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Introduction

Sugarcane (*Saccharum officinarum* L.), an old energy source for human beings and more recently is a replacement of fossil fuel for motor vehicles. Sugarcane growing countries of the world are lying between the latitude 36°N and 31°S of the equator extending from tropical to subtropical zones. World wide in 107 countries, sugarcane occupies area of 20.42 million ha with a total production of 1333 million tons [21]. Sugarcane area and productivity differ widely from country to country. Brazil has highest area (5.34 million hectare) while Australia has highest productivity (85.1 t ha^{-1}). The largest producers are Brazil, India, China and Pakistan accounting more than 50% of world production [14].

Sugarcane is the second largest cash crop of Pakistan and is being cultivated on 0.966 million hectares contributing around 3.6 % of Gross domestic production (GDP) [15]. Sugarcane currently accounts 4.8% of cropped area and 11% value added of the total crops [12].The sugar industry plays a pivotal role in the national economy of our country. Sugarcane provides sugar, besides biofuel, fiber, organic fertilizer and myriad of by products/co-products with ecological sustainability. Molasses is the cheapest feed stock for the distilleries. The bagasse has been accepted as a viable alternative raw material to wood in the paper and pulp industry. The industry contributes around 4 billion rupees under the head of general sales tax and other indirect taxes levies to the Govt. [13]. The industry employs over one million people, including management experts, technologists, engineers, financial experts, in addition to skilled and unskilled work force. Sugar industry contributes substantially to the rural economy as the mills are located in rural areas. [11].

Ecological factors for sugarcane cultivation

a. Photosynthetic efficiency

Sugarcane is one of the most efficient photo-synthesizers C_4 plant converts up to 2% of incident solar energy into biomass. It excels all other crop plant as a converter of solar radiation and carbon dioxide of the air into food, fiber and fuel with photosynthetic rate of 12-14 μ Mol $CO_2/m^2/sec$. [21].

b. Climate

Sugarcane cultivation requires a tropical or subtropical climate, with a minimum of 600 mm annual rainfall. In Pakistan sugarcane is cultivated in three ecological zones i.e. north western, central and southern zones. Climatic conditions of lower Sindh (southern) are more favourable having hot and semi-humid climate. The climate of Pakistan is mainly subtropical arid to semiarid. Temperature ranges from a mean of minimum 4°C during December and January, maximum of 38°C during June and July. Although in very small tracts the minimum temperature during winter sometimes retards or stops sugarcane growth. The climate generally favours crop productivity through-out the year. But inclement weather conditions specifically limited amount of rainfall is a critical factor for sugarcane crop production hindrance in Pakistan [1].

Area, productivity and utilization

In spite of all efforts sugarcane production in the country is still much lower than most of cane growing countries of sugar world. Amongst the many constraints responsible for low productivity, inappropriate plant population, substandard method of cultivation, poor nutrition management, inadequate irrigation water supply and lack of plant protection practices are the major ones and need immediate attention [(22)]. This shows that during last 50 years, area under sugarcane increased 310 %, production 566 %, cane yield 200 % (Table-1a) and sugar recovery as a national average improved from 7.50 to 8.70 (Fig.1).

Total cane produced, cane crushed in the factories and their utilization percentage (Table-1b) show that all the available cane was utilized by the factories. The utilization of sugarcane by the factories during low yield years ranged 62 % to 68 %. So assuming 80 % utilization during coming crushing seasons is merely a wishful thinking. The diversion towards gur production has always been more attractive during the short supply of sugarcane. Sugarcane production (2004-05) was 43.5 million tons against 64.65 million tons installed capacity of 78 sugar factories. Therefore, 21.2 million tons of additional cane production would be required to run factories at the existing installed capacity. If new factories are installed or existing units are being expended, they should be aware that they have to put in special efforts to enhance cane productivity for this new capacity. Cane yield status under different levels is given in Fig.2.

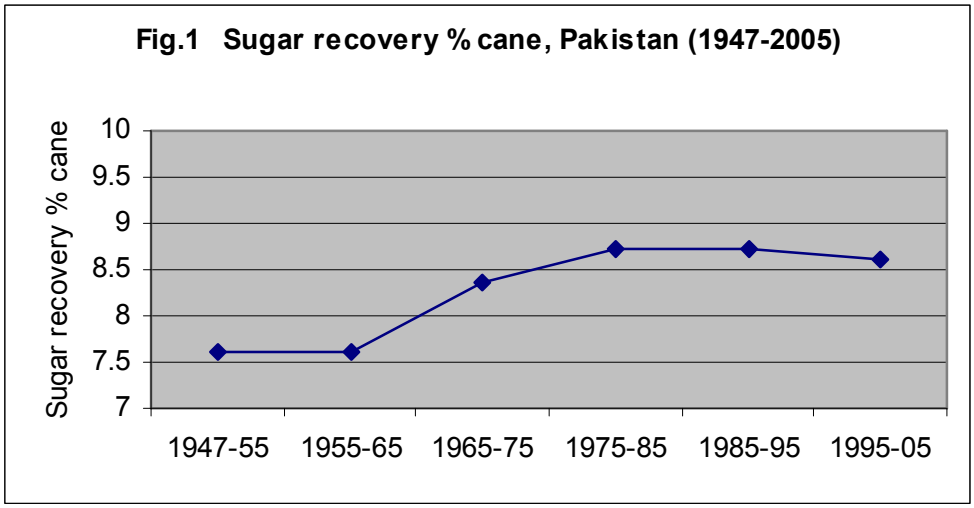
Table-1a Area, production and cane yield, Pakistan (1947-05)

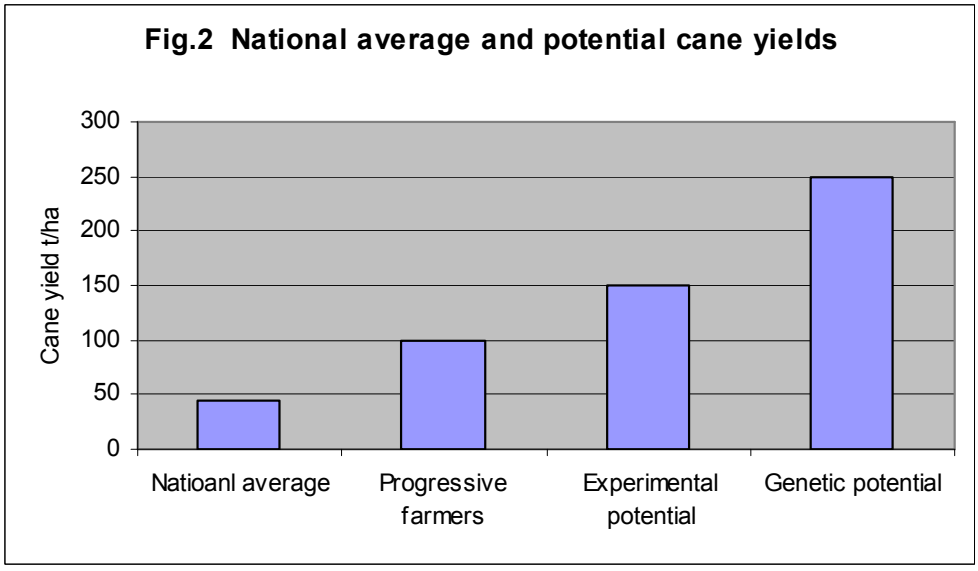
Years	Area "000" ha	Production "000" tons	Cane yield M. t ha^{-1}
1947-55	245	7192	29.2
1955-65	468	15847	33.7
1965-75	608	21648	35.7
1975-85	896	33579	37.5
1985-95	927	40883	43.9
1995-05	1020	47899	46.9

Table-1b Cane produced, cane crushed and utilization percentage (1995-2005)

Year	**1995-96**	**1996-97**	**1999-00**	**2000-01**	**2004-05**
Area (000 ha)	963.1	964.5	1009.8	960	966.6
Sugarcane production (000 tons)	45229.7	41998.4	42000	43590	43533
Installed capacity (000 tons)	54300	54750	55800	56250	64650
Cane utilized by mills (000 tons)	28151	27352	28982	29408	32101
% age of utilization	62.24	65.13	69.00	67.47	73.74

(*Source PSMA Annual Report 2005*)





Research and development

Without good R & D, an industry would find it difficult to sustain itself. When the industry is relatively small, it can beg or borrow information from others, or remain in-efficient. When an industry is large by world standards, it is a very different matter. The sugar industry in Pakistan can no longer afford luxury of doing little research work in relation to its size. It is a major industry not investing required amount of resources in R & D on sugarcane, which contributes about 70% of the total cost of production of sugar [(1)]. The industry is working on adhocism, no sustained effort for sugarcane improvement is being adopted by the industry. With adequate funds and research staff it could be possible to evolve varieties having better yields and better disease resistance. The need of the hour is to adopt better plant protection practices and better agronomic practices. The need in improvement of better milling and processing practices can not be over emphasized [(7)].

Eleven research institutes (two in private sector) are working on multifarious aspects of sugarcane crop in different ecological zones, out of which six in Punjab, three in Sindh and two are in NWFP. Research work done in above mentioned institutes on important aspects is development of new cane varieties, biological control of insect pests, tissue culture propagation of elite clones, studies on disease tolerance and insect resistance, agronomic trials, soil and water advisory services, workshops/seminars on R & D activities on sugar crops and technical training of scientists in the country or abroad [3].

Varietal improvement

a. Import of cane fuzz

The variety evolution program in Pakistan depends mainly on imported fuzz, which is imported invariably from USA, Brazil, Barbados, South Africa, Mauritius and Australia. These research stations have a good germplasm in various selection stages [19].

b. Production of fuzz under local condition

The coastal area of Sindh can be very effectively utilized for cane hybridization. The area has a good scope of producing hybrid seed for developing desired varieties. The only problem being faced in the area is night temperature during flowering 10-15^{o}C, which has drastic effect on anthesis and seed viability. The low temperature is a barrier in making viable crosses for profitable selection. However, developing a temperature control room facility, a successful breeding programme could be materialized [19].

c. Tissue culture technique

Tissue culture technique is being largely utilized for micro-propagation for new varieties for disease free, true to type and rapid seed multiplication. The technique is also being used to produce soma clonal resistant variants of disease susceptible varieties [18].

d. Use of molecular biology

In this case DNA selected for certain characters are transferred to desired cultivars. Anther culture or cell cultures are also diffused to combine the traits. This is the sophisticated technology. The technique has been used in genome mapping for identification and detection of transformed characters in progeny lines. Hopefully, in future molecular breeding development for transgenic plants may replace traditional breeding of sugarcane crop [18].

Major agronomic factors to improve productivity

Integrated management of high yielding varieties, irrigation water, nutrition and pests of plant and ratoon crop has shown capability of producing cane and sugar yield at lower cost than could be attained with existing practices [1].

a. High yielding varieties

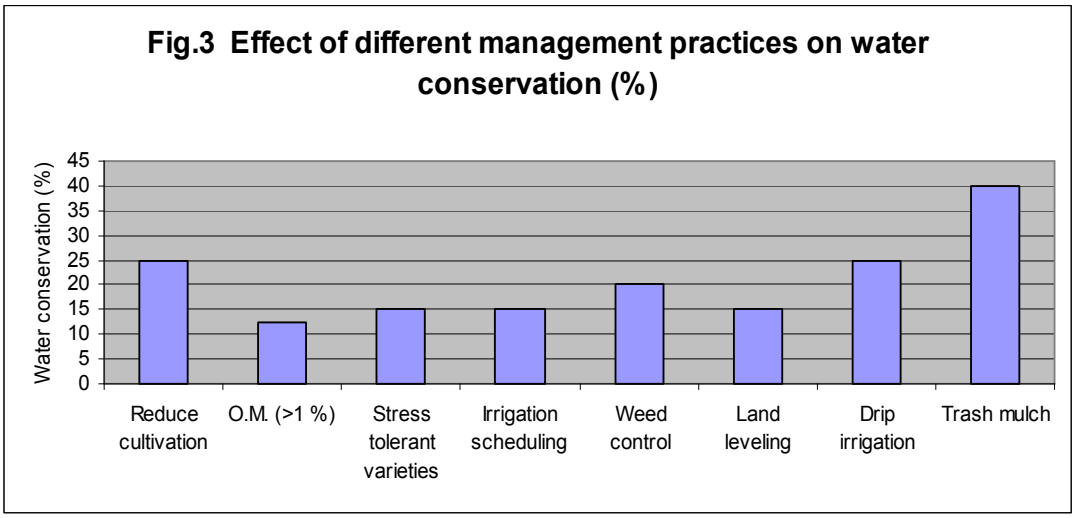
It is law of thumb of world's sugar industry that area under a very good sugarcane variety must not be more than 20 to 25 percent of the total sugarcane area. This has been adopted to avoid un-expected epidemics. This rule is not operative in Pakistan sugar industry. Unapproved varieties are being propagated and no measure is being taken to replace existing unapproved varieties [3]. Biometric characteristics of cane varieties recommended for general cultivation in different provinces are given in table-2.

Table-2 Biometric characteristics of sugarcane varieties (2002-2005)

Sr. No.	Varieties	Maturity	Yield (t/ha)			Ratoonability
			Spring	Autumn	Ratoon	
	Punjab					
1.	SPSG-26	Early	115	112	70	Poor
2.	CP77-400	Very early	90	100	80	Good
3.	CPF-237	Very early	107	115	100	Good
4.	SPF-213	Early	110	120	100	Good
5.	HSF-240	Medium	104	112	101	Excellent
6.	SPF-234	Medium	120	130	110	Good
7.	CPF-243	Medium	130	135	120	Excellent
	Sindh					
1.	SPSG-26	Early	125	125	80	Good
2.	NIA-98	Early	129	132	125	Excellent
3.	Lark-2001	Very early	126	141	114	Good
4.	BL-4	Early	110	120	105	Medium
5.	Thatta-10	Very early	114	120	100	Good
6.	SPF-234	Medium	120	130	110	Good
	NWFP					
1.	Mardan-93	Very early	116	120	110	Excellent
2.	S87US-1873	Early	117	125	110	Good
3.	SPSG-394	Early	150	160	150	Excellent
4.	CP77-400	Very early	90	100	80	Good

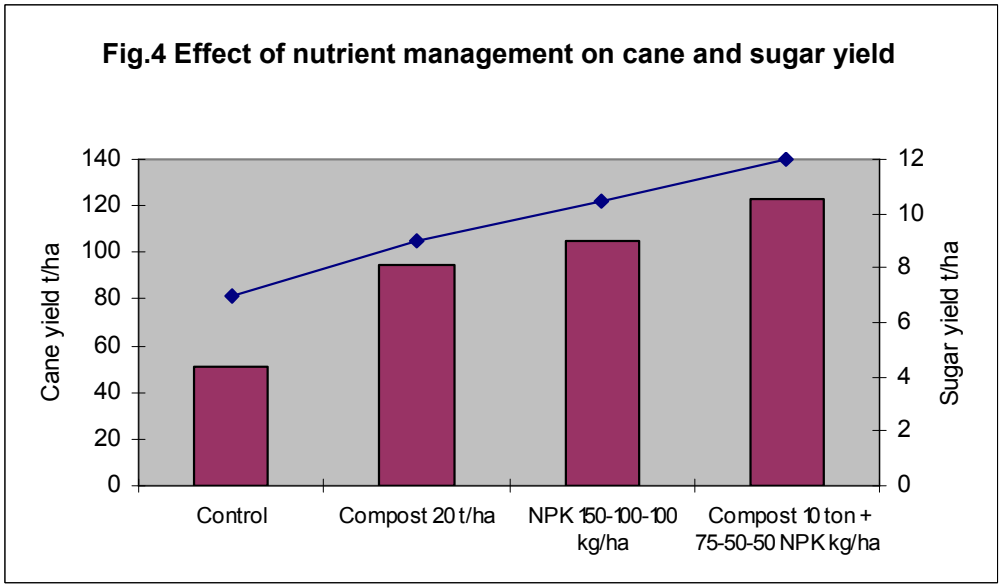
b. Irrigation management

Pakistan ranks fifth in the world and third among the developing nations in terms of the size of its irrigated area. Its 4:1 ratio of irrigated to non irrigated agriculture which is the highest in the world. Canal command area is 16.2 million ha out of the total cultivated area of 20.6 million ha. However despite the extent of this canal system, it supplies only 70 % of the gross water requirements of sugarcane [23]. In Pakistan water is main constraint and costly input affecting cane and sugar yields. It has been worked out that to produce one ton of cane, 200-250 tons of water is required. The availability of water of sugarcane crop is almost static, even decreasing in cane growing areas over the years. There is an imperative need to optimize production of sugarcane by efficiently managing water resources and their reliability. About 50-70 % of water is lost through surface evaporation, run-off leaching beyond root zone and transpiration by weeds. Anytime water becomes limiting factor growth is reduced so does yields. Cane variety, water deficit severity, and the stage of development affect the amount of yield reduction [4]. Efficient utilization of water is the only alternative to increase productivity of the soil [5]. Results of research studies done on water conservation are given in Fig.3. Adaptation of these valuable practices would be helpful for profitable cultivation of sugarcane in Pakistan. The practices that could give conservation of 12.5 to 40 % irrigation water are reduced cultivation at early crop stage, addition of organic matter in soil, use of stress tolerant cane varieties like HSF-240, irrigation scheduling, land leveling, weed control, drip irrigation and trash mulch of ratoon crop.



c. Nutrient management

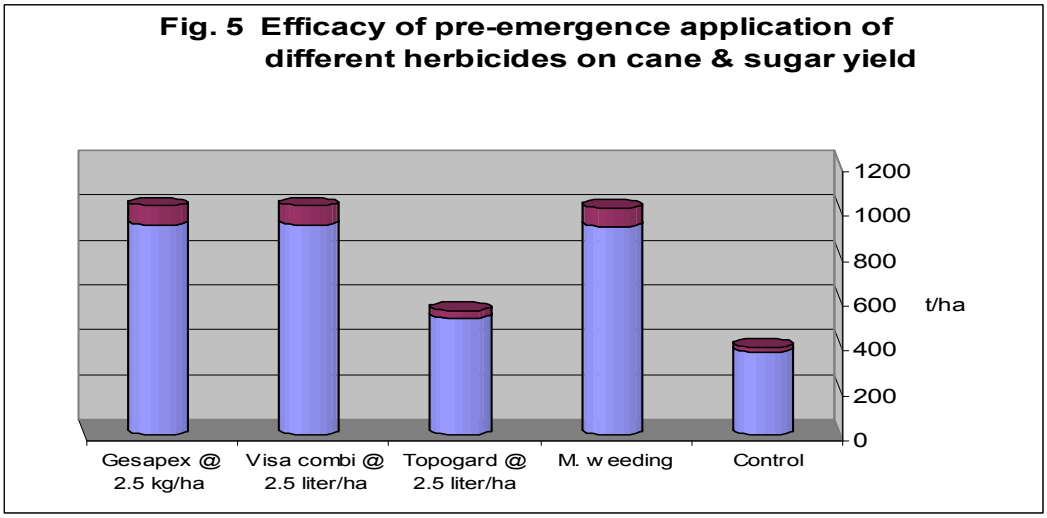
Soil testing before planting is desirable as it helps in determining the optimum quantity of macro and micro nutrient application. Chemical constraints in the soil, such as salinity/sodicity and low fertility, are relatively easy to correct or control, which can make a great difference in crop yield. The nutrient requirements of sugarcane, especially for NPK are higher than any other commercial crop because it is C_4 plant having potential of higher net assimilation rate and CO_2 fixation per unit area. Normally a crop yielding 125-t ha^{-1} removes about 84 kg N, 67 kg P, and 168 kg K. Our soils are universally deficient in nitrogen, about 90 percent lack adequate content of phosphorus, while 40-50 percent has insufficient potash to support bumper crops. Fertilizer use status in sugarcane has shown that 22 percent farmers use N alone, 75 percent farmers use N + P and only 3 percent use balanced dose of NPK [10]. Effect of nutrient management on cane and sugar yield is given in Fig. 4.



d. Pest management

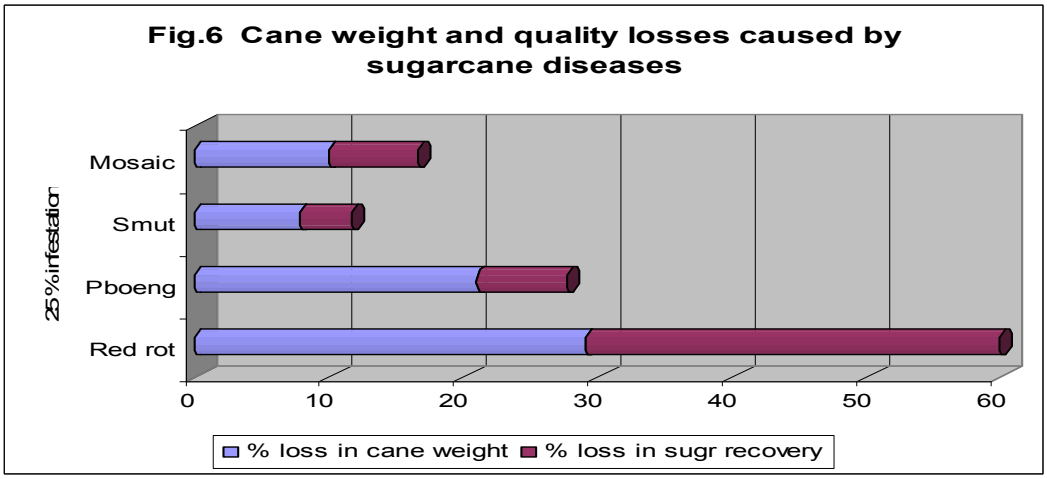
i. Weed control

Weeds compete with sugarcane for light after germination, mineral nutrients and moisture throughout growing period, which cause greatest loss of cane and sugar yield [5, 20]. A method of weed control which could suppress weeds from initial 90-120 days would leave the sugarcane crop in a condition when it can keep weeds under control through smothering [2, 6]. Efficacy of pre emergence application of herbicides on cane and sugar yield (fig.5) shows Gesapax @ 2.5 kg ha^{-1}, Visa combi 2.5 liter ha^{-1} or manual weeding are equally good for weed control in sugarcane crop.



ii. Disease control

This aspect of the sugarcane crop has been mostly ignored and attention has not been given to keep the crop free from diseases. Major diseases are red rot, whip smut, pokkah boeng, red stripe, rust and sugarcane mosaic virus (SCMV). According to an estimate 10 to 77 percent losses are caused in cane yield due to different diseases and they also affect sugar recovery from 4 to 74 %. Red rot, some times cause destruction of the whole field. Sugarcane mosaic is present in almost all the varieties with varying intensity and causes 10 to 20 percent losses in different varieties [16]. Cane weight and quality loss caused by sugarcane diseases are given in Fig.6.



iii. Biocontrol of insect pests

Bio-control of insect pest is most efficient, economical and eco-friendly. World wide emphasis is given on this useful tool because chemical control of sugarcane insect pests creates health hazards, relatively less effective and costly. The research and development work is rather scanty in Pakistan. *Trichogramma chilonis* is an egg parasite of borer complex and *Chrysoperla carnea* is an effective predator of most of insect pest [20].

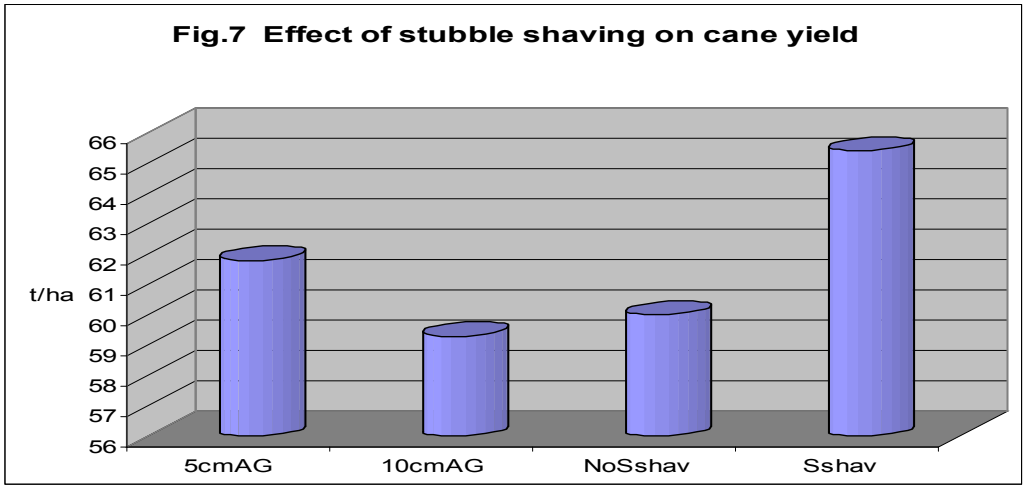
Ratoon management

Ratoon is an integral component of raw material production through-out the world. The cane yields, thus, are greatly influenced by low ratoon yields as they contribute 40-50 percent to the total cane production in Pakistan. With so little share in total production particularly when its area is high, low ratoon yields are indeed an alarming challenge to sugarcane cultivation. Research work done so far on production technology of ratoon crop is not more than nothing [3].

Successful ratoon cultivation economizes cane and sugar production. At present there is an appreciable gap between cane and sugar yield of plant and ratoon crops. There is an urgent need to elucidate behavioral differences between the productivity gaps. How best we can improve upon the existing productivity of sugarcane, research work on ratoon management technology should be started as early as possible [24]. Intensity of sugarcane ratooning in various parts of the world is presented in table-3 and effect of stubble shaving on cane yield of ratoon crop is given in fig.7.

Table-3 Intensity of sugarcane ratooning in various parts of the world

Ratoon intensity	Countries
Plant Crop	China and Indonesia
Plan Crop + 1 ratoon crop	Pakistan and Fiji
Plant Crop + 2 ratoon crops	India, U.S.A., Hawaii and Taiwan
Plant Crop + 2-3 ratoon crops	Australia, Brazil and Mexico
Plant Crop + 3-4 ratoon crops	Dominican Republic and Panama
Plant Crop + 4-6 ratoon crops	Barbados, Jamaica and Reunion
Plant Crop + more than 6 ratoon crops	Mauritius and Zaire



Economics of cultivation

The cost of cultivation of sugarcane has steeply increasing because the crop is labour and input intensive. Harvest and transport costs, non-availability of labour are rising costs of this bulky crop. Cost of production (ha^{-1}) is given in table-4. This indicates, high cost of inputs are eroding the profits, making sugarcane a "high cost" crop [9].

Table-4 Cost of production of sugarcane crop on non-rental basis (Rs. ha^{-1})

Sr. No.	Description	Plant crop	Ratoon crop
1	Pre sowing	7200	-
2	Seed & sowing	15050	-
3	Fertilizer	11250	11250
4.	Weedicide	2500	2500
5.	Inter culture /earthing up	1000	1000
6.	Plant protection	3350	3350
7.	Irrigation (18 irrigations @ 875 irrigation $ha^{-1)}$	15750	15750
8.	Watch & wards	7500	7500
9.	Land revenue & agriculture tax	1250	1250
	Total cost of production ha^{-1}	**64850**	**42600**

Improvement of quality of raw material

The quality of furnished good is directly proportional to the quality of the raw material. Different techniques in the world are being adopted to improve the raw material. In sugarcane the time between cut and crush pays a key role in sugar recovery [18]. This is only possible when a scientific cane procurement program is being run. In the present prevailing uncertain situation no sugar mill is in a position to plan a cane procurement program. The sugarcane crop is being harvested without any procurement schedule [3].

Another practice which is flourishing at a very rapid speed is the procurement of biological yield of sugarcane instead of economical yield. Before this unethical competition the percentage of extraneous material did not increase from 4 to 5 where as now there is no consideration that how much extraneous material is purchased.

a. Transfer of technology

There is a considerable scope for improving sugarcane production in Pakistan, using existing knowledge. This will require demonstration of best farming practices, already being used by the best farmers in the localities, to other farmers. The work being done by some mills in promoting and demonstrating better cane varieties is a good example [17]. Estimated potential cane yield (t ha^{-1}) in Pakistan is 150-200 for Sindh province, 100-150 for Punjab province and 75-100 for NWFP [19].

b. Availability of credit facilities

Sugarcane is a long duration and heavy input demand crop. The growers having millable size of cane supply, are not in a position to raise their crop with their own resources. Some agricultural credit facilities were provided by most of sugar mills up to 1985. The recently established sugar mills did not pay enough attention towards cane development activities. As the requirement for agricultural credit still exist a new segment of

community (Middleman) came into action and started investing with the cane growers at the local level. They started giving agricultural inputs on credit and in turn started supplying the cane to sugar mills against their own names. They also started purchasing cane procurement receipts (CPRs) on commission. This situation prolificated and hard luck to the industry that some mills management also supported the middleman. Now the situation is that the middlemen are doing business at their own terms [3].

c. Utilization of cess fund

A fragmented approach of sugarcane research work is being taken by some of the sugar mills on local problems. No collective approach has ever been made to have a collective R & D program [17].

A sugar development cess fund with an equal contribution from growers and mills was created with an idea that enough funds would be made available out this cess to have proper research on sugarcane. The very unfortunately fund which is in billions was specified only for development of communication net work [19].

Future thrust

- Research and development work at industry level.
- Credit facilities in kind to small cane growers at their doorstep.
- Technologies for reducing cost of production for profitable cultivation of sugarcane
- Mechanized plantation and harvest of cane crop.
- New cane varieties for low input conditions giving multiple ratoons with high yields
- Efforts to improve water and nutrient use efficiency

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