1.8 ha/h. The cost of the unit is about Rs. 2,50,000/-.
Aero blast sprayer

Even though many chemical applying devices are available, their efficiency and coverage are poor leading to either loss of chemicals due to runoff and drift or due to non application of chemicals to the target places. The aeroblast sprayer, which can produce minute droplet size of chemicals and can spray at all the surfaces of the crop canopy, is of much use besides covering larger area.

Aeroblast sprayer is operated by the tractor PTO and it can cover a distance of 10 to 15 m on one side of the tractor. The field capacity of aeroblast sprayer ranges from 10 to 20 ha/day while operating at the speed of 2 to 3 km/hr. The cost of the unit is about Rs. 95,000/-.

Harvesting

Manual cane harvesting knife (IISR design)

IISR Lucknow has developed a cane knife. This manual cane harvester is similar to the popular (Pankati) cane knife used in Western Uttar Pradesh & Meerut. Keeping the essential features of Pankati, some improvements have been incorporated in IISR knife so that human fatigue is reduced. It consists of blade fitted to a curved wooden handle. During cane cutting, bending of operator is minimum resulting in lesser fatigue. The cost of the knife is Rs. 150/-.

CARIB sugarcane harvester

CARIB Sugarcane Harvester was imported by VSI Pune. This harvester has been assembled on a standard tractor base. It has two spiral scrolls to separate standing canes, which are either lodged or bent, and to gather the canes towards the center of the cutting row for base cutting.

The base cutting is twin blade cutter harvesting adjustable depth wheels to take care of field undulations to maintain a constant height of cut. The cut cane stalks are windrowed beneath harvester along the direction of travel. Thus in this method more labour is required to separate, pile up and clean harvested canes.
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**BUNMEI NB – 11 BB sugarcane harvester**

This is a walk behind whole stalk harvester having a 610 mm diameter disc cutter with 8 blades. This may be suitable for very small size, erect canes. The machine performs the functions of cutting and windrowing. Subsequent detopping and detrashing has to be carried out separately. This is a Japanese machine, which is marketed in India by M/s. Farm Implements India Private Ltd., Chennai. Operation of this machine is difficult under ridges and furrow condition. Output of the machine is very low.

**BUNMEI NB – 11 TR sugarcane harvester**

This is a tractor operated whole stalk harvester having 610 mm diameter disc cutter with 8 blades. This may be suitable for low yielding erect cane. The machine performs the functions of cutting and windrowing. Subsequent detopping and detrashing has to be carried out separately. This is a Japanese machine, which is marketed in India by M/s. Farm Implements India Private Ltd., Chennai. It is difficult to operate the machine under lodged crops.

**BUNMEI sugarcane detopper-cum-leaf stripper**

This machine has been developed with the purpose of detrashing and detopping individual canes. This is also a Bunmei make, Japanese machine and is usually used along with the BUNMAI harvester as supplementary unit. Low output of this machine is its limitation. There is possibility for acceptability this design provided output per unit time is increased. The cost of the unit is Rs. 1,25,000/-.

**GK – 75 whole stalk sugarcane harvester**

The Moller GK – 75 Whole Stock Cane Harvester is a low cost machine specially designed to increase harvesting efficiency and reduce labour costs. This machine has been designed to cut standing erect cane with a lean of not exceeding 10 degrees.
AUSTOFT 7000 sugarcane chopper harvester

This is a chopper type sugarcane harvester. This has been imported by M/s. Shakthi Sugars Ltd., Erode, Tamil Nadu and is being used in Tamil Nadu and Maharashtra.

During cane harvesting, only 15% time is spent for harvesting and the rest 85% is used for dressing and sizing the cut cane into cane bits, bundling, carrying and gathering the cane bundles and finally loading in to the cane trucks. In chopper harvester, all these functions are carried out in one go besides blowing out the dry cane trash into the field as a “Trash blanket” (Nagendran, 2012). This machine performs the functions of base cutting, detopping, detrashing, chopping of cane, removal of trash, green leaves, tops and blowing billets into tractor trailer and transport trucks. The machine is suitable for sugarcane grown at 150 cm row to row spacing. Hence, the present method of sugarcane cultivation in India with a spacing of 90 cm row to row spacing is not suitable to use this machine. The cost of the machine is about ₹ 1.3 crore.

CLAAS sugarcane harvester

This is a German make sugarcane combine, which is being imported and sold in India by M/s. Escorts Ltd and is introduced by Cooperative Sugar Mills of Maharashtra on custom hiring.

The salient feature of the machine is that, the row spacing of header unit can be adjusted from narrow row spacing i.e. 90 cm to 150 cm which makes the machine suitable for harvesting sugarcane cultivated in most parts of the country. This is also a chopper type harvester. Green top is detopped and pushed aside, which is collected manually for feeding to the cattle. The cost of the machine is about ₹ 1 crore.

CAMECO CH-2500, 3500 sugarcane harvester

This chopper type combine harvester is suitable for harvesting cane grown at 150 cm spacing.

CAMECO S 30 sugarcane harvester

This is a whole stalk harvester imported by Vasantdada Patil Sugar mill, Sangli, Maharashtra. This is a single row machine having a single spiral scroll at the left to separate entangled and lodged cane stalks from adjoining rows of standing crops.

It has upper and lower conveyors for gathering and conveying standing cane stalks for
base cutting along the rows. Height of these conveyors can be adjusted independently. Windrowing unit has a conveyor which can discharge detopped and base cut canes at desired angle, to a maximum distance, perpendicular to the direction of travel. The topper detops the green leaves and shreds the immature canes. All functional components and sub systems are hydraulically powered. Since, it is a paired, wide row / staggered row crop harvester, it is not suitable for sugarcane harvesting in India.

CAMECO S 32 whole stalk sugarcane harvester is a two row whole stalk harvester commercially manufactured by M/s. CAMECO, USA. Presently the design is out of production, however, on order basis, units are manufactured by M/s. Hone Iron works, a subsidiary of CAMECO, USA.

AUSTOFT HX – 1800 sugarcane chopper harvester

This is a chopper type sugarcane harvester and is being marketed by M/s. Shakthi Sugars Ltd., Erode. This machine is being used in Tamil Nadu and Maharashtra. This machine carries out functions of base cutting, detopping, detrashing, chopping of cane, removal of trash and green leaf tops and loading billets into tractor trailer moving along with the machine. Later on billets are loaded in the trucks for transport to the sugar mills for crushing. The machine is suitable for sugarcane grown at 100 cm row to row spacing (Singh et al., 2010). However, it is a very costly machine. Presently cost of operation of this machine per unit weight of cane is more as compared to traditional harvesting. In many respects Austoft 7000 is more effective and balanced machine. The cost of the machine is around Rs. 1 crore.

ORBACH tractor operated sugarcane harvester

This machine is of South African origin being manufactured and marketed by M/s. Orback. It harvests the cane from ground level with a circular base cutter operated by tractor PTO. It also does sugarcane detopping along with base cutting, conveys it and windrow in heaps with the help of a manually operated trolley by an operator in sitting posture on a seat fitted on the frame. Later on sugarcane is loaded on a trailer. The design is quite promising for harvesting erect cane. This machine is in use for the last 4-5 years. In order to reduce the trash, sugarcane is burnt before using the harvester. Thereby trashes are removed. Otherwise about 30 per cent of the cost of sugarcane harvesting will be required for detrashing of cane.
Rane-NATP(ICAR)-VSI sugarcane chopper combine harvester

An indigenous sugarcane chopper combine harvester has been developed by the collaborative efforts of VSI-Pune, Rane Industries and ICAR under NATP on Sugarcane Mechanization. The unit can be used in sugarcane fields cultivated with a row to row spacing of 90-100 cm. The expected capacity of the unit is 10 to 25 MT/hr. The unit is under extensive field trials. The cost of the unit may be around ₹75 lakhs.

Loading and Transport

BUNMEI grab loader

This is used to lift harvested whole stalk cane and place it in transport wagon. It is a tractor operated Japanese machine, which is marketed in India by M/s. Farm Implements Private Ltd., Chennai.

BELL loaders

This loader is used to lift harvested whole stalk cane and place it in transport wagons. This machine is recently introduced in India and is being commercially manufactured by Telco Construction Equipment Limited.

UTTAM loaders

This loader is also used to lift whole stalk canes and place it in transport wagon. This is an indigenous model similar to BELL loader. This model can load the cane in field and at collection centers, stack up the sugarcane in convenient bundles, and handle bagasse efficiently. This machine is commercially manufactured by M/s. Uttam Industrial Engineering Ltd., New Delhi.

Ratoon and Trash Management

Tractor mounted two –row sugarcane stubble shaver

It is a tractor mounted implement suitable for shaving sugarcane stubbles after harvest. This implement was developed by IISR, Lucknow. The stubble shaver consists of rotary blades run by tractor P.T.O. The unit can also be used for off baring and fertilizer application. The cost of the unit is about ₹25,000/-
Scientific Sugarcane Cultivation

**Tractor operated sugarcane trash shredder**

Sugarcane produces about 10 to 12 tonnes of dry leaves per hectare per crop. The detrashing is done on 5th and 7th month during its growth period. This trash contains 28.6% organic carbon, 0.35 to 0.42% nitrogen, 0.04 to 0.15% phosphorus, 0.50 to 0.42% potassium. Sugarcane trash is lengthy one. Handling and heaping the trash will be more cumbersome. The old practice of burning the dry leaves in the field produces ash and smoke which causes environmental pollution and more over the good organisms in the soil get destroyed due to fire, which is again a loss to the farm land ecology. It is recommended to shred the waste into small particles. Sugarcane trash shredder can be used for in-situ shredding of sugarcane leaves in the field. The sugarcane trash incorporation in the soil influences physical, chemical and biological properties of the soil. There is a reduction in soil EC, improvement in the water holding capacity, better soil aggregation and thereby improves porosity in the soil. Sugarcane trash incorporation reduces the bulk density of the soil and there is an increase in infiltration rate and decrease in penetration resistance. The direct incorporation of chopped trash increases the availability of nutrients leading to soil fertility.

**Tractor operated sugarcane trash shredder (single row)**

A tractor operated sugarcane trash shredder was developed at MPKV, Rahuri. The unit consists of trash compressing unit, shredding unit and power transmission unit. It can be operated with a 35 hp tractor. The width of operation is 60 cm. The field capacity of the unit is 1.5 ha/day. The cost of the unit is Rs. 60,000/

**Tractor operated sugarcane trash shredder (two row)**

A tractor operated two row sugarcane trash shredder was developed at TNAU. The main component of the unit is the rotating member with two rotary units. The spacing between them can be varied according to the row spacing of the crop. Swinging type curved blades are fitted on the rotary member in staggered manner. The rotating speed of the rotary unit is 1990 rpm. The field capacity of the unit is 2 ha/day. The cost of the unit is Rs. 85,000/-

Mechanization is needed to get over some of the major constraints to enhance productivity and to make farming less arduous and attractive enough to enable educated youth taking willingly agriculture as vocation. Mechanization also aims at increasing land labour efficiency by improving the safety and comfort of agricultural labour and to protect the environment by allowing precision operations and increasing the overall income. Efficient machinery helps in timely farm operation, input use efficiency, increasing productivity by
about 30%. Development and introduction of high capacity, precise, reliable and energy efficient equipment and their judicious use can bring in precision and timeliness in field operations. The challenges in sustainable sugarcane agriculture can be met effectively by adopting the appropriate mechanical alternatives not only for increasing the productivity but inculcating cost efficiency in sugarcane production system.

References


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