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Assessment of production potential of ratooned crop of sugarcane by using different planting methods

Asad Ur Rehman[1], Arshad Ali[1], Abdur Rehman[1], Faisal Mushtaq[1], Muhammad Junaid Iqbal[1], Danish Alim[1], Muhammad Tariq[2]

[1]Department of Agronomy, University of Agriculture, Faisalabad, Pakistan.
[2]Wheat Research Institute, Ayub Agricultural Research Institute, Faisalabad.
[2]Cereal and Pulses Section, Agronomic Research Institute, Ayub Agricultural Research Institute, Faisalabad.
[**]Corresponding author's email: arshadali2797@gmail.com

Abstract: The study regarding accessing ratooning ability of sugarcane planted under various planting dimensions which was planted previously in spring 2015 on a loam soil at Agronomic Research Area, University of Agriculture, Faisalabad, Pakistan. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Sugarcane variety HSF-240 was sown in March, 2015, as plant crop on soil which was having 0.041% N, 6.99 ppm P_2O_5, 176 ppm K_2O and 0.59% organic matter. Plant crop was fertilized @ 175, 115 and 115 kg NPK ha^{-1}. While ratoon crop was fertilized @ 227, 150 and 150 kg NPK ha^{-1} that was about 30% higher the plant crop. The whole P, K, and 1/3rd of N were applied as a basal dose at the time of sprouting, while remaining N was applied in two splits, 1/3rd at the start of tillering and 1/3rd before earthing up by side dressing. Earthing up of sugarcane in T_1 was done 90 days after emergence of sprouts. Planted crop of sugarcane was harvested at 24th of January, 2016 and kept as a ratoon crop. Ratoon crop was harvested manually after maturity on 20th of January 2017. All agronomic practices were kept normal and uniform for all the treatments under study. The first year crop was grown in120 cm spaced trenches, 90 cm spaced round pits having diameter 90 cm, 60 cm spaced round pits having diameter 90 cm,90 cm spaced square pits having area 90 cm × 90 cm, 60 cm spaced square pits having area 90 cm × 90 cm, 75 cm spaced square pits having area 75 cm × 75 cm and 45 cm spaced square pits having area 75 cm × 75 cm. Planting dimensions and planting geometry factor was significant for parameters like number of millable canes, plant height, cane length, cane diameter, stripped cane weight, tops and trash weights and harvest index. Highest stripped cane yield of sugarcane (102.26 t ha^{-1}) was noted at 90 cm spaced square pits having area 90 cm × 90 cm. Lowest stripped cane yield of sugarcane (96.15 t ha^{-1}) was obtained from 45 cm spaced square pits having area 75 cm × 75 cm. Greater stripped-cane yield in 90 cm spaced square pits having area 90 cm × 90 cm was ascribed to more millable canes per square meter, less plant mortality, more cane length, thicker canes and more weight per stripped cane. As regard the quality parameters like brix percentage, sucrose content (%) in cane juice, commercial cane sugar (%), and sugar recovery (%) were not significantly affected by different pit dimensions and planting geometry under ratoon crop. Maximum net return of Rs. 181346 ha^{-1} was achieved in ratooned sugarcane grown at 90 cm spaced square pits having area 90 cm × 90 cm as against minimum of Rs. 157517 ha^{-1}for cane grown in 45 cm spaced square pits having area 75 cm × 75 cm. Similarly the maximum BCR of 1.65 was obtained from ratooned sugarcane grown at 90 cm spaced square pits having area 90 cm × 90 cm, while BCR of 1.57 was produced by the crop at 45 cm spaced square pits having area 75 cm × 75 cm.

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Introduction

Sugarcane (*Saccharum officinarum* L.) is an important sugar and cash crop of Pakistan. It has a wide range of ecological adaptability and abundantly grown in tropical and sub-tropical regions of world. Being a perennial crop, sugarcane belongs to poaceae family. It is capable of growing successfully as a ratoon for several years if managed properly and looked after carefully. It plays an important role in the economy of country as well as the farmers and also provides raw material for sugar industry, which is second to textile in Pakistan. Naqvi (2005) reported that employment of more than 4 million people is directly or indirectly related with sugar and allied industries. It takes about 8 to 24 months to attain maturity (Nazir, 2000). Sugarcane holds a strong position in national economy by supplying raw material for white sugar production. Several associated industries like, paper, chip board, beverage and ethanol also depend on sugarcane in terms of providing raw material (Govt. of Pakistan, 2015). Pakistan ranks 5th with respect to area, while it ranks 8th with regards to sugar production globally (FAO, 2012). In short, it contributes to agro-industrial economy of Pakistan significantly. Due to industrialization and urbanization the chances of further increase in area under sugarcane cultivation are minimal. So, for attaining the maximum sugarcane production to compensate the increasing demand for sugar and other sugarcane-based products, the yield gap should be minimized by improving the management techniques and utilization of inherent resources. Among various management techniques, the ratooning is considered one of the most important in this regard (Majid, 2007).

In Pakistan conventional planting method is also one of the main cause for low sugarcane production due to less plant population, lodging, dwarf and thin cane (Ali *et al.,* 2009; Ehsanullah *et al.,* 2011). Average sugarcane yield of Pakistan can be increased more than 100% by employing improved and appropriate package of production technology (Majid, 2007). Different planting techniques effect all physiological and quantitative traits of sugarcane considerably (Bashir and Saeed, 2000). Optimum plant population per unit area can be obtained with conventional 60-75 cm spaced sugarcane planting method (Vains *et al*., 2000), but this method makes crop growth difficult by causing hindrance in various crop management practices and bounds yield up to a certain level (Chattha *et al*., 2004; Ehsanullah *et al.,* 2011). Maximum potential can be exploited by adopting pit planting method of sugarcane, because this method has demonstrated a massive scope of achieving the maximum biological yield potential in various studies as compared to conventional method of planting. Pit planting of sugarcane provides applicable alternative to farmers to increase the efficiency of land, water and labour (Yadav *et al.*, 2009).

Ratooning is a practice of growing full crop of sugarcane from sprouts of underground stubbles left in the field after harvest of the plant (main) crop. Plant crop as well as ratoon crops are highly exhaustive crops having higher demand for nitrogenous fertilizer because of shallow root system, decay of old roots, sprouting of stubble buds, and immobilization of nitrogen. Therefore, it is necessary to use 20-25% more nitrogenous fertilizer over recommended dose of nitrogen for ratoon crop (Lal and Singh, 2008). Shukla *et al.* (2013) reported that ratooning in sugar cane saves the cost of seedbed preparation, seed material and planting operations. Ratoons help in extending the crushing period of sugar mills as they mature earlier than the plant crop. However, most often ratoon crop yields are lower than the plant crop. Malik (1997) reported that in the Punjab province of Pakistan, more than 50% of total sugarcane cropped area is kept as ratoon crop. Its contribution to the total cane production is about 25-30% (Rehman and Ehsanullah, 2008). However, more than 35% of its productivity is lost due to improper attention of the farmers towards ratoons (Malik, 1997). Naturally the productivity of ratoon is 10-30% less than the plant crop of sugarcane. Low yield of ratoon crop is mainly due to low and differential ratooning potential of cultivars and suboptimal crop management. However, the economic ratoon sugarcane farming communities, have the cost of production which is lower than the 25-30% of crop plants and seed material savings. A ratoon crop matures earlier to plant crop thus makes sure timely supply of cane to mills. Under similar conditions sugarcane ratoon have a supplementary advantage of better juice quality and sugar recovery than plant crop of same variety (Yadav, 1991).

At farmer's field ratoon sugarcane yield has always been less than the plant crop. Late maturing cultivars having good yield are suitable for growing ratoon but early maturing cultivars are poor ratooners. There are certain reasons for low cane yield in Pakistan and one of those is the planting of low yielding varieties. Therefore, there is dire need to introduce new high yielding varieties with good ratoonability in the country (Chattha and Ehsanullah, 2003). The main reasons for low cane yield of ratoon crop are low soil fertility, sub-optimal plant population density, poor management and improper planting methods. This necessitates to develop a suitable agro-technology for harvesting good yield of a ratoon crop. The major components of a ratoon sugarcane agro-technology are planting methods which may help in maintaining proper plant population and facilitating light and air circulation including tillage operations. Therefore the present study was conducted with the objective to explore the production potential of ratoon crop of sugarcane planted under varying planting methods.

Materials and method

A field experiment to assess the ratooning ability of sugarcane planted at different planting dimensions was conducted at Directorates of Farms, University of Agriculture, Faisalabad, Pakistan. Soil samples of the experimental soil were collected before sprouting up to a depth of 48 cm for the physio-chemical analysis. The soil analysis revealed that the experimental soil was a loamy with slight alkaline in nature. The soil was productive for crop husbandry. However, the experimental soil was deficient in nitrogen, phosphorus, and potash. Experiment was laid out in Randomized Complete Block Design (RCBD) having three replications. The net plot sizes were 10.80 m × 3.60 m for treatments T_1, T_2 and T_4, 10.50 m × 3.30 m for T_3, T_5 and T_6 and 10.80 m × 3.30 m for T_7.

Treatments

T_1 = 120 cm spaced trenches

T_2 = 90 cm spaced round pits having diameter 90 cm

T_3 = 60 cm spaced round pits having diameter 90 cm

T_4 = 90 cm spaced square pits having area 90 cm × 90 cm

T_6 = 75 cm spaced square pits having area 75 cm × 75 cm

T_7 = 45 cm spaced square pits having area 75 cm × 75 cm

Crop husbandry

Trenches were made with ridger and pits were dug to a depth of 60 cm with post hole digger for round pits and manually for square pits and again filled up with the same soil (Nazir *et. al,* 1990). Pits were dug at zero tillage. No hoeing and earthing up were done to the pit planted sugarcane for irrigation purposes. Pits in each row were connected with one another by a small water channel like basin system of irrigation. Along the width of the plot, pit to pit spacing was kept constant while along the length of the plot pit to pit spacing was changed. Water and fertilizers were applied only in pits. Trench planted sugarcane was given normal tillage operations including hoeing and earthing up. The sugarcane variety HSF-240 was used as experimental material for this experiment. The seed rate was 75,000 double budded setts ha^{-1} to sow the last planted crop. The sugarcane was planted on 4th of March 2015. The planted crop of sugarcane was harvested at 24th January, 2016, and kept as a ratoon crop. The plant crop was harvested manually after its maturity on 24th of January 2016. Ratoon crop was harvested manually after maturity on 20th of January 2017. Data pertaining to the following observations like Number of sprouts per m^2, Number of millable canes per m^2 at harvest, Plant height (cm), Number of internodes per cane, Length of internodes (cm), Cane length (cm), Cane diameter (cm), Weight per stripped cane (kg), Un-stripped cane yield (t ha^{-1}), Stripped cane yield (t ha^{-1}), Tops weight (t ha^{-1}), Trash weight (t ha^{-1}), Harvest index (%) Brix (%), Sucrose in juice (%), Cane juice (%), Commercial cane sugar (%), Cane sugar recovery (%), Total sugar (t ha^{-1}) were recorded by using standard procedures during the course of study. Data recorded on each parameter was tabulated and analyzed statistically by using Fisher's Analysis of Variance technique. Least significant difference (LSD) test at 5% probability level was used to compare the difference amongst treatment means (Steel *et al.*, 1997).

Results and discussion

Number of sprouts

Table 1: No. of sprouts per m^2 of ratooned sugarcane as affected by different planting dimensions, Comparison of treatment means

Planting pattern		Sprouts per m^2
T_1	120 cm spaced trenches	14.0 ab
T_2	90 cm spaced round pits having diameter 90 cm	13.33 b
T_3	60 cm spaced round pits having diameter 90 cm	14.33 ab
T_4	90 cm spaced square pits having area 90 cm × 90 cm	13.33 b
T_5	60 cm spaced square pits having area 90 cm × 90 cm	14.67 a
T_6	75 cm spaced square pits having area 75 cm × 75 cm	12.0c
T_7	45 cm spaced square pits having area 75 cm × 75 cm	11.67 c
LSD = 1.29		

Any two means not sharing a letter in common differ significantly at 5% probability level

Sprouting potential is pre requisite of final yield in ratoon sugarcane crop. Sprouting or shoot formation in sugarcane is a process of branching from very short joints on the stem of primary shoot (Kakde, 1985). Sprouting capacity or shoot formation during the process of cane development could be affected by planting techniques, planting time, moisture supply, nutrient availability, temperature and light intensity prevailing around the crop plant (Dillewijn, 1952). Data regarding the number of sprouts per $m^2$are presented in (Table 1) which revealed that pit dimensions and planting geometry significantly affected the number of sprouts. Statistically, higher number of sprouts (14.67 m^{-2}) were recorded in 60 cm spaced square pits having area 90 cm × 90 cm that was at par with 120 cm spaced trenches and 60 cm spaced round pits having diameter 90 cm. Statistically, minimum number of sprouts (11.67m^{-2}) were recorded in 45 cm spaced square pits having area 75 cm × 75 cm that was at par with 75 cm spaced square pits having area 75 cm × 75 cm. These results are in contradiction with earlier findings of Malik *et al*. (1996) and Bashir *et al*. (2005) who found wider row spacing markedly increased the sprouts count per m^2as compare to narrow row spacing under various planting techniques.

Number of millable canes

The number of millable canes is the most important yield contributing parameter in sugarcane, which is the result of germination percentage and number of sprouts per square meter. Analysis of variance in (Table 2) shows that pit dimensions and planting geometry has significant effect on the number of millable canes. Statistically, the highest number of millable canes ($11.67m^{-2}$) were recorded in 60 cm spaced square pits having area 90 cm × 90 cm that was statistically at par with 60 cm spaced round pits having diameter of 90 cm followed by 120 cm spaced trenches followed by 90 cm spaced round pits having diameter 90 cm and 90 cm spaced square pits having area 90 cm × 90 cm. The lowest value of number of millable canes ($9m^{-2}$) were recorded in 45 cm spaced square pits having area 75 cm × 75 cm was at par with 45 cm spaced square pits having area 75 cm × 75 cm.

Table 2: No. of millable canes per m^2 of ratooned sugarcane as affected by different planting dimensions. Comparison of treatment means

Planting pattern		Millable canes per m^2
T_1	120 cm spaced trenches	10.67 b
T_2	90 cm spaced round pits having diameter 90 cm	10.33 b
T_3	60 cm spaced round pits having diameter 90 cm	11.0 ab
T_4	90 cm spaced square pits having area 90 cm × 90 cm	10.33 b
T_5	60 cm spaced square pits having area 90 cm × 90 cm	11.67 a
T_6	75 cm spaced square pits having area 75 cm × 75 cm	9.33 c
T_7	45 cm spaced square pits having area 75 cm × 75 cm	9.0c
LSD = 0.79		

Any two means not sharing a letter in common differ significantly at 5% probability level

Table 3: Plant height (cm) of ratooned sugarcane as affected by different planting dimensions, Comparison of treatment means

Planting pattern		Plant height (cm)
T_1	120 cm spaced trenches	315 cd
T_2	90 cm spaced round pits having diameter 90 cm	316 cd
T_3	60 cm spaced round pits having diameter 90 cm	344 b
T_4	90 cm spaced square pits having area 90 cm × 90 cm	366 a
T_5	60 cm spaced square pits having area 90 cm × 90 cm	332 bc
T_6	75 cm spaced square pits having area 75 cm × 75 cm	314 cd
T_7	45 cm spaced square pits having area 75 cm × 75 cm	307 d
LSD = 19.69		

Any two means not sharing a letter in common differ significantly at 5% probability level

The number of millable cane was ranged between 9 and 11.67 per m^2. The better number of millable canes in 60 cm spaced square pits might be due to the better light penetration and circulation of air. However, a little decrease was observed in 90 cm spaced round pits and 90 cm spaced square pits this decrease might be due to sprouting of lateral shoots which produced more non-millable canes and caused substantial reduction in millable canes. These results are in line with previous findings of Maqsood *et al.* (2005) and Yadav and Kumar (2005) who reported that lesser interplant competition and wider row spacing linearly increased the millable canes. These results are in contradiction with previous findings of Cheema *et al*. (2002) who reported that planting geometry had non-significant effect on number of millable canes grown under different planting pattern.

Plant height

Plant height is an important morphological character which is indirect determinant of yield. It can vary according to genetic makeup of plant, nutrient status of soil in which it grow, environmental conditions and different types of stresses faced during growing period. Data regarding the plant height of sugarcane given in (Table 3) showed that crop planted in different pit dimensions and geometry exhibited different plant height. Statistically, the highest plant height (366 cm) was observed in 90 cm spaced square pits having area 90 cm × 90 cm, followed by sugarcane planted in 60 cm spaced round pits having diameter 90 cm which was at par with 60 cm spaced square pits having area 90 cm × 90 cm. Meanwhile the lowest plant height (307 cm) was recorded in 45 cm spaced square pits having area 75 cm × 75 cm. The highest plant heights in pits might be attributed to better availability and penetration of light into plant canopy. The higher plant height also attributed to better conditions for growth which intercepted more radiation which ultimately produced the higher plants. These results are in line with earlier findings of Cheema *et al*. (2002) who observed that higher plant in 90 cm spaced rows as compared to 60 cm.

Cane length (cm)

Cane length is an important yield parameter that possesses a positive relationship with stripped cane yield of sugarcane crop. Data regarding the cane length are presented in (Table 4). It is clear from the results that planting geometry and pit dimensions markedly affected the cane length. Statistically, the highest cane length (234.67 cm) was recorded in 90 cm spaced square pits having area 90 cm × 90 cm followed by 60 cm spaced round pits having diameter of 90 cm that was at par with 90 cm spaced round pits having diameter 90 cm, 60 cm spaced round pits having diameter 90 cm and 75 cm spaced square pits having area 75 cm × 75 cm. Whereas, statistically minimum cane length (196.67) was recorded in 45 cm spaced square pits having area 75 cm × 75 cm and was at par with 75 cm spaced square pits having area 75 cm × 75 cm 90 cm spaced round pits having diameter 90 cm and 120 cm spaced trenches.

Table 4: Cane length (cm) of ratooned sugarcane as affected by different planting dimensions, Comparison of treatment means

Planting pattern		Cane length (cm)
T_1	120 cm spaced trenches	206.93 bc
T_2	90 cm spaced round pits having diameter 90 cm	208.83 bc
T_3	60 cm spaced round pits having diameter 90 cm	214.17 b
T_4	90 cm spaced square pits having area 90 cm × 90 cm	234.67 a
T_5	60 cm spaced square pits having area 90 cm × 90 cm	213.27 b
T_6	75 cm spaced square pits having area 75 cm × 75 cm	205.87 bc
T_7	45 cm spaced square pits having area 75 cm × 75 cm	196.67 c
LSD = 13.70		

Table 5: Cane diameter (cm) of ratooned sugarcane as affected by different planting dimensions, Comparison of treatment means

Planting pattern		Cane diameter (cm)
T_1	120 cm spaced trenches	2.34 b
T_2	90 cm spaced round pits having diameter 90 cm	2.31 bc
T_3	60 cm spaced round pits having diameter 90 cm	2.36 b
T_4	90 cm spaced square pits having area 90 cm × 90 cm	2.45 a
T_5	60 cm spaced square pits having area 90 cm × 90 cm	2.31 bc
T_6	75 cm spaced square pits having area 75 cm × 75 cm	2.27 bc
T_7	45 cm spaced square pits having area 75 cm × 75 cm	2.23 c
LSD = 0.09		

Any two means not sharing a letter in common differ significantly at 5% probability level

More cane length in wider spaced pits might be due to better light penetration into the crop canopy and cross air circulation because of wider spacing. More cane length at pits may also be attributed to more light interception that might be resulted in increased crop growth rate, which finally produced longer canes. These results are in line with previous findings of Cheema *et al*. (2002) who recorded the maximum cane length in 90 cm spaced row spacing against the 60 cm spaced rows.

Cane diameter (cm)

Cane thickness is an important index which has significant contribution in yield of sugarcane. Data regarding the cane diameter are represented in (Table 5) which showed that pit dimensions and planting geometry considerably affected the cane diameter. The mean maximum cane diameter (2.45) was recorded in 90 cm spaced square pits having area 90 cm × 90 cm followed by 60 cm spaced round pits having diameter 90 cm that was at par with T_1, T_2 and T_3 respectively. While, the lowest cane diameter (2.23) was recorded in 45 cm spaced square pits having area 75 cm × 75 cmthat was at par with 60 cm spaced square pits having area 90 cm × 90 cm and 75 cm spaced square pits having area 75 cm × 75 cm. Square pits showed more significant effect on cane diameter as compared to the round pits and trenches. The variability in cane diameter among pits might be due to the availability of spacing area and the level of light penetration which led to variable crop growth rate which resulted in variable cane diameter. These results are in line with previous findings of Cheema *et al*. (2002) and Raskar and Bhoi (2003) who recorded a linear increase in cane diameter with increasing the row spacing. However, these finding are in contradiction with previous findings of Vains *et al*. (2000). They reported that planting pattern had non-significant effect on the cane diameter.

Weight per stripped cane

Stripped cane determines the overall yield of the crop and efficiency of the treatments. The individual stripped cane weight is the combined result of many yield contributing components as these components more or less were affected by different pit dimensions and planting geometry under investigation. Significantly, highest weight per stripped cane (1.05) was recorded in 90 cm spaced square pits having area 90 cm × 90 cm followed by 60 cm spaced round pits having diameter 90 cm that was at par with 90 cm spaced round pits having diameter 90 cm and 90 cm spaced square pits having area 90 cm × 90 cm, respectively.

Table 6: Weight per stripped cane (kg) of ratooned sugarcane as affected by different planting dimensions, Comparison of treatment means

Planting pattern		**Weight per striped cane (kg)**
T_1	120 cm spaced trenches	0.88 bc
T_2	90 cm spaced round pits having diameter 90 cm	0.90 bc
T_3	60 cm spaced round pits having diameter 90 cm	0.98 ab
T_4	90 cm spaced square pits having area 90 cm × 90 cm	1.05 a
T_5	60 cm spaced square pits having area 90 cm × 90 cm	0.88 bc
T_6	75 cm spaced square pits having area 75 cm × 75 cm	0.83 c
T_7	45 cm spaced square pits having area 75 cm × 75 cm	0.81 c
LSD = 0.15		

Stripped cane yield (t/ha)

The effect of planting dimensions and planting geometry was found significant on the stripped cane yield. Treatment means given in (Table 7) showed that planting dimensions and planting geometry considerably affected the stripped cane yield. The maximum stripped cane yield (102.26 t/ha) was recorded in 90 cm spaced square pits having area 90 cm × 90 cm followed by 60 cm spaced round pits having diameter 90 cm where the stripped cane yield 99.68t/ha was recorded that was at par with 90 cm spaced round pits having diameter 90 cm and 120 cm spaced trenches. The lowest stripped cane yield (96.15 t/ha) was recorded in 45 cm spaced square pits having area 75 cm × 75 cm that was similar with 75 cm spaced square pits having area 75 cm × 75 cm. The highest stripped cane yield in 90 cm square pits might be due to high value of yield contributing factors like cane length, cane diameter and cane weight. These results are in conformity with findings of Bashir *et al*. (2005) who reported that wider row spacing markedly increased the stripped cane yield compared to narrow row spacing. These results are also in line with previous findings of Cheema *et al*. (2002) and Raskar and Bhoi (2003) who observed that high cane yield in 90 cm spaced trenches compared with 60 cm row spacing.

Table 7: Stripped cane yield (t/ha) of ratooned sugarcane as affected by different planting dimensions, Comparison of treatment means

Planting pattern		**Stripped cane yield (t/ha)**
T_1	120 cm spaced trenches	98.4 b
T_2	90 cm spaced round pits having diameter 90 cm	99.39 b
T_3	60 cm spaced round pits having diameter 90 cm	99.68 b
T_4	90 cm spaced square pits having area 90 cm × 90 cm	102.26 a
T_5	60 cm spaced square pits having area 90 cm × 90 cm	99.52 b
T_6	75 cm spaced square pits having area 75 cm × 75 cm	97.83 bc
T_7	45 cm spaced square pits having area 75 cm × 75 cm	96.15 c
LSD = 2.04		

Any two means not sharing a letter in common differ significantly at 5% probability level

Tops weight (t/ha)

The growth and development behavior of a cane is reflected by its tops weight. Tops weight is important as it effect the cane quality indirectly by influencing the lodging and directly by influencing the photosynthesis. The analysis of data pertaining to tops weight as affected by different pit dimensions and planting geometry depicted a significant differences among the treatments as show in Table 8. The maximum cane tops weight (15.01 t/ha) was observed in 45 cm spaced square pits having area 75 cm × 75 cm that was at par with all the other treatments except 90 cm spaced square pits and 120 cm spaced trenches. These results are in contradiction with previous findings of Cheema *et al*. (2002) who reported more cane tops weight in 90 cm spaced row crop as compare to 60 and 45 cm spaced row crop.

Table 8: Tops weight (t/ha) of ratooned sugarcane as affected by different planting dimensions, Comparison of treatment means

Planting pattern		Tops weight (t/ha)
T_1	120 cm spaced trenches	13.62 b
T_2	90 cm spaced round pits having diameter 90 cm	14.22 ab
T_3	60 cm spaced round pits having diameter 90 cm	14.74 ab
T_4	90 cm spaced square pits having area 90 cm × 90 cm	12.17 c
T_5	60 cm spaced square pits having area 90 cm × 90 cm	14.73 ab
T_6	75 cm spaced square pits having area 75 cm × 75 cm	14.18 ab
T_7	45 cm spaced square pits having area 75 cm × 75 cm	15.01 a
LSD = 1.33		

Any two means not sharing a letter in common differ significantly at 5% probability level

Trash weight (t/ha)

Trash weight indicates the vegetative growth behavior of sugarcane crop. The analysis of the data pertaining to trash weight as affected by different pit dimensions and planting geometry are depicted in Table 9. The data regarding trash weight per hectare showed considerable differences among the treatments under different pit dimensions and planting geometry. The highest trash weight (6.73 t/ha) was recorded at45 cm spaced square pits having area 75 cm × 75 cm that was at par with all the other treatments except 90 cm spaced square pits having area 90 cm × 90 cm. Differences in trash weight of sugarcane in all planting methods were ascribed to variable number of leaves and plant population and moisture percentage at maturity in leaves. Similar results were also reported by Bashir *et al*. (2005).

Table 9: Trash weight (t/ha) of ratooned sugarcane as affected by different planting dimensions, Comparison of treatment means

Planting pattern		Trash weight (t/ha)
T_1	120 cm spaced trenches	6.57 ab
T_2	90 cm spaced round pits having diameter 90 cm	5.92 ab
T_3	60 cm spaced round pits having diameter 90 cm	5.35 ab
T_4	90 cm spaced square pits having area 90 cm × 90 cm	5.16 b
T_5	60 cm spaced square pits having area 90 cm × 90 cm	5.40 ab
T_6	75 cm spaced square pits having area 75 cm × 75 cm	6.43 ab
T_7	45 cm spaced square pits having area 75 cm × 75 cm	6.73 a
LSD = 1.45		

Harvest index

Harvest index is the ratio of economic yield to biological yield and it is usually expressed in percentage. The harvest index of the ratooned sugarcane crop as affected by different planting dimensions varied significantly by different planting dimensions under study presented in Table 10. It is clear from the Table 10 that sugarcane crop grown in pattern of 90 cm spaced square pits having area 90 cm × 90 cm showed the highest value of harvest index (84.79%) which was similar where crop planted at 90 cm spaced round pits having diameter 90 cm and 60 cm spaced round pits having diameter 90 cm. The lowest value of harvest index was observed in crop planted in 45 cm spaced square pits having area 75 cm × 75 cm. The results showed that narrow row spacing caused a substantial reduction in the harvest index value of ratooned sugarcane. This might be due to less availability of light which reduced the crop growth rate and ultimately the biological yield. The highest value of harvest index in wider row spacing attributed to the better crop growth rate. These results are validated by Yadav and Kumar (2005) and Ahmad (2002). They observed more harvest index in crop grown at 90 cm spaced row than at 45 cm spaced rows. However, these results are supported by findings of Maqsood *et al.* (2005) who found that row spacing has non-significant effect on the harvest index value.

Table 10: Harvest index (%) of ratooned sugarcane as affected by different planting dimensions

Planting pattern		**Harvest index (%)**
T_1	120 cm spaced trenches	82.87 b
T_2	90 cm spaced round pits having diameter 90 cm	83.15 ab
T_3	60 cm spaced round pits having diameter 90 cm	83.24 ab
T_4	90 cm spaced square pits having area 90 cm × 90 cm	84.79 a
T_5	60 cm spaced square pits having area 90 cm × 90 cm	83.17 ab
T_6	75 cm spaced square pits having area 75 cm × 75 cm	82.61 b
T_7	45 cm spaced square pits having area 75 cm × 75 cm	81.62 b
LSD = 1.89		

Brix percentage

Total concentration of solutes in a biological solution such as cane juice is expressed on 'brix' degree basis. Cane maturity is commonly measured on the basis of brix degree. Data presented in Table 11 revealed that planting dimensions and planting geometry had not significantly affected the brix (%) of cane. Although brix percentage in cane juice was different in cane grown at various planting dimensions but this difference could not reached to the level of significance and it ranged between 21.62% and 22.11%. These findings are in line with previous studies of Chattha (2007) who found non-significant effect of planting geometry on brix (%). Likewise in other studies Maqsood *et al.* (2005) also found a non-significant effect of planting technique on brix (%).

Table 11: Brix (%) of ratooned sugarcane as affected by different planting dimensions

Planting pattern		**Brix (%)**
T_1	120 cm spaced trenches	21.71
T_2	90 cm spaced round pits having diameter 90 cm	21.98
T_3	60 cm spaced round pits having diameter 90 cm	22.04
T_4	90 cm spaced square pits having area 90 cm × 90 cm	22.11
T_5	60 cm spaced square pits having area 90 cm × 90 cm	22.08
T_6	75 cm spaced square pits having area 75 cm × 75 cm	21.82
T_7	45 cm spaced square pits having area 75 cm × 75 cm	21.62
LSD = NS		

Sucrose content in juice (%)

Gross carbohydrate i.e. pol % (total sugars of all kinds in the cane juice) is another most important yield-determining factor and usually controlled by genetic make-up of a variety and environmental conditions under which the crop grown. Treatment means revealed a non-significant effect of various planting dimensions on sucrose contents. However, sucrose contents ranged between 19.15% and 19.85%. These findings are supported by previous findings of Khan *et al.* (2003) who found a non-significant effect of planting techniques on sucrose contents.

Table 12: Sucrose content in juice (%) of ratooned sugarcane as affected by different planting dimensions

Planting pattern		**Sucrose contents in juice (%)**
T_1	120 cm spaced trenches	19.56
T_2	90 cm spaced round pits having diameter 90 cm	19.85
T_3	60 cm spaced round pits having diameter 90 cm	19.71
T_4	90 cm spaced square pits having area 90 cm × 90 cm	19.61
T_5	60 cm spaced square pits having area 90 cm × 90 cm	19.79
T_6	75 cm spaced square pits having area 75 cm × 75 cm	19.45
T_7	45 cm spaced square pits having area 75 cm × 75 cm	19.15
LSD = NS		

Any two means not sharing a letter in common differ significantly at 5% probability level

Cane juice percentage

Data given in Table 13 exhibited that effect of different pit dimensions and planting geometry on cane juice percentage was significant. On an average, cane juice percentage ranged between57.66 and 60.4% in different pit dimensions and planting geometry. The maximum cane juice percentage (60.4%) was recorded in cane grown in the pattern of 90 cm spaced square pits having area 90 cm × 90 cm that was at par with 60 cm spaced round pits having diameter 90 cm. Similarly the minimum cane juice percentage (57.66) was recorded at 45 cm spaced square pits having area 75 cm × 75 cm. These results are in contradiction with the findings of Chattha (2007) who reported non-significant influence of sowing techniques on cane juice content. However, these results are supported with the findings of Thangavelu (2004) who found a significant effect of planting techniques on cane juice percentage.

Table 13: Cane juice (%) of ratooned sugarcane as affected by different planting

Planting pattern		Cane juice percentage
T_1	120 cm spaced trenches	59.033 bc
T_2	90 cm spaced round pits having diameter 90 cm	58.333 cd
T_3	60 cm spaced round pits having diameter 90 cm	60.033 ab
T_4	90 cm spaced square pits having area 90 cm × 90 cm	60.400 a
T_5	60 cm spaced square pits having area 90 cm × 90 cm	58.667 cd
T_6	75 cm spaced square pits having area 75 cm × 75 cm	57.667 d
T_7	45 cm spaced square pits having area 75 cm × 75 cm	57.667 d
LSD = 1.34		

Commercial cane sugar (%)

The real cane quality is reflected by its commercial cane sugar (CCS) percentage. Commercial cane sugar (CCS %) is the final goal to achieve optimum sugar yield. It is mainly controlled by genetic make-up of a variety and environmental conditions prevailing during the growth and development of cane crop. Commercial cane sugar was not significantly affected by different pit dimensions and planting geometry. it is clear from Table 14 which showed that planting dimensions and planting geometry did not non-significantly affected the commercial cane sugar. However, the commercial cane sugar ranged between14.56% and15.28%. These findings are validated by Chattha (2007) who found that sowing technique has no remarkable effect on commercial cane sugar. Likewise in other studies Maqsood *et al.* (2005) found that commercial cane sugar was not affected by planting techniques of sugarcane.

Table 14: Commercial cane sugar (%) of ratooned sugarcane as affected by different planting dimensions, Comparison of treatment means

Planting pattern		Commercial cane sugar (%)
T_1	120 cm spaced trenches	15.03
T_2	90 cm spaced round pits having diameter 90 cm	15.28
T_3	60 cm spaced round pits having diameter 90 cm	15.07
T_4	90 cm spaced square pits having area 90 cm × 90 cm	14.92
T_5	60 cm spaced square pits having area 90 cm × 90 cm	15.16
T_6	75 cm spaced square pits having area 75 cm × 75 cm	14.85
T_7	45 cm spaced square pits having area 75 cm × 75 cm	14.56
LSD = NS		

Cane sugar recovery (%)

Cane sugar recovery is an important index of sugarcane quality which depends upon many factors like environmental conditions, plant genetic makeup and the tool used for the cane sugar recovery. Data regarding the sugar recovery given in Table 15 indicates that planting dimensions had non-significant effect on sugar recovery in cane grown under different planting dimensions. Cane sugar recovery ranged between 13.69% and 14.36, this depicts that planting dimensions failed to affect sugar recovery. These results are supported by Chattha (2007) whom reported that planting geometry had non-significant effect on cane sugar recovery.

Table 15: Cane sugar recovery (%) of ratooned sugarcane as affected by different planting dimensions, Comparison of treatment means

Planting pattern		Cane sugar recovery (%)
T_1	120 cm spaced trenches	14.13
T_2	90 cm spaced round pits having diameter 90 cm	14.36
T_3	60 cm spaced round pits having diameter 90 cm	14.17
T_4	90 cm spaced square pits having area 90 cm × 90 cm	14.03
T_5	60 cm spaced square pits having area 90 cm × 90 cm	14.26
T_6	75 cm spaced square pits having area 75 cm × 75 cm	14.26
T_7	45 cm spaced square pits having area 75 cm × 75 cm	13.69
LSD = NS		

Total sugar (t/ha)

The total sugar yield (t ha^{-1}) is the interactive effect of stripped cane yield (t ha^{-1}) and CCS%. Data regarding the total sugar yield are presented in Table 16 which revealed that in ratoon sugarcane pit dimensions and planting geometry had non-significant effect on total sugar yield. However, the maximum total sugar yield (15.31 t/ha) recorded at 90 cm spaced square pits having area 90 cm × 90 cm and the minimum total sugar yield (14.28 t/ha) was recorded at 45 cm spaced square pits having area 75 cm × 75 cm. These findings are not justified with previous findings of Chattha (2007) who reported that planting geometry and pit dimensions has significant effect on total sugar yield.

Table 16: Total sugar (t/ha) of ratooned sugarcane as affected by different planting dimensions

Planting pattern		Total sugar (t/ha)
T_1	120 cm spaced trenches	14.79
T_2	90 cm spaced round pits having diameter 90 cm	14.94
T_3	60 cm spaced round pits having diameter 90 cm	15.00
T_4	90 cm spaced square pits having area 90 cm × 90 cm	15.31
T_5	60 cm spaced square pits having area 90 cm × 90 cm	15.11
T_6	75 cm spaced square pits having area 75 cm × 75 cm	14.47
T_7	45 cm spaced square pits having area 75 cm × 75 cm	14.28
LSD = NS		

Economic Analysis

As farmers are more concerned in variable costs and net returns of certain treatments so to look the experiment from the farmer's point of view economic analysis becomes important. It helps researcher to plan for more investigation or to make recommendations to the farmers. The analysis was made by using standard procedures as mentioned in chapter 3.

Net return

Farmers are very interested in change in net return than change in yields, therefore net returns were calculated against the cost of production. They also want to estimate all the changes that are involved in adopting a new practice. It is therefore, important to take into concern all inputs related with the experimental treatments. Maximum net return of Rs. 181346 ha^{-1} was achieved in ratooned sugarcane grown at 90 cm spaced square pits having area 90 cm × 90 cm during 2016-17. The minimum net return of Rs. 157517 ha^{-1} was obtained at 45 cm spaced square pits having area 75 cm × 75 cm. The economic analysis of ratooned sugarcane grown under various planting dimensions showed that cost of production was greater in pit system than conventional method of planting and deep trenches, but more net return was recorded by pits than the other planting methods (Yadav *et al.,* 1991).

Benefit Cost Ratio

Benefit cost ratio is further important to farmers because they are interested in achieving more net returns with a given increase in total costs. The maximum BCR of 1.65 at 90 cm spaced square pits having area 90 cm × 90 cm shown in Table 5.2. Minimum BCR of 1.57 was produced by the ratooned crop grown at 45 cm spaced square pits having area 75 cm × 75 cm during 2016-17. BCR is an indicator that attempts to summarize the overall value for money of a project or proposal.

Detail of input and output cost of ratooned grown sugarcane (Rs. ha^{-1}) during 2016-17

Table 17 Permanent cost

Sr. #	Operations / Inputs	2016-17		
		Average No. of operation/units/ ha	Cost / Unit (Rs.)	Total cost (Rs.)
1	Interculture / Hoeing			
	1.1 One application of Herbicides with Tractor	1	3250	3250
	1.2 Interculture with tractor.	6	1625	9750
	Sub total			**13000**
2	Irrigation			
	2.1 Cleaning of water courses (Man. days).	5	350	1750
	2.2 Labour charges (canal Irrigation) (M. days)	8	350	2800
	2.3 Canal water charges (Abiana/ ha)	-	-	338
	2.4 Additional irrigation charges	5	3500	17500
	2.5 Labour charges (additional irrigation) (M. days).	2.5	350	875
	Sub total			**23263**
3	Fertilizer (Bags)			
	3.1 Urea	7.25	2000	14500
	3.2 DAP.	6.5	3500	22750
	3.3 SOP	6	4200	25200
	3.4 Transportation. (Fertilizer)	19.75	20	395
	3.5 Fertilizer application (M. days).	2	350	700
	3.6 F.Y.M. (Trolly)	10	1000	10000
	3.7 Transportation & spreading (F.Y.M.)	10	350	3500
	Sub total			**77045**
4	Plant Protection			
	4.1 Treatments (granules + labour)	5	1560	7800
	4.2 Chloropyriphos flooding	5 Liter	800	4000
	Sub total			**11800**
	Total (Item 1-4)			**125108**
5	Markup on Investment @ 9% for 12 Months on Items (1-4)	125108	-	11260
6	Land Rent for 12 Months	1	75000	75000
7	Agricultural Income Tax	-	-	100
8	Management Charges for 12 Months of Manager @ Rs. 20000 pm 100 acres.	1	6000	6000
9	**Gross fix Cost (Item 1 to 8) Including Land Rent**			**217468**

Table 18 Variable cost

	Operations / Inputs	T_1			T_2			T_3		
		Average No. of operation/units/ ha	Cost /Unit (Rs.)	Total Cost (Rs.)	Average No. of operation/ units/ ha	Cost /Unit (Rs.)	Total Cost (Rs.)	Average No. of operation/ units/ ha	Cost /Unit (Rs.)	Total Cost (Rs.)
1	1.1 Interculture and earthing up	2	1500	3000	--	--	--	--	--	--
	Sub total			**3000**			**--**			**--**
2	Harvesting / Stripping & Loading									
	2.1 Harvesting, tops, trash, binding stripping etc. (1000 kg).	98.4	225	22140	99.39	225	22363	99.67	225	24918
	2.2 Loading charges (1000 kg).	98.4	125	12300	99.39	125	12424	99.67	125	12458
	2.3 Marketing Expenses (Transport + Cess Fund) per ton	98.4	250	24600	99.39	250	24848	99.67	250	24918
	Sub total			**59040**			**59635**			**62294**
3	**Gross variable Cost (Item 1 to 2)**			**62040**			**59635**			**62294**
4	**Support Price (per mound)**	--	--	180	--	--	180	--	--	180
5	Yield per hectare (tonns)	--	--	98.4	--	--	99.39	--	--	99.67
6	**Total income**	98.4	180	**442800**	99.39	180	**447255**	99.67	180	**448515**

Table 19 Variable cost

	Operations / Inputs	T_4			T_5			T_6			T_7		
		Average No. of operation/units/ha	Cost / Unit (Rs.)	Total Cost (Rs.)	Average No. of operation/units/ha	Cost / Unit (Rs.)	Total Cost (Rs.)	Average No. of operation/units/ha	Cost / Unit (Rs.)	Total Cost (Rs.)	Average No. of operation/units/ha	Cost / Unit (Rs.)	Total Cost (Rs.)
1	1.1 Interculture and earthing up	--	--	--	--	--	--	--	--	--	--	--	--
	Sub total			--			--			--			--
2	Harvesting / Stripping & Loading												
	2.1 Harvesting, tops, trash, binding stripping etc. (1000 kg).	102.26	225	23008	99.52	225	22392	97.83	225	22012	96.15	225	21634
	2.2 Loading charges (1000 kg).	102.26	125	12783	99.52	125	12440	97.83	125	12229	96.15	125	12018
	2.3 Marketing Expenses (Transport + Cess Fund) per ton	102.26	250	25565	99.52	250	24880	97.83	250	24458	96.15	250	24038
	Sub total			**61356**			**59712**			**58699**			**57690**
3	**Gross variable Cost (Item 1 to 4)**			**61356**			**59712**			**58699**			**57690**
4	**Support Price (per mound)**	--	--	180	--	--	180	--	--	180	--	--	180
5	Yield per hectare (tonns)	--	--	102.26	--	--	99.52	--	--	97.83	--	--	96.15
6	**Total income**	102.26	180	**460170**	99.52	180	**447840**	97.83	180	**440235**	96.15	180	**432675**

Table 20. Net returns, net field benefits and benefit-cost ratio of ratooned sugarcane grown at different planting dimensions

Treatments	**Variable Cost (Rs. ha^{-1})**	**Total cost (Rs. ha^{-1})**	**Gross income (Rs. ha^{-1})**	**Net return (Rs. ha^{-1})**	**Benefit cost ratio**
T_1= 120 cm spaced trenches	62040	279508	442800	163292	1.58
T_2= 90 cm spaced round pits having diameter 90 cm	59635	277103	447255	170152	1.61
T_3= 60 cm spaced round pits having diameter 90 cm	62294	279762	448515	168753	1.60
T_4= 90 cm spaced square pits having area 90 cm × 90 cm	61356	278824	460170	181346	1.65
T_5= 60 cm spaced square pits having area 90 cm × 90 cm	59712	277180	447840	170660	1.61
T_6= 75 cm spaced square pits having area 75 cm × 75 cm	58699	276167	440235	164068	1.59

Conclusions

Pit dimensions and planting geometry had significant effect on quantitative traits like number of millable canes, plant height, cane length, cane diameter, tops and trash weights and harvest index. The highest stripped-cane yield of sugarcane (102.26 t ha^{-1}) was noted at 90 cm spaced square pits having area of 90 cm × 90 cm. It should preferably be grown in 90 cm spaced square pits having area of 90 cm × 90 cm which not only give highest returns but also give more BCR as well.

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