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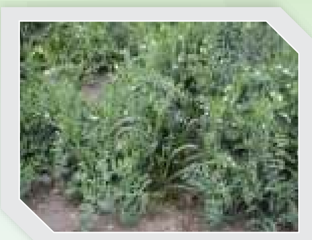
AICRP (S) Technical Bulletin - No. III

LOW COST TECHNOLOGIES IN SUGARCANE AGRICULTURE



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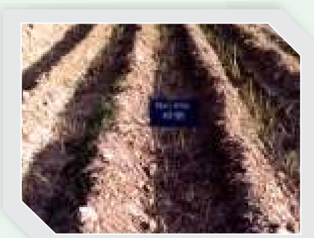

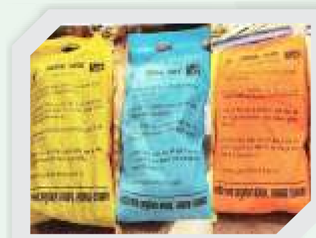

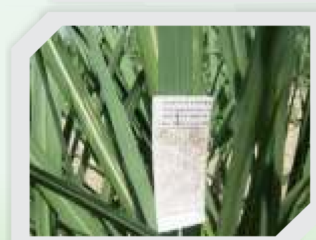

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Printed : October, 2018

Publication No. : AICRP (S) Technical Bulletin No. III

Published by : Dr. S.K. Shukla
Project Coordinator
ICAR-All India Coordinated Research
Project on Sugarcane.

Correct Citation : S.K. Shukla , S.K. Yadav, Menhi Lal, A.D. Pathak (2018). Low cost technologies in sugarcane agriculture Published by ICAR-All India Coordinated Research Project on Sugarcane, IISR, Lucknow Page No. 1-55

Printed at Army Printing Press, 33 Nehru Road, Sadar Cantt, Lucknow, Ph: 2481164, 8604565333

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FOREWORD

Sugarcane crop occupies a very prominent share in the agricultural sector of India covering 5 m ha area in sub-tropical as well as tropical regions. India ranked second in sugarcane production in the world with total production of 355.0 million tonnes having productivity of 74.4 t/ha during 2017-18. Sugarcane is grown as a major cash crop after cotton in India. Adoption of effective management practices holds great promise for remunerative sugarcane yield in the country. Self-sufficiency in production of sweeteners through research and development and dissemination of technologies done by the various institutions and AICRP on sugarcane have been one of the main planks of our country since independence. The country has not only become self-sufficient in sugar but a sizeable portion is also earmarked for export, earning foreign exchequer. The production technology of sugarcane is two pronged. One is to maximize sugarcane productivity and the other is to reduce the cost of cultivation to derive optimum benefits. Among important inputs for sugarcane cultivation, seed cane proves because of high cost and its overall impact on crop growth and yield. Hence, selection of a appropriate variety for a specific cropping season and suitable method of planting ensures adequate crop stand resulted in higher yields.

The cost of cultivation is the function of the costs of inputs, land, energy involved on cultivation practices and time. The technological interventions and experiences of peasantry gained over the years have devised several ways and means of lowering the cost production by evolving more efficient techniques without compromising yield of the sugarcane crop and adopting more rationalized approaches with respect to location specific issues. Such technology identified as low cost technology with respect to monetary and non monetary inputs in sugarcane agriculture and enhanced the additional return. I hope that the bulletin **“Low Cost Technologies in Sugarcane Agriculture”** will be very much useful to sugarcane growers for increasing their profitability and prosperity in time to come.

I appreciate the efforts of Project Coordination unit at ICAR-IISR, Lucknow to give focus on low cost technologies in sugarcane agriculture and bring out the present publication.

(A.K. Singh)

October 03, 2018
New Delhi

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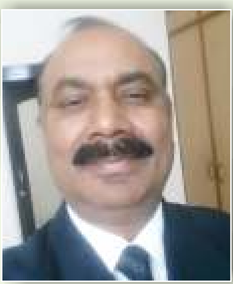

MESSAGE

It is my proud privilege with immense pleasure to know that Project Coordination Unit, IISR, Lucknow has compiled the information for reducing the cost of sugarcane cultivation in the form of a bulletin on **"Low Cost Technologies in Sugarcane Agriculture".** No doubt a large number of technologies have been developed by the institute and AICRP on sugarcane, which certainty enhanced the productivity of sugarcane. Competitive prices of sugarcane in the international market restrict to increase the price by sugarcane policy makers at national level. These situations jeopardize the profitability of sugarcane growers. Hence, it is necessary to identify certain monetary and non monetary inputs in sugarcane agriculture having tremendous potential to increase the productivity of sugarcane in respect to meager increase in input cost. Selection of variety, method of seed treatment, method of planting, plant geometry and timely field operations are the examples of either non monetary or having very low cost but leads higher benefit cost ratio.

The AICRP on Sugarcane is playing a pivotal role in developing appropriate technologies to economize the cost of production of sugarcane. I appreciate the efforts made by Project Coordination Unit at ICAR-IISR, Lucknow and all the concerned scientists, centre's In-charges for providing the useful information and making document for its further use.

I am sure that the bulletin "**Low Cost Technologies in Sugarcane Agriculture**" will be useful for sugarcane growers, stake holders and policy makers.

September 19, 2018
New Delhi

(R.K. Singh)

भाकृअनुप
ICAR

MkO v'ouh nRr ikBd
निदेशक
Dr Ashwini Datt Pathak
Director

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MESSAGE

It is my great pleasure to know that a technical bulletin on Low Cost Technologies in Sugarcane agriculture has been developed by the concerted efforts of Project Coordination Unit. The agriculture is becoming costlier day by day because of the increasing input cost. At the same time, farmers are struggling for price of the product. In this time, the interventions through low cost technologies will certainly increase the income of farmers in time to come.

There are about 7 million cane growers in India having the average cane farm-size of 0.77 ha. The average holding of cane growers indicates that more than 90% sugarcane in the country is grown by small and marginal farmers. This small size of holdings of the average cane farm makes difficult to adopt costly improved sugarcane production technologies. Hence, adoption of low cost technologies in such scenario has become essential to improve the profitability of farmers. Leveling of land before sugarcane planting, timely field operations, sett treatment, selection of appropriate variety, use of biofertilizers, method of planting and optimizing crop geometry are associated with monetary and non monetary inputs playing crucial role in enhancing productivity of sugarcane with higher benefit cost ratio.

The AICRP on Sugarcane is playing pivotal role in identifying such technologies for sugarcane growers to enhance their farm income. I am sure that the technical bulletin on **"Low Cost Technologies in Sugarcane Agriculture"** will be very much useful for sugarcane growers, millers, stake holders, and policy makers.

I appreciate the efforts of authors and all the concerned scientists, technical officers and centre In-charges in providing the input for present technical bulletin.

September 20, 2018
Lucknow

(A.D. Pathak)

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ACKNOWLEDGEMENTS

More than seven million farming community is directly involved in the sugarcane production. Living standards of these farming communities are directly related to successful cultivation of the crop. Increasing the farmer's income are the major challenge to supply safe and nutritional food and reducing health risk. Most of the farmers using high inputs for cultivation of sugarcane are deteriorating the quality of environment and increasing the cost of production and reducing the profit per unit area per unit time. At present, there is urgent need of adoption of low cost technologies related to sugarcane production that includes selection of appropriate varieties especially developed for that region, appropriate method of planting, seed treatment before planting in the fields, crop diversification, intercropping, use of biofertilizers, use of organic sources of nutrient like farm yard manure, composting, soil and water conserving practices, reducing the human drudgery in agriculture by adoption of mechanical cultivation, and popularizing the plant protection measures such as use of biological pest control measures.

Thus, need was felt to document the available low cost technologies for sugarcane developed by various research centers of the country for effective transmission among cane growers at the national level. Thus, present technical bulletin on **"Low Cost Technologies in Sugarcane Agriculture"** has been developed for sugarcane growers, research workers and state development personnel working in sugarcane sector.

I express my heartfelt gratitude to Dr. T. Mohapatra, Secretary (DARE) & Director General, Indian Council of Agricultural Research, New Delhi for providing all kinds of support to AICRP on Sugarcane. I profusely thank Dr. A.K. Singh, Deputy Director General (Crop Science & Horticultural Science), ICAR, New Delhi for technical guidance and support us. I thank Dr. R.K. Singh, Asstt. Director General (Commercial Crops), ICAR, New Delhi for encouragement and valuable guidance.

I am also thankful to colleagues working in Coordination Unit and IISR Lucknow *viz.*, Dr. G.K. Singh, CTO, Dr. Radha Jain, Principal Scientist and Head (Plant Physiology and Bio chemistry), Dr. A.K Singh, Principal Scientist (Agronomy), Dr. Deeksha Joshi, Senior Scientist (Plant Pathology), Shri Braham Prakash, CTO (PME Cell), Dr S. K Awasthi, CTO, Shri Adil Zubair, ACTO and in Soil Plant Water Analysis and Microbiology Lab *viz.*, Dr. V. P. Jaiswal, Senior Scientist, Dr. Lalan Sharma, Scientist, Mrs. Asha Gaur, CTO for providing assistance in various ways. I am thankful to Shri Ambrish Kumar Sahu for assisting in computer work and typing the manuscript.

(S.K. Shukla)
(S.K. Yadav)
(Menhi Lal)
(A.D. Pathak)

ICAR

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PREFACE

Sugarcane is the second most important cash crop after cotton in India. It plays an important role in national economy as it supports 7.0 million farmers and their families in rural areas. Socio economic condition of the farming community is directly linked with productivity of sugarcane. The technologies developed and adopted in different agro-climatic zones demonstrated tremendous scope to improve crop yield. In India 22 per cent of its population is still living below the poverty line and more than 90 per cent farmers belong to the category of small and marginal. Majority of these farmers having low income, insecurity, lack of dignity in the eyes of the society are not in position to adopt high cost technology up to the significant level. In such scenario, dependence on high cost external inputs becomes difficult to resource poor farmers due to their low purchasing power. In sugarcane, per cent reduction in the cost of production is directly related to the percent profit. Keeping this in view, an attempt has been made for identification of low cost technology in sugarcane cultivation with objectives to improve productivity, profitability, input use efficiency and sustainability of sugarcane agriculture. Most of low cost technologies are based on concept of non-monetary inputs or cost effective input having higher potential to increase the level of profit. This bulletin embodies majority of those technologies which incur low cost of cultivation proportional to enhancing additional benefits. Such technologies are especially either non monetary in nature or require little bit cost (less than 5% of the total cost of production) but play an important role in increasing crop productivity & farmers income. We are sure that adoption of these technologies will reduce the cost of production and enhance the farmers income besides improving the productivity and sustainability of sugarcane plant-ratoon system.

October 05, 2018
Lucknow

(S.K. Shukla)
Project Coordinator (Sugarcane)

CONTENTS

CONTENTS OF TABLE

Introduction

Sugarcane cultivation in India dates back to pre-Vedic period and presently the country stands second largest producer of sugarcane (355.0 mt) and sugar (>32.0 mt) in the world after Brazil. In India, evolution of 'Co' canes and scientific interventions in terms of its production and protection technologies have revolutionized the sugarcane cultivation with the result that present productivity level ranges from 70 t/ha in the subtropics to 85 t/ha in the tropics on total acreage of over 4.77 m ha with productivity of 74.4 t/ha realized at the national level. Variations in yield levels are mainly attributed to the changed climatic conditions prevailing in sugarcane growing zones. Other factors like rising cost of inputs, scarcity of timely labour supply and cyclicality in sugar sector also affect sugarcane productivity and thereby sugar production adversely. Besides, poor resource management and negligence of plant protection measures sometimes led poor yield and quality of sugarcane. Despite all these, sugarcane is one of the preferred cash crops because of its certain inherent features *viz.*, capacity to cope up with the adverse weather, good survival under poor management, higher photosynthetic efficiency and huge biomass accumulation.

On the basis of an average return/month, sugarcane is rather more remunerative as compared to other crops. Intercrop price parity as compiled by CACP based on returns during 2010-13 showed that sugarcane gave ₹ 4934/month as compared to ₹ 3565 for wheat and ₹ 1137 for rice at the national level. A sugar mill in its command area plays pivotal role for socio-economic development of the region by mobilizing rural resources and generating higher employment and income opportunities. Further, the majority of farmers having marginal to small size of holdings whose farm operations can be optimized may switch over to the low cost agricultural technologies. Many of these technologies are supported by low input available farm resources and simple machines.

Majority of technologies developed for improving sugarcane production in the country certainly enhanced the productivity of sugarcane irrespective of reduction in cost of cultivation. The maximum cost of production (₹ 278 /q) of sugarcane is found in Haryana followed by Uttar Pradesh as ₹ 234/q while the minimum cost of production has been recorded in Maharashtra (₹183/q) in the country during 2016-17. Hence, the cost of production of sugarcane has been aggravated in the subtropical region of India which jeopardized the profit due to narrowing the additional margin in the form of net return. The high cost of production is also beyond the limit of majority of sugarcane growers in the country like India where more than 85 % farmers having small size land holding. Therefore, keeping the technological cost of production in the mind, an attempt has been made to find out an appropriate technologies referred to low cost technologies having comparatively higher additional margin in profit through net return in sugarcane agriculture.

Essentially, low cost agricultural technologies are those that results in more than 5-10 percent increase in terms of yield/profit over that obtained from farmers practice with less than 5 percent investment. Thus due to adoption of low cost technology, benefit: cost ratio may be increased as compared to the traditional farmers' practices. The technologies may include selection of appropriate varieties, land preparation, planting time, seed treatment, crop geometry, planting method, seed multiplication technique, use of bio-fertilizers, integrated nutrient management, integrated disease and pest management, irrigation and drainage methods, through use of simple tools etc. In the present bulletin, low cost technologies available for various sugarcane growing regions have been documented. The work on particular technologies has also been reviewed and focus on important technologies has been given for increasing sugarcane yield and farmers income.

1. Land Leveling

Proper land leveling is the first step to increase the water use efficiency which results in improved sugarcane productivity and quality. Land slope should not be more than 0.5% in any case for getting the optimum yield with higher water use efficiency. Practically upper surface of field loses moisture earlier than lower depth. Sometimes, waterlogging due to high rainfall or higher depth of irrigation, reduces the oxygen supply to root zone and reduces cane yield. The water use efficiency in leveled fields increases through increase in water application efficiency which leads to the higher yield as well as increase in water and nutrient use efficiencies. Hence, leveling becomes essential component depending upon the area and socio economic conditions of farmers. Land laser leveling has been adopted by the farmers for saving in irrigation water. Application of land laser technique enhances crop yields and environmental quality by reducing emission of green house gases in waterlogged situation.

Subdivision of fields is based on obstructions, soil boundaries, land slopes and cropping systems. It is important to retain the existing facilities of irrigation, drainage and farm roads as for as possible. The width of border or basin is based on the size of the irrigation stream and the type of equipment used in land preparation. In border and check basin methods of irrigation, the width of a field are a multiple of the width of the irrigation strip. The fields are laid out as nearly rectangular as possible. Sharp turns in field boundaries should be avoided in order to facilitate the use of modern equipments. Laying out fields of workable size and shape is important to successful irrigation. A profile of each proposed centre line is needed to compute the amount of excavation is required.

Where topography permits, the water supply lines may be located as to serve the fields on either side for irrigation, the location of the supply lines is determined by standard route-type survey. The water surface in field should be 20 to 30 cm higher than the ground to be irrigated. If possible, these channels should be leveled (less than 0.1 per cent slopes) so that water can be traveled to the maximum distance. Field channels and underground pipelines to irrigation water to the field are located along the upper reach of the irrigation runs. They are perpendicular to the direction of irrigation for irrigation methods. The elevations of the source of water supply, the land between the water source and the area to be irrigated and the different parts of the farm are be irrigated and the drainage outlets must be known to properly farm irrigation system. The topography is a major factor selecting the method of irrigation, estimation of number and kind of water control structures and determining the need for land leveling.

Integrated irrigation and drainage planning is often necessary for laying out a farm area for efficient water use. Interceptor drains may be necessary at the upper boundaries of the low-lying area to divert the seepage and prevent waterlogging. Seepage from over irrigated areas at higher elevations and irrigation canals can damage lands in the low-lying area. If the land is not naturally well drained, artificial drainage must be established at the time when the irrigation system is installed. Provision should be made to drain the excess rainfall promptly and safely. Surface drainage may be needed to prevent or modify saline- alkali conditions in a soil by leaching. Good drainage, both surface and subsurface, is essential for successful irrigation. It is essential to provide a field road system for ready access to all areas of the farm for farm equipments, transportation of farm produce, and easy operation of the irrigation system. Field roads are provided above irrigation channels and below the level of field drains.

The following contour patterns may warrant subdivision of land for successful irrigation farming:

1. Separation of fields may be desirable along the line of slope change for sharp change in slope.
2. Separation of fields at the bend is desirable for surface irrigation methods for straight contour topography.
3. Contour lines either close together or far apart means, slope is steep or flat. In such cases, the lengths of the fields are kept to the minimum required for efficient irrigation so as to reduce the amount of cuts and fills required.
4. Non-uniform slope may be set apart to be graded individually as unit.
5. Excessively irregular areas may be planned for irrigation with sprinkler or drip method.

After having the elevation of each grid point with respect to bench mark considered for these purpose, draw contour line at a suitable contour interval as given in Table 1.

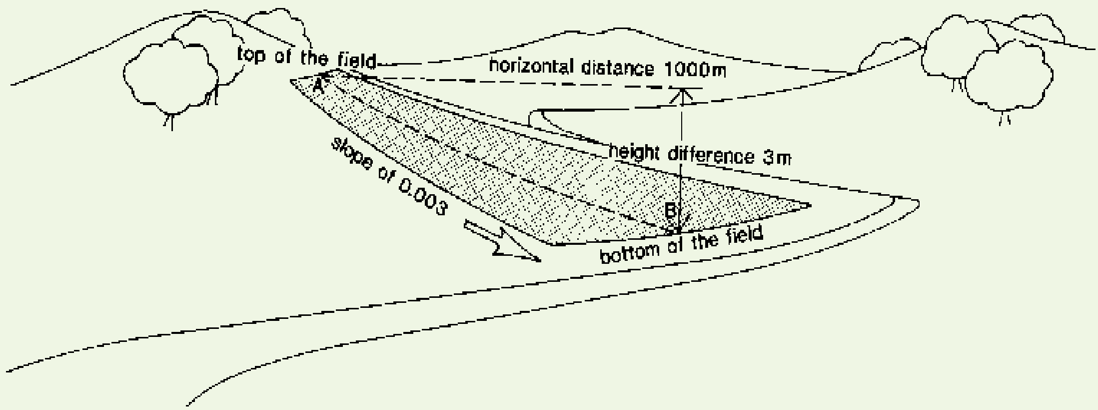
Table 1: Suitable contour interval for drawing contour line

Sl. No.	Slope % required	Contour interval
1.	0-1	5-15 cm
2.	1-2	15-30 cm
3.	2-5	30-60 cm
4.	5-10	60-150 cm

Tractor drawn laser leveler

Slope

The slope of a field is expressed as a ratio. It is the vertical distance, or difference in height, between two points in a field, divided by the horizontal distance between these two points. The maximum recommended furrow slope is 0.5 % to avoid soil erosion. Furrow can also be leveled, however, a minimum grade of 0.05% is recommended to provide effective drainage of water. If the land slope is lower than 0.05%, furrows can be made along with the same direction of contour to keep the furrow slope within the recommended limit.



2. Treatment of seed cane (Setts)

Pathogens of majority of diseases of sugarcane are primarily transmitted through setts due to vegetative propagation of crop. Hence, utmost care should be taken to protect the crop at the early stage. The concept of 'prevention is better than cure' is one of the components of non-monetary inputs in sugarcane agriculture. Planting material should be obtained from the registered Government authenticated agencies and should be free from diseases and pests. If farmers use their own planting material, it should be treated properly through systemic / non-systemic fungicide to protect the disease spread. Non-systemic fungicides belong to organomercurials group and also control the surface disease of setts and help in increasing the seed vigour. But nonsystemic fungicides are not effective to controlled the sett borne pathogens. Therefore, selection of fungicides for sett treatment has prime importance in sugarcane agriculture. Use of systemic fungicides like Benlate, Bavistin and Thyophonate methyl to control sett borne infection of red rot and wilt pathogen is promoted. However, a mixture of fungicides likes Thiram and Bavistin provide broad spectrum protection against many pathogens.

Shukla et al. (2011) reported that yield enhancement in total cane yield (about 13.6 t/ha) was recorded due to sett treatment with inoculation of *Trichoderma viride* in plant crop and its carry over effect on ratoon crops. The cost of treatment was merely ₹ 1800/ha for sett inoculation in plant crop but earned the monetary additional net returns of ₹ 39000/ha. Similarly the benefit cost ratio of seed treatment was recorded 23:1. The details analysis of setts treatment has been shown in Table No 2.

Table 2: Economics of sett treatment with *Trichoderma viride* on plant cane yield and its carryover effect on ratoon crop

Seed treatment	Plant cane yield (t/ha)	Ratoon cane yield (t/ha)	Cost of sett treatments ₹/ha	Additional benefit due to seed treatment (₹/ha)	B:C ratio due to treatment
With Trichoderma viride	71.4	67.9	1800.0	39000.0	23.1
Without *Trichoderma viride*	66.1	59.6	00.0	-	-
CD (P=0.05)	3.1	4.3	-	-	-

Source: Modified from Shukla et al. (2011)

The planting of commercial sugarcane should be done by certified seed cane and 3 tier seed production programme should be followed involving treatment of setts with moist-hot air (54^0C for 2.50 hrs) or hot water (50^0C for 2 hrs), effective against virus and other seed borne diseases. Moist hot air treatment (MHAT) of seed cane proves beneficial in controlling the sett borne diseases.

ICAR-IISR: Moist hot air treatement chamber

Rao and Satyanarayana (1995) reported effective control by treating single bud setts both at 50^{0}C for 2 hours or at 52^{0}C for 30 minutes along with treatment of Bavistin 0.1%. However, a fungicidal treatment alone was only partially effective in controlling sett borne infection of red rot (Table 3).

Table 3. Efficacy of hot water treatment in controlling sett borne infection of red rot in single bud setts.

Treatments	% Tissue yielding red rot fungus			% Germination	% Germination exhibiting red rot
	Internal tissue	Leaf scar	Bud		
Hot water 50^{0}C 2 hours	0.0	0.0	00	16	0.0
Hot water 50^{0}C 2 hours + Bavistin 0.1%	0.0	0.0	0.0	15.0	0.0
Soaking setts in 0.1% Bavistin for 2 hours	26.6	13.3	8.0	25.0	28.5
Check (setts soaked in cold water)	80.0	53.3	66.6	8.0	100.0
Hot water 50^{0}C 30 minutes	0.0	0.0	0.0	40.0	0.0
Hot water 50^{0}C 30 min +Bavistin 0.1%	0.0	0.0	0.0	48.0	0.0
Soaking setts in % 0.1 Bavistin for 30 min	40.0	26.6	33.3	25.0	60.0

Source**:** Rao and Satyanarayana (1995)

Selected healthy seed cane (two or three bud setts), should be dipped in a solution of Bavistin (200 g dissolved in 100 liters water) for 30 minutes for planting one hectare. For protection from termite, shoot and root borers, apply solution of *Chlorpyriphos* 20 EC (6.25 l/ha or *Clorantraniliprole* 18.5 SC (500-600 ml/ha) or *Fipronil* 5 SC (0.75 l/ha) in 1500 – 1600 liters water over setts in furrows. In saline-alkali soils (pH > 7.5), solution of Imidacloprid 17.8 SL (500 ml/ha) in 1500-1600 liters water should be applied. The seed rate varies from 2-2.5 quintal/ha in cane node technology to 6-7.5 t/ha in conventional planting and 10-12 tonnes/ha in trench/pit method of planting depending upon row distance, planting time and soil type.

Results of 22 AICRP (Sugarcane) centers located in five different agro-climatic zones revealed that planting of setts after overnight soaking in 100 ppm ethrel solution followed by spray of GA_3 @ 35 ppm at 90,120 and 150 days after planting (DAP) recorded the highest cane yield in all the sugarcane zones (North West, East Coast, Peninsular and North East) except North Central zone. Whereas planting of setts after overnight soaking in 50 ppm ethrel solution was found at par with farmers practice. However, both the treatments were significantly superior to the conventional planting/farmers practices (Table 4). Similar trend was also recorded with respect to commercial cane sugar (CCS) yield in all the zones. Hence, planting of setts after overnight soaking in either 50/100 ppm ethrel solution followed by spraying of GA_3 @ 35 ppm at 90,120 and 150 DAP proved effective in increasing sugarcane yield.

Table 4: Effect of plant growth regulators (PGRs) on sugarcane yield (t/ha) of sugarcane.

Treatment	North West Zone	Peninsular Zone	North Central Zone	North East Zone	East Coast Zone
T1: Conventional planting/farmers Practice (3 bud setts)	76.90	93.58	67.00	39.6	98.17
T2: Planting of Setts after overnight soaking in water.	82.73	96.99	71.95	44.9	100.40

T3: Planting of Setts after overnight soaking in 50 ppm ethrel solution.	91.69	102.85	81.75	46.6	105.67
T4: Planting of Setts after overnight soaking in 100 ppm ethrel solution	95.91	104.56	81.55	48.8	111.50
T1 + GA_3 spray (35 ppm) at 90, 120 and 150 DAP	82.75	97.04	80.40	42.4	109.17
T2 + GA_3 spray (35 ppm) at 90, 120 and 150 DAP	89.24	103.61	85.00	54.8	111.47
T3 + GA_3 spray (35 ppm) at 90, 120 and 150 DAP	96.88	110.35	93.20	53.2	114.93
T4 + GA_3 spray (35 ppm) at 90, 120 and 150 DAP	100.26	111.48	92.90	57.8	118.03
SE(d)	1.73	3.05	8.26	-	2.97
CD at 5%	3.48	6.13	NS	7.82	6.37

***Source*:** AICRP Annual report of crop production (2017)

Economic analysis

Monetary benefit due to use of plant growth regulator has been worked out and presented in Table 5. Planting of setts after overnight soaking in 100 ppm ethrel solution + GA_3 spray (35 ppm) at 90, 120 and 150 DAP revealed the maximum additional return of ₹ 62982/ha with investment of additional input cost of ethrel and GA_3 as ₹ 6300/ha. The parameters taken in the economic analysis are being given below:

Ethrel

- Quantity of ethrel needed for treating of setts for planting one ha @ 50 ppm = 250 ml.
- Quantity of etherel needed for treating of setts for planting one ha @ 100 ppm= 500 ml
- 25 ml ethrel taken in 100 litres of water for preparation of 100 ppm solution.
- Volume of water needed for treating the setts for planting 1 ha = 2000 litres
- Ethrel is available in the market @ ₹ 1500/litre

Gibrelic acid

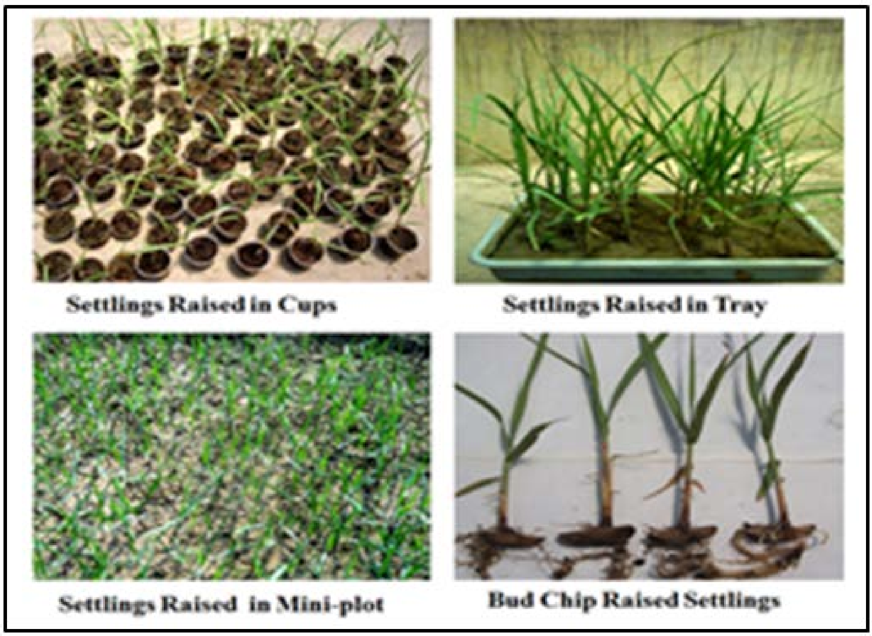
- Quantity of GA_3 needed for spray of 1 ha of sugarcane in 400 liter water at 90 DAP = 14 g.
- Quantity of GA_3 needed for spray of 1 ha of sugarcane in 600 liter of water at 120 DAP= 21g.
- Quantity of GA_3 needed for spray of 1 ha of sugarcane in 800 liter of water at 150 DAP = 28g.
- The price of commercial grade of GA_3 (Pro-gibb) available in the market @ ₹ 50/g

Table 5: Analysis of additional benefit due to application of plant growth regulator on sugar cane yield in all the sugarcane growing zones

Treatment	Mean yield of zone (t/ha)	Additional cost (₹/ha)	Additional Return (₹/ha)	Increased B:C ratio due to treatment
Conventional planting/farmers practice (3 bud setts)	75.1	0	0	0
Conventional planting/farmers practice (3 bud setts) + GA_3 spray (35 ppm) at 90, 120 and 150 DAP	82.4	4350	21756	5.0
Planting of setts after overnight soaking in water + GA_3 spray (35 ppm) at 90, 120 and 150 DAP	88.8	5550	41172	7.4
Planting of setts after overnight soaking in 50 ppm ethrel solution + GA_3 spray (35 ppm) at 90, 120 and 150 DAP	93.7	5925	55836	9.4
Planting of setts after overnight soaking in 100 ppm ethrel solution + GA_3 spray (35 ppm) at 90, 120 and 150 DAP	96.1	6300	62982	10.0

3. Bud chip technology for rapid seed multiplication

This is the most important low cost technology for rapid seed multiplication of sugarcane. This method of bud chip technology in sugarcane has become popular seed rate @ 6-8 tones/ha is used in growing of comparison to the conventional method of planting, where two or three but setts are used. Generally in commercial crop of sugarcane. This large quantity of planting material poses a great problem in transport, storage and involves high cost. Therefore, through bud chip technology, volume of seed cane can be reduced, quality can be improved and quick multiplication of sugarcane is possible besides improving seed cane yield. In this method, bud chip seedlings are raised preferably in small plastic cups/trays and transplanting is done in the field. It proved economically viable than traditional method of planting using two to three bud setts. In the bud chip technology, the return from crop is relatively higher and substantial saving in the seed material could be possible. The left over cane could be utilized for crushing since it remains a full cane except for the scooped up bud portion (Jain et al. 2014).



Advantages of bud chip seed material:

- Generally bud chips raised in cups are less bulky and transport of planting material is easy.
- Higher bud germination (90 per cent) as against 30-35 per cent in conventional 3 bud setts.
- Nearly 80 per cent (by weight) of the planting material can be saved by using bud chips as it requires about <1.0 tonne seed per hectare while in conventional system of cane cultivation, 6-8 tonnes seed per hectare is needed.
- Bud chip technology is viable and economical in reducing the cost of sugarcane production.
- Higher seed multiplication ratio (1:60) over the conventional method (1:10), hence this technique is most suitable for faster multiplication of new released varieties.
- Higher tillering, cane weight and cane height against setts planting method hence higher cane yield (100 t/ha) as compared to the conventional method (67 t/ha).
- The left-over sugarcane can be utilized for juice or sugar/jaggery making.

4. Selection of appropriate varieties

Selection of an appropriate variety is one of the most important non monetary input deciding the production and productivity of sugarcane. A large numbers of varieties developed by different research stations and SAUs/ICAR Institutes for cultivation in different zones have been recommended. Most of the farmers are attracted towards high yielding varieties. However, varieties having higher sucrose content are the choice of sugar industry. Besides, sugarcane ratoon crop matures earlier than plant crop in 10 months and behave like early maturing variety (sugar accumulation). Thus development of sugarcane varieties having higher yield, sucrose and ratoonability is a major challenge for the sugarcane scientists. A list of latest recommended sugarcane varieties (early and midlate) for different zones is given in Table 6.

Table 6: List of latest recommended sugarcane varieties for different zones

Zones	Varieties
Peninsular zone	Co 09004, PI 07131, Co 06027, CoN 05071, Co 06022, CoSnk 05104, CoSnk 05103, Co 0403, Co 065
East cost zone	CoA 11321, CoC08336, CoA 08323, Co 05323, CoA 05322, CoA 03081, CoOr 03151
North west zone	CoLk 11203, CoLk 11206, CoLk 09204, Co 09022, CoPb 08212, Co 06034, CoLk 07201, CoPant 05224, Co 05009, CoPK 05191, Co 05011, Co 0238, Coo 118
North central and north eastern zone	UP 09453, CoP 09437, CoP 06436, CoSe 05451, CBln 04174, BO 146, CoLk 94184

(***Source:*** Shukla et al. 2018)

Criteria for selection of variety among population of early & midlate maturing have been given below in brief :

- ***Early maturing*** varieties having 16% sucrose with 85% purity in juice on 15th December (crop duration is up to 10 months).
- ***Midlate Maturing*** varieties are those having sucrose content of 16% with 85% purity in juice in February (crop duration is about 11-12 months).
- ***Late maturing*** varieties are those having sucrose content of 16% with 85% purity in juice (crop duration is more than 12 months).

Proper varietal balance is required for utilizing the full time of crushing and maximizing the profit of both farmers and millers due to regulated supply of cane for crushing. A tentative balance sheet of percentage area under cultivation for different maturity groups for subtropical India is given in following Table 7.

Table 7 : Proportion of sugarcane varieties recommended under cultivation

Area under cultivation	North central / north eastern zone	North western zone
Early maturing varieties	20-25%	25-30%
Midlate maturing varieties	55%	55%
Late maturing varieties	20-25%	15-20%

The balance sheet of varietal area under field also provides insurance against aberrant natural calamities especially extreme weather conditions.

Promising sugarcane varieties under moisture stress condition

The studies conducted at Shahjahanpur by Singh et al. (2017) during spring season of 2012–15 on 10 promising varieties of sugarcane revealed that varieties CoS 01434, CoS 08279, and CoS 07250 produced significantly more cane yield under moisture stress condition with less yield reduction (below 10%) confirming their drought tolerant nature. Hence these varieties may be grown in moisture stress condition with same level of inputs for higher cane yield (Table 8).

Table 8: Effect of water stress on growth, yield and quality of sugarcane (pooled over 3 years)

Varieties	Cane yield (t/ha)			Yield reduction %
	Normal	Deficit	Mean yield	
CoS 07250	90.86	83.43	87.15	8.18
CoSe 01434	91.36	84.69	88.03	7.30
CoSe 06455	77.33	70.83	74.08	8.41
UP 05125	78.5	71.47	74.99	8.96
CoS 07240	79.52	73.95	76.74	7.00
CoS 08279	90.62	84.69	87.66	6.54
CoSe 06456	75.31	62.46	68.89	17.06
CoS 08272	78.06	59.73	68.90	23.48
CoS 10239	77.04	62.21	69.63	19.25
CoS 09240	76.52	61.24	68.88	19.97
CD (P=0.05)	5.26	3.28	-	-

Source: Singh et al. (2017)

5. Optimum Planting Season of Sugarcane

Optimum time of planting of sugarcane in different agro-climatic zones is one of the most important factor that provide the favourable environment to achieve higher sugarcane and sugar yields. Sugarcane crop goes through four phases *viz*., germination, tillering, elongation and maturity. The distinct environmental conditions for different phases are given below in Table 9.

Table 9: Crop growth phase of sugarcane with distinct environmental conditions.

Crop stage /phase	Temperature		Climatic conditions
	Maximum	Minimum	
Germination	30^0 C	16^0 C	Optimum temperature and humidity
Tillering	40-45^0 C	25^0 C	High temperature and low humidity
Elongation/grand growth	35- 38^0 C	22^0 C	High temperature and high humidity
Maturity /sugar accumulation	26^0 C	7-10^0 C	Low temperature and low humidity

Keeping above thermal regimes in view in subtropical India, sugarcane is planted in autumn (October), spring (February–March) and summer (April-May) seasons. Delay in planting during autumn season reduces the germination because of low temperature during winter months. Spring season is favourable and delay in planting after March, poses crop through high temperature regimes during germination phase. Irrigation water requirement increases and weed management during germination phase becomes critical problem. Besides, tillering period of sugarcane is also reduced which it affects sugarcane productivity adversely. Thus planting time may be a non monetary input but affects crop productivity and farmers' income in a big way.

Delay in planting within each season, also effects sugarcane productivity. Delay in planting during autumn season delays germination of sugarcane because of low temperature. In this connection, sometimes November planting crop may behave like February planted crop because of the poor germination in earlier case. February planting crop goes through optimum temperature and buds get sprouted faster. Sometimes delay in planting after 15th April may cause one tonne reduction in cane yield /ha by each day delay up to 10th May in subtropical India.

Thus, any deviation in optimum planting time may results in drastic yield reduction in sugarcane crop due to poor germination/tillering/growth and reduced period for sucrose accumulation. The sugarcane crop requires 10-18 months to attain its maturity in different agro-climatic conditions of India. However, 12 month crop duration is the most common in north India. In Peninsular India, planting is done in the months of January-February. Spring crop is also known as *Suru* in Maharashtra and *Eksali* in Gujarat and Andhra Pradesh. Autumn planting in sub-tropical India is done during October. This is also known as pre-seasonal planting in Maharashtra and Gujarat. The pre-seasonal crop matures in 13-15 months and sugarcane is supplied during early crushing period. Early crop also fetches higher prices. *Adsali* planting is preferred in Maharashtra and Karnataka and planting is done during July to August and crop matures in 16-18 months. The biggest advantage of *Adsali* crop is that it passes through only one summer season. In the present scenario, the area under *Adsali* planting is declining because of less availability of irrigation water. The appropriate time of planting in different agro climatic zones has been given in Table 10.

Table 10: Sugarcane planting seasons in India

Sl. No.	Agro-climatic zones	Planting seasons				
		Autumn/ Pre-seasonal	Spring season/ *Suru*	Late spring/ early summer	Early spring planting	*Adsali* planting
1	North West Zone	September to October	February to March	March to April	-	-
2	North Central Zone	October to November	February to March	March to April	-	-
3	North Eastern Zone	February to March	October to November	March to April	Late January to February	-
4	Peninsular Zone	October November	January to February	-	-	July- August
5	East Coast Zone	October to November	2nd fortnight of December to end of February	-	-	2nd fortnight of June to end of July

Source: AICRP (S) Technical Bulletin - No. 1

6. Seed Rate and Planting Material

Higher sugarcane yield can be achieved by increasing the number of mother shoots instead of tillers. Singh et al. (1984) developed a new planting technique i.e. ring system (pit planting method of sugarcane) through which the growth of mother shoot is encouraged and that of tillers is suppressed. They observed almost double cane yield (184 t/ha) to that obtained in conventional flat planting (94.1 t/ha). Thus planting method plays an important role in optimising the cane productivity particularly in sub-tropical India, where germination is a serious problem in sugarcane. Two bud setts were reported to give higher cane and sugar yields when compared with single bud under conventional method of planting due to early vigour, higher cane length and individual cane weight (AICRPS, 2009). The pre- germinated cane settlings can be a good source of planting material to ensure optimum plant population in pit method planting particularly in areas where there is problem of poor germination. A detailed analysis of seed rate in pit has been worked out to find out the economics of seed rate (Table 11).

Table 11: Effect of seed rate/settling density on economic parameters of sugarcane in pit method of planting (mean over 2 years)

Treatment	Cane yield (t/ha)	Cost of cultivation (₹ 000/ha)	Net return (₹ 000/ha)	B:C ratio
18 two bud setts/pit	133.95	107.15	101.5	1.95
21 two bud setts/pit	145.8	112.85	114.05	2.01
24 two bud setts/pit	147.75	116.25	113.8	1.98
24 single bud setts/pit	81.95	89.55	38.05	1.42
30 single bud setts/pit	107.4	98.35	68.95	1.70
36 single bud setts/pit	123.05	104.95	86.65	1.83
42 single bud setts/pit	143.65	112.65	110.95	1.98
18 settlings/pit	134.55	100.5	109	2.08
21 settlings/pit	142.95	103.55	119	2.15
24 settlings/pit	146.25	105.5	122.15	2.16
CD (P=0.05)	4.85			

***Source*: Modified table of Chand et al. (2011)

Marginal differences in cost of production among different planting densities have been attributed to the small variation in cost of seed material with each increment in seed rate and cost on raising pre-germinated cane settlings. Planting of 21 two bud setts was found to give higher net return and B:C ratio. The yield increase in pit methods compensates the extra cost on higher seed rate.

7. Crop Diversification and Intercropping

The slow initial growth and wider row spacing in sugarcane offer great opportunity for generation of mid-season income to farmers by introducing short duration crops as intercrop. This not only generates mid-season income for the marginal farmers to meet the expenses incurred on sugarcane cultivation, but also fulfills the household requirements of food, fibre and oilseed and mitigates the ill-effects of sugarcane monoculture. The inclusion of short duration, high value crops in sugarcane based production system as intercrops such as potato, onion, coriander, mustard, cabbage, etc., holds great promise in increasing the land utilization efficiency, reducing the production cost, economizing the use of market purchased costly inputs and making the system sustainable (Table 12).

Table 12: Crops suitable for intercropping with sugarcane at different locations

Location	Intercrops
Autumn planted sugarcane	
Shahjahanpur	Wheat, *lahi*, pea, potato
Lucknow	Wheat, *toria*, sugarbeet, berseem, onion, lentil, garlic, *kalaunzee*, coriander, pea,potato, rajmash, maize (For cabs)
Pantnagar	Wheat, sugarbeet, lentil, *lahi*
Muzaffarnagar	Pea, gram, sugarbeet
Gorakhpur	Berseem, potato, wheat
Jalandhar	Sugarbeet, wheat, *rayatoria*, potato, maize
Sriganganagar	Sugarbeet
Pusa (Bihar)	Lentil, coriander
Spring planted sugarcane	
Lucknow	Cowpea, moong, urd
Pantnagar	Onion, *moong*, *urd*, soybean, cowpea
Muzaffarnagar	Onion
Pusa (Bihar)	*Moong*
Hisar	*Moong*
Coimbatore	*Moong*
Anakapalle	*Urd*, *moong*, soybean, cowpea
Parbhani	Guar, cowpea
Sameerwadi	*Moong*, onion, ground nut
Padegaon	Onion, lucerne, berseem

Selection of an appropriate intercrop variety as a component of cropping system acts as non-monetary input and net profit could be increased without influencing the cost of production. Due to wide spacing and initially slow growing nature of sugarcane, it lends ample scope for intercropping with short duration, mid season income generating crops to provide house hold economic security to the cane growers. Intercropping plays an important role in promoting autumn planting of sugarcane in sub tropical zone of India which provides additional income to farmers besides enhancing cane yield by 15-20 per cent and sugar recovery by 0.5 unit than spring planted cane.

Inter crops are successfully taken with sugarcane due to its wide spacing and long duration. These intercrops raised with autumn and spring cane provides an opportunity to the farmers to earn additional income from the sale of intercrops. At IISR, Lucknow several profitable sugarcane based intercropping systems have been evaluated. The crop diversification option through prominent intercropping systems generates ample opportunities in employment generation in sugarcane farming. Hence, selection of appropriate crop with their economic impact should be considered in achieving high benefit cost ratio. Suitable intercrops in different planting seasons and B:C ratio obtained through intercropping of various pulses has been given in Table 13. Intercropping of Rajmash in autumn planted cane showed the highest B:C ratio (2.54), showing the profitability of taking intercrop.

Table 13: Intercropping of sugarcane with pulses

Intercropping system	Benefit : cost ratio
In autumn planted sugarcane	
Rajmash	2.54
Lentil	1.73
In spring planted sugarcane	
Cowpea	1.48
Mungbean	1.38
In winter initiated ratoon	
Berseem	2.43
Shaftal	2.35
Lucerne	1.96

Source : *Technorama* IISR (2014)

A field demonstration on intercropping of autumn and spring sugarcane was conducted at farmer's fields in Sitapur and Lakhimpur Kheri districts of U.P. covering 20 ha area. The data presented in Table 14 shown that the highest net profit of ₹388250/ha was earned in case of potato grown as intercrop with sugarcane. The net profit for all intercrops was much higher than the profit recorded with sole sugarcane crops.

Table 14: Economic analysis of intercropping with sugarcane at ICAR-IISR, Lucknow

Cropping system	Yield t/ha		Net profit ₹ /ha	% increase in profit	B:C ratio
	Cane	Intercrop			
Sugarcane + Vegetable pea	90	7.5	307500	141.2	3.6
Sugarcane + Potato	85	29.0	388250	204.5	4.2
Sugarcane + Lentil	84	1.5	225000	76.5	2.9
Sugarcane + Chick pea	82	1.95	228400	79.1	2.9
Sugarcane + Mustard	83	1.60	210550	65.4	2.8
Sugarcane + Maize	80	1.5	164000	68.6	2.4
Sugarcane + Ground nut	84	1.6	201000	57.7	2.7
Sugarcane + Pigeon pea	81	2.0	243250	90.8	3.0

Source : IISR- Annual report 2017-18.

Sugarcane + Potato

- Seed rate: Sugarcane- 60 q/ha, Potato-25 q/ha
- 1:2 row ratio, sugarcane planted at 90 cm and two rows of potato are accommodated at 30 cm spacing.
- Weed control through Simazine @ 1 kg a.i./ha as pre-emergence followed by hoeing and earthing up at 30 and 50 DAP respectively.
- Apply N:P:K fertilizers for sugarcane @ 150:60:60, for Potato @ 120px:80:100.

Sugarcane + Rajmash

- Seed rate: Sugarcane- 60 q/ha, rajmash- 80 kg/ha
- 1:2 row ratio, sugarcane planted at 90 cm accommodating two rows of rajmash at 30 cm spacing
- Apply N:P:K fertilizers for sugarcane @ 150:60:60, for rajmash @ 80:40:30.
- Control weeds through Pendimethalin as pre-emergence @ 2 kg a.i./ha followed by 2 to 3 hoeing after harvest of rajmash.

Sugarcane + Mustard

- Seed rate: Sugarcane: 60 q/ha, mustard: 5 kg /ha
- 1:2 row ratio, sugarcane planted at 90 cm and two rows of mustard accommodated at 30 cm spacing
- Apply N:P:K fertilizers for sugarcane @ 150:60:60, for mustard @ 30:20:0.
- Control weeds through Pendimethalin @ 2 kg a.i./ha as preemergence followed by two hoeing at 30 and 60 days after harvest of mustard.

Saini et al (2003) conducted a field experiment consecutively for three years (1996-99) at P.A.U. Sugarcane Research Station, Jalandhar to study the relative performance of different vegetable crops *viz*., pea, radish, palak and turnip as double row intercropped in the autumn planted sugarcane. A perusal of the data on economics presented in Table 15 revealed higher cane equivalent yield in all the intercropping systems than pure cane. However, accounting the cost incurred for raising pure crop of sugarcane and intercrops revealed that intercropping of peas in autumn sugarcane gave the highest net profit (50%) over sole sugarcane followed by (47.9%) cane+radish. Hence, an additional income of more than 50% was obtained due to peas intercropping. The additional profit of 47.9% and 37.2% was observed due to intercropping of radish and *Palak*, respectively. The intercropping of turnip was not at all profitable rather there was a loss of 4.7% as compared to sole sugarcane crop.

Table 15: Economics of intercropping systems (mean over 3 years)

Treatments	Cane yield (t/ha)	Intercrop yield (t/ha)	cane equivalent yield (t/ha)	B:C ratio	% Net Profit over sole crop
Sugarcane sole	75.2	-	-	1.36	0.0
Sugarcane + Peas (Two Rows)	75.3	62.9	103.4	1.40	50.1
Sugarcane + Palak (Two Rows)	66.5	193.4	98.7	1.38	37.2
Sugarcane + Radish (Two Rows)	71.4	231.4	97.1	1.43	47.9
Sugarcane + Turnip (Two Rows)	69.6	160.1	87.3	1.28	-4.7

***Source*:** Modified from Saini et al. (2003)

Technological package for sugarcane intercropping with vegetable pea at Jalandhar (Punjab)

- Seed rate: Sugarcane: 60 q/ha, pea: 55 kg /ha.
- Plant sugarcane in the first week of October in rows 90 cm.
- Sow two rows of peas with variety Bonneville in between two rows of sugarcane.
- Supply with recommended dose of fertilizers i.e. 225 kg N/ha to the main sugarcane crop only while P and K are not required as soil was sufficient in these two nutrients.
- The intercrops pea was supplied with 35 kg N and 40 kg P_20_5.

Thirumurugan et al. (2011) observed that intercropping black gram with sugarcane increased the sugarcane yield (Table 16) due to better nodulation in legume crops. Fixation of nitrogen in soil is also made available to sugarcane crop over and above applied nitrogen. Hence, the intercropping with pulses irrespective of crop geometry had significant effect over sole planting of sugarcane. However, among all the treatments, conventional two bud setts planted on one side of ridges + black gram on other side of ridges recorded the highest cane yield and reduced the incidence of shoot borer also. Sugarcane intercropping with black gram reduced the shoot borer incidence in all the treatments due to manipulations in the rhizospheric environment through intercrop as a non host crops acted as physical barrier for shoot borer. Moreover, cultivation of sugarcane with intercrop with optimum planting geometry reduced the fertilizer requirement and increased the profitability.

Table 16: Effect of planting geometry cum methods on incidence of shoot borer and yield of sugarcane

Treatments	Cumulative shoot borer incidence (%)	Sugarcane yield (t/ha)
Single bud raised bed seedlings transplanted in furrow + black gram on ridges	31.07	58.77
Single bud polybag seedlings transplanted in furrow + black gram on ridges	22.94	81.46
Single bud raised bed seedlings transplanted on one side of ridges + black gram on other side of ridges	30.20	61.20
Single bud polybag seedlings transplanted on one side of ridges + black gram on other side of ridges	22.87	84.24
Conventional two budded setts planted in furrows	23.55	98.35
Conventional two budded setts planted on one side of ridges + black gram on other side of ridges	21.32	107.25
CD(=0.05)	9.11	10.55

Source: Thirumurugan et al. (2011)

Diversification of sugarcane-based production system is one of the strongest incentive to reduce negative on and off site impacts of its monoculture. Intercropping of short-duration dual-purpose legume would bring temporal and spatial diversity in sugarcane. *In situ* incorporation of intercrop residues would add and maintain soil carbon for improving soil quality and consequently its productivity. Singh et al. (2005) condcuted an experiment on intercropped dual-purpose legumes in spring sugarcane (plant) - ratoon system during 1997-98 to 1999-2000 at the Indian Institute of Sugarcane Research, Lucknow (Table 17). The yield of sugarcane (67.01 t/ha) intercropped with cowpea [*Vigna unguiculata* (L.) Walp. and green gram (*Phaseolus radiatus* L.) was comparable to that intercropped with sesbania for green-manuring (72.18 tonnes/ha). Significantly, the highest cane-equivalent yield (80.3 tonnes/ha), sugar-equivalent yield (9.47 tonnes/ha), net monetary return (₹ 33,341/ha) and nitrogen addition (71.6 kg/ha) to the soil through incorporation of green biomass were recorded with sugarcane + cowpea intercropping system. Population density (125%) gave significantly higher sugracane yield (73.7 tonnes/ha) and sugarcane-equivalent yield (78.7 tonnes/ha). Sugarcane + cowpea intercropping system proved highly productive and most economical.

Table 17: Intercropped dual-purpose legumes in spring sugarcane plant-ratoon system

Treatments	Cane yield (t/ha)	Intercrop yield (kg/ha)	Cultivation Cost (₹/ha)	Net returns (₹/ha)	B:C ratio
Cropping system					
Sugarcane sole	73.52		23057	31357	1.36
Sugarcane + cowpea	67.01	1946	26048	33341	1.28
Sugarcane + green gram	68.49	533	26270	32838	1.25
Sugarcane + Dhaincha	72.18		23050	30656	1.33
CD (P=0.05)	5.34				

Source: Modified from Singh et al. (2005)

Field experiments were also conducted by Singh et al. (2007) during 2000-01 and 2001-02 at Lucknow to study the effect of berseem [*Trifolium alexandrinum* (L.) Juslen.] and senji (*Melilotus* sp.) intercropping on profitability of winter initiated sugarcane ratoon. Ratoon cane + berseem system fetched the highest net return (₹ 64,191 /ha), and B:C ratio (2.93), followed by ratoon cane + senji (Table 18). Application of 125% RDN proved more profitable (₹ 60,041/ha). The ratoon cane + berseem intercropping system supplied with 125% RDN gave the highest net returns (₹ 71,570/ ha) and benefit: cost ratio (3.13). The profitability of the ratoon cane + berseem intercropping system at recommended dose of fertilizer N was higher compared to ratoon cane + senji at 25% higher N level. However, the ratoon cane + senji intercropping system fetched higher profit than sole ratoon cane. It was concluded that intercropping of winter-initiated ratoon with berseem holds promise in realizing higher cane productivity, especially from early-maturing sugarcane varieties. Further, winter-initiated ratoon requires 25% higher N than recommended to maintain higher level of productivity and profitability.

Table 18: Net return and benefit: cost ratio of winter-initiated ratoon-based inter cropping systems

Treatment	**Net returns at N levels**			
Ratoon sole	Control	Recommended N	125% RDN	75% RDN
Cost of cultivation (x 10^3 ₹/ha)	17911	19901	20379	19423
Net return (₹/ha)	30731	44211	47613	45165
B:C ratio	1.72	2.22	2.34	2.33
Ratoon cane + berseem				
Cost of cultivation (₹/ha)	20500	22412	22890	21934
Net return (₹/ha)	54424	67336	71570	63433
B:C ratio	2.65	3	3.13	2.89
Ratoon cane + senji				
Cost of cultivation (₹/ha)	19550	21462	21940	20948
Net return (₹/ha)	44644	56990	60939	52163
B:C ratio	2.25	2.66	2.78	2.49

Source: Singh et al. (2007)

8. Nutrient Management

All the primary, secondary and micronutrients are essential for optimum growth and yield of sugarcane. The requirement and contribution of plant nutrients in productivity of sugarcane may vary due to variations in inherent fertility and texture of soil besides crop duration. Low cost technologies emphasized selection of right source, application of nutrients at right rate, right time and right places (4R). The importance of effectiveness of 4R in sugarcane cultivation has been explained by Patil et al. (2016) is given here:

Right sources

The right sources could be chemical fertilizers, farm yard manure, compost, cake and biofertilizers to supply the essential nutrients. Different types of manures have been applied on fields for maintaining soil fertility and crop yield stability. Devi et al. (2012) based on three years of experimentation reported that diammonium phosphate (DAP) yielding 97.9 t/ha proved to be superior to single super phosphate (SSP) yielding 95.8 t/ha. This could be due to higher percentage of germination and initial vigour of the cane plants that leads to an even higher number of millable canes at the harvest with the application of DAP as source of phosphorus. Application of ammonium sulphate as source of nitrogen and sulphur has been found superior to urea. Shukla and lal (2007) also showed superiority of elemental S as compound to SSP and gypsum at IISR Lucknow.

Right Rate

Gopalasundaram et al. (2012) reported that nutrient requirement varied with varietal selection. Besides common farmer fertilization practice, other practices are based on state recommendation, a soil test-based recommendation, a recommendation based on tissue analysis, and a determination via site-specific nutrient management through omission plot techniques (Patil et al. 2016). The state fertilizer recommendations for sugarcane in the major sugarcane growing states of India vary across states depending on the soil type, crop duration, yield level, and irrigated or rain-fed conditions. The recommended rates ranged from 70 to 400 kg N, 0 to 80 kg P_2O_5, and 0 to 141 kg K_2O/ha (Singh and Yadav 1996). The fertilizer rates recommended are generally higher in tropical states compared to subtropical states. Saini et al. (2006) also reported that application of nutrients up to 400 kg N, 170 kg P_2O_5, and 180 to 190 kg K_2O/ha are recommended for sugarcane depending upon its duration and fertility status of the soil. In several experiments, applied P did not influence yield or quality of sugarcane ratoon to an appreciable extent. This was due to the fact that in most of the cases the soils were high in available P status (Gopalasundaram et al. 2012). However, the need for phosphate application ranging from 30 to 100 kg P_2O_5 /ha has been reported to maintain productivity. In general, and as observed at Mandya (Karnataka), pockets of Haryana, and Jalandhar and Kheri in Punjab, a ratoon crop is relatively more responsive to P application than a plant crop (Gopalasundaram et al. 2012). Based on a critical review of the response of sugarcane to K fertilizers, Verma (2004) recommended application of 50 to 200 kg K_2O/ha in tropical states where significant response is observed, but responses were very limited in subtropical states. However, application of 66 kg K_2O/ha with irrigation water in standing plant cane improved bud sprouting, dry matter accumulation, and nutrient uptake in following ratoon crop (Shukla et al. 2009). Phonde et al. (2005) reported that site-specific nutrient management produced significantly higher yields compared to a generalized state recommendation, a state laboratory soil test-based recommendation, and farmer practice. Sugarcane yield was significantly influenced by application of both P and K. Yields produced with 0 and 60 kg P_2O_5 /ha were 125 and 130 t/ha, respectively. The cane yield response to 0, 60, and 120 kg K_2O/ha appeared to be linear, suggesting that even greater productivity may be achieved under K application rates beyond 120 kg K_2O/ha. Application of nutrients should be done on the basis of nutrient stokes of that field. Soil texture, crop and cropping system affect the rate of nutrient application. In this direction, soil health cards developed by State/Extension agencies are helpful to farmers. Farmers should apply the right dose of nutrients. Extra application may not be beneficial and sometimes it may invite the insect-pests & disease incidence more and affects the juice quality and crop yield adversely.

Right Time

The timing of fertilizer application assumes great significance in maximizing the benefits. Application of N fertilizer after completion of tillering phase in sugarcane did not result in yield or sugar increase. In drip system also, fertigation during the tillering phase through 12-15 split doses gave better results. However, in normal irrigated condition, application of N in 3-4 split doses produced better results. Nitrogen initiates tillering in sugarcane and increases earlier formed tillers. The vigorous growth of mother shoots and primary and secondary tillers converted in millable canes may be observed. Many times tertiary tillers are not able to become millable canes and growth of tertiary tillers at the cost of primary and secondary tillers is waste. Late application of nitrogen encourages the growth of tertiary tillers. The nutrient application timing should match the nutrient demand of high-yielding varieties throughout the season. In Belguam district of Karnataka, a study was conducted to understand the effect of fertigation on yield and quality of sugarcane in a medium-black soil. The results showed that application of N and K at a recommended rate at six day intervals through drip irrigation, starting from 30 days after planting (DAP) to 240 DAP produced 25% higher yield and saved 46% of the water applied. This was compared to the recommended fertilizer rate applied with surface irrigation. In this study, N and K were applied at recommended rates of 250 and 185 kg/ha, respectively (Rajanna and Patil 2003). Another study conducted at Coimbatore, Tamil Nadu, found that an application of urea under a fertigation schedule starting from day 15 day to 180 day (at a fortnightly interval, reduced volatilization and leaching losses and increased N use efficiency in sugarcane ratoon crops follow a plant crop or the preceding ratoon on the same soil (Hemalatha and Chellamuthu 2013). Due to the impoverished physical soil conditions and relatively poor root system, absorption of nutrients by the ratoon cane may be negatively affected. Therefore, it is necessary that ratoons are given adequate quantities of manures and fertilizers to result in higher yields. Several experiments proved the need for early fertilizer application to ratoon sugarcane (Gopalasundaram et al. 2012). For ratoon crop, N fertilizers may be applied in two or three splits. Even in cases of split application, a third to half of the N dose should be applied immediately at the time of ratoon initiation to ensure the adequate amount of available N in the soil to overcome the temporary immobilization of N due to microbial activity on the decomposing stubble. A full dose of P should be applied at the same time as the first dose of N application at ratoon initiation. Compared to a planted crop, a ratoon crop requires more N to produce 1 t of cane because of poor nutrient use efficiency. Response to a higher level of N application in the ratoon crop has been reported from all the sugarcane-growing states. It has been found that ratoon crops generally need 25 to 50% more N than the plant cane. Application of 25% higher N at five to seven days after the ratoon initiation operation produced the highest cane and sugar yields in Tamil Nadu (Mahendran et al. 1995). The yield response to applied N, at the recommended dose for ratoon sugarcane, was reported by Verma (2004) as given in Table 19.

Table 19: Yield response to recommended in sugarcane ratoon applied N at various locations

Location	Cane yield response per kg N applied
Anakapalle	254 kg
Kanpur	215 kg
Shahjahanpur	160 kg
Muzaffarnagar	160 kg
Mandya	136 kg
Lucknow	120 kg
Jalandhar	119 kg

Right Place

Solubility and mobility of nutrients applied in soil varies greatly with nature of elements, soil type, cropping system followed. Nitrogen is more mobile in soil and application on soil surface reaches to the root zone for absorption by roots. However, P and K fixation occurs and must be applied in root zone for higher availability. Band placement of P and K fertilizers or basal application during the planting in furrows below the seed cane is recommended to improve their use efficiencies. The adoption of the proper method of fertilizer application is essential to minimize the loss of nutrients from the soil and to increase fertilizer use efficiency. Besides increasing cane yield, proper placement also reduces volatilization loss of nitrogenous fertilizers and prevents the fixation of phosphatic fertilizers. Placement can be done at 8 to 10 cm deep furrows on either side of the cane rows using implements, placing the fertilizers in the furrows, and then covering them. Nitrogen flux pathways in the soil are beneficially influenced by management techniques such as mounding of the rows, subsurface banding in narrow fertilizer bands, reduced fertilizer rates, and trash retention along with the timing of fertilizer application. These techniques help the coincide with the optimum uptake by the plant (Reghenzani et al. 1996). Foliar feeding of N for sugarcane is a well-recognized technique. Foliar application is the best used when there are adverse soil moisture conditions, such as waterlogging and limited water supply situations. The use efficiency of foliar applied N could be as high as 90 to 95% (Singh and Yadav 1996). Foliar application of urea with potash during the formative phase (2.5% each of urea and KCl at 60, 90, and 120 DAP) was found to be beneficial when moisture was limiting. This method can increase cane yield by 19% over the control. Soil application of 75% K and foliar application of the remaining 25% at 90 DAP was found beneficial in Kerala where soils are K deficient (Mathew et al, 2004). Fertigation is another method of nutrient application, considered very effective for sugarcane. Fertigation enables adequate supplies of water and nutrients with precise timing and uniform distribution to meet the crop nutrient demand. Fertigation can be a more efficient means of applying crop nutrients, particularly N and K as compared to surface application (Bharadwaj et al. 2007; Hemalatha and Chellamuthu 2013). Several studies reported that drip irrigation can increase the sugarcane yield from 111 to 150 t/ha in Tamil Nadu, while keeping the fertilizer application rates the same (Bharadwaj et al. 2007). Bangar and Chaudhuri (2004) also reported that application of fertilizers through drip irrigation resulted in significant increase in cane yield (28%) and water use efficiency (114%) over the surface irrigation method. Pawar et al. (2013) reported that 100% drip fertigation showed 42% increase in yield. Yield increased up to 25% (about 166 t/ha) by applying only N through drip against the conventional method (133 t/ha). Fertigation also resulted in saving 40% of the fertilizer (Hemalatha and Chellamuthu, 2013).

9. Integrated Nutrient Management

Judicious application of organic and inorganic sources of nutrients is one of the crucial factors to enhance the sugarcane productivity. Several experts have reported that nutrient utilization efficiency of the sugarcane is increased due to integrated application of different nutrient sources. Organics improve the physical condition of soil and soil microbial activities by increasing the population of beneficial macro and micro organisms. These organisms help enhance availability of nutrients to plant and reduce the losses of these nutrients through other means. The Results of 21 AICRP (S) centres in five different zones revealed that application of FYM /Compost @ 20 tonnes/ha + inorganic nutrient application based on soil test (rating chart) recorded the highest sugarcane and CCS yields in North West zone, Peninsular zone and North central zone . However, application of FYM/Compost @ 10 tonnes / ha + biofertilizer + Non-soil test basis recorded the highest sugarcane and CCS yields in North East and East coast zones. However, both the treatments were found at par to each other and were significantly superior to other treatments involving trash application (Table 20).

Table 20: Effect of integrated application of organics and inorganics on cane yield (t/ha)

Treatment	North West Zone	Peninsular Zone	North Central Zone	North East Zone	East Coast Zone
Trash @ 10 tonnes/ha + 50% RDF	59.05	71.33	37.3	42.30	66.63
Trash @ 10 tonnes/ha + 100% RDF	73.36	83.24	61.8	46.50	87.40
Trash @ 10 tonnes/ha + soil test based recommendation	75.10	87.07	64.2	48.00	89.83
FYM/Compost @ 20tonnes/ha +50% RDF (inorganic source)	68.73	87.50	61.9	49.75	81.10
FYM/Compost @ 20 tonnes / ha +100% RDF (inorganic source).	80.69	89.86	79	53.70	94.73
FYM/Compost @ 20 tonnes / ha + inorganic nutrient based on STRC	85.21	99.27	80.2	55.35	96.23
FYM/Compost @ 10 tonnes / ha + biofertilizer + 50% RDF.	66.56	84.06	54.8	51.55	87.47
FYM/Compost @ 10 tonnes / ha + biofertilizer + 100% RDF.	78.80	93.23	72.2	58.65	100.30
FYM/Compost @ 10 tonnes / ha + biofertilizer + soil test basis.	82.81	92.57	71.4	60.35	100.83
CV(%)	8.02	7.98	14.9	3.81	11.65
SE(d)	2.99	3.76	5.6	1.974	8.50
LSD at 5%	5.99	7.51	16.8	4.5525	18.03

***Source*:** AICRP Annual report (2017)

There is a great need for nutrient replenishment through addition of organic material along with inorganic fertilizers to achieve higher yields in plant and subsequent ratoon crops without deterioration of soil health. Organic wastes are considered as a rich source of macro and micronutrients. The huge quantity of pressmud and spent wash are being generated from Indian sugar mills and distilleries. The bio-compost is prepared by the decomposition of pressmud and spent wash in ratio of 1:3 using *Trichoderma viride* as decomposer. Bio-compost is an easily biodegradable source of organic matter rich in plant nutrients. The integrated use of organic and inorganic plant nutrient sources not only recycles organic waste but also conserves rich pool of nutrients resources, which can reduce the sole dependence on chemical fertilizers. The effect of integration of nutrient sources on cane yield (plant and ratoon) reported by Sinha et al. (2017) revealed that integrated use of 50% N through Bio-compost + 50% N through inorganic fertilizer in sugarcane plant crop was found suitable for obtaining higher cane and sugar yield of sugarcane (plant)-ratoon system resulting in saving of 50% N (Table 21). Other cellulose decomposers are available in the market.

Table 21: Effect of bio-compost on yield of sugarcane (plant)–ratoon system (pooled over 3 years)

Treatments	Yield (t/ha)		
	Plant	Ratoon	Mean yield
Control (No NPK)	48.00	43.13	45.6
RDF (100% NPK)	58.70	55.40	57.1
25% N, BC + 75% N, IF	68.90	63.80	66.4
50% N, BC+50% N, IF	74.14	69.70	71.9
75% N, BC+25% N, IF	69.70	66.25	68.0
100% N, BC	58.80	63.23	61.0
125 % N, BC	59.90	64.87	62.4
150% N, BC	61.60	65.25	63.4
CD (P = 0.05)	9.69	8.11	8.90

Source : Sinha et al. (2017) IF = Inorganic fertilizers; BC =Bio compost

Virdia and Patel (2010) reported that integrated nutrient application had significant impact on number of cane yield. Among the treatments tested, RDF along with 25% additional dose of N through FYM + bio-fertilizer application to sugarcane plant crop increased cane yield (92.3 t/ha) followed by RDF along with trash incorporation and bio-fertilizer application in ratoon crop (73.1t/ha). The net profit due to additional application of FYM, TICC and biofertilizers over RDF application was worked out (Table 22). Net return due to application of these bio-products could be increased by Rs. 31100/ha.

Table 22: Effect of integrated nutrient management on cane yield (t/ha) of plant and ratoon sugarcane crop (pooled over 3 years).

Nutrient management		Cane yield (t /ha)	
Plant crop	**Ratoon crop**	**Plant crop**	**Ratoon crop**
RDF	RDF	87.2	63.5
75% RDF + 25% N as FYM	RDF + TICC	81.3	64.0
75% RDF + 25% N as (PM)	RDF + TICCC	80.3	62.7
RDF	75% RDF + GM	87.8	58.6
50% RDF + 25% N as VC + BF	75% RDF + 25% N as VC + BF	78.8	62.2
100% RDF + 25% N as FYM + BF	RDF + TICC + BF	92.3	73.1
CD (P=0.05)	CD (P=0.05)	5.6	5.4
Additional cane yield due to 100% RDF + 25% N as FYM + BF in plant and RDF + TICC + BF in ratoon as compare to RDF only (5.1+9.6=14.7 t/ha)		5.1	9.6
Additional return due to 25% N as FYM + BF in plant and TCCC + BF in ratoon=(14.7 t/ha x ₹ 3000/t =44100)			44100
Cost incurred for 25% N as FYM + BF in plant &TCCC + BF in ratoon (₹10000/ha			10000
Net return due to FYM, TICC and biofertilizers application rupee per hectare			31100

Source: Virdia and Patel (2010) Bio-fertilizer (BF), Vermicompost (VC), Pressmud (PM)

Another experiment was carried out by Umesh et al. (2013) on the integrated use of chemical fertilizer with organic manures also showed improvement in sugarcane and sugar yields besides soil fertility. Thus, integrated use of organic and inorganic fertilizer not only sustained soil and crop productivity but also improved soil health and prevents emergence of multiple nutrients deficiencies in the system (Table 23).

Table 23: Long term integrated use of inorganic fertilizers and organics on yield of sugarcane

Treatments	Sugarcane yield (t/ha)
$N_{50}P_{100}K_{100}$	47.0
$N_{100}P_{100}K_{100}$	57.0
$N_{50}P_{100}K_{100}$ + 20t Biogas Slurry	56.2
$N_{100}P_{100}K_{100}$ + 20 t Biogas Slurry	70.2
$N_{50}P_{100}K_{100}$ + Green Manure (Moong)	55.4
$N_{100}P_{100}K_{100}$ + Green Manure (Moong)	62.5
$N_{50}P_{100}K_{100}$ + 10 t Sugarcane Trash + 10t sulphitated pressmud	59.3
$N_{100}P_{100}K_{100}$ + 10 t Sugarcane Trash + 10t sulphitated pressmud	65.9
C.D. (P = 0.05)	5.2

Source : Umesh et al. (2013)

10. Biofertilizers

Bio-fertilizers are one of the eco-friendly sources of plant nutrient, used for replacing conventional synthetic fertilizers and play an important role in low cost agriculture. The cost of biofertilizers is minimum as compared to other inputs used as source of nutrients in enhancing productivity of crop. Bio-fertilizer usually contains living microorganisms that enhances the supply of essential nutrients to the host plants. Biofertilizers help in maintaining soil fertility for longer time without affecting environment quality. Several experiments have been carried out at different locations showed role of different N and P fixers in sugarcane based system.

Shukla and Yadav (2011) at IISR, Lucknow reported that application of PSB + PMC improved the ratoon cane yield and commercial cane sugar yield (Table 24). The highest cane (67.86 t/ha) and commercial cane sugar yields (8.01 tonnes/ ha) was obtained with PSB+ PMC. Application of PSB + PMC moderately increased shoot population density in ratoon cane. It facilitated crop establishment with production of greater number of primary shoots. The higher number of millable canes in ratoon was counted with application of PSB + PMC. It was due to vigorous tillers formed in ratoon cane that contributed larger share in millable cane formation as compared to the control. Ratoon yield improved by 15.86% with application of PSB + PMC over the control.

Table 24: Additional (add.) effect of biofertilizers (Bio.) and Press mud cake (PMC) over farmers practices

Treatments	Cane yield (t/ha)	Additional Cane yield (t/ha)	Add. Cost of Bio. + PMC (₹/ha)	Additional return (₹/ha)	Additional B: C ratio
Control (Farmer's practices)	58.57	0	0	0	0
Trichoderma +PMC	63.27	4.7	6000	14100	2.4
Gluconacetobacter +PMC	62.63	4.06	6000	12180	2.0
PSB+PMC	67.86	9.29	6000	27870	4.6

Source: Shukla and Yadav (2011)

Tomar et al. (1994) also reported positive effect of PSB with 60 kg P_2O_5/ha on sugarcane yield and net return. Application of 60 kg P_2O_5/ha alongwith PSB increased the cane yield up to 77.0 t/ha as compared to without PSB (70.46 t/ha). Application of PSB fetched net sugarcane yield (6.54 t/ha) and improved B:C ratio up to 19.6 with additional PSB application due to lower cost of treatments (Table 25).

Table 25: Effect of PSB at various level of Phosphorus on the yield of sugarcane

P_2O_5 doses	With PSB yield (t/ha)	Without PSB yield (t/ha)	Increase in yield due to PSB (t/ha)	Addition cost of PSB (₹/ha)	Additional returns due to PSB (₹/ha)	Additional B:C ratio due to PSB
0	65.98	61.66	4.32	1000	12960	13.0
40	68.08	65.45	2.63	1000	7890	7.9
60	**77.00**	70.46	6.54	1000	19620	19.6
80	80.10	74.00	6.1	1000	18300	18.3
100	85.30	78.60	6.7	1000	20100	20.1
120	88.40	83.40	5.0	1000	15000	15.0

Source **:** Modified table of Tomar et al. (1994)

a. *Trichoderma* inoculated trash, nitrogen level and biofertilizer on sugarcane

Field experiments were conducted during 2006-07 to 2008-09 at Sugarcane Research Institute, Pusa, Bihar to study the effect of *Trichoderma* inoculated trash, nitrogen level and biofertilizer on yield, nutrient uptake, juice quality of sugarcane (*Saccharum officinarum* L.) and soil nutrient availability in calciorthents. Trash was inoculated with *Trichoderma viride* @ 500 g/t, one week before planting and applied @ 10 t/ha alone or in conjunction with different levels of N (75,112.5 and 150 kg/ha). Application of trash alone increased the mean cane yield by 1.8% over the control (45.4 t/ha). Application of N doses 75,112.5 and 150 kg/ha, increased the cane yield to the tune of 5.5, 3.3 and 0.8%, respectively over sole application of N. Application of trash and biofertilizer along with recommended dose of nitrogen (150 kg/ha) gave the highest net income (₹ 22,832/ha) and B:C ratio (1.43). Hence, application of *Trichoderma* inoculated trash @10 t/ha along with 150 kg N/ha and *Azotobacter* @ 4 kg/ha were found beneficial in enhancing sugarcane yield and getting higher net return (Table 26).

Table 26: Effect of inoculated trash, nitrogen level and biofertilizer on cane and sugar yields (pooled over 3 years)

Treatment	Cane yield (t/ha)	Cultivation cost ($\times10^3$ ₹/ha)	Net return ($\times10^3$ ₹ /ha)	B:C ratio
Control	45.4	51.09	3.39	1.07
Sugarcane trash (ST)	46.2	52.13	2.31	1.06
N_{75}+ ST	54.3	52.77	12.39	1.23
N_{75}+ ST+ *Azotobacter*	55.3	52.97	13.39	1.25
$N_{112.5}$+ ST	58.8	52.09	18.47	1.35
$N_{112.5}$+ ST+ *Azotobacter*	59.7	53.29	18.35	1.34
N_{150}+ ST	63.0	53.41	22.19	1.42
N_{150}+ ST+ *Azotobacter*	63.7	53.61	22.83	1.43
CD (P=0.05)	6.6	-	-	-

Source : Thakur *et al.* (2010)

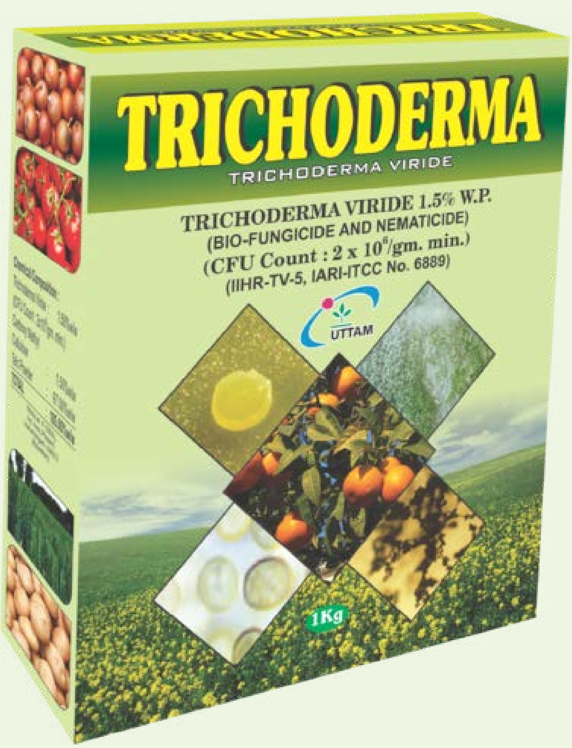
b. Effect of inoculated trash, nitrogen and biofertilizers on sugarcane

A field experiment was conducted during 2005-08 at Lucknow to find out the effect of inoculated trash and nitrogen level through organic sources along with biofertilizers on sugarcane ratoon. Application of FYM 10 t/ha + *Trichoderma viride* @ 20kg/ha recorded the highest sugarcane yield (80.2 t/ha) and benefit cost ratio 2.19 (Table 27).

Table 27: Effect of inoculated trash, nitrogen level and biofertilizer on cane yield (pooled over 3 years)

Treatment	Sugarcane cane yield (t/ha)	B:C ratio
Absolute control (No organic /inorganic sources)	47.4	1.53
Control 200kg N /ha	69.4	2.08
FYM 10 t/ha (50 kg N/ha)	73.5	2.03
FYM 10 t/ha +*Trichoderma viride* @ 20kg/ha	80.2	2.19
FYM 10 t/ha + *Gluconacetobacter* @ 12.5kg/ha	76.2	2.08
Trash 7.5 t/ha (18.75 kg N/ha)	67.5	2.04
Trash 7.5 t/ha +*Trichoderma viride* @ 20kg/ha	71.5	2.14
Trash 7.5 t/ha + *Gluconacetobacter* @ 12.5kg/ha	68.5	2.04
CD (P=0.05)	5.6	-

Source : Shukla et al. (2011)



Another field experiment was conducted by Murumkar et al. (2017) during *suru* season (January planting) of 2012–13, 2013–14 and 2014–15 at Central Sugarcane Research Station, Padegaon, Satara (Maharashtra State, India) to study the effect of *G. diazotrophicus* and PSB with varying N and P levels on yield seed cane and possibilities of saving nitrogen and phosphorus doses through inorganic fertilizers. The two bud-setts were dipped in the biofertilizer suspension prepared by mixing of 10 kg *G. diazotrophicus* and 1.25 kg PSB in 100 litres water for 30 min prior to planting (one ha). The economics of *G. diazotrophicus* and PSB sett treatment with varying N and P levels on sugarcane yield of seed cane is given in Table 28. Among the fertilizer levels, 75% of the recommended N and P_2O_5 recorded the highest B:C ratio. The interaction of fertilizer levels and inoculation treatments showed that 75% of recommended N and P_2O_5 coupled with the fresh planting material inoculated with G*luconacetobacter* showed the highest B:C ratio (4.63). Hence, it is recommended to treat the sugarcane setts with 10 kg *Gluconacetobacter diazotrophicus* &1.25 kg PSB in 100 litres water/ha for 30 min before planting for saving of 25% N and 25% P for sugarcane seed plot besides improving seed cane yield.

Table 28: Economics of *G. diazotrophicus* and PSB sett treatment with varying N and P levels on sugarcane seed yield (pooled over 3 seasons)

Nitrogen Phosphorus level & culture	Two bud-sett yield (thousands/ha)	Cost of cultivation (₹ thousand/ha)	Net return (₹ thousand/ha)	B:C ratio
$N_{300} + P_{115} + I_1$	657.1	136.2	337.5	3.48
$N_{300} + P_{115} + I_2$	682.1	136.6	355.2	3.60
$N_{300} + P_{173} + I_1$	704.4	138.4	369.6	3.67
$N_{300} + P_{173} + I_2$	769.8	138.8	416.6	4.00
$N_{300} + P_{230} + I_1$	727.3	140.5	384.1	3.73
$N_{300} + P_{230} + I_2$	764.1	141.0	410.3	3.91
$N_{450} + P_{115} + I_1$	742.0	138.0	397.3	3.88
$N_{450} + P_{115} + I_2$	729.1	138.4	387.5	3.80
$N_{450} + P_{173} + I_1$	758.6	140.1	407.2	3.91
$N_{450} + P_{173} + I_2$	900.7	140.6	509.7	4.63

Source: Murumkar et al. (2017)

I_1 = Planting material from last-year *Gluconacetobactor* inoculated plot

I_2 = Fresh planting material inoculation with *Gluconacetobacter*.

11. Dose and Source of Sulphur in Sugarcane

Now a days deficiency of sulphur is being observed due to use of straight fertilizers and minimal use of organic manures in intensive cropping system. Sulphur is required for synthesis of chlorophyll and is constituent of chlorophyll. The tillering and growth of cane is adversely affected in S deficient soil despite application of NPK fertilizers. Generally in sugarcane crop a dose of 30-40 kg/ha is sufficient to provide the balance and adequate nutrition. Shukla and Lal (2007) also observed the response upto 80 kg S/ha in increasing the ratoon cane yield in sugarcane plant-ratoon-wheat cropping system. Sugarcane in north India responds to sulphur application and higher production from plant as well as ratoon cane is obtained by supplementing sulphur fertilizer. The elemental S resulted in the highest net return and benefit: cost ratio in plant-ratoon system. Higher mean benefit: cost ratio in ratoon cane as compared to plant cane was due to lower cost of production of ratoon that maximized profit. Thus, it could be concluded that application of 80 kg S/ ha improved the yield and net return of sugarcane with almost same level of cost of cultivation. Elemental sulphur appeared to be better than others source of S (Table 29).

Table 29: Influence of different S treatments on economics of sugarcane (plant)-ratoon system (mean over 2 cropping seasons)

Treatment	Plant-ratoon system			
Sulphur dose (kg/ha)	**Cane yield (t/ha)**	**Cultivation cost (₹ /ha)**	**Net return (₹ /ha)**	**B:C ratio**
40	80.80	49810	95284	2.91
60	82.91	50321	103485	3.06
80	91.93	50857	111032	3.18
CD (P=0.05)	4.51	-	-	-
Sulphur source				
Elemental sulphur	86.39	51123	110272	3.16
Single super phosphate	86.22	50523	102161	3.02
Gypsum	83.10	49322	97529	2.91
CD (P=0.05)	NS	-	-	-

Source : Shukla and Lal (2007)

12. Direction of planting

Direction of planting does not involve the monetary cost in the production system. Planting of sugarcane in east west direction (rows) is recommended to trap maximum solar radiation and avoid adverse impact of east west winds. Passage of air in east west winds through rows is allowed and lodging of sugarcane particularly during grand growth phase may be avoided. Besides, incidence of insect-pest & diseases may also be reduced due to maximum photosynthesis and vigour of crop. Additionally, better growth of intercrops/component crop may be obtained when sugar cane is planted in east west direction.

13. Planting Method

An increased plant population density in the form of number of millable canes and individual cane weight per unit area and time are the most important factors deciding higher sugarcane yield. These issues are addressed by improved planting method. Certain modifications over earlier developed trench planting leads to development of modified trench method (MTP) of sugarcane planting ensuring enhanced sugarcane productivity and profitability besides improving sugar recovery (Singh et al. 2012).

The higher margin of profit under modified trench method was virtually due to increase in the production of sugarcane with minimum of 18.72% to the maximum of 27.01% as compared to other planting methods, and thus resulted in a profitable planting method even after slightly higher cost incurred on its cultivation (Table 30). The study thus concluded that the modified trench method of planting offers benefit in terms of producing higher yields of cane and sugar over other conventional methods of planting and that would be worth adopting by farmers for increased sugarcane productivity in sub-tropical India.

Table 30: Comparative benefits of different planting methods (mean over 2 years)

Methods of planting	Sugarcane yield (tonnes/ha)	Cost of cultivation (₹./ha)	Net return (₹/ha)	B:C ratio
Conventional furrow planting at 90 cm apart	94.87	56319	119340	2.10
Deep furrow (20 cm) planting at 90 cm apart covering setts with 2.5 cm of soil layer	99.14	61981	121688	1.94
Paired row furrow planting at 120 : 60:120 cm	97.02	56657	123285	2.15
Paired row deep furrow (20 cm) planting at 120: 60:120 cm covering setts with 2.5 cm of soil layer.	101.23	62301	125354	1.99
Modified trench planting at 120 cm apart placing setts across the furrow and covering them with 2.5 cm of soil layer	120.18	68192	154436	2.23
CD(P=0.05)	4.93	-	-	

Source: Singh et al. (2012)

Furrow irrigated raised bed (FIRB) method of planting:

Manipulation in planting methods may require a machine but sometimes pays more than the investment. Planting of wheat and sugarcane under FIRB (Furrow Irrigated Raised Bed) is the best example in wheat-sugarcane system to improve the crop productivity and farmers income. Sugarcane (plant)-ratoon-wheat is the most prevalent cropping system of north western zone of sub-tropical India. The region comprised Uttar Pradesh, Punjab, Haryana and *Terai* part of Uttarakhand, accounting sugarcane area of more than 8.0 lakh hectares. Due to delayed planting of sugarcane after wheat harvest results in reduction of cane yield to the tune of 30-35% compared to spring season crop. An innovative technology (wheat + sugarcane) in furrow irrigated raised bed system (FIRB) has been developed at Indian Institute of Sugarcane Research, Lucknow to reduce the losses in cane yield under delayed planting by advancing sugarcane planting in standing wheat. In this system wheat is sown on raised beds in the months of October-November and sugarcane is planted in furrows in the month (February-March) in standing wheat crop.

Key features of FIRB are as follows:

- Develop appropriate FIRB configuration (50-30-50) after preparing the field by deep ploughing.
- Sowing 2-3 lines of wheat on each raised bed using 80 kg seed /ha in the month of October-November.
- Apply Chloropyriphos 20 EC @ 5 litres/ha in the furrows before planting of sugarcane to prevent the soil born insects.
- Manual planting of sugarcane in the furrow in the month of February-March just after irrigation in standing wheat crop.
- Apply Atrazine @ 2 kg ai /ha after irrigation in sugarcane to manage the weeds.
- Irrigating the sugarcane crop at 20-25 days interval till onset of monsoon.

Identification of optimum time of planting of sugarcane in furrow irrigated raised bed system is one of the crucial non-monetary input in enhancing the profit of farmers. It is an ideal alternative to minimize the yield loss due to delayed planting of sugarcane in the prevailing wheat-sugarcane sequential system. Under this system of planting, sugarcane yield may be enhanced by 30-35% and full yield of wheat is obtained as in sequential wheat-sugarcane system. Singh et al. *(*2012) found that FIRB method fetched maximum mean net return (₹ 81400 to 83027 /ha) at three locations at Punjab Agricultural University (PAU), Ludhiana at its Regional Research Station, Faridkot and Ladhowal (Fig 1) during autumn 2005–2006 and 2006–2007.

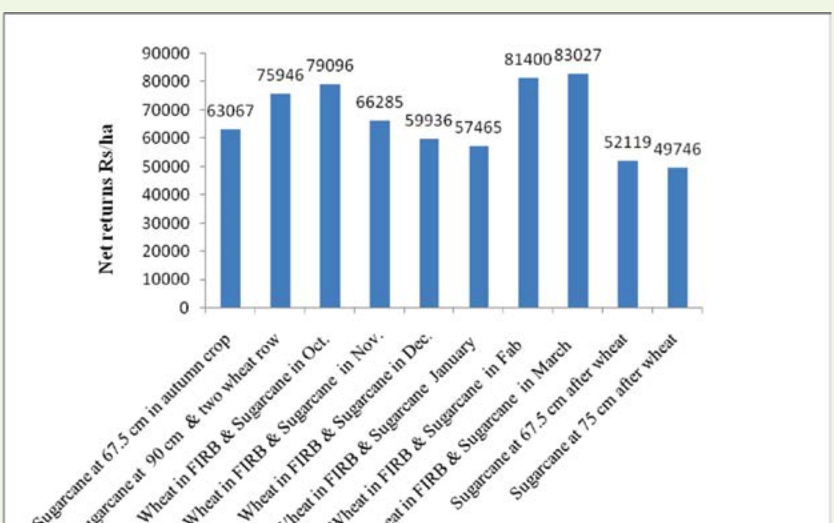


Fig .1 Comparative monetery benefits of FIRB technology over conventional planting

***Source*:** Singh et al. (2012)

Trench method of planting:

This method is spreading fast in sugarcane growing areas of sub-tropics as growers can realise high input use efficiency and it provides ample scope for accommodating inter-crops between sugarcane rows. Sugarcane planting at a depth of 25-30 cm in trench results in higher yield of plant and ratoon crops. Besides, it also avoids crop lodging in multi ratooning system. It also increases water use efficiency, weed control efficiency and nutrient use efficiency. Digging of trench at a depth of 25-30 cm breaks the hard pan in subsoil layer which normally occurrs due to shallow ploughing. It also increases percolation of water in deep layers and facilitates root respiration as well. In this method, trenches of 30 cm wide and 25-30 cm deep are opened at 120 cm centre to centre distance. The sugarcane setts are placed along both the walls of the trench (30:90 cm). This method offers opportunity for mechanized operations requiring less labourers and enhances input use efficiency. Under normal subtropical conditions planting through this method produces cane yield of 110 t/ha with 2.15 benefit cost ratio. Singh et al. (2013) obtained the maximum net return from the trench method with sugarcane and wheat intercropping followed by the conventional (flat) and pit methods (Table 31 & Fig 2).

Fig.2.Trench method of planting

Table 31: Effect of planting method on yield and economics of sugarcane

Planting method	Cane yield (t/ha)	Wheat yield (q/ha)	Cane equivalent yield (t/ha)	Cost of cultivation (₹/ha)	Gross return (₹/ha)	Net returns (₹/ha)
Pit RS	76.7	-	76.7	67675	94837	27163
Pit 2RS	80.4	-	80.4	81455	99547	18092
Flat	59.8	41.1	85.7	55981	105752	49772
Trench	62.9	40.3	88.3	56322	109054	52732
CD (P=0.05)	3.6	-	3.6	-	-	-

Source: Singh et al. (2013)

Another study on planting method was conducted by Bhullar et al. (2008) at Ladhowal (Punjab) on two plant (2004-06) and ratoon (2005-07) crops of sugarcane (*Saccharum* spp.). Three planting methods *viz*., flat (conventional planting in 15 cm deep furrows at 75 cm apart), trench (planting in paired rows on both sides of trench 30 cm wide, 30 cm deep, spaced 120 cm apart) and pit method (60 cm diameter, 45 cm deep, spaced 120 cm apart) along with three seeding rates *viz*., 4.0 t/ha (transplanted), 8.0 t/ha (sett planting, recommended) and 16.0 t/ha (sett planting) were evaluated. In sugarcane plant crop, trench planting with seed rate @ 8.0 t/ha recorded the highest net return (₹ 29,500/ha), whereas conventional method gave the highest benefit: cost ratio (0.56) at the same seed rate (Table 32). The higher cost incurred with sowing in pit method reduced net return compared with other two planting methods. In ratoon crop, trench planting with 16.0 t/ha seed cane recorded the highest net return (₹ 44,800/ha) and B: C ratio (1.74) followed by the same method with 8.0 t/ha seed cane. In sugarcane plant - ratoon system, trench planting with

8.0 t/ha revealed the highest total net return (₹ 73,800/ha) as well as benefit: cost ratio (0.92). Trench transplanting proved economically better than conventional sett planting with recommended seed rate. It was concluded that sugarcane planting in trenches in paired rows with 8.0 t/ha seed could help in achieving the highest productivity and profitability from sugarcane plant-ratoon system. Trench transplanting with 4.0 t/ha seed could be the second best option.

Table 32: Economics of sugarcane plant-ratoon system under different planting methods and seed rates (mean of 2 cropping seasons)

Planting method	Seed rate (t/ha)								
	Plant crop			Ratoon crop			Plant-ratoon system		
Conventional method	**4.0**	**8.0**	**16**	**4.0**	**8.0**	**16**	**4.0**	**8.0**	**16**
Cane yield (t/ha)	63.1	70.8	80	44.1	50.6	49	107.2	121.4	129
Cost of cultivation (x 10^3 ₹/ha)	50.6	51.5	71.6	25.5	26.4	26.2	76.1	77.9	97.8
Net return (x 10^3 ₹/ha)	21.6	29.3	20	28.2	35.2	33.5	49.8	64.5	53.5
*B:C ratio	0.42	0.56	0.28	1.1	1.33	1.28	0.65	0.82	0.54
Trench method									
Cane yield (t/ha)	72	73	79.6	51.4	57.6	57.8	123.4	130.6	137.4
Cost of cultivation (x10^3 ₹/ha)	54	54.4	74.3	25	25.9	25.7	79.0	80.3	100
Net return (x 10^3 ₹/ha)	28	29.5	17.2	37.6	44.3	44.8	65.6	73.8	62
* B:C ratio	0.51	0.54	0.23	1.5	1.71	1.74	0.83	0.92	0.62
Pit method									
Cane yield (t/ha)	66	62.6	62.6	52.9	49	56.7	118.9	111.6	119.3
Cost of cultivation (x 10^3 ₹/ha)	61.4	64.1	64.1	26.3	26	26.8	87.7	90.1	90.9
Net return (x 10^3 ₹/ha)	11.3	7.7	7.7	38.2	33.7	42.4	49.5	41.4	50.1
*B:C ratio	0.17	0.12	0.12	1.45	1.29	1.58	0.54	0.46	0.41

Source: Bhullar et al. (2008) *B: C ratio was calculated on the basis of net return

Ring-pit and conventional flat planting methods in north-west India

On farm experiments were conducted during 2003 on the fields of 96 farmers in 8 districts of Punjab to compare the yield and juice quality of sugarcane under ring-pit and conventional flat methods of planting (Table 33). In all the districts, sugarcane yielded higher planted through ring-pit method compared with the conventional flat method. On an average of locations, cane yield was 64% higher in ring-pit method over the conventional flat method because of the formation of 114% higher millable canes and use of higher amounts of plant nutrients (N and P) in ring-pit method than that in conventional flat method (Yadav and Kumar 2005).

Table 33: Sugarcane yield as influenced by methods of planting on farmers' fields at different locations in north-western India

Locations	Ring pit method (t/ha)	Conventional flat method (t/ha)	Higher yield (%)
Faridkot	117.1	68.5	70.9
Ferojpur	113.1	65.7	72.1
Ropar	103.6	64.8	59.9
Patiala	106.6	68.3	56.1
Jalandhar	119.9	71.0	68.9
Ludhiana	129	82.3	56.7
Gurdaspur	124.5	71.3	74.6
Amritsar	127.1	81.8	55.4
Mean yield	117.6	71.7	64.3

Source: Yadav and Kumar (2005)

14. Crop Geometry

Selection of appropriate crop geometry is one of the major factors for improving the productivity of sugarcane in a specific agro-climatic condition. Increase in plant density in plant crop through reduced plant to plant spacing significantly enhanced number of millable canes and cane yield in sugarcane plant crop and ratoon crops due to uniform plant stand and higher number of millable canes. Singh et al. (2013) recorded the highest cane yield (103.17 t/ha) at 60 x 30 cm spacing of crop geometry at Karnal which was higher by 17.3 % and 62.6% as compared to 60 x 45 cm spacing and 60 x 60 cm spacing, respectively. Although the quantity of planting material increased due to reducing plant to plant spacing than wider spacing but proportionate enhancement in crop yield was much more at 60 x 30 cm spacing. Hence, spaced transplanting of sugarcane in Karnal condition with 60 x 30 crop geometry may be recommended for enhancing the sugarcane yield without significant increase of cost of cultivation (Table 34).

Table 34: Effect of spacing on millable canes and cane yield of transplanted sugarcane

Row x Plant (Spacing in cm)	NMC (000/ha)	Cane yield (t/ha)
60x30	125.1	103.17
60x45	104.7	87.95
60x60	72.3	63.45
CD at 5%	3.2	2.39

Source: Singh et al. (2013)

Another field experiment was conducted by Singh et al. (2010) at IISR, Lucknow to study the effect of planting geometry on yield of sugarcane ratoon (Table 35). The crop was planted using 4 planting geometries, i.e. single rows at 60, 75 cm spacing, paired rows at 75:45 and 105:45 cm spacing. The various planting geometries influenced the cane yield significantly. The paired row planting (75:45 cm) recorded significantly the highest sugar yield (7.95 t/ha) and net return (₹ 65460/ha) with B:C ratio (2.55) in two subsequent ratoons over planting at 60 cm, 75 cm and paired row planting at 105:45 cm, respectively. The paired row planting (75:45 cm) resulted in the combined positive blend of both narrow spacing (for more viable stubble in ratoon) and wider spacing which facilitated better interception of light, avoided shading effect, produced moderately thicker canes unlike narrow spaced plants. Therefore, planting of sugarcane with proper geometry is also helpful in enhancing profitability of sugarcane in north central region.

Table 35: Effect of crop geometry on sugar yield and economics of sugarcane ratoon

Crop geometry	Sugar yield (t/ha)	Net return (₹/ha)	B:C ratio
Planting at 60 cm	7.08	59 873	2.14
Planting at 75 cm	6.96	55 802	2.18
Paired planting at 75:45 cm	7.95	65 460	2.55
Paired planting at 105:45 cm	6.75	52356	2.04
CD (P=0.05)	0.36	-	-

Source: Singh et al. (2010)

Another field experiment was carried out by Kumawat et al. (2016) on crop geometry at Junagadh in Gujarat. The results (Table 36) revealed that modifying the planting geometry of sugarcane as paired row (60: 90 cm) enhanced the productivity and net return over normal planting and other paired row spacing as 60: 120 cm. Increasing the cost of cultivation in paired row (60: 90 cm) was approximate ₹ 5000/ ha but the net return of ₹ 21000.0 / ha was enhanced as compared to the paired row planting (60: 120 cm).

Table 36: Effect of crop geometry on cane yield and economics of sugarcane (pooled data)

Crop geometry	Cane yield (t/ha)	Sugar yield (t/ha)	Cost of cultivation (x 10^3 ₹/ha)	Net return (x 10^3 ₹/ha)	BC Ratio
Normal planting (90 cm)	97.34	11.59	108.64	113.40	2.04
Paired row (60 : 90 cm)	101.04	12.09	112.39	118.08	2.05
Paired row (60 : 120 cm)	88.82	10.70	105.11	97.49	1.93
SEm+	1.75	0.24			
CD at 5 %	4.94	0.67			

Source: Kumawat et al. (2016)

15. Spaced transplanting technique

This technique was developed at IISR Lucknow which facilitates maintaining optimum plant population in field condition and offers unique low cost technology. In this technique, seedlings are raised in small area in nursery one month prior to actual planting. The seed bed is prepared to a depth of 15 cm and small plots ($1m^2$) are made. Before dibbling setts vertically upward, chloropyriphos @1 kg a.i./ha is applied. Single bud setts from upper half of the cane are cut just above growth ring leaving 9-10 cm, followed by dipping for 30 minutes in 0.2% Carbendazim (Bavistin) of the internodes below the bud. The setts are dibbled vertically (600-800) setts/ sq.m in the nursery. Trash or paddy straw is spread over the setts and later on mulched with pulverized soil. Most of the buds sprout and produce 3-4 green leaves within 3-4 weeks. Settlings are carefully removed and leaf lamina detopped. Transplanting of settling is done as per region like trench / flat / furrows method, in row with 90x60 cm spacing or 75x45 cm spacing depending upon the planting seasons. Settlings are

Spaced transplanting technique (STP)

dibbled and covered with soil leaving at least 5 cm of the shoot above the ground level, followed by immediate application of life saving irrigation. Gaps may be filled within ten days after transplanting by keeping the settlings in reserve nursery. This technology is very cheap and simple and helps synchronize tillers in the field. Consequently number of earlier formed tillers increases per unit area. By adopting this technology, higher number of millable canes can be obtained than conventional system of planting. This technique is boon for rapid multiplication of seed cane particularly under late planting condition in subtropical India.

16. Integrated Weed Management

Weeds are the most important factor affecting sugarcane growth and yield adversely. They compete for nutrients, light, moisture and sometimes also provide shelter for pathogens. The losses caused by weeds in sugarcane crop may range from 10 per cent to total failures depending upon density, soil and climatic conditions. The crop weed completion is critical for the first 120 days of spring cane crop and 150 days for autumn planted crop. Normal cultural methods are not very effective in controlling the weeds. However, pre emergence sprays of Atrazine @ of 2.0 kg ai/ha suppresses most of the annual monocot and dicot weeds in sugarcane field. This followed by 2,4-D @ 1 kg ai/ha at 60 days after planting and hoeing at 90 days after planting keeps the weed population below the threshold level. Intercropping with cowpea, green gram, and black gram in spring planted sugarcane has been found effective in smothering the weed population during early growth stages up to 60 days after planting. Trash mulching @ 8-10 tonnes/ha also suppresses the weed growth in sugarcane ratoon crop.

Weed management in spring-planted sugarcane based intercropping systems

Field studies were conducted by Bhullar et al. (2006) during spring seasons of 2000-01, 2001-02 and 2002-03 on the sandy loam soil to evaluate relative profitability of intercropping in spring sugarcane (*Saccharum officinarum* L.) with green gram (*Phaseolus radiatus* L. Wilczek, black gram (*Phaseolus mungo* L.) Hepper] and okra (*Abelmoschus esculentus* L.) in 1:1 ratio as compared to its sole cultivation. Four weed-control treatments *viz.*, un-weeded control, two hand-hoeing (30 days after sowing and after harvest of intercrops), Pendimethalin @ 0.75 kg a.i./ha as pre-emergence and Trifluralin @ 1.0 kg a.i./ ha as pre-plant to intercrops were applied. The data of 3 years showed that intercropping of okra reduced the cane yield by 8.1% compared with sole sugarcane (Table 37). However, this intercropping system recorded the highest mean cane-equivalent yield (74.2 tonnes/ha) as well as net return (₹ 37,461/ha) among the cropping systems. The net return under sole sugarcane was ₹ 24,950/ha. Uncontrolled growth of weeds reduced the yield of sole sugarcane by 26.7%. One pre-emergence application of Pendimethalin @ 0.75 kg a.i./ha or pre-plant incorporation of Trifluralin @ 1.0 kg a.i./ha recorded effective control of annual weeds and gave cane yield, intercrop yield and net return comparable to two hand hoeings.

Table 37: Effect of cropping systems and weed-control treatments on weeds of sugarcane and intercrops, cane-equivalent yield and net return (pooled data over 3 years)

Treatments: Cropping system	Cane yield (t/ha)	Cane equivalent yield (t/ha)	Net return (₹/ha)
Sole sugarcane	56.2	56.2	24450
Sugarcane + Green gram	56.7	62.8	28197
Sugarcane + Black gram	52.2	61.3	26838
Sugarcane + Okra	51.6	74.2	37461
CD (P=0.05)	4.3	4.3	4331
Weed-control treatment			
Unweeded control	44.7	52.2	18436
Two hand weeding	61.0	70.4	34780
Pendimethalin @ 0.75 kg/ha	57.7	66.5	32334
Trifluralin @ 1.0 kg/ha	56.7	65.5	31496
CD (P=0.05)	4.3	4.3	4331

Source: Bhullar et al. (2006).

17. Time and level of earthing up

The earthing-up changes the furrow in to ridges and ridges in to furrows which permit drainage of excess water during rains, besides serving as irrigation channels during post-monsoon period. Earthing-up is done at the maximum tillering stage during rainy season to suppress the formation of late shoots and prevent lodging of crops. When the crop plants attain more than 2.5 m height, the possibility of cane lodging is considerably enhanced. In order to prevent cane lodging, the clumps are tied up by its lower dry leaves as single clumps or two or more clumps in later stages. However, appropriate timing and level of earthing up particularly in sugarcane ratoon crop should be considered. Dev et al. (2011) carried out a field experiment during the spring season of 2008-09 and 2009-10 at Varanasi, Uttar Pradesh to find out the exact time and the level of earthing up for getting higher productivity and monetary return for sugarcane ratoon (*Saccharum officinarum* L.). The data presented in Table 38 revealed that cost of earthing up of ratoon crop is same irrespective of date of planting but net return was the highest for earthing up of sugarcane on 25th April compared to other dates. They recommended that hence, farmers can get higher profit by earthing up on 25th April up at 20 cm height.

Table 38. Effect of time and level of earthing up on gross return, total cost of cultivation, net return and benefit: cost ratio of sugarcane ratoon

Treatment	Cane yield (t/ha)	Cultivation cost ($\times 10^3$ ₹/ha)	Net return ($\times 10^3$ ₹/ha)	B:C ratio
Time of earthing up				
25th April	158.8	86.9	378.9	5.4
25th May	145.2	86.9	339.0	4.9
25th June	139.2	86.9	321.4	4.7
CD (P=0.05)	7.3	-	-	-
Level of earthing up				
Light (10cm Height)	143.3	86.3	333.8	4.9
Heavy (20 cm Height)	151.9	87.4	359.1	5.15
CD (P=0.05)	6.0	-	-	-

Source: Dev et al. (2011)

18. Trash mulching

Trash mulching is one of the most important low cost renewable sources of plant nutrient. Besides conserving the soil moisture, mulching controls the weed population and enriches the organic carbon in soil after decomposition. It is clear from the data contained in Table 39 that application of unchopped trash @ 5.0 t/ha gave additional return of ₹ 23400/ha and increased B:C ratio to 9.4. Chopped trash @ 7.5 t/ha could increase ratoon cane yield by 12.8 t/ha and the practice gave maximum additional return of ₹ 38400/ha.

Table 39 : Comparative analysis of trash mulching in sugarcane ratoon crop

Treatments	Cane yield (t/ha)	Increased yield t/ha)	Additional cost (₹/ha)	Additional return (₹/ha)	B:C ratio
Control (No trash)	140.7	0	0	0	0
Chopped trash @ 2.5 t/ha	145.5	4.8	3000	14400	4.8
Chopped trash @ 5.0 t/ha	150.1	9.4	6000	28200	4.7
Chopped trash @ 7.5 t/ha	153.5	12.8	9000	38400	4.3
Unchopped trash @ 2.5 t/ha	144.0	3.3	1250	9900	7.9
Unchopped trash @ 5.0 t/ha	148.5	7.8	2500	23400	9.4
Unchopped trash @ 7.5 t/ha	152.0	11.3	3750	33900	9.0
FYM @ 5.0 t/ha	149.8	9.1	5000	27300	5.5
CD (P=0.05)	2.42				

Source: Modified from Shinde et al. (1992).

Price of FYM @ ₹ 1000/t, chopped trash @ ₹ 1200/t, unchopped @ ₹ 500/t

In general, sugarcane crop yielding 100 t/ha cane yield provides 10-12 tonnes of dry leaves depending upon variety and growing conditions. After completing the cultural practices for ratoon initiation, the trash can be spread uniformly between two rows of ratoon crop. The sugarcane trash application in the soil influences physical, chemical and biological properties of the soil. This trash contains 28.6% organic carbon, 0.35-0.42% nitrogen, 0.04-0.15% phosphorus and 0.50 to 0.42% potassium. It improves water holding capacity, better soil aggregation and thereby improves porosity in the soil. Thus trash along with bioagents (*viz.,Trichoderma, Gluconacetobacter* and phosphate solubilizing bacteria) are effective for water and nutrient economy. The direct effect of mulching has been worked out by Shukla et al. (2011) on sugarcane ratoon at Lucknow (Table 40). It increases the yield, reduces the negative impact of burning and promotes the soil environment by adding organic carbon. Hence mulching has become one of the most important part of low cost technology in sugarcane production.

Table 40: Effect of trash mulching and nitorgen level on ratoon sugarcane yield

Nitogen level (kg/ha)	Yield of cane (t/ha)		Increse in yield due trash mulching	
	without trash mulch	with trash mulch	t/ha	% increase
50	60.41	73.22	12.8	17.5
100	67.12	79.62	12.5	15.7
150	72.03	85.68	13.7	15.9
Mean	65.52	79.51	14.0	17.6

Source (Shukla et al. 2011)

A field experiment on integrated nutrient management including trash was carried out at Pusa Bihar (Thakur et al 2012). The data presented in Table 41 revealed that the application of 75% NPK through inorganics + 25% N through organic manures (PMC) + biofertilizers (*Azotobactor* + PSB) + biopesticide (neem cake) in sugarcane plant and 75% NPK through inorganics + 25% N through organic manures (PMC) + biofertilizers (*Azotobactor* + PSB) + trash mulching and green manuring with green gram inoculated with *Rhizobium* in alternate rows + biopesticide (Neem cake) in ratoon were found suitable practices for sustaining sugarcane productivity and getting higher monetary return in sugarcane plant and ratoon system in calcareous soil.

Table 41: Effect of farming system on cane yield and economics of plant and ratoon crop of sugarcane (pooled over 3 years)

Treatments	Cane yield (t/ha)		Net return		B:C ratio	
	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon
100% NPK + trash burning +control of pest /diseases through chemical.	64	63.7	15204	47545	1.28	1.8
100% N through organics + biofertilizers + trash mulching and green manuring in alternate rows + control of pest/diseases through chemical.	67.5	67.9	21355	53482	1.41	2.3
100% N through organics + biofertilizers + trash mulching and green manuring in alternate rows +biopesticide + detrashing of dry leaves.	68.4	70.5	21305	58634	1.41	2.46
75% N through organics +25% NPK+ biofertilizer + trash mulching and green manuring with moong alternate rows + biopesticides.	73	74.2	23135	58158	1.41	2.31
75% NPK + 25% N organics + biofertilizers + trash mulching and green manuring in alternate rows + biopesticide.	74.2	75.8	25746	61916	1.46	2.41
CD (P=0.05)	6.1	6.1	6402	8065	0.11	0.59

Source: Thakur et al. (2012)

The technological package for trash management in sugarcane has been developed by Indian Institute of sugarcane research Lucknow as given below:

- Keep the trash about 8-10 t/ha at both ends of the field after harvesting.
- Irrigate the field just after collection of trash and stubble shaving.
- Filling the gaps (> 60 cm distance between stubble to stubble) through germinated setts after off barring/hoeing.
- Apply urea @ 140 kg, DAP @130 kg/ha and Murate of potash @ 100 kg/ha as basal dose along the cane rows.
- Spread trash uniformity of 6-8 cm thickness in inter row spaces and spray a solution of 5 liters Chlorpyriphos (20 EC)in 1000 litre of water on the trash to control infestation of termites.
- Irrigate the fields one month after ratoon initiation (at the first order of tillering. Apply third irrigation, one month of after second irrigation (at second order of tillering) followed by weeding and interculture operation as and when required in the row having no trash mulch. Apply fourth irrigation one month after third irrigation (at the third order of filling).
- Top dress urea @ 100 kg /ha along the cane rows in mid May. Top dress another dose of urea @ 100 kg /ha along the cane rows during mid June.
- Apply Furadon 3G @ 33 kg per hectare along the cane rows in the last week of June to control the infestation of top borer. Plant protection measures are followed as per recommendation.
- By adoption of IISR trash management practices, the farmers may save irrigation water upto 30-40%. Bud sprouting and survival of tillers and growth is improved while weed goroth is checked. Mulch also adds organic matter to the soil besides conserving soil moisture and controlling weed. Thus soil health is also improved besides improvement in crop yields (Solomon et al. 2014).

19. Irrigation and planting methods for improving water use efficiency

In India around 88% water is being used in agriculture sector, which covers around 80 m ha area under irrigation. Achieving food security is a high priority in India and agriculture must not only provide food for rising population, but also save water for other uses. Now the challenges are to develop and apply water saving technology and management method and through capacity building enable farming community to adopt new approaches in irrigated agriculture (*Water Resources Development in India 2010).* Efficient water management using different technologies for improving agriculture productivity, therefore, holds prime importance. Water saving technologies such as drip/sprinklers system is mostly practiced in horticulture/vegetables and sugarcane crop at present for enhancing water and nutrient use efficiency (Rajput and Patel 2016).

Alternate/skip furrow method

Considerable amount of irrigation water goes waste through evaporation from wet soil surface in conventional method of irrigation by flooding the entire field with water. Alternate skip furrow method of irrigation to sugarcane is one of the low cost techniques to improve the productivity of sugarcane. In skip furrow technique, furrows are made in alternate inter row spaces and the crop is irrigated through these furrows. The soil surface of alternate inter-row spaces in which furrows are not made, remains almost dry. The evaporation losses are reduced to the extent of 35-40 per cent, resulting in saving of irrigation water. Thus results in less evapo-transpiration and improvement in water use efficiency (Solomon 2014). In this method, sugarcane is planted on flat bed as usual and after germination, 45 cm wide and 15 cm deep furrows are made in alternate inter-row spaces. The length of furrows is determined on the basis of soil permeability, size of irrigation stream and by the steepness of the slope. Usually 35-40 meter furrow length is considered to be convenient for uniform water distribution. Where land is sloppy and undulated, the furrows can be made along the adjusted contour lines. At the time of irrigation, water is provided in the furrows only.

Key features of the technology are as follows:

- ✓ Irrigation water is saved to the extent of 35-40 per cent.
- ✓ Water use efficiency is increased by 60-65 per cent.

Alternate furrow method of irrigation

Skip furrow method of irrigation

- ✓ Normal yield and quality of sugarcane is obtained with less irrigation water.
- ✓ Weed infestation is reduced considerably.
- ✓ The cost of cultivation is reduced due to saving in irrigation water and less expenses incurred on weed control.
- ✓ The profit of margin to the farmer is increased.

In alternate furrows, normal planting in furrows is done and irrigation water is is given alternating furrows. Such as if 1, 3, 5 no of rows are irrigated in first irrigation, 2nd irrigation will be given in 2,4, 6 no of rows.

Prasad et al (1988) reported that trash mulching over skip furrows with 150 kg N/ha resulted in maximum water use efficiency in sugarcane crop.

Hunsigi and Shankaraiah (1982) reported that under water scarcity situation, it is advisable to adopt skip/alternate furrow irrigation. They reported that alternate furrow irrigation and skipped double row planting economized the total water use by about 32%. The treatment improved the cane yield by 14% compared to the normal practices (Table 42). Another low cost technology is to irrigate alternatively –alternate irrigation. In this system, the first furrow is irrigated and second furrow is skipped. In the next irrigation, the second furrow is irrigated and the first furrow is skipped and so on. There is a minimum 30% saving of water and this is suited to areas under well irrigation and drought prone areas.

Table 42. Effect of irrigation treatments on yield, yield attributes, quality and total water used by plant cane

Treatments	Spacing between rows (cm)	Plant per m^2	Weight per cane (kg)	Cane yield (t/ha)	Total water used (mm)
Alternate furrow irrigation	90	15.72	1.00	110	1292
Skipped furrow irrigation	90	14.94	1.01	101	1193
Double row planting with 120 cm skipped	60	16.72	1.05	129	1193
Normal practices (Conventional)	90	16.50	1.25	113	1541

Source: Hunsigi and Shankaraiah (1982).

Planting methods and water use economy

A field demonstration was carried out during 2008-11 at Haidergadh (U.P.) revealed that yield of sugarcane was higher under demonstrated technologies as compared to that of farmers practices. The highest cane yield was recorded under ring pit method of technology compared to others. The increase in IWUE under ring pit system of planting was the highest followed by irrigation at critical stages, trash mulching and skip furrow methods. The benefit: cost ratio (B:C ratio) under demonstrated technologies improved significantly. The highest improvement in B:C ratio was observed in trash mulching . However, the improvement in B:C ratio under ring pit system of planting and skip furrow irrigation was statistically at par but significantly higher than that of farmer's practices. The details of treatments of demonstrated technologies have been presented in Table 43.

Table 43: Average yield, irrigation water use efficiency, B:C ratio and soil health in demonstration and under farmer's practices (2008-11)

Technology	Yield (t/ha)	IWUE (kg ha^{1}cm^{1})	B: C ratio
Ring pit method of planting	125.3	2367.5	1.80
Skip furrow method of irrigation	88.5	1648.2	1.95
Irrigation at critical growth stages	81.8	1807.1	1.55
Trash mulching	80.2	1682.2	2.40
Farmers practices	63.8	975.96	1.24
CD (P=0.05)	22.3	473.6	0.53

Source: Srivastava et al (2011)

Pit maker implement

Placing setts in pit

Young cane plant in pit

20. Tiller synchronization in sugarcane

Number of effective tillers per unit area is one of the most important factors for deciding the productivity of sugarcane. The initiation and number of tillers depend upon the biotic and abiotic factors of the region. However, the synchronization of tillers and not initiation is a greater problem. Most varieties of sugarcane are capable to produce large number of tillers but the problem is their survival and synchronization during initiation stage. Few tillers become mature cane while others become parasite on host. This creates uneven maturity and causes problem during harvesting and also results in poor ratooning. Several studies have been conducted at IISR Lucknow and concluded that nutritional requirement is one of the most important factors determining the number of effective tillers and its maturity. For example, optimum dose of nitrogen and phosphorus plays crucial role in tiller initiation and its growth. If soil is deficient in both the elements, number of tiller production may be reduced and growth and vigour of tillers may get adversely affected. Further higher dose of nitrogen (>300 kg/ha) may increase the tiller population, but may reduce the vigour of tillers. Hence balanced use of fertilizers based on soil test and targeted yield level becomes essential for optimization of effective tillers in sugarcane crop. In sugarcane ratoon crop most of the tillers emerge during early phase in the crop growth is generaly better than plant crop before monsoon. Durring elongation phase tiller mortality in ratoon crop is higher as compared to the plant crop. Nutritional imbalances, old root system, soil physical, chemical and biological parameters affects in intigrated manner. In this situation crop managment techniques for better growth holds great promise. Time of application, dose of nutrient, placement, trash mulching, earthing up, weed control, depth of planting affect the growth of plant as well as ratoon crop and provides syncronisation of tillers in sugarcane.

21. IISR combo trap for insect-pest management

White grubs are one of the important insect-pests of sugarcane that damage the crop by eating roots leading to drying foliage. White grubs are larval stage of the beetle, mostly nocturnal. Adults and grubs are active stage of these insects; hence these stages are more crucial from management point of view. Keeping in view of nocturnal habit of insects, IISR Lucknow has developed a management technology by using a light cum pheromone combo trap made by GI sheet. This trap is used at strategic location of the village preferably near the host tree for mass trapping followed by destruction of the beetle on community basis. A large numbers of traps are now being used in different sugarcane growing regions to minimize the problem of white grub. The cost of this trap is reasonable @ ₹ 1200-1500 per trap in comparison to its impact on controlling the pest in sugarcane as well as others crops in that region.

Collected insect-pest

IISR combo trap

22. Integrated Disease and Pest Management

Integrated disease and pest management is an eco-friendly and cost effective approach to manage the pest population below threshold level. It is holistic approach to control the insect-pest population in the crop. Outburst of the pest is not possible in this approach due to slower chances of developing resistance that usually happened with chemical control. The chemical control of insect-pest is very costly and beyond the approach of small and marginal farmers. IISR has practised and tested all the methodologies of biological control of pest. *Trichogramma chilonis*, an egg parasitoids is effective against sugarcane borers, being multiplied and released against larval parasitoids like *Cotesia flavipes*, *Isotima javensis* etc. Shoot borer *granulosis* virus and muscardine fungi like *Metarhizium anisopliae* are used in management of sugarcane insect-pest. The other studies include restricted use of harmful insecticides, cultivation of resistant varieties of sugarcane to many diseases and pests, use of healthy seed material, crop rotation including leguminous crops and use of recommended doses of fertilizers are to be adopted. At some places, staggered planting and soil solarization including summer ploughing have been found effective to control diseases and pest.

General management of common diseases:

- Treatment of cane in Moist Hot Air (MHAT) at 54^0C and 95-99% RH for 2.30 hours eradicates sett borne infection of ratoon stunting disease, grassy shoot disease and smut (99-100%). It also reduces the sett borne infection of leaf scald and red rot up to 80%.
- Removal and destruction of infected plants on the first appearance of disease in case of red rot, smut, GSD and leaf scald.
- Treatments of cane setts with fungicides like Bavistin, Vitavax, Dithane M-45 etc at the time of planting protects the setts in surface borne pathogens and superficial infection and rotting.
- Management of saddling disease in nursery beds through pre planting treatment with formaldehydes and seed cane treatment with Thiram.
- Preplanting application of *Trichoderma* and post planting application of Ridoml have been found quite effective to manage the several pathogens causing severe diseases in sugarcane crops.

23. Mechanization on Custom Hired Basis

Mechanization plays an important role for fast completion of all the field operations. The effectiveness of human resources will be the cutting edge in sustaining the productivity. The impact of mechanization has shown the emphasis on timeliness, precision and general improvement in the quality of work. It has undoubtedly contributed to increase the yield, cropping intensity and total production and cost effectivity of majority farming community. Sugarcane remains in the field for almost a year and right from land preparation to harvesting of crop, there is heavy demand of labourers and machinery throughout its crop cycle. Sugarcane is one crop in which there has been little mechanization in India, all farm operations from planting to harvesting being labour dependents.

Use of machinery helps in labour saving, ensures timeliness of operation, reduces drudgery, helps repetition in improving quality of work, reduces cost of operation and ensures effective

Deep furrow opener device

Mechanized intercultural operation

utilization of resources. In case of sugarcane crop although machineries have been developed, however, the adoption of these implements and machineries has not reached to the desired level. Majority of machines suitable for sugarcane culture have been developed by ICAR-IISR, Lucknow. The machines may be used by small farmers either through direct purchase on custom hired basis by making their own group depending upon the cost of machines and its utilization. Availability of machines on custom hired basis is the good example by which cost of operation could be minimum besides improving quality and efficiency. Timely completion of field/farm operation, reducing the drudgery of farm family and enhancing socio economic condition can be achieved through the approach. Machine Bank at village *Panchayat*, block or sugar mill level may serve the purpose in making availability of different equipments to the farmers. In this process collaboration of State Cane Deptt., sugar mills & cane societies will be helpful in achieving the objectives.

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Raebareli Road, P.O. Dilkusha, Lucknow - 226 002 (U.P.)
www.iisr.nic.in/aicrp/index.htm

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