BED PLANTING – A NOVEL TECHNIQUE TO ENCOURAGE MULTIPLE LAND USE

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Cover page
Front : Water saving with bed planting technique (left), Wheat (centre) and Onion (right) on beds in Sugarcane.

Back : Inter-Cropping of Sugarcane and Wheat.

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PREFACE

First phase agriculture growth from 1966 to the 1980s brought new short statured varieties that required high input use; the second, from 1980 to 1990s, witnessed high input use that included fertilizers, irrigation and pesticides; and the third, led to the second generation problems of poor soil health, receding water table and large scale yield losses due to development of resistance in insects and weeds. Now the new development is witnessing the evolution of new type of GM crops like Bt-cotton and resource conserving technologies to find answer to problems related with second and third phases of agricultural development. In the last 40 years, development agencies talked only about new varieties. Although the issue of new varieties will always remain with us, yet the case for efficient use of inputs and conservation of natural resources has become more important than ever. It was an attempt to incorporate technology directly at farmer's field. The interest in this type of approach has been created by the successful introduction of zero tillage which was at the dead end when tested in 1970s. Interest in this work was also created when bed planting was successfully demonstrated in the last 10 years but was not accepted in the sole crop of wheat.

Since farmers may remain unwilling to accept diversification of rice-wheat cropping system because they cannot take risk or do not have enough land to target risky diversification, there may be an opportunity to diversify within this cropping system. The furrow irrigated bed planting system provided an opportunity to diversify cropping system by making the multiple land use possible.

AUTHORS

Background

The favoured position of Rice-Wheat Cropping System (RWCS) in the Indo-Gangetic Plains (IGP) is due to least risk associated with this cropping system. It is also the most convenient cropping system as most of field operations are mechanized or done by hired labour. Farmers generally do not get stable and more income from alternate cropping systems that involve pulses and/or oilseed crops. The value of pulses in the diversification pursuit against the leading crops like rice and wheat has been consistently low. The place of this cropping system compared to other cropping systems has been questioned when the sustainability of natural resources like water and soil organic matter is analyzed. This cropping system has imposed a large scale loss on the reserve of such natural resources. This cropping system has consumed much of these resources leading to nutrient mining and water draft. The deficiency of some nutrients specially the micronutrients has been noticed. The ecosafety demands that the only way to cut further losses of natural resources is to diversify in favour of alternate cropping system. However, a significant increase in the price of wheat in the recent past shows that we cannot afford a loss of production in wheat and rice from states like Haryana and Punjab which contribute maximum to the central pool of our food basket. The pressure of supply and demand will always set the food prices and, therefore, sustaining this cropping system in North-West India is the key to the comfortable food supply in India. The imminent pressures of food security and, therefore, price stability further strengthen this system as the most favoured cropping system. Latest case of wheat import in 2006 and 2007 indicates that there is a cost to diversify this cropping system. Advances in conservation agriculture technology mean that natural resources can be conserved and diversification within this cropping system is possible. Bed planting can help creating comparative advantage to introduce inter cropping.

To avoid risk associated with profitability, dual purpose technologies like bed planting can help facilitating the multiple land use. The multiple land use will take care of the losses in the profit margins and will lead to saving of water resources, energy and labour at the same time. In order to encourage profitable diversification, this bulletin has included data mainly from Yamuna Nagar with a validation support from Kurukshetra and Jind. The objective of this publication is to discourage sugarcane planting after wheat.

Urbanisation is happening with housing and manufacturing now competing with agriculture. It means we will have to make multiple use of our land to compensate for the land going to other sectors.

Approach

While evolving technologies, we may have to seek participation of farmers at every stage of technology development starting from conceiving the idea, articulating the way it will be accepted, inviting the partners who can help outsourcing technical inputs, demonstrating the technology and marketing at the same time. Squeezing lots of components in any candidate technology at farmers' field is not easy. Technologies leading to conservation agriculture can be evolved in bottom-up mechanism between scientists and the farmers. The evolution of technologies,

therefore, rests as much on its farmers as its scientists. Experience has shown that farmers always love new technologies and they also love to try new things. It is, therefore, necessary to develop technologies which are demand driven. Instead of perfecting a technology behind the fore walls of research station, they should be perfected at farmers' fields. Many of our peers do not respond and it is always hardest thing to do. Innovations are driven by leaders and collaboration. Getting all of them towards the end objective is important. It has to be farmers centric. Farmers centric do not mean a passive group of farmers. It means that we have to target certain individuals who then spread and confirm or negate the virtues of any new technology that we evolve and accelerate. The success is then based on the word of mouth as a personal example. The evolution of technologies like zero tillage is explicitly based on such social interactions which are more effective to further accelerate the process of adoption. This process adopted by CCS Haryana Agricultural University, Hisar has not only made it easy to evolve and accept zero tillage in India but also helped transferring this technology across borders including Pakistan and Nepal. The process itself has given better access to farmers to technology and that is why it has diffused across borders.

The successful evolution and accelerated adoption of resource conservation technologies in rice-wheat cropping system using the model of farmer's participatory approach represents a significant shift both in ways agriculture scientists think about resource conservation to sustain agriculture growth and how they think about investigating in it. Policy makers and other stakeholders including farmers stand to gain from this approach. These technologies are being introduced not only to boost the profits of farmers but also to reduce the long-term harmful effect of decrease in soil health and decline in water table. This approach has accelerated the adoption process of some technologies like zero tillage, multiple land use, inter-seeding of wheat, raya, onion and garlic on beds with autumn planting of sugarcane in furrows, intrusion of summer moong to displace summer rice, laser land levelling, evolution of zero-tillage in transplanted rice using paddy transplanter and direct seeded rice. In contrast to 5-6 years it takes to generate new recommendations using conventional approach, the farmer's participatory approach takes 2-3 years. During last 11 years, the network of scientists from National Agricultural Research System and from International Agricultural Research System has created insight into number of resource conserving technologies. More than that their quality research is demonstrated by accelerated acceptance by farmers, has made the difference as to how some researches need to be conducted.

Participatory approach represents an opportunity in :

- **Double zero tillage in RWCS (ZT wheat fb ZT rice)**
- **Intercropping based bed planting**
- **Introduction of summer moong in RWCS**
- **Laser land levelling**
- **Direct seeded rice.**

Research Efforts and Extension Strategy

Any technology for its wider dissemination should fit in farmer's own scheme of things. It should adapt to his agro-ecological matrix. So, instead of testing the technology in smaller plots at research station, farmer participatory approach was adopted with twin methodologies :

1. Those farmers who are already doing intercropping in one or the other way were encouraged to have the sugarcane based intercropping system under furrow irrigated raised bed system (FIRBS).
2. Those farmers going for post wheat planting of sugarcane in the month of May were introduced to autumn planting of sugarcane + wheat in FIRBS system.
3. In addition to this, the concept of vegetables as intercrops was tried in those cases where farmers were growing vegetables and sugarcane as sole crop.

Water Resources

For the last many years RWCS faced the serious problem of depletion in water table in North-West India. As part of our effort to introduce resource conservation technologies in RWCS, bed planting is being seen to have greater merit to save water. The economic worth of this has been debatable when introduced in the sole crop of wheat or rice. However, the simultaneous introduction of this technology as part of value addition through intercrops has proved to be an elegant intellectual construct which has shown relevance in sugarcane based cropping system.

The logic of intercropping in autumn planted sugarcane includes synergies in operations leading to improved profits. Not all these profits will flow from reduced cost of overlapping field operations such as tillage, irrigation, weed management and fertilizer application but also through improved productivity of crops.

Least risk and more profits from rice-wheat cropping system is creating pressure on sugarcane. The issue of water shortage, labour productivity & energy and making sugarcane cultivation more profitable will need this to happen.

Making it Happen

The virtues of bed planting have been demonstrated at farmers' field for the last 10 years. The technology was not accepted by the farmers in the sole crop of wheat or rice because farmers look at the glaring advantages in terms of profits rather than savings in natural resources. One possibility to incorporate the component of profits was to perfect the technology in the intercropping system. The value addition in the technology through this system of bed planting and intercropping led to a composite dual purpose technology which makes an alternative to diversification. In this system, the virtues of technology in respect of water saving have been advocated by taking autumn sugarcane in the furrows and intercrops on the beds. This type of composite technological package pushed up both yields and income. Details have been described in the bulletin. Farmers by and large gave frosty response to bed planting in sole crops and saw

no prospect of such a move but this package has convinced them through better profit margin and water savings at the same time.

Large scale acceptance of this technology by farmers of district Yamuna Nagar is because it was evolved and accelerated at the same time. It is also because farmers in this district have been practicing diversification more than other districts.

Sugarcane – Market Needs

Sugarcane is the main source of sugar in India and holds prominent position as cash crop. In India, sugarcane is grown in 4 million hectares area with an average productivity of 64-71 tonnes ha^{-1}. In Haryana, sugarcane is grown in 1.6 lac ha and average productivity ranges between 55-68 tonnes ha^{-1}. Among sugarcane growing districts, Yamuna Nagar, Kurukshetra, Ambala and Karnal contribute 60% of sugarcane production in Haryana. Limited growth period is the main reason for low productivity of sugarcane in northern states.

The optimization of planting time in sugarcane has to be integral part of varietal balancing exercise. To ensure the availability of cane to the sugarmills for at least six months, there should be almost 1/3 area under each group (early, mid and late season varieties). There is a contradiction in the industries priority and farmer preferences. The mills vie for early varieties for the reason of better recovery and early start of crushing season. These varieties are comparatively less yielder in terms of cane yield and also prone to insect-pest and disease complex. Farmers strongly favour late varieties due to their high tonnage and high degree of tolerance to insect-pests. However, the mills are reluctant to purchase due to poor recovery on account of high fibre content. The price policy of sugarcane is designed in a way to encourage the early varieties, often procured at premium price.

From Table 1 it is evident that remunerative price offered to the farmers in successive years recorded an increase of 25.5, 20.8 and 21.1 per cent in early, mid and late season varieties, respectively. Intensification of sugarcane based cropping system through intercrops and resource conservation, therefore, has the potential to address the above discussed issues of contradictions.

Table 1. Price of different sugarcane varieties during different years in Haryana

Year	Cane price (Rs. q^{-1})		
	Early varieties	Mid season varieties	Late season varieties
2003-04	110	106	104
2004-05	111	114	117
2005-06	133	123	121
2006-07	138	128	126
2007-08	138	128	126

The objectives are as under :

1. The staggered sowing should be done away with to concentrate planting of sugarcane in October to mid November or in mid February to end March. Staggered sowing of course acts as a paradise for insect-pest and diseases.

2. The autumn planted sugarcane can be safely grown with suitable intercrops.

3. The post wheat sowing of sugarcane in the month of May is poor yielder with heavy infestation of early season weeds and poor early growth of crop due to hot and desiccating winds in May and June.

The late planting of sugarcane has been practiced in western Uttar Pradesh. Farmers in Haryana have adopted this practice out of convenience rather than a good agronomic practice. This practice also uses excess water for the establishment of sugarcane crop. This loss in the productivity of sugarcane in Haryana is definitely associated with late planting. Although planting of sugarcane is associated with varietal spectrum of rice or cropping system as a whole but only that part which is planted after wheat harvest is the cause of concern. Details of sugarcane planting scenario are given on next page.

A. Some of the planting is done in the month of October where the preceding crop is early maturing rice.

B. Some of the planting is done in the month of November where the preceding crop is main season rice.

C. The planting of sugarcane is also done in the months of February and March where the preceding crop is Raya/Toria/Potato.

D. Bulk of the planting is done in the month of May after the harvest of wheat crop.

It is evident from the data presented in Table 2 that the area under sugarcane crop planted after the wheat crop in district Yamuna Nagar alone is 25 to 30 per cent.

As per the crop ontogeny and climatic sequences for vegetative growth and inversion process thereafter, the best time for planting of sugarcane is the month of October and February-March. It is an Industrial crop. Fortunately, there is good varietal diversity in sugarcane. As per the maturity conditions these varieties are divided into three groups.

Table 2. Area under sugarcane in district Yamuna Nagar

Year	Area of sugarcane under different categories (ha)			
	Group (A+B)	Group (C)	Group (D)	Total
2002-03	80	40380	17340	57800
2003-04	320	38040	16440	54800
2004-05	600	33408	9592	43600
2005-06	760	33680	14460	49200
2006-07	1300	51080	18298	52280

(a) Early maturing varieties

Those varieties which can develop about 16% sucrose content in nine months period are considered early maturing varieties, *e.g.* COJ 64, COH 56, COH 92 and CO 89003.

(b) Mid season varieties

Those varieties which can develop about 16% sucrose content in 9-11 months period are considered mid season varieties, *e.g.* COS 88230, COS 8436, CO 7777, COH 99 and COH 119.

(c) Late maturing varieties

Those varieties which can develop about 16% sucrose content in about 12 months period are considered late maturing varieties, *e.g.* COS 767, CO 1148, COH 35, COH 110 and COS 8432.

The sugarcane planted after wheat has to face unfavourable season, limited period for vegetative growth and cane development. This area should be weaned away in favour of autumn planting. The farmer does so because he is not ready to sacrifice the wheat crop. His concern can be adequately addressed by taking wheat as an intercrop in the autumn planted sugarcane.

Inter-cropping has a chance to succeed even in spring planted sugarcane. Ziad crop of summer moong/mash is best fit that ensures resource conservation, cost recovery through additional income and even lessens the weed problem.

As part of conservation agriculture strategy, sugarcane which uses excesss water in hot months of May and June, may be avoided and this space can be fitted up with summer moong. The inclusion of moong in the summer can also help in displacing summer rice. In some part of Yamuna Nagar the crop of mash (*Vigna mungo*) can be introduced in summer. These crops can serve the purpose of cover crops in addition to the advantage of green manuring. A good cover can help in reducing the recruitment of weed seed bank in the long run. The advantage of green manuring will be in addition to the grain yield advantage of such crops. The KVK system has evolved and accelerated this practice in rice-wheat cropping system.

Experience So Far – Bed Planting

A natural bounty of good water resource in the rice-wheat cropping system in half of India made it the granary of India. This area is dominated by relatively prosperous farmers. The needs of expanded rice-wheat cropping system have already begun to outstrip the capabilities of water resources. The good quality water resource has started depleting. This has been happening for many years now. For how long, we will keep digging our tubewells deeper due to fall in water table. It is, therefore, necessary to carefully examine every potential solution that leads to savings in water use. We need to take steps to ensure a sustained use of water. Policy makers are desperate to find way to conserve water resources either through diversification of rice-wheat cropping system or through water saving technologies. Bed planting has been found successful specially in regard to water savings, mechanical weed management possibilities, fertilizer placement and bolder grain production. The farmers' participatory research done so far has shown the promise of this technology both in respect of productivity and water saving but farmers did not accept

bed planting in the sole crop of wheat or rice mainly due to the following problems (Singh *et al.*, 2002; Yadav *et al.*, 2002).

- Previous crop residues/stubbles hamper smooth working of bed planter at the time of sowing. Though such problems can be avoided by preparing the field very well. But it will again add to the cost of cultivation. However, provision of coulters or modification in furrow openers, frame height, attachment of rollers and driving wheel may be looked to solve this problem.
- Problem of termites on dry top of the beds may require more and more attention for seed treatment.
- Adjustment in seeding depth needs top most attention particularly in sandy or loamy sand soils because if seeding depth remains less, soil dries up in an hour or two. Crust formation takes place when sowing is done deep in a little bit wet surface. Making beds before applying pre-seeding irrigation can settle this problem to some extent and needs investigation.
- During manual harvesting (which is most common), plants sometimes get removed with soil sticked roots which deteriorate quality of straw which is very important for animals. How residues can be retained in this system particularly on permanent beds is another important researchable issue.

Field trials on bed planting of wheat were conducted at research farm as well as at farmers' field in rice-wheat cropping system. In this system 35-40 cm wide beds with interfurrow spacing of 70 cm were formed with the help of a bed planter, fitted with seed-cum-fertilizer mechanism. Results indicated that wheat could be sown in 2 or 3 rows per bed with lower seed rate in bed planting. Bed planting increased the efficiency of fertilizer besides saving in irrigation water. This technique provided the possibility of mechanical weed control and reduced the dependence on herbicides. The average grain yield of wheat increased by 5.5% in bed planting technique compared to conventional sowing (Table 3). The data given in Table 3 indicates that yield

Table 3. Results of trials conducted on raised bed planting of wheat at farmers' fields during 1997-98 to 2000-01 in Karnal district

Years	No. of locations	Hours required for irrigating one ha with tubewell		Grain yield (q ha^{-1})	
		FIRBS	Conventional	FIRBS	Conventional
1997-98	3	7	14	44.6	41.1
1998-99	8	5	9	52.0	50.0
1999-2K	16	6	11	56.6	54.3
2000-01	9	6	12	58.2	55.1
Mean		6	11	52.9	50.1

Source : Singh *et al.* (2002).

Despite plenty of evidence that wheat does better in bed planting but farmer still feel that the technology is at high cost. We need to add value.

advantage may not be the sole criteria for farmers to accept technologies. The technology has to be simple and cost effective. Scientists need to articulate as to how to make a technology to work. In sugarcane value addition has to be done to cover cost and avoid risk. Intensive studies were, therefore, advocated to explore the possibilities of intercropping and other crops including vegetables.

Complete Package – Intercropping

Bed planting in an agronomic intervention where intercrop is sown on beds. The setts of sugarcane are placed end to end in the furrows. Immediately, the setts are covered with thin mass of soil (1 inch) through locally designed Pyramid shaped raker, then light irrigation is given in the furrows of furrow irrigated raised bed system (FIRBS).

The intercrops of wheat or raya emerge as usual within a week. Whereas the emergence of sugarcane commences 2-3 weeks after planting. Sugarcane crop remains dormant during winter months and offer no competition during the grand growth period of wheat/raya. Because of this nature any crop of vegetable which fits in the system can be taken up. The experience during last three years has shown that garlic and onion are the best intercrops in addition to wheat and raya. This crop offers no competition during wheat maturity because of its slow growth behaviour upto wheat harvest. Even the mechanical harvesting of wheat is not affected due to sugarcane which starts its re-growth from end March. Sugarcane itself a widely spaced and very slow growing during winter period offers no competition to the wheat crop. Both crops grow in complementary manner. It is possible to get the potential yield of wheat crop with no significant effect on the cane yield. The salient features of the technology are :

1. The longevity of the sugarcane crop period by autumn planting translates into yield gains.
2. The early maturity of the cane in case of autumn planting is always welcomed by sugar industry ensuring longer crushing period.
3. The potential yield of wheat crop is an incentive to the farmers in terms of better profitability.
4. The May planting of sugarcane can be avoided and farmers mindset about wheat crop is properly addressed.
5. The plant population in sugarcane is the most important determiner of cane yield. The proper moisture situation in FIRBS system ensures better and synchronous emergence of sugarcane. The yield is definitely high. Such gain can be further strengthened with two key interventions:

   (a) Field should be laser levelled prior to the adoption of FIRBS. This makes water management easy by reducing the infiltration opportunity time, quick flow in the furrows with no chance of water stagnation.

   (b) The farmer can use two-budded setts of sugarcane with much higher percentage of emergence. The two-budded setts have the advantage over three or more budded setts even in conventional practice. The gain is comparatively more in FIRBS system.

6. In FIRBS system here or in any crop situation saves water and ensures proper moisture regime to the crop. This is a kind of resource conservation technology permitted in one or the other system.

Synergy with Laser Levelling

Precision land levelling with laser leveller is the basic requirement for uniform crop stand. Unevenness in the soil surface adversely affects the uniform distribution of irrigation water in the fields and leads to poor crop stand. Laser levelling helps to overcome this inefficiency and reduces water requirement through transmission losses and uniformity in moisture distribution. Laser land levelling helps to :

- Save irrigation water.
- Increase cultivable area by 3 to 5 per cent.
- Improve crop establishment.
- Improve uniformity of crop maturity.
- Increase water application efficiency upto 50 per cent.
- Increase cropping intensity by about 40 per cent.
- Increase crop yields.
- Facilitate management of saline environments.
- Reduce weed problems and improve weed control efficiency.

The use of laser leveller would further help farmers to make better use of furrow irrigated bed planting system based intercropping (Fig. 1).

Fig. 1. Laser land levelling – Key to success of intercropping.

Laser levelling will help this technology to deliver profits in fundamentally different way and at much lower cost. Huge benefit to integrate different crop cultures within one season.

Sugarcane+Wheat

Sugarcane+wheat was the thrust of exercise as the majority of the farmers have general preference for wheat crop in **rabi** season. Sugarcane+wheat was planted in last week of October to 1st week of November with the help of bed planter. Three rows of wheat were sown on beds. The whole process of sugarcane+wheat intercropping is illustrated in Fig. 2.

Over 50 demonstrations were organized at village Allahar (Yamuna Nagar) where May planting of sugarcane was in vogue till now. It was worthwhile intervention. The yield of wheat raised on beds was at par with the yield obtained in case of sole crop of wheat. Simultaneously, an increase in the yield to the extent of 222 q ha^{-1} was recorded in case of sugarcane. This is a paradigm shift in the way sugarcane and wheat can be grown together with no yield penality to wheat or sugarcane. That is how we can make multiple use of land specially when we introduce onion, garlic, wheat and raya.

Laser levelling of field

Sowing of wheat on beds

Cutting of sugarcane setts

Planting sugrcane setts in furrows

Sugarcane setts in furrows

Covering sugarcane setts with soil

Irrigation in furrows

Germinating wheat crop on beds

Wheat on beds & sugarcane in furrows

Close view of sugarcane in wheat

Wheat harvesting at maturity

Sugarcane crop after wheat harvest

Fig. 2. Intercropping of wheat (on beds) in sugarcane (in furrows).

An impact analysis was done. The study revealed that area under May planted sugarcane had gone down from 80 ha to nil. The technology found peripheral expansion in hinterlands. An Additional area of 126 ha was brought to autumn planting under FIRBS that was supposed to be planted in the month of May.

The technology is ready to take off in the entire district of Yamuna Nagar. Over 1200 ha (1000 ha under wheat and 200 ha under vegetables) was brought under FIRBS system during the year 2006-07. This technology needs major push through favourable policies and even some kind of subsidy instrument either on bed planter or even to those farmers who will do it by custom hiring. The sugar mill authorities are positively inclined and have agreed in principle to adopt as the main plank of their cane development programmes. For control of broadleaf weeds in wheat crop Algrip @ 8 g/acre is used. For control of *Phalaris minor* sulfosulfuron @ 13.5 g/acre is used.

Synergy with Early Wheat Sowing

The rice-wheat cropping system (RWCS) is one of the widely practiced cropping systems in India and covers about 10 million ha. About 90% of this area is concentrated in the Indo-Gangetic Plains (IGP) comprising the states of Punjab, Haryana, Uttar Pradesh, Uttaranchal, Himachal Pradesh, Bihar and parts of Rajasthan, Madhya Pradesh and West Bengal. Almost 90-95% of rice area in Punjab, Haryana and western Uttar Pradesh is under intensive RWCS. The success of wheat can be shaped by advancing its sowing time by the end of October similarly, the success of sugarcane can also be enhanced by allowing this crop to stay in the field for maximum number of days. Autumn sowing of sugarcane and end of October sowing in wheat will provide both crops a significant advantage in terms of sufficient time for their growth and development. This can be possible by evolving synergies between two crops when taken in intercropping system.

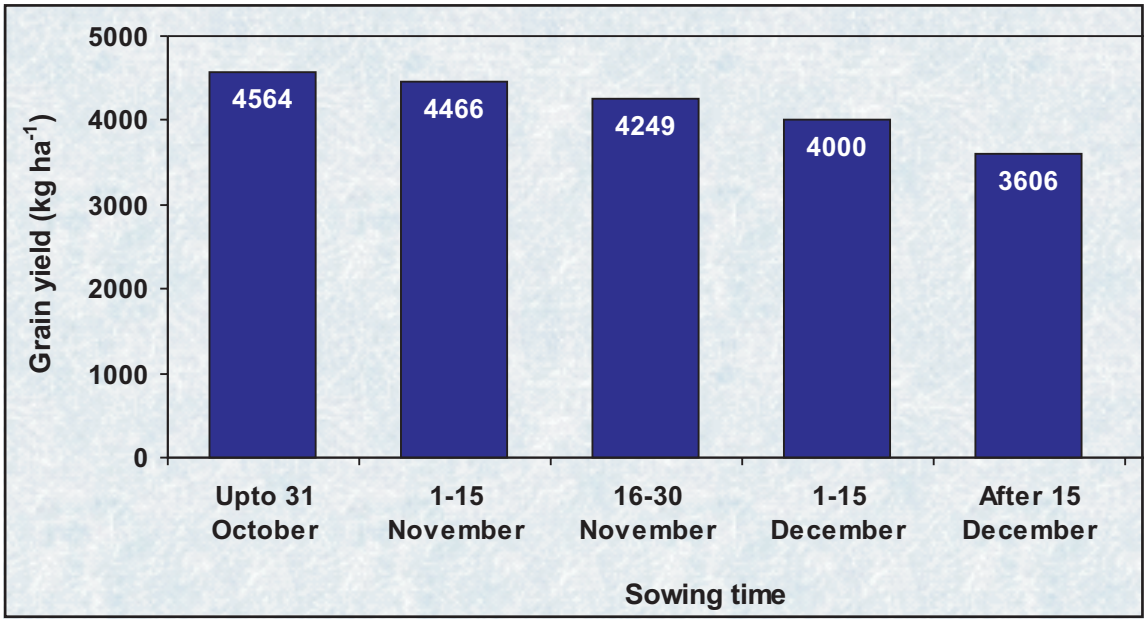


Fig. 3. Grain yield of wheat under different sowing dates.

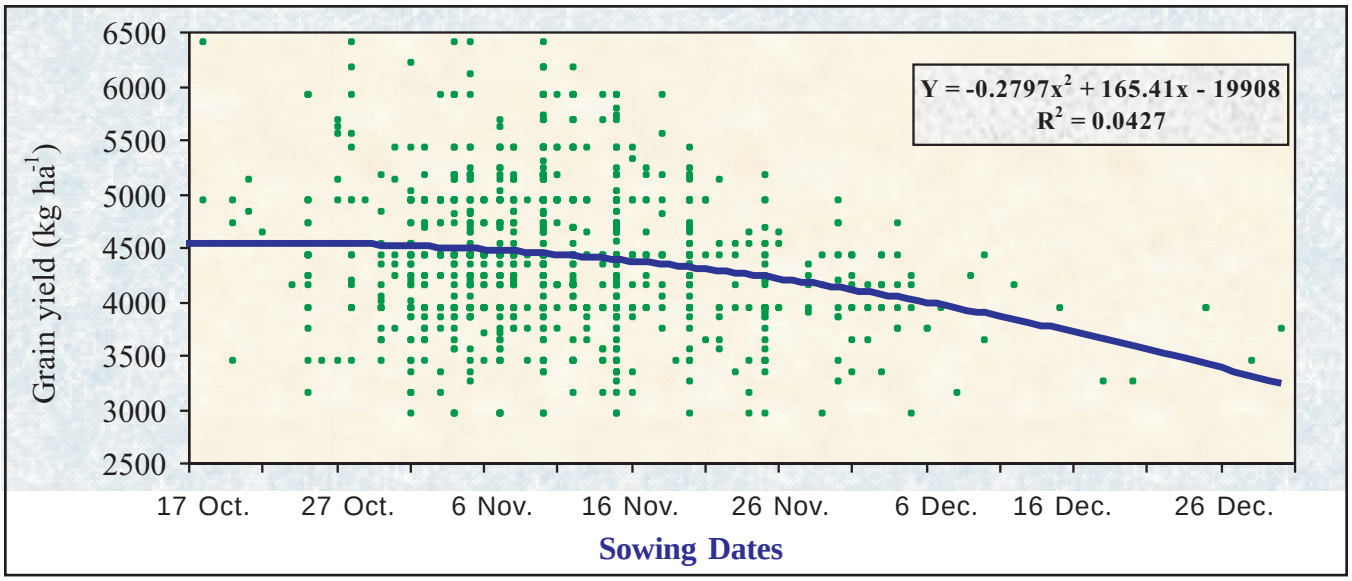


Fig. 4. Polynomial relationship between sowing time and grain yield of wheat.

The technology has to be dual purpose so that both crops give maximum productivity with minimum unput use. An ecologically correct intercropping system using bed planting can prove to contribute to the success of each crop. This system can help to achieve a substantial surge in the earning as well. The survey conducted during last three years has already shown that the only way to improve wheat productivity is to sow the crop in the end of October to mid November.

A survey was conducted for four years (2000-01, 2002-03, 2003-04 and 2005-06) by scientists of CCS Haryana Agricultural University, Hisar to scrutinize the wheat productivity in districts of Haryana where RWCS is followed. Information about planting time and grain yield of wheat was collected through personal interview using a structured questionnaire. The survey consisted of a sample size of 1110 cultivator households (100, 148, 492 and 370 during 2000-01, 2002-03, 2003-04 and 2005-06, respectively).

Grain yield of wheat decreased significantly with delay in sowing dates. Highest grain yield (4564 kg ha^{-1}) was recorded when the sowing was completed within the month of October (Fig. 3). The polynomial regression relationship between sowing time and grain yield of wheat shows drastic reduction in grain yield of wheat with delayed sowing (Fig. 4). The linear relationship between sowing date and grain yield of wheat showed that these were significantly negatively correlated (r = -0.193). The grain yield of wheat increased upto 23 October, reaching its maximum (4545 kg ha^{-1}), and thereafter it started to decline. However, the increase in grain yield upto 23 October and decline upto 31 October was not significant, averaging only 0.74 kg ha^{-1} day^{-1} reduction in grain yield. Thereafter, the reduction in grain yield started boosting up with daily reduction of 8.85 kg ha^{-1} in the first fortnight of November. The reduction in grain yield was about 17.25 kg ha^{-1} day^{-1} in the second fortnight of November which reached to 30.11 kg ha^{-1} day^{-1} in the month of December (Fig. 5).

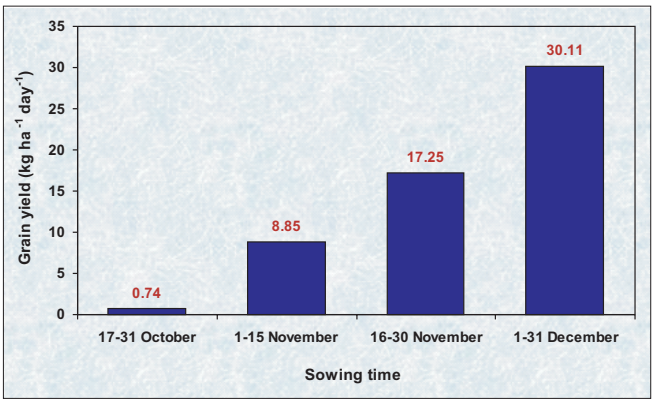


Fig. 5. Daily reduction in grain yield of wheat under different sowing dates.

Fig. 6. Intercropping of wheat (6 rows) in autumn planted sugarcane.

A linear decline in yield of 1-1.5% per day was observed when wheat was planted after the end of November irrespective of short-or medium-duration varieties (Hobbs and Mehla, 2003). Similarly, Ladha (2003) reported that sowing of wheat after 15-20 November resulted in decrease of yield by 1% per day. The decrease in grain yield of wheat under late sowing i.e. because of rise in temperature at grain filling stage. Late planting not only reduces yield but also reduces efficiency of inputs applied to the wheat crop. The present day rice-wheat cropping system, keeping in view monsoonal irregularities, has compelled wheat crop to be subjected to rapidly ascending temperatures coupled with hot dry winds during the post anthesis stage, specially during grain development. These unfavorable environments terminate grain growth prematurely and reduces yield considerably. It has already been established that high temperature stress can be a significant factor in reducing yield and quality of wheat (Stone and Nicolas, 1995).

The major reasons reported by the farmers for late planting of wheat in the rice-wheat system are (i) late harvest of the preceding rice crop, (ii) a short-duration third crop planted after rice, (iii) preference of farmers in some parts of the Indo-Gangetic Plains to grow *Basmati* rice, a long-duration crop, despite its lower yields, because of its high quality rice, high market value, good quality straw for livestock, and lower fertilizer requirements, (iv) difficulty of replacing *Basmati* varieties readily with a shorter duration rice variety, (v) long turn around time between the rice harvest and wheat planting.

These large wheat yield reductions (upto 30 kg ha^{-1} day^{-1}) due to late planting could be minimized by intercropping of wheat with autumn planted sugarcane (Fig. 6) through bed planting. Since the autumn planting of sugarcane coincides with the sowing date of wheat in the month of October, it will increase the productivity of the intercropping system as a whole. This will also lead to multiple land use, which is the need of the hour. October sown wheat out yielded the other dates of sowing. Seeing the present water crisis October sowing of wheat on bed can also reduce the water requirement, thus improving the water productivity.

Sugarcane+Raya

Fig. 7. Intercropping of raya in sugarcane.

Sugarcane+Raya is also a viable system (Fig. 7). There is complementarity between two crops.

1. The most optimum time of sowing of both crops coincides i.e. 1st fortnight of October.
2. The sugarcane germination takes place within 3-4 weeks, whereas in winter sown crop buds remain dormant till February and germination starts thereafter.
3. The raya crop vacates the field by mid March, thus provides best time for interculture operations, nutrient management, etc.

Farmers who practiced this technique have managed to advance wheat sowing with following details :

(a) Between short duration varieties and main season varieties of paddy consistent to their relative profitability. Sharbati/RH-10 are the most preferred varieties in early group which are harvested by the end of September and facilitate the sowing around 10-15 October. Among the main season varieties, PB1/Pro-Agro 6444/PHB 71 are the natural choice of the farmers and sowing is possible only by mid November.

(b) Relative economics of raya and wheat has a say in the choice of the farmers. For the last two years, wheat is proving more remunerative than raya, so, some bias towards wheat is observed. Otherwise, raya is equally popular as an intercrop.

In sugarcane+raya intercropping system, the target is often for a moderate yield of raya with potential yield of sugarcane. The yield of 15-18 q ha^{-1} of raya is achievable in this system with no effect on the sugarcane yield.

Sugarcane+Gram/Lentil

Fig. 8. Intercropping of gram in sugarcane.

In this system, erect type varieties of gram should be preferred. Two lines of gram/lentil are sown on beds with the help of bed planter and sugarcane is sown as discussed in case of sugarcane+ wheat (Fig. 8). Light irrigations as per requirement of sugarcane crop are applied. This system produces 12-15 q ha^{-1} yield of gram/lentil. Since gram is not a preferred crop of rice-wheat cropping system, this option may not be accepted by the farmers on large scale.

Sugarcane+Garlic

As the spices (garlic/onion) are very remunerative and labour intensive, their intercropping in autumn sugarcane may increase the income level as well as employment potential for small

farmers. Apart from this, these crops also possess peculiar odour which may serve as a repellent to the insect-pests of sugarcane. Verma *et al.* (1981) observed significant reduction in top borer incidence when spices were intercropped with sugarcane crop. In case of garlic+ sugarcane intercropping system, planting of sugarcane is done in the month of October and simultaneously cloves of garlic are manually planted on beds in rows (Fig. 9) and field is immediately irrigated. Garlic yield from sugarcane+garlic intercropping system ranges from 50-62.5 q ha^{-1}.

Fig. 9. Intercropping of garlic in sugarcane.

Sugarcane+Onion

Four to five rows of onion are planted on beds depending upon the spacing (Fig. 10). Sugarcane crop is planted in the end of September to first week of October alongwith the potato as intercrop. After uprooting the potato for vegetable purpose, the onion crop is transplanted between inter row spaces. Sugarcane+onion intercropping may be done after taking sole crop of potato for vegetable purpose and after uprooting of potato, sugarcane+onion crops are intercropped in bed furrow system simultaneously. Onion crop produces yield of 175-200 q ha^{-1} without any adverse effect on sugarcane yield. For control of weeds in vegetable crops, application of Stomp @ 2.5-3 l ha^{-1} is recommended.

Fig. 10. Intercropping of onion in sugarcane.

Sugarcane+Potato

Intercropping of sugarcane+potato is also very profitable. In this system, sugarcane is planted at 90 cm distance in 1st week of October and one row of potato is planted between two rows of sugarcane (Fig. 11). Sugarcane crop is irrigated as per needs of potato crop. Potato yields to the tune of 225 q ha^{-1} may be obtained from intercropping system. Based on the existing agronomy, patato based intercropping is not easy and may not be practiced.

Fig. 11. Intercropping of potato in sugarcane.

Sugarcane+Other Vegetables

In autumn planted sugarcane, vegetables like coriander, cauliflower, spinach, cucumber, etc. (Fig.12) can also be grown successfully as intercrop depending upon the resources available with the farmer. Some more enterprising farmers first take potato as an intercrop. The potato is

Sugarcane+potato+cucumber

Sugarcane+cauliflower

Sugarcane+coriander

Sugarcane+spinach

Fig. 12. Intercropping of some other vegetables in sugarcane.

dug out in the month of January and then transplanting of onion or cucumber is done in inter-row as intercrop. Such systems are area specific and there are enormous opportunities to integrate one or the other crop in FIRB system.

Economics of Different Intercropping Systems

Economics of different intercropping systems presented in Table 4 clearly showed the advantage of intercropping system over sole crop of sugarcane. Among different intercropping

Table 4. Economics (Rs. ha^{-1}) of sugarcane based intercropping systems

Intercropping system	Yield (q ha^{-1})		Total expenditure	Gross returns	Net return
	Sugarcane	Intercrop			
Sugarcane+Garlic	975	62.5	108750	256050	147300
Sugarcane+Onion	975	200	83000	204800	121800
Sugarcane+Potato	1000	200	87500	188000	100500
Sugarcane+Potato+Cucumber	1000	200	100000	213000	113000
Sugarcane+Wheat	875	42.5	75000	153125	78125
Sugarcane+Cauliflower	875	125	90000	162000	72000
Sugarcane sole	925	–	60000	118400	58400

systems, sugarcane+garlic gave maximum net return to the tune of Rs.1,47,300 ha^{-1} followed by sugarcane+onion (Rs.1,21,800 ha^{-1}). The net returns obtained from sugarcane+vegetable crop depend on prevailing market prices. Net returns obtained from sugarcane+wheat crop were Rs.19,723 ha^{-1} higher compared to the sole crop of sugarcane.

In the three years of the study, vegetable based intercropping systems were found more profitable, sugarcane + garlic being the highest followed by sugarcane+onion, sugarcane+potato+ cucumber and sugarcane+cauliflower. The contribution of the vegetable component is responsible for certain edge over the sugarcane+wheat. Despite the favourable economics, we can not undermine the fact that vegetables are perishable commodities and often exhibit wild price fluctuations. There has been years in the past where glut in the market caused market crash and the farmers running hard even to recover the cost of production. The case of garlic in the year 2000-01 is with us. Consistent with the general inflation in the economy during last three years, all horticultural crops showed price increase with reasonable degree of stability. The sustainability of this price trend may be a problem in the future, when the government is also trying hard to control the inflation. So, this economic trend needs to be analyzed with caution and the jumping on conclusions may prove an illusion. In contrast wheat is our principal food crop enjoying the umbrella of support price. Keeping in view the global trends and food availability within the country wheat prices are most likely to increase in the coming years. Therefore, sugarcane+wheat may be good option.

Any piece of technology can generate tangible benefits if adopted at certain volume. Even marginal increase in widespread technology may contribute much more to the economy of the farmer and the country than a technology with handsome returns but restricted to few people. There is a limit to horizontal expansion of vegetable based intercropping systems. But there is no restriction as far as wheat is concerned. The saturation in sugarcane+wheat cropping system if at all comes it will be because of sugarcane. There is no chance of landing in crisis even if every acre of autumn planted sugarcane is intercropped with wheat. So, despite slightly lower than the other treatments during the three successive years it would be worthwhile to pursue sugarcane+wheat intercropping system as the most viable option for the farmers.

Labour for agricultural purpose is a constraint in industrial hubs. The state of Haryana is witnessing an industrial revolution. All agrarian work is dependent on migratory workforce from Bihar and adjoining states. The vegetable based intercropping systems are labour intensive. These are good options for employment generation in case we have surplus manpower. But the costly labour and restricted availability many a times creates logistic problems, timely operations are not done, means loss of production and profit margin. This issue has relevance in any plan of horizontal expansion of these crops. Conversely, there is no such problem in sugarcane+wheat intercropping system. Moreover, the technology has the flexibility. For one or the other reason if planting of sugarcane is not possible in the month of October-November, it can be safely done in the month of January-February as the furrows are clear for sett placement. This system is equally

good in productivity. Hence, under the circumstances sugarcane+wheat intercropping system will be the tagged option in the pursuit of multiple land use system.

Intercropping in Spring Sugarcane

Sugarcane+moong/mash

In this system, sugarcane is planted during mid February to March. Two rows of moong/mash are sown on beds. A seed rate of 15 to 20 kg ha^{-1} is required for sowing of moong/mash in this system. Short duration varieties of moong/mash should be preferred. Moong/mash produces 5-6 q ha^{-1} grain in the intercropping system without affecting the cane yield.

Experience in other districts

The results of trials on autumn sugarcane + wheat conducted at farmers' field in Kurukshetra district reveals that the sowing of sugarcane in last week of October to first week of November registered 87-100 tonnes cane yield. The yield of wheat sown as intercrop ranged from 4.5 to 5.5 t ha^{-1} which was as good as yield obtained from sole crop of wheat. Sugarcane + onion intercropping system gave cane yield of 105 t ha_{-1} (2004-05), 87.5 t ha^{-1} (2006-07) and yield of onion obtained was 27.5 t ha^{-1} and 35 t ha^{-1} during 2004-05 and 2006-07, respectively.

Sugarcane equivalent yield obtained from sugarcane based intercropping systems was much higher than sole crop of sugarcane in district Jind. The results of trials conducted in three villages during 2006-07 in district Jind revealed that maximum sugarcane equivalent yield was obtained from sugarcane + onion (139.4 t ha^{-1}) followed by sugarcane + wheat (106 t ha^{-1}) sugarcane + raya (102.1 t ha^{-1}) and minimum yield of 82.5 t ha^{-1} was obtained from sole sugarcane planted in autumn season (Fig. 13).

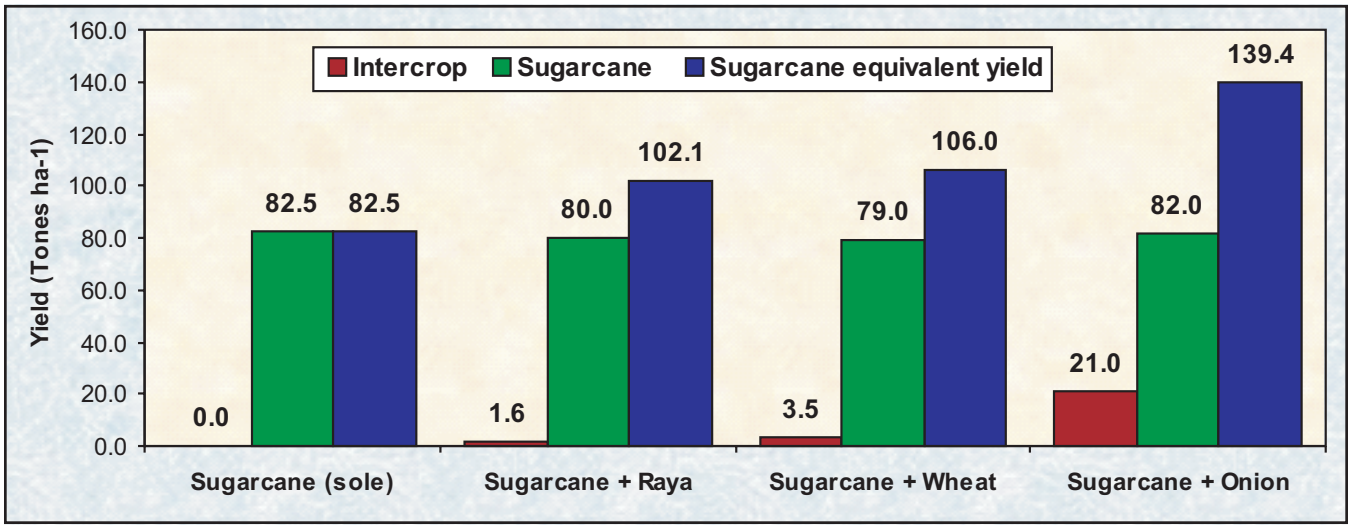
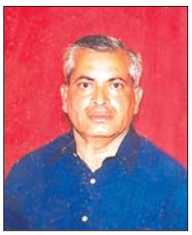


Fig. 13. Sugarcane based inter-cropping under bed planting in district Jind.

Success Story I



Sh. Bhagwan Das S/o Sh. Shankar Das, resident of village Antawa, district Yamuna Nagar having 16 acres of land came in contact with Krishi Vigyan Kendra, Damla (Yamuna Nagar) in the year 1997-98 and he was advised to grow pulses and oilseed crops in crop rotation to get better income from his farm. He was given front line demonstration on gram. He adopted the improved technology and was able to harvest 20 q ha^{-1} yield of gram. He adopted new method of sowing of sugarcane with intercrop in autumn season. With this new technology, germination of sugarcane improved from 55 to 80% and ultimately got higher yield of sugarcane. He was suggested to grow intercrops like garlic, onion, potato, etc. in autumn planted sugarcane. He was able to obtain additional income by growing intercrops in autumn sugarcane but best results were obtained with sugarcane+garlic in the year 2003-04. Now Sh. Bhagwan Das is fully satisfied with this technology and continuously growing various intercrops in autumn planted sugarcane and getting higher net returns from this system (Table 5). He is helping KVK in organizing various transfers of technological activities.

Table 5. Economics of autumn sugarcane based intercropping systems (Sh. Bhagwan Das)

Year	Intercropping system	Yield (q ha^{-1})		Gross returns (Rs.)	Total expenditure (Rs.)	Net returns (Rs.)
		Sugarcane	Intercrop			
2003-04	Sugarcane (COS 8436)+Garlic	1125	62.5	206250	85000	121250
2004-05	Sugarcane (COJ 64)+Garlic	1100	67.5	211250	87500	123750
	Sugarcane+Potato+Cucumber	1000	225.0	205000	82500	122500
	Sugarcane+Ajowain	1000	12.5	150000	52500	97500
2005-06	Sugarcane (COS 8436)+Garlic	1175	55.0	254500	90000	164500
	Sugarcane (COS 8436)+Potato+ Cucumber	1063	125.0	217500	85000	132500
	Sugarcane (COS 8436)+Onion	1000	200.0	182500	67500	115000
2006-07	Sugarcane+Onion	938	188.0	236563	82500	154063
	Sugarcane+Garlic	1000	62.5	284250	107500	176750

Success Story II

Sh. Gurmail Singh S/o Sardar Jaswant Singh resident of village Talakaur, district Yamuna Nagar having 21 acres of land came in contact with Krishi Vigyan Kendra, Damla (Yamuna Nagar) in the year 1998-99. He started intercropping of different crops in autumn planted sugarcane about 5-6 years ago. Now he is taking his major crops as intercrops in sugarcane and is harvesting good yield of these crops alongwith improved germination of sugarcane (Table 6). He is also taking summer crop of hybrid maize with average yield of about 70 q ha^{-1}. Last year he prepared mat type nursery of paddy and he mechanically transplanted 7 acres of paddy at his farm. His farm is totally laser levelled.

Table 6. Economics of autumn sugarcane based intercropping systems (Sh. Gurmail Singh)

Year	Intercropping system	Yield (q ha^{-1})		Gross returns (Rs.)	Total expenditure (Rs.)	Net returns (Rs.)
		Sugarcane	Intercrop			
2003-04	Sugarcane+Potato+Wheat	1005	332.5 * 25.0 **	230500	72500	158000
2004-05	Sugarcane+Garlic	755	62.5	170500	77500	93000
2005-06	Sugarcane+Garlic	913	45.0	179500	77500	102000
	Sugarcane+Onion	813	175.0	143250	50000	93250
2006-07	Sugarcane+Garlic	1000	70.0	303000	108750	194250
	Sugarcane+Onion	975	200.0	219800	83000	136800

*Potato yield.

**Wheat yield.

Limitations

1. Field should be levelled as light irrigation needs to be applied in furrows. Water stagnation in furrows even for a short period may hamper the germination of sugarcane by creating anaerobic environment.

2. There needs to be compatible varieties of intercrops which offer least competition to main crop of sugarcane. Short duration, erect growing habit are the desirable characters. In the long run breeding programmes need to be oriented to have a varietal basket exclusively for intercropping system.

3. Chemical weed control sometimes becomes a problem. Atrazine is recommended herbicide for sugarcane but it is fatal to wheat and vegetable crops. Similarly, 2,4-D will kill the raya crop. Weed management package has to be worked out with both the crops in view. In sugarcane+ wheat, sulfosulfuron and 2,4-D can be safely used. In case of pulses and vegetables pre-emergence application of pendimethalin is quite effective.

4. Depth of sowing should be maintained for intercrops to have optimum crop stand.

5. The operator of bed planter machine should be a trained person.

Conclusion

Sugarcane crop planted in autumn season with various intercrops will improve the tonnage and quality of cane, help in advancing the crushing season of the sugar mills, generate additional returns from intercrop and fetch extra income to the farmers. Bed planting technique has made the system practically feasible, economically viable and proved helpful in minimizing the yield gaps in cane yield besides additional income from intercrops. Intercropping of pulses in spring planted sugarcane crops improves the soil health and additional returns from intercrops without affecting the sugarcane yield.

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INTER-CROPPING OF SUGARCANE AND WHEAT

Create a perfect blend of resource conservation and money making

What we need Use bed planting method, plant sugarcane in furrows and wheat on beds.