



Prospects of Precision Farming in Sugarcane Agriculture to Harness the Potential Benefits

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Authors' contributions

This work was carried out in collaboration among all authors. Author GSS conceptualized and designed the study based on the emerging trends in sugarcane agriculture and wrote the first draft of the manuscript. Authors AK and RB managed the analyses and graphical presentation of the study along with management of the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Sugarcane on one side considered important for crop diversification and important for human civilization while on other sugar industry is facing a long term losses in terms of monetary issues. Moreover, farmer is also not clear about which techniques is to adopt for practising the sugarcane cultivation for precision farming. Therefore, range of new sugarcane cultivation technologies pertaining to its cultivars, fertilization, weed control, insect-pest and disease control needs to be invented and recommended to the cane farmers. Precision farming is an approach where inputs are utilised in precise amounts to get increased average yields, compared to traditional cultivation techniques. Adoption of precision agriculture in sugarcane has been slow due to a wide range of uncertainties and conflicting opinions. There is need to reduce cost of cultivation and to improve the canes yield and quality by adopting precision sugarcane techniques. In developing countries like India, Pakistan etc. precision agricultural techniques if adopted, is a powerful tool and should

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be started with a basic, affordable and effective integration of technologies and practices. Present article aims to review published and unpublished information on precision sugarcane farming must be applied for improving the cane yield and quality so as to improve livelihoods of the cane farmers.

Keywords: Sugarcane; precision farming; sustainable agriculture; site-specific technologies.

1. INTRODUCTION

Precision farming based considered intra field variations and thus recommended a set of technologies which helps to improve both the quality as well as quantity of his produce and deals with farm management practices and considered site specific management practices. Aim is to improve crop production and minimize environmental damage along with reducing overall cost of cultivation [1]. Precise land leveling to manage landscape variability, variable rate technology, site specific planting, site specific nutrient and other input management are important [2]. The crop inputs are distributed on a spatially selective basis through grid sampling or management zone approach. India, being a land of geo-physical, agro-climatic and greater socio-economic variability and simultaneously making indiscriminate use of irrigation and pesticides and imbalanced use of fertilizers during last two and half decades, badly needs precision farming for increasing use efficiency of crop inputs especially in crops like sugarcane and also maintaining the sustainability with enhanced productivity and reduced environmental damage. Precision farming in India could be unique in nature, different from what is being practiced in developed nations. It would be primarily based more upon knowledge and less upon sophisticated techniques [3]. So, precision farming refers to accuracy in any aspect of production viz. land leveling, proper crop cultivars, land, nutrients and water management. According to Stafford [4] precision farming involves the targeting of inputs to arable crop production according to crop requirements on the localized basis. Thus, the intent of precision farming is to match agricultural inputs and practices to localized conditions within a field to do the right things, in the right place, at right time and in the right ways [5]. Based on various discussions, the definition of precision farming may be defined as the application of technologies and principles to manage spatial and temporal variability associated with all aspects of agricultural production for the purpose of improving crop performance and

environmental quality. The objectives of precision farming are to increase production efficiency, improve product quality, use of chemicals more efficiently, energy conservation and soil and ground water protection.

Being C4 grass plant, sugarcane being most efficient in converting solar energy into sugars. Initially, canes being adapted for its sweetness by the Polynesians [6] but now all over the world it has many other uses viz. paper, ethanol and other alcohol, animal feed, antibiotics, particle board, bio-fertilizer and for electricity generation because of which its precision cultivation is a must [7]. Sugarcane industry run in parallel to the growth of human civilization and is as old as agriculture. For improving the benefits in cane farming, recovery rate in terms of brix of sugarcanes in mills while extraction is required and that could only be improved by adopting the complete set of precision sugarcane farming which one side reduces the cost of cultivation. Precision sugarcane farming's practices (most scientific and modern approaches) for improving yield as well as quality gaining momentum in 21st century. This review provides a comprehensive information of the important cane production advanced technologies for precision farming and seed quality assurance systems to harness better cane and sugar yields for sustaining sugar industry.

2. RECENT APPROACHES FOR PRECISION FARMING IN SUGARCANE

Conventional crop management practices from last many decades in India is capital, labour and water intensive which ultimately results in poor yields and thus returns. That's why new generations of farmers refused to get involved in the farming and tried to get some government jobs or settled abroad. This is challenge for the scientists particularly of agriculture to test and recommend scientific set of precision agricultural techniques, which inspired the future generations to remain in agriculture. But before recommending any technologies for a region

their indigenous technologies must also be considered. In comparison to state farming of western countries, field size is very small in India as the majority being small and marginal farmers with continuous subdivision and fragmentation of land. Therefore, the grid sampling and production level management zone approach may not be feasible in Indian agriculture. The different small fields in possession of a farmer or farmer may consider as management zones and the recommendations could be on random sampling from each zone. If the field size is found very small to study, the in-field variability and recommend variable rate application in an area.

2.1 Precision in Crop Establishment Techniques

Despite much progress in mechanization, use of country ploughs for tillage is not obsolete in India. Germination, crop stand, vigour and yield are dependent on proper tillage and crop establishment methods. Simply, mechanization does not ensure precision therefore, low cost precision planters with precise seed metering devices are to be popularized to ensure optimum plant stand with less seed rates. The recent approaches of conservation agriculture with the development of precision planters viz. no-till multi-crop planter with new generation seed metering systems reduced till raised bed planter with multi-crop planting systems in one of the right direction of precision farming in Indian perspective and can be properly followed when the soil physico-chemical variability and constraints are well known. Generally, deep ploughings (4-6) are required to produce good tilth in field to prepare land for sugarcane planting. However, ploughing must followed after each ploughing to pulverize the soil for better soil texture and aeration.

Sub soiling is a process of deep tilling of the ground mainly practiced to un-compact the soil that has occurred due to use of heavy machinery in present day farming. It also improves aeration of the soil and diffusion of nutrients. Deep criss-cross sub-soiling (1.0 m) would incorporate the subsoil with the top soil and must be repeated after every 3-4 years. Generally, chiseler used for this purpose (Fig. 1) which breaks the hard pan, improves the water and air movements, increased water infiltration rate which further helps in better rhizosphere area from where sugarcane could extract the nutrients from the soil solution.

2.2 Tractor Operated Sugarcane Cutter Planter

Sugarcane planting (required 30-35 labors ha⁻¹) include sett cutting and treatment, furrow opening, application of fertilizers in furrows on soil test basis, cane setts dropping in furrows, insecticide and pesticide application, covering of setts with soil in furrows and finally, planking. labor input costs and availability increased significantly now a days. Shrunken window period between spring and summer planting increased the extent of problem. Further, loss of moisture also adversely affected the germination of the planted canes in the furrows. For coming out of this problem, two-row tractor operated sugarcane cutter planter introduced and adopted by the farmers (Fig. 2). Further labor requirement also reduced to 4 laborer's with which one can plant 1.50-2.0 hectares daily and perform all the planting operations in a single pass.

Further, no loss of soil and sett moisture occurred which also results in 8-10 per cent higher germination which also delineated in the final yields. Cutter planter required with 35.0 HP tractor which automatically cut sugarcane complete length into small pieces before dropping into the furrows 90 cm apart along with which fertilizers also put into the furrows with a seed rate of 32-35 q/acre. Overall, it could reduced cost of cultivation by about 25%. Considering the cost efficiency, this machine can be used on custom hiring basis also. The comparative performance along with the benefit-cost ratio of different equipments used for sugarcane planting [8] is elaborated (Fig. 3a&b).

2.3 Paired Row Trench Planting

Sugarcane farmers using 'single row trench plantation technique' with 2-3 ft inter-row distance is 60-70 cm which results in 90-95 trenches acre⁻¹. For planting of sugarcane, 30-35 qtl seed sett is required for one acre. Further, around 130 kg of two urea splits required at an interval of one month. Around a total of 10-15 irrigations required annually depending upon the received rainfalls. Narrow row spacing, high seed rate, high labour input, high water consumption and difficult crop management operations and weeding are the major problems with single row trench planter followed by the higher insect- pest and disease attack due to lesser inter row spacing which further results poor wind circulation and sunlight penetration etc.

For better crop stand and saving irrigation water, paired row trench planting of sugarcane must be adopted. In this technique, paired rows of sugarcane are planted at a spacing of 1ft with 20-25 cm deep trenches. Cane sets placed at the bottom of the trenches, which further covered with the soil (Fig. 4). The distance between two trenches should be 3 ft. Newly developed tractor operated PAU designed trencher could be used which inspite of water saving also results in higher cane yield, labour

saving for weeding, easy propping up operation and reduces lodging, there also promoted quality. On account of the more inter-row area, intercropping of garlic or onion can also be done by which system productivity can also be increased. The wider space between two sets of cane allows easy transportation of harvested cane and no damage to roots. Thereby, this technology already recommended for the cane farmers of the Punjab.

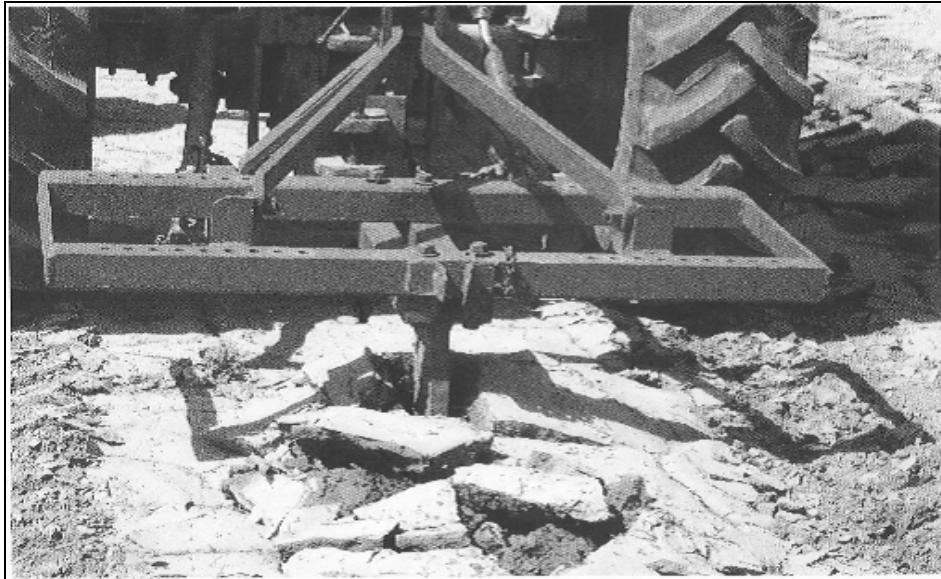


Fig. 1. Sub soiling with tractor drawn chiseler



Fig. 2. Two-row tractor operated sugarcane cutter planter

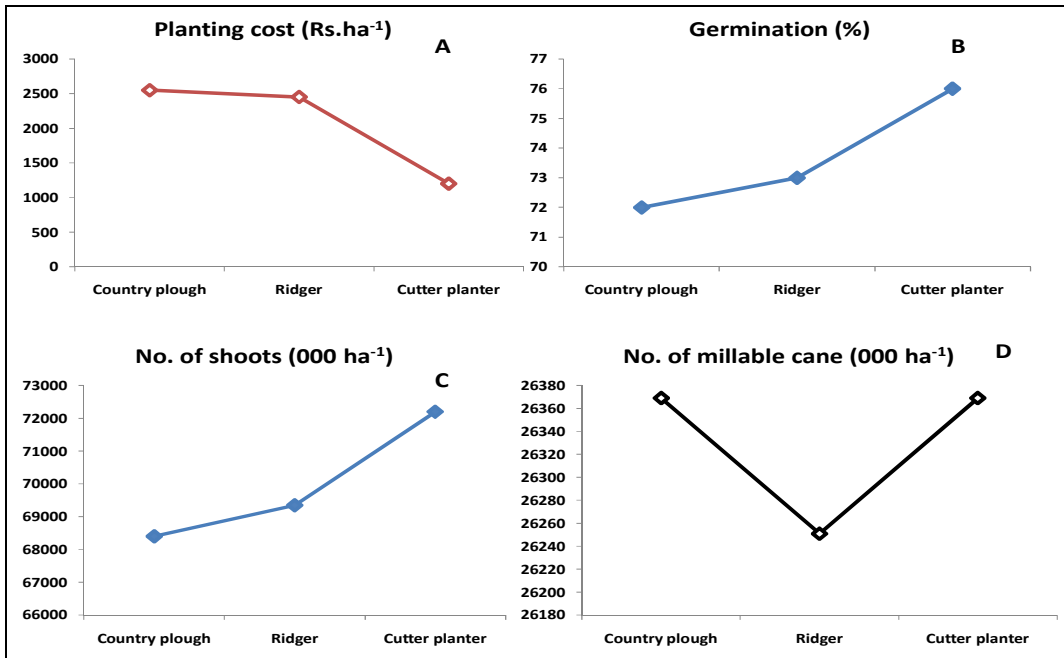


Fig. 3a. Comparative analysis of various implements used for sugarcane planting on germination, number of shoots and millable canes

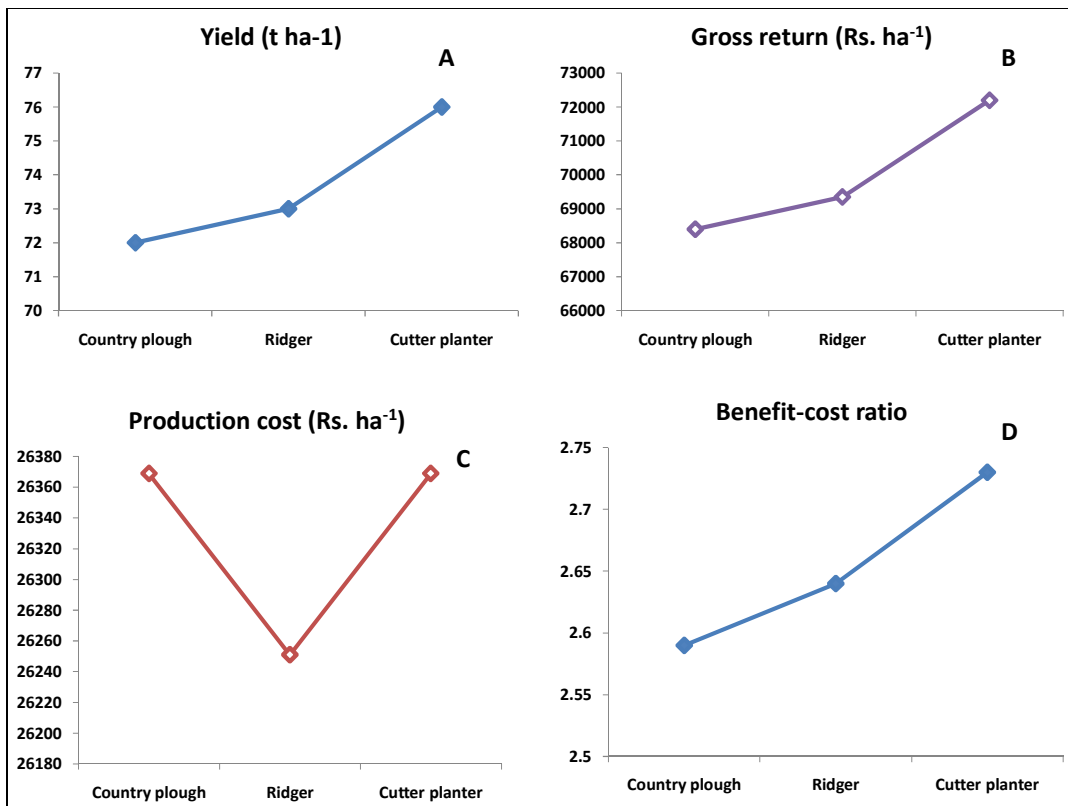


Fig. 3b. Comparative analysis of various implements used for sugarcane planting on cane yield and their economic returns

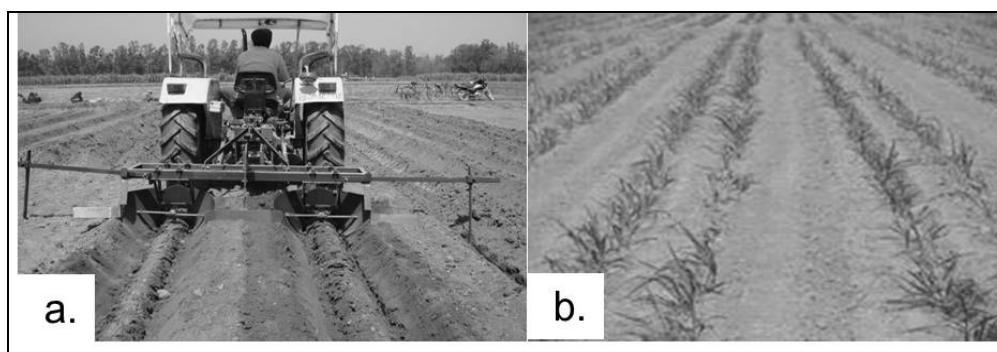


Fig. 4a. Tractor drawn paired row trench planter in operation, b. View of sugarcane germination in paired row planting

2.4 Precision Nutrient Management

From the last few decades, much of the discussions are there for improving nutrient use efficiency for overall having positive effect on the ecology. As per traditional knowledge farmers applied fertilizers as per use by their neighbouring farmers on the whole field without taken into consideration the spatial variability. Further, different sugarcane cultivars might have different nutrient requirements which further affected by the inherent nutrient supplying capacity of the soils. Similarly, by the use of lesser fertilizer use than required also hinder the yield achievements as per their potentials. Therefore, both the higher or lower fertilizer usage is not required rather their adequate use is a must for the precision sugarcane farming which is the need of the time. Generally, fertilizer recommendations varied from field to field due to variations of field characteristics including soil organic carbon, soil texture, soil structure, soil nutrients, field topography and other properties. Sampling techniques of soil to describe field variability have been recommended [9]. Before Global Positioning System (GPS) and Geographic Information System (GIS), delineating spatial variation is not an easy task and their effectiveness in the agricultural field depends on proper ground truth studies. Further, these techniques help us in studying complex spatial relationships between soil fertility factors. Soil sampling techniques that attempt to describe the variability in soil fertility factors within a field has gained more importance. Thus, precision agriculture through more judicious use of crop inputs and mapping of yield and quality variability, proved to be a tool which further helped to improve the overall sugarcane yields as well as quality. New techniques could reduce the total amount of nutrients and other inputs

applied to a field and thereby also minimize variability of that input (nutrient). Increased crop quality, improved sustainability, lower management risk, increased food safety due to produce traceability, environment protection are some of the benefits of the precision agriculture [10]. Site-specific nutrient management (SSNM) recognizes the inherent spatial variability associated with most fields under crop production [11]. SSNM practice responds significantly not only to the primary nutrients but also to the secondary and micro-nutrients due to emerging deficiencies for the targeted yields. SSNM tools viz. leaf colour charts helps to consider the spatial variability within the field. It also took into consideration of the effect of different added inputs viz. farm yard manure or may also advocate the higher use of the nutrients at some deficient sites, which otherwise ignored in the conventional methods, thereby resulting in lower production particularly in these pockets with lesser fertility. Among the most important soil factors influencing yield patterns, soil pH, soil organic carbon (%), extractable Ca^{2+} and Mg^{2+} , K-Saturation, clay content (0-15 cm) and N:P ratio are the main which must be considered [12]. Site specific nutrient management within field on cluster basis coupled with target yield approach may further enhance the nutrient use efficiency and helps to sustained yield level of crops.

Sugarcane crop, after textile industry is the second largest agricultural industry impacting economy of a country, therefore, proper and judicious nutrient management played an important role. Attempts being made to improve the nutrient use efficiency by one or other way in the sugarcane farming. Integrated nutrient management also played an important role in this regard to sustain the soil health, Therefore, 8 t

acre⁻¹ already recommended 15 days prior to the cane planting. Hence, water and nutrients management issues in sugarcane needs to be addressed as early as possible in relation to climate. Sugarcane takes up nearly 208 kg N, 53 kg P, 280 kg K, 6.3 kg Fe, 1.2 kg Mn, 0.6 kg Zn and 0.2 kg Cu from soil by an average crop producing 40 t acre⁻¹ of sugarcane [13] which indicates higher amounts of nitrogen and potassium need to be applied. In spite of this, in Punjab, India potash is not recommended to the sugarcane as the state has abundance of illite which through its lattice structure could strengthen the soil solution, but there is a need to rethink the potassium dose for the deficient soils to have optimum cane yields with desired quality. Further, higher costs of these fertilizers appeal for their judicious use through newer technological options seems ideal. Among them wider/paired rows, drip/fertigation and split application as per crop demand/growth stage etc., are worthy for adoption. Further, nitrogenous fertilizer being a basic and widely applied nutrient in Indian agriculture wishes special attention. For improving nitrogen use efficiency, nitrogen losses and environmental pollutions should be reduced, through leaf color charts (Fig. 5A) and chlorophyll meters (SPAD) (Fig. 5B). The leaf color chart (LCC) based on real time nitrogen management can be used to optimize or synchronize nitrogen application with crop demand or improve existing fixed split nitrogen recommendations [14]. They further reported that the net returns in rice-wheat cropping system were increased by 19-31 in LCC based N-management then in fixed time nitrogen application. The yield and yield attributes of rice were significantly higher in the LCC based nitrogen application compared to other treatments [15,16]. The performance of LCC in sugarcane also needs to be tested for having need based application of N-fertilizers to the canes.

2.5 Site-specific Weed Management

In general farmers uniformly broadcast or spray herbicides to control weeds. However, it is well recognized that a degree of spatial variability exists in weed [17]. Therefore, over application and under application of herbicides occurs obviously. Higher use of herbicides causes environmental contamination, increased cost and polluted the water bodies. Likewise, under application causes poor weed control with substantial yield loss. The spatial variability in weed practice of managing landscape variability

in India is leveling through animal or tractor drawn scrappers. The precision weed management involves three main components viz. preventing weeds through adapted crop management, improvised decision making on weed control, and developing precision control technology.

2.6 Micro-irrigation Technologies

Crop yield generally shows linear correlation with amount of water transpired [18]. When water is a limiting factor, crop yield is much lower than the potential yield. The excess watering may induce stresses with respect to aeration and nutrient availability. Therefore, the only option is precision water management which has three approaches viz. variable rate irrigation soil-landscape management and drainage [19]. Irrigation demand of any crop has a direct relationship with the evapo-transpirative (ET) water demand, where objective is to reduce the evaporation (E) share to the transpiration (T) share to have overall higher cane yields. The cumulative pan evaporation can be used to decide the time of irrigation. The IW/CPE ratio of 0.80 was found better than 0.50 ratios at Karnal (sandy loam soil), Sehore (Clay loam) and Lucknow (Loam). In sugarcane surface and sub surface drip irrigation systems are found better in conserving 29.2 per cent irrigation water over conventional ridges and furrow irrigation [20].

2.7 Crop Geometry for Mechanical Harvesting

Sugarcane - the important cash crops providing employments but is very labour intensive and requires heavy use of machinery, which needs to cut down for reducing its overall cost of cultivation. Further, reduced labour during peak window period further complicated the situations. The increase in labour wages as well as its scarcity has led to enhanced dependency of growers on farm machinery in different operations. For making various equipments to be economically viable, cost of the equipment, and utilization, the limitations and suitability of the equipment, slope of the land, field access and other factors such as soil compaction and crop damage and harvesting losses must be considered. Wider row spacing is preferred for mechanization and should be compatible with the wheel tracks of infield machinery. For newly introduced harvester (Fig. 6) a row spacing of 120 cm is recommended. Under mechanically

harvesting, the cultivars should also have the attribute like non-brittle cane, lodging resistant, minimal tops and trash, self-trashing or loose leafed to facilitate trash removal and ratoonability must be considered. Chopper harvesters (Fig. 6) met most of the above mentioned requirements of harvesting. However, due to higher cost involvement, presently it is there only in the sugar-mills of the state, further on cooperative basis (as that of laser leveler) it must be popularize at the farmer's fields. The extraction vehicles for harvester supporting need to be considered. But due to high level of infield traffic, mechanical harvesting systems also require infield management for minimizing field and stool damage.

2.8 General Considerations for Opening Future Avenues of Mechanical Harvesting of Sugarcane

1. Facilities received by the sugar-mills, cane payment mode, proper inter-row spacing and new sugarcane cultivars suitable for mechanised harvesting operations required.
2. Shortage of manual labour main driving force behind the adoption of mechanical harvesting.
3. Performance of mechanised harvesting system is directly related to pre-planning and level of supervision for sugarcane planting area. The level of efficiency required may only be reached after the second or third season.
4. Skills and techniques of the operators necessary to maximise machinery performance.

5. Viability of the relatively more sophisticated and expensive mechanized harvesting machinery improved by formation of harvesting or contracting groups.

2.9 Intercrops for Sugarcane Precision Farming

Sugarcane is a long duration crop that remains in field for 12-14 months. To harness better returns or enhanced productivity per unit area it is beneficial to grow it with other small duration crops suitable for spring and autumn planting seasons. Some promising crop combinations are detailed below:

2.9.1 Spring planting

Spring planted sugarcane could be grown profitably with other inter-crops viz. summer moong, summer mash and mentha crop and recommended by the state universities for improving overall livelihoods as it results in additional grain yield of 1.5 to 2.0 qtl acre⁻¹ of summer moong/summer mash. Further, it also improves the soil fertility by improving the organic matter of the soil. Mentha can also be grown as an intercrop in spring planted sugarcane crop. One row of mentha between two rows of sugarcane may be planted. Mentha and sugarcane can be planted simultaneously in the first fortnight of February. Use one quintal of mentha suckers per acre. In addition to fertilizers recommended, additional 18 kg N (39 kg Urea) and 10 kg P₂O₅ (62 kg Super Phosphate) per acre must be applied. Almost, 50% N and 100% P must be applied during planting and remaining N may be applied about 40 days after planting.

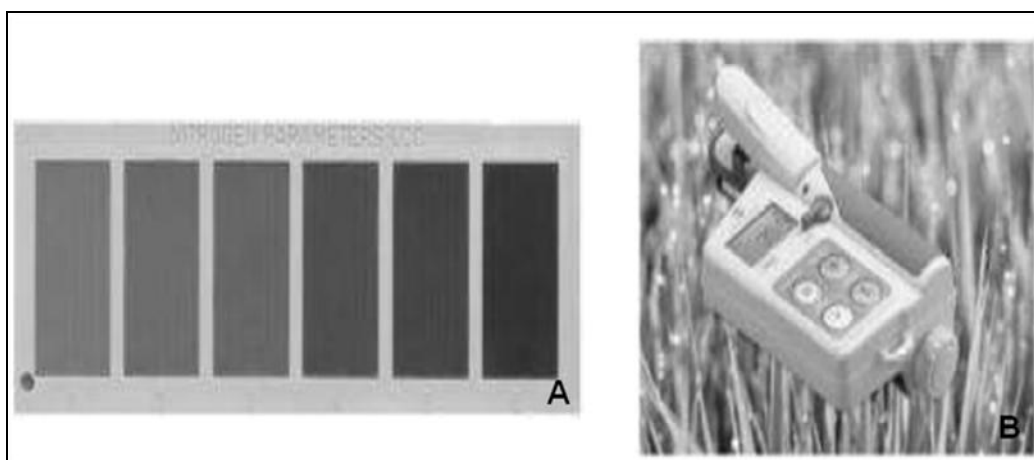


Fig. 5. Leaf colour chart (A) and SPAD meter (B) for the judicious use of the N-fertilizers



Fig. 6. Chopper mechanical sugarcane harvester exhibition cum demonstration at riar farm Punjab

2.9.2 Autumn planting

Intercropping is a tool to promote autumn planting giving 15-20 per cent higher cane yield and 0.5 units more sugar recovery than spring planted cane along with higher income. The autumn sugarcane based intercropping systems involving pulses, oilseeds, cereals and vegetables. Many crops like wheat, raya, toria, gobhi sarson, potato, garlic etc. can be used as intercrops in autumn planted sugarcane crop [21]. Autumn sugarcane + winter maize (cobs), autumn sugarcane + garlic, autumn sugarcane + wheat etc are some of the most profitable intercrops cropping rotations [22,23].

3. PRECISION IN PEST AND DISEASE MANAGEMENT

Use of bulky cane cuttings in sugarcane as cane seed results in many pests and diseases thereby decreasing cane yield and quality drastically [24]. Build up of diseases over vegetative cycles leads to further yield decline along with quality. Poor quality seed is a major constraint to get good returns from the sugarcane farming [25]. There is normal practice in sugarcane growing States to use commercial crop of sugarcane for seed purposes. Application of chemicals for management of pest and diseases is increasing rapidly in India leading the problem of chemical residues and resistance in pest. Although, commendable research has been made on integrated pest management but in many cases it is not been practically feasible and the farms are not aware of the components of IPM. Much

research is required on IPM for different crops and cropping systems at different locations. The pests could not manage without proper monitoring which is essence of precision pest management. Assessing pest incidence at regional level in predominant crops concentrated in specific locations could be made through the precision farming technologies (remote sensing and geographical information system) and the pesticides to manage the specific pest can be suggested to the farmer at regional scale. This type of information based technologies help in reducing pesticide loads as well as better management with less investment.

Early Shoot Borer (ESB) attacks the crop during the early part of cane growth during April-May, before internode formation. There are different pathways with which insects entered into the sugarcane and done the damage as larvae enter the cane laterally, bores downwards as well as upwards thereby killing the growing point and finally causes a significant damage if not controlled by forming a 'dead heart'. Dead heart (emits offensive smell) can be easily pulled out. Borer infestation resulting in the drying up of the entire clump (during the germination phase) kills the mother shoots. To overcome its attack, application of 10 kg granules of Regent 0.3 G (Fipronil) in the furrows along the cane setts before covering with soil or spraying 150 ml Coragen 18.5 SC (Chlorantraniliprole) or 2 litres of Chlorpyrifos 20 EC in 400 litres of water/acre along the rows at post-germination stage (about 45 days after planting) effectively controls the early shoot borer [21]. Slight earthing up after

application of insecticide followed with light irrigation is mandatory.

Top borer, a white moth, attacks the terminal portion of the cane during cane formation stage and induces axillary buds to germinate, causing bunchy top. Subsequently, third and fourth generations cause maximum damage. The larva first tunnels into the midrib of the leaves and causes a white streak which later turns reddish brown, usually in the second to fifth leaf from the top. As a result of biting across the spindle, a number of shot holes are formed in the leaf. In tillering phase of the crop, the attacked shoots die, side shoots (tillers) develop producing a bunchy top appearance. Severe yield loss and quality deterioration occurs due to top borer. Depending upon the incidence level yield loss may be up to 20-30%. For its effective control, apply 10 kg granules of Ferterra 0.4 GR or 12 kg Furadan encapsulated 3G (Carbofuran) or Thimet encapsulated 10 G (Phorate) at the base of the shoots in the last week of June or in the first week of July only if the top borer damage exceeds 5% level. Earth up slightly to check the granules from flowing with the irrigation water and irrigate the crop immediately. This operation will control the third brood of the top-borer which does the maximum damage.

4. QUALITY SEED PRODUCTION AND ASSURANCE

Sugarcane is propagated vegetatively for commercial cultivation and requires 30-35 qt of seed per acre. Among different classes of cane seeds whether it is breeder, foundation and certified, generally not maintained, therefore the exact quantum of different sugarcane seeds could not be quantified, which further creates problem in delineating the SRR (Seed replacement rates) in sugarcane [25]. Different kinds of planting materials viz., cane setts; settlings and bud chips are used for raising sugarcane crop. Stem cuttings or sections of the stalks called "setts" propagate sugarcane. Each set contains one or more buds. Cuttings are taken from the selected canes under normal conditions, commercial crop of sugarcane for seed purposes. Sugarcane yields and recovery of sugar deteriorate because of lack of good quality seed. Inadequate availability of quality seed of new sugarcane varieties and poor seed replacement rate adversely affect the realization of potential cane yield of varieties. Seed replacement with fresh commercial seed is done only after 4 years [26]. Diseases are one of the

major constraints in the profitable cultivation of sugarcane. It is vegetatively propagated and it favours accumulation of pathogens of most of the diseases [27]. Hence along with seed canes, disease causing pathogens are also introduced into new areas. Slow accumulation of different pathogens over a period of time makes minor diseases into major one. Several epidemics due to red rot, smut, wilt, grassy shoot, ratoon stunting, yellow leaf and leaf scald occurred in the past indicated that disease infected seed can played significantly in their creation and further spread [28]. Affected planting material poses a major problem in propagation and exchange of germplasm, and eventually in breeding and distribution of superior genotypes. To obtain disease-free seed, a separate seed nursery should be maintained. Some rapid multiplication techniques (RMTs) used for quality seed cane production are given below:

4.1 Micro-propagation

Micro-propagation is the first main and widely established practical application of plant biotechnology. It is a key device of plant biotechnology that has been widely exploited to meet the growing demands for elite planting material in the current century. Sugarcane micro-propagation involves the use of small explants (meristems) which are cultured on a nutrient medium under sterile conditions. Using the proper growth medium and growing environment explants can be induced to rapidly produce several shoots, and, with the addition of suitable hormones produce new roots [29].

Sugarcane micro-propagation is the practice of swiftly multiplying stock plant material to produce a large number of offspring plants under aseptic conditions using modern plant tissue culture methods [30].

This is a simple method because of the ease of development, saves cost of producing planting material. Micro-propagated sugarcane plants are used as breeder's seed in seed reproduction system and seed obtained from micro-propagated plants are used as foundation seed [31,32]. The plants should be spaced 60 cm apart with a row to row to spacing of 90 cm, followed by immediate irrigation.

4.2 Bud Chip Technologies

Sugarcane is normally propagated by stalk cuttings consisting of 2 to 3 bud setts. In

Table 1. Economic comparisons for sugarcane crop establishment through conventional and bud chip technique [7]

S. no.	Particulars	Conventional method	Bud chip technique	Savings (%)
1	Current rate of seed/ha (kg)	8,700-10,000	165-200	95
2	Cost of seed/ha (Rs.)	26,000-30,000	13750	53
3	Seed requirement for state (tons)	564,220	84,633	85
4	Seed cost for state (Rs. crores)	169.26	25.38	85
5	Area for seed requirement (ha)	9,466	1,410	85

conventional system, about 6-8 tons seed cane /ha is used as planting material [33]. Establishing the sugarcane crop using bud chips in place of setts could save about 80% by weight of the stalk material, however this technology has not been scaled up at commercial levels due to poor survival of bud chips under field conditions [33]. So, it is advised to prepare a pre-hand nursery of seedlings from bud chips and then transplanting the seedlings in field at a suitable time. For the nursery, an area of 40 square meters is used to create seed for one acre land. This is covered with shade net over the little plants and to create more favorable conditions for growth. Only five quintals (5 qtls.) of healthy, disease-free, 7-9 month old canes are required for establish one acre of field [33]. Out of this, only buds are taken. They are separated from the cane with the help of a specially-designed tool called bud chipper. Damaged, split and sprouted buds are leftover after chipping. The weight of chipped buds is about 85 kg (<5% of the cane weight). The rest of the canes can be sold to sugarcane juice vendors. The chipped buds are chemically treated with fungicides to prevent any disease infestation and are filled into gunny bags. A plastic sheet is broaden in a corner of the shaded net and sugarcane trash/rice straw is extend evenly on it and water was sprinkled over the material. Chemical-treated gunny bags are laid flat, side by side, on the trash and the buds are spread inside the bags evenly. One more layer of trash is spread above the moist gunny bags and water is scattered over it. The entire packs are covered with a polythene sheet. The buds are kept in this position for 5-6 days for pre-sprouting. After the 6th or 7th day, the gunny bags are opened and the well- sprouted bud chips are transferred into plastic trays [33]. The well sprouted buds are placed in cavities of plastic trays (one per cavity) having a mixture of sawdust, coco-peat and vermicompost below and above the buds. After filling, all the trays are spread inside the net shed and a plastic sheet is placed over them for two days by tightly covering

for avoiding entry of water, air or sunlight into the trays. Watering to the trays having seedlings is done in the evenings based on their moisture content for the next 25 days using spray cans. About 30-35 days after sowing of the nursery, transplanting is done at spacing of 4 ft x 2 ft in the field immediately followed by irrigation in furrows rather than by inundating the whole field. This resulted in saving of huge quantity of water. These seedlings are also used for gap filling in the field. In sugarcane cultivation, seed is the main input cost, amounting to Rs. 25,000-30,000 per hectare. The cost of seed can be greatly reduced by produce seed in a special seed nursery as describe above. For this, farmers can be motivated to produce their own seed nurseries using the above said method; they can reduce the cost of cultivation of sugarcane crop by a huge amount. The economic aspect of sugarcane crop establishment through straight and bud chip technique is given in Table 1.

5. KEYS TO SUCCEED IN PRECISION FARMING

Doberman, et al. [34] has suggested that there are three main points in implementation of successful precision farming under field conditions and are detailed below:

Information: Information is most valuable resource for modern farmers. Timely and accurate information is crucial in all phases of production from planning through post-harvest. Information available to the farmer includes crop characteristics, soil properties, fertility requirements, weed populations, insect populations, plant growth response, harvest data and post-harvest processing data. The precision farmer must seek out and use the information available at each step in the system.

Technology: Second key to success is adoption of modern technology in agriculture. Computer software, spreadsheets, databases, geographic

information systems and other types of application software are readily available. The global positioning system has given the farmer means to locate position in the field to within a few feet. This also helps in evaluating the performance of precision farming techniques viz. soil test based fertilization.

Management: Third key to success, combines information obtained and available technology into a comprehensive system is the management aspect. Precision crop production would not be effective with its all objectives unless until proper management followed. Farmers must know how to interpret the information available, how to utilize the technology and how to make sound production decisions.

6. CONCLUSIONS

Sugarcane agriculture has been continued to be a keystone of Indian economy. In future, precision farming in this crop may help farmers to harvest the fruits of different frontier technologies without compromise quality of land and produce. The implementation of such a novel techniques would activate a techno-green rebellion which is the need of hour. Since precision farming is integration of both modern skills and past experiences to practice crop production. It has potential to progress both the productivity of farm and reduce environmental damage in sugarcane agriculture. Further, it can improve the fertilizer use efficiency and other input use competence so that farmers can save considerable amount of fertilizer. In sugarcane, wider row spacing, surface and subsurface drip irrigation system conserve about 29.2% irrigation water over conventional ridges and furrow irrigation system. Multi tasked sugarcane cutter planter saves operational cost of planting by 50% and hence requires popularization in sugarcane cultivated States. Level of farm mechanization in the country and mechanization adoption gaps needs to be identified. Also there is a need to develop Hi-tech machinery like sugarcane harvester etc., indigenously with cost efficacy. Popularization of machineries like planters, power weeder, boom sprayers etc., through front line demonstrations is also highly necessary. Therefore, adoption of precision sugarcane farming practices will certainly help on one side, to improve overall cane yields along with its juice quality and to minimize the cost of cultivation on other, with which the cane farmers certainly has good profits and livelihoods throughout the country.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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