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RESEARCH ARTICLE

Assessment of using bud chips as an alternative to cane cutting for late planting of sugarcane

Galal, M.O.A.* and E.M.M. Yousif

Sugar Crops Research Institute, Agricultural Research Center, 12511 Giza, Egypt.

Abstract

The current study was conducted at El-Mattana Research Station (latitude: 25.25° N, longitude: 32.31° E), Agricultural Research Center, Luxor Governorate, Egypt on a plant-cane in 2020–2021 and its first ratoon in 2021–2022 seasons to determine the benefits of using bud chip technology compared to traditional sugarcane planting using cane cuttings, whether earlier (In March) or late (In May).The findings showed that planting sugarcane in March (as recommended) using cane setts was comparable to employing bud chips technology in terms of cane and sugar yields per hectare as well as the number of millable canes per hectare, as well as stalk length, diameter, and weight. The first ratoon crop and plant cane both displayed the same trend in terms of quality features.When sugarcane was planted late (in May), bud chips produced better yields of canes and sugar per hectare than cane cuttings did in the plant's cane and first ratoon (14.95 and 3.23 tonnes and 10.20 and 2.07 tonnes, respectively). Meanwhile, May's late planting resulted in a significant decline in the values of the examined quality parameters of both the plant and the first crop of rats.
Applying the bud chips approach had a comparative economic advantage over the traditional planting of cane cuttings in both early and late sugarcane planting, in terms of planting expenses, gross and net return, as well as benefit-cost ratio.

Keywords: Bud chips; Conventional method; Planting dates; Sugarcane economics.

1. Introduction

Egypt's total sugar production in (2021) was about 2.71 million tons of white sugar. Meanwhile, sugar consumption reached 3.320 million tons of sugar *i.e.*, the self-sufficiency of this commodity was 81.7%. The cultivated area of sugarcane reached 139.64 thousand hectares in Minya, Sohag, Qena, Luxor and Aswan governorates, which produced about 15.71 million tons of canes, of which 75.7% was delivered to sugar mills. The average of productivity was 112.3 tons of canes/ha. Sugar Crops Council Report, (2021). In Egypt, sugarcane is grown commercially in March using stalk cuttings. This conventional method of planting has gradually become unprofitable owing to the shortage and high wages of casual agricultural labours. Moreover, due to the fragmentation of land tenure, farmers are obliged to grow more than one crop to meet their seasonal economic and social needs. Therefore, wheat is usually grown prior to sugarcane causing the delay of its spring planting to May or June, resulting in a severe reduction in cane and sugar yields/fed, as well as quality characteristics, resulted from the reduction its growing season by about three months. In the same context, in the conventional planting system, prevailed in Egypt, about 14.2-16.6 tons of cane seeds/ha (about 2.9% of the total production) is used as planting material. This large mass of planting material represents a major problem in the transportation,

***Corresponding author:** **Mohamed O. A Galal**
Email: maweias2007@gmail.com
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handling and storage of the cane seeds. It is also subjected to weather conditions, which reduces the viability of buds. Moreover, the other alternative to reduce the mass and improve the quality of seed cane would be to plant excised axillary buds of cane stalk, popularly known as bud chips. These bud chips are less bulky, easily transportable and more economical seed material. In case of using bud chips in planting, 357-476 kg/ha of material will be markedly sufficient, where it results in a saving of about 97% of cane by weight. This saves a few thousand tons of raw materials that can be delivered to mills for sugar extracting. Mostly important to mention that a considerable amount of irrigation water can be saved during the period of cane seedlings production using bud chips in the nursery, compared to the field irrigation in the usual planting.

The previously mentioned statement suggests that these problems can be effectively addressed through the adoption of bud-chip technology for sugarcane planting to avoid the inconveniences associated with conventional planting methods.

Many workers proved the negative influence of decreasing the length of growing season on sugarcane yield, among them Kamel (2020) and Chaudhari *et al* (2017). Also, Galal *et al.* (2015) reported that growing sugarcane using seedlings transplanted to the field in April did not result in any reduction in cane yield and allowed the harvesting of broad bean winter crop intercropped with sugarcane, compared to the conventional planting of sugarcane using cane setts.

Studies have shown that bud chip could be one of the most viable and economical planting method in increasing the net return of sugarcane production and increasing cane and sugar yields. Narendranath (1992) mentioned that use of seedlings raised from bud chips for planting of sugarcane was three times more cost-effective than use of conventional planting materials. Mohanty *et al.* (2015) recorded higher net return of Rs 84,300/ha under bud chips technology of sugarcane planting as compared to conventional method of planting (Rs.30, 950/ha). Similarly, Arthi *et al.* (2016) reported that the net return (Rs 123739/ha) obtained under bud chips method was more than that of conventional method (Rs 87473/ha). As reported by Patnaik *et al.* (2016) sugarcane cultivation by bud chips produced cane yield of 106.8 t/ha, which was 13.86 % higher than that of conventionally planted cane crop. They added that bud chip technology produced 32.63 % higher net returns than that obtained from of conventional sugarcane planting. Samant (2017) and Mishra (2019) showed that the improved practice of bud chip method recorded 39.7 % higher cane yield than farmer's practice of conventional method. The same methods also produced higher tillers/plant and number of millable canes/clump with 93.2% survival. Bud chips also resulted in higher gross return, net return and benefit-cost (B:C) ratio by planting bud chips as compared with conventional method of planting. Sugeerthi *et al.* (2018) mentioned that, in spite of involvement of higher input cost, the economic benefit obtained from chip budded seedlings was much higher. They also gained the maximum net income of Rs.1,83,040/ha and the highest B:C ratio of 2.63 with planting of chip bud seedlings. Parajuli *et al.* (2019) recorded a saving of 60-70 per cent of the seed cost when single bud seedlings were raised in nursery as compared to conventional method of planting. Abdul Khaliq *et al*. (2020) revealed that planting setts on 15 April gave maximum cane and sugar yields, while the simultaneous planting of bud chips produced higher yields. They added that the benefit cost ratio (BCR) was high in bud chips planting than setts planting of sugarcane. El-Soghier (2021) found that planting sugarcane by bud chips seedlings attained significant increases in the number of millable canes, stalk length, stalk diameter, stalk weight, and juice quality traits, as well as cane and sugar yields in the plant cane and 1st ratoon crops, compared to the conventional method. Moreover, bud chips technology saves 97% of the seed cost. The same author suggested that transplanting of sugarcane through the bud chips technology can be a useful tool to overcome the problem of reduced cane and sugar yields associated with delayed planting of spring plant cane when another crop is grown before it. Economically, cane yield increased by 6.9 % over the conventional method. The total net profit of the farmer was 11610 Egyptian pounds ($ 1765), in case of planting using bud chips, compared with conventional method in May.

2. Materials and methods

The present work was carried out at El-Mattana Research Station (latitude of 25.25° N and longitude of 32.31° E), Agricultural Research Center, Luxor Governorate, Egypt on a plant-cane in 2020/2021 and its 1st ratoon in 2021/2022 season. The main objective was to assess the advantages of using bud chip technology over the conventional planting of sugarcane using cane cuttings. Randomized complete block design was used with four replications. Each plot contains six rows of seven meters in length and one meter in width. Sugarcane variety G.T.54-9 was planted on the 1st of March and May using a total number of 126 of 3-budded setts/plot (29988 setts/ha) (1 ha. = 2.38 fed.). Also, healthy seedlings of 60 days age, previously produced using bud chips, was transplanted to the main field on the 1st of May, at the rate of 108 seedlings/plot (25704 seedlings/ha), spaced at approximately 40 cm.

The late conventional planting of sugarcane using cane cuttings and seedlings produced by bud chips were planting and/or transplanting in the main field after harvested the wheat and main field preparation on the 1st of May.

2.1. Main field preparation

The soil of the experimental field was clay loam, containing 57.20 available N, 11 P_2O_5 and 35.1 K_2O, as mg/kg soil. The permanent field was prepared by plowing three times and levelling. An overall dose of phosphorus fertilizer was applied during land preparation as calcium super phosphate (15% P_2O_5) at the rate of 142.8 kg P_2O_5/ha. Potassium fertilizer was added at 114.2 kg K_2O/ha as potassium sulphate (48% K_2O) once, with the second N-dose. Nitrogen fertilizer was applied as urea (46% N) at the rate of 571.2 kg N/ha, which was divided into three doses in the plant cane (after the 1st, 2nd hoeing and 30 days later *i.e.*, 45, 75 and 105 days except for the first dose at bud chips technology that was added in the nursery.

Nitrogen was given to the 1st ratoon crop at the rate of 656.88 kg N/ha as urea, at 30 days after harvesting of the plant cane crop and 30 days later.

2.2. Production of sugarcane seedlings using bud chips

Bud-chip seedlings production started on the 1st of March. Fresh harvested canes free, from disease and pests were topped and bud chips were separates using bud chipping machine Figure (1). The machine separates the bud with adequate portion of root band, to be used planting the nursery Figure (2). The average weight of a bud chip was nearly 11 g. Bud chips were soaked for five minutes in the Rizolex-T 50% fungicide. The buds were sown in an upright position at 3-5 cm depth in polythene bags of 13*6 cm dimensions, filled with soil taken from the permanent field. The nursery was irrigated daily. Nitrogen fertilizer was added in the nursery at the rate of 5 kg ammonium nitrates (33.5% N) per 1000 seedlings, which was divided into two doses at 25th and 35th day after planting. Stalks remained after the separation of buds from them was piled to be delivered to the mill Figure (3).

For the production of sugarcane seedlings, 28560 buds were planted in the nursery. The germination rate exceeded 95%. After two months, healthy seedlings were transplanted into the permanent field Figure (4).

2.3. The recorded data

2.3.1. Growth characters

- Seedling survival % using bud chips was calculated after 45 days after transplanting in main field as follows:

Seedling survival% = total seedling survived/total number of buds sown × 100

- Number of tillers was count/plot then converted into 1000/ha. This was done when tiller population reached its maximum (Tmax) *i.e.*, at 150 days after the usual late planting and/or transplanting of seedlings, and after 60 days after harvesting the plant cane crop (in the 1st ratoon).

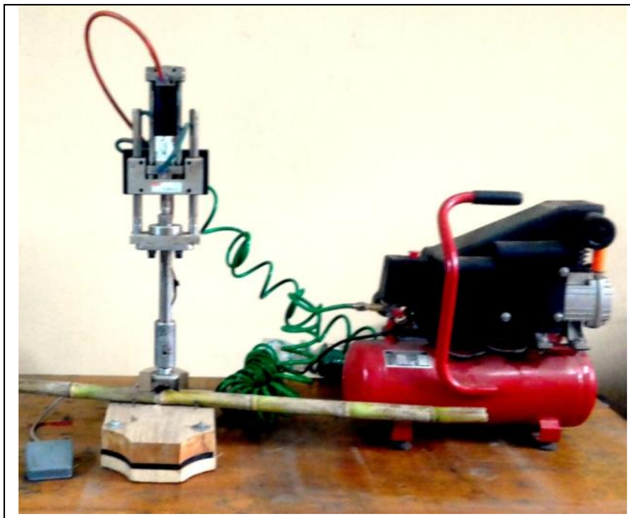

Figure 1. Bud chipping machine**.**

Figure 2. Bud chips**.**

Figure 3. Cane stalks after separating bud chips.

Figure 4. Healthy seedlings

2.3.2. Yield components

At harvest (1st of April in plant-cane and 1st of March in 1st ratoon crop), four guarded rows of each treatment were harvested, topped and cleaned to determine the following traits:

- Number of millable canes (thousand/ha), which was count on plot basis and converted into thousand/ha.
- Millable cane length, cm, which was measured from land level up to the top visible dewlap (average ten stalks).
- Millable cane diameter, cm, which was measured at the middle part of stalk (average ten stalks).
- Millable cane weight, kg was determined as an average of the collected millable canes/plot.

2.3.3. Juice quality traits.

A representative sample of 20 millable canes from each plot was taken at random, stripped, cleaned and squeezed. The primary juice was extracted by an electric pilot mill, screened and mixed thoroughly. One liter of juice was taken in glass cylinder to determine the following quality characteristics:

- Total soluble solids (TSS %) in cane juice (brix %) was determined in the laboratory using "Brix hydrometer" standardized at 20 °C.
- Sucrose percentage was determined using "Sacharemeter" according to A.O.A.C. (1995).
- Juice purity percentage was calculated according to the following equation:

$$\text{Juice purity percentage} = \frac{\text{sucrose percentage}}{\text{brix percentage}} \times 100$$

- Sugar recovery percentage was calculated as follows:

Sugar recovery % = [sucrose % - 0.4 (brix % - sucrose %) × 0.73] as shown by Yadav and Sharma (1980).

- Pol percentage was calculated according to the following equation:

Pol percentage = [brix % - 0.4 (brix % - sucrose %) × 0.73] according the method of Satisha *et. al.* (1996).

2.3.4. Cane and sugar yields/ha.

- Cane yield/ha (ton) was determined from the weight (kg) of millable canes of each plot, which was converted into tons/ha.
- Sugar yield/ha (ton) was estimated as follows:

Sugar yield/ha (ton) = cane yield/ha (ton) x sugar recovery %.

2.4. Economic analysis

Economic analysis was done by calculating the cost of cultivation, gross return, net return, and benefit-cost (B: C) ratio. Final crop yields (cane) were recorded and the gross return was calculated on the basis of prevailing market price of the product. Net return was calculated by deducting all costs from a gross return. benefit-cost (B: C) ratio was calculated using the following equation (CIMMYT, 1988):

Benefit-cost ratio = gross benefit/ gross cost.

Wheat was grown in November and harvested in April. The productivity of grain yield was 6.43 tons/ha, at a price of $ 298.19/ton, in addition to the production of 11.175 tons of straw yield/ha, at a price of $ 127.80/ton.

The total costs of production of wheat, preceding late planting of sugarcane, using seedlings and/or cane cuttings was $ 1520.7/ha and the gross return was $ 3345.69/ha, *i.e.* the net return of wheat was $ 1824.92/ha.

2.5. Statistical analysis

The collected data were statistically analyzed according to the procedures outlined by Snedecor and Cochran (1981). Means of significant variance were compared using LSD at 5% level of probability Steel and Torrie (1980).

3. Results and discussion

3.1. Growth characters

Data in Table 1 show that seedlings produced by bud chips significantly recorded 34.06 and 37.32% higher values of survival %, compared to germination % of early and late conventional planting of sugarcane using cane cuttings, respectively. These results were probably due to that seedlings, produced using bud chips, had healthy shoot (leaves) and root systems enables them to uptake water and nutrients as soon as they transplanted to the permanent field. On the contrary, buds on cane cuttings may face some difficulties for germination and emergence above soil surface as planting depth or clouds, and hence they may fail to sprout. These results were in correspondence with the findings of Mishra (2019) and El-Soghier (2021).

In the plant cane and 1st ratoon crops (Tables 1 and 2), the population of tillers was count at various times. Tiller population peaked at 150 days after planting (DAP) and/or transplanting (DAT) in the plant cane crop, while it peaked at 60 days in the ratoon crop. In comparison to plant cane crop, the peak of tiller production in the 1st ratoon crop was 60 days earlier. Because there are more buds accessible to create primary shoots and the buds are closer to the surface in the ratoon crop than in the plant cane crop, canopy development in the ratoon crop is faster than in the plant cane crop (Thompson, 1988).

Data in Table 1 show that sugarcane planting using bud chips technology markedly enhanced the number of tillers/ha by 9.34 and 23.37 thousand over those produced in case of planting sugarcane early and late conventionally in March and May, respectively, in the plant cane, corresponding to 7.29 and 9.11 thousand tillers/ha, in 1st ratoon cane. The obtained results are in accordance with Loganandhan *et al.* (2013), who recorded 55% more tillers in bud chips technology as compared to conventional method of planting.

3.2. Yield components

In plant cane, bud chips technology along with early conventional planting using cane cuttings in March were statistically higher than that of late conventional planting in May in yield components (Table 1). These results were supported by the findings of Galal *et al.* (2015), who found that direct planting in March and transplanting in April produced more millable canes/ha, as well as cane length, cane diameter and weight.

Data in Table 1 indicated that the sugarcane planting by bud chips technology substantially produced higher number of millable canes/ha, stalk length, stalk diameter and stalk weight, compared to that conventionally grown by cane setts in May. The same results were reported by Bhanupriya *et al.* (2014). Moreover, Sugeerthi *et al.* (2018) recorded heavier canes with planting of chip budded seedlings as compared to other methods of planting.

In the 1st ratoon of sugarcane that was previously planted with seedlings produced by bud chips recorded 16.22 and 13.53 thousand millble canes/ha higher than that gained in case of early and late conventional planting, respectively. Similar trend was observed concerning the single cane weight (Table 2). It can be noticed that the 1st cane crop produced higher number of tillers per unit area and lower stalk diameter and fresh weight, compared to those gained by the plant cane crop. These results could be due to higher number of buds buried beneath the soil after harvesting of the plant cane crop, which resulted in more tillers. However, the competition among higher number of tillers for water, nutrients and solar radiation may lead to lower values of stalk diameter and weight. Milligan *et al.* (1996) also found that sugarcane stalk diameter and weight decreased, while stalk number increased with older cane crops.

Table 1. Survival %, number of tillers/ha, number of millable canes/ha, stalk length, stalk diameter and stalk weight of the plant cane crop planted in 2020/2021 season.

Treatments	Survival (%)	Number of tillers (1000/ha)	Number of millable canes (1000/ha)	Stalk length (cm)	Stalk diameter (cm)	Stalk weight (kg)
Conventional planting in March	62.41	197.89	162.84	301.50	2.65	1.40
Planting seedlings of bud chips	96.47	207.23	166.34	298.80	2.67	1.39
Conventional planting in May	59.15	183.86	140.28	282.60	2.54	1.26
LSD at 0.05 level	2.28	2.48	5.18	6.18	0.04	0.04

Table 2. Number of tillers/ha, number of millable canes/ha, stalk length, stalk diameter and stalk weight of the first ratoon cane crop grown in 2021/2022.

Treatments	Number of tillers (1000/ha)	Number of millable canes (1000/ha)	Stalk length (cm)	Stalk diameter (cm)	Stalk weight (kg)
Conventional planting in March	328.07	248.77	297.00	2.51	1.17
Planting seedlings of bud chips	335.36	265.00	308.00	2.52	1.31
Conventional planting in May	326.24	251.48	297.50	2.52	1.18
LSD at 0.05 level	0.90	5.11	NS	NS	0.04

3.3. Juice quality traits

The means listed in Table 3 revealed that bud chips technology followed by early conventional planting using cane cuttings in March had the highest measured values for quality traits in the plant cane and 1st ratoon crop. As the length of the growing season increased, the recorded quality traits values increased. This is due to longer span where photosynthesis took place in March and bud chips as compared to late conventional in May. The quality traits (brix, sucrose, sugar recovery and pol%) with bud chips technology increased by 6.28, 9.39, 10.95 and 7.41%, respectively, compared to late conventional planting using cane cuttings in May in the plant cane. The same result was reported by El-soghier (2021). Meantime, there were insignificant differences in quality traits in ratoon crops for all planting methods. Generally, the juice quality traits were increased with older cane crops. These results were supported by the findings of Milligan *et al.* (1996)

Table 3. Quality traits of sugarcane grown through bud chips technology and conventional planting methods of the plant cane in 2020/2021 and first ratoon cane crop in 2021/2022

	Brix %	Sucrose %	Purity %	Sugar recovery %	Pol %
Plant cane 2020/2021					
Conventional planting in March	19.65	17.47	88.93	12.11	13.71
Planting seedlings of bud chips	19.88	17.48	88.00	12.06	13.81
Conventional planting in May	18.70	15.98	85.52	10.87	12.86
LSD at 0.05 level	0.37	0.21	Ns	0.24	0.17
First ratoon cane crop 2021/2022					
Conventional planting in March	20.25	17.25	85.16	11.71	13.91
Planting seedlings of bud chips	20.28	17.44	86.00	11.90	13.97
Conventional planting in May	20.10	16.82	83.69	11.32	13.72
LSD at 0.05 level	Ns	Ns	Ns	Ns	Ns

3.4. Cane and sugar yields

In plant cane, bud chips technology and early conventional planting using cane cuttings in March gave similar results regarding the cane and sugar yields (Table 4).

Data in Table 4 indicated that the sugarcane planting by bud chips technology produced 14.95 and 3.23 tons of cane and sugar/ha higher than that of late conventional planting using cane cuttings in May, respectively. These results can be due to higher a value of the number of millable canes/ha and heavier stalks produced by bud chips technology (Table 1). The same results were reported by Patnaik *et al.* (2016), Samant (2017) and Mishra (2019). In the 1st ratoon crop, bud chips technology resulted in a significant increase of 7.72 and 10.20 tons of canes/ha and 1.19 and 2.07 tons of sugars/ha higher than that gained in case of early and late conventional planting, respectively. Here also, the effect was mainly associated with both cane tonnage and sugar recovery, which are the component of the extracted sugar yield.

Cane and sugar yields increased in the the 1st ratoon crop by 17.74 and 17.04%, respectively, compared to plant cane. The same results reported by Mehareb *et al.* (2015) found that Cane yield across the evaluated varieties significantly increased in the first ratoon by 8.5% compared to plant cane.

3.5. Economic analysis

3.5.1. Cost of cultivation operations.

The cost of cultivation operations increased by $ 129.65 (4.48%) and $ 112.92 (3.88%), when sugarcane was planted with seedlings produced by bud chips, compared to the conventional method in March and May, respectively, in the plant cane. The increase in cost of cultivation in case of planting with seedlings produced by bud chips could be probably due to increase seedlings production, Narendranath (1992) and Sugeerthi *et al.* (2018).

Table 4. Cane and sugar yields of sugarcane grown through bud chips technology and conventional planting methods of the plant cane in 2020/2021 and first ratoon cane crop in 2021/2022.

Plant cane 2020/2021		
	cane yield t/ha	sugar yield t/ha
Conventional planting in March	135.21	16.39
Planting seedlings of bud chips	133.65	16.13
Conventional planting in May	118.70	12.90
LSD at 0.05 level	1.83	0.45
First ratoon cane crop 2021/2022		
Conventional planting in March	150.36	17.62
Planting seedlings of bud chips	158.08	18.81
Conventional planting in May	147.88	16.74
LSD at 0.05 level	1.76	0.57

3.5.2. Total cost of cultivation

Data in Table 5 showed that the total cost of cultivation decreased by $ 351.30 (6.8%) and $ 246.74 (4.88%), when sugarcane planted by cane cuttings in May compared to using seedlings and cane cuttings in March, successively. The higher total cost in the conventional method in March and bud chips technology than the conventional method in May was due to the higher cost of harvesting, loading, and transportation because of higher cane yield for the conventional method in March and bud chips technology. These results were in line with those found by Patnaik *et al*. (2016). The total cost of cultivation for 1st ratoon crop decreased by 23.93% less than the plant crop because it saves seed cane cost, labor force and cost of land preparation (Shukla *et al.*, 2013).

After addition the costs of wheat production ($ 1520.77/ha) to the costs of late planting of sugarcane in May using seedlings and cane cuttings, the total costs of early conventional planting in March decreased by $ 1625.32 and $ 1274.03/ha, as compared to planting with seedlings produced by bud chips or late conventional method in May, respectively.

3.6. Gross return

3.6.1. Gross return for sugarcane

Data in Table 6 indicated that the gross returns obtained with sugarcane grown by seedlings and cane cuttings in March were higher by $ 772.39 and $ 853.70/ha as compared to conventional method in May in the plant cane, respectively. The increase in the gross returns of planting sugarcane using seedlings and earlier conventional may be referred to higher cane yield. Abdul Khaliq *et al.* (2020) and Mishra (2019) obtained similar results.The first-ratoon of sugarcane, that was previously planted with seedlings, gave the highest gross returns recording $ 399.13 and $ 528.48/ha higher than that grown conventionally by cane setts, in March and May, respectively.

For the crop cycle (Plant cane and its 1st ratoon crop), the gross return increased by $ 317.83 (2.15%) and $ 1300.87 (9.43%), when sugarcane was planted with seedlings compared to cane setts in March and May, respectively.

Table 5. Costs of the plant and 1st ratoon cane crops, using seedlings and cane cuttings planting in 2020/2021and 2021/2022.

Particulars of sugarcane cultivation	Planting using seedlings produced by bud chips			Planting using cane cuttings					
				In March			In May		
	Plant cane	1st ratoon	Total ($)	Plant cane	1st ratoon	Total ($)	Plant cane	1st ratoon	Total ($)
Seedlings production	1367.55*	—	1367.55	—	—	—	—	—	—
Land preparation	205.30	—	205.30	205.30	—	205.30	205.30	—	205.30
Seed cane cost	—	—	—	739.09	—	739.09	862.27	—	862.27
Planting/ Transplanting	121.66	—	121.66	243.32	—	243.32	258.53	—	258.53
Hoeing	182.49	—	182.49	364.98	—	364.98	364.98	—	364.98
Furrows opening	30.42	30.42	60.83	30.42	30.42	60.83	30.42	30.42	60.83
Fertilization	541.39	650.89	1192.28	614.39	650.89	1265.28	614.39	650.89	1265.28
Irrigation	486.65	608.31	1094.95	608.31	608.31	1216.61	486.65	608.31	1094.95
Tying	91.25	91.25	182.49	91.25	91.25	182.49	91.25	91.25	182.49
Cost of cultivation operations	3026.71	1380.86	4407.56	2897.06	1380.86	4277.92	2913.79	1380.86	4294.65
Cost of harvesting, loading and transportation	2134.78	2525.23	4660.01	2159.87	2402.05	4561.92	1896.40	2362.13	4258.53
Total costs for cane $/ha	5161.48	3906.09	9067.57	5056.93	3782.91	8839.84	4810.19	3742.99	8553.17

* Costs of seedlings/ha [costs of seed cane ($ 34.98) + Polythene bags ($ 85.54) + Fill the bags with soil ($ 182.49) + Separation of bud chips ($ 76.04) + bud treatment with fungicide ($ 53.23) + bud planting ($ 97.33) + irrigation ($ 38.02) + Fertilization ($ 76.04) + Soil mixture ($ 723.88)] = $ 1367.55.

Table 6. Gross return, net return and B:C ratio of the plant and 1st ratoon cane crops, using seedlings and cane cuttings planting in 2020/2021 and 2021/2022.

Planting methods	Planting using seedlings produced by bud chips			Planting using cane cuttings					
				In March			In May		
Sugarcane & Wheat	Plant cane	1st ratoon	Total ($)	Plant cane	1st ratoon	Total ($)	Plant cane	1st ratoon	Total ($)
Cane yield ton/ha	133.64	158.08	291.72	135.21	150.37	285.58	118.71	147.87	266.58
price per ton, $	51.76	51.76	—	51.76	51.76	—	51.76	51.76	—
Gross return for cane yield, $/ha	6917.05	8182.20	15099.25	6998.36	7783.07	14781.42	6144.66	7653.72	13798.38
Gross return for wheat, $/ha	3345.69	—	—	—	—	—	3345.69	—	—
Total gross return $/ha	10262.74	—	18444.94	—	—	—	9490.35	—	17144.07
Net return for cane, $/ha	1755.57	4276.11	6031.68	1941.43	4000.16	5941.59	1334.47	3910.73	5245.20
Net return for wheat, $/ha	1824.92	—	—	—	—	—	1824.92	—	—
Total net return for cane and wheat, $/ha	3580.49	—	7856.60	—	—	—	3159.39	—	7070.12
B:C ratio*	1.54	2.09	2.03	1.38	2.06	1.67	1.50	2.04	2.00

* B:C = Benefit to costs ratio

3.6.2. Total gross return for sugarcane and wheat

After addition the gross return of wheat ($ 3345.69/ha) to the gross return of planting using seedlings and late conventional planting in May, the total gross return of early conventional planting in March decreased by $ 3264.39 and $ 2491.99/ha, as compared to planting with seedlings produced by bud chips or late conventional planting in May, respectively (Table 6).

3.7. Total net return

3.7.1. Net return of sugarcane

Data in Table 6 indicated that the net return increased by $ 185.86 and $ 606.95/ha, when sugarcane planted by cane cuttings in March, compared with the planting with seedlings produced by bud chips or late conventional planting in May, successively.

In the subsequent 1st ratoon cane crop, that was previously planted with seedlings, gave the highest net return recording $ 275.95 and $ 365.38/ha higher than that grown conventionally by cane setts, in March and May, successively. The increase in net return for bud chips technology may be attributed to higher cane yield. Mohanty *et al.* (2015) and Arthi *et al.* (2016) came up with similar results.

For the crop cycle (Plant cane and its 1st ratoon crop), the net return increased by $ 90.09 (1.52%) and $ 786.47 (14.99%), when sugarcane was planted with seedlings compared to cane setts in March and May, respectively.

3.7.2. The total net return for wheat and sugarcane

Data in Table 6 cleared that the total net return increased by $ 1639.06 (84.43%) and $ 421.10 (13.33%), when sugarcane was planted with seedlings compared to cane cuttings, in March and May, respectively, after the addition of the net return of wheat to late planted sugarcane using seedlings and conventional method using cane cuttings. For crop cycle (Plant cane and its 1st ratoon cane crop), the total net return increased by $ 1915.01 (32.23%) and $ 786.47 (11.12%) in case of planting sugarcane with seedlings compared to conventional method in March and May, respectively.

3.8. Benefit-Cost Ratio (B:C ratio)

Data on B:C ratio of both plant and ratoon cane crops of sugarcane in Table (6) pointed out that the maximum B:C ratio was recorded with bud chips technology. However, the least B:C ratio was noted with early conventional planting in March. These findings were in agreement with those reported by Samant (2017), Sugeerthi, *et al.* (2018) and Abdul Khaliq *et al.* (2020).

Overall, the maximum B:C ratio values were recorded in ratoon cane crop, because no land preparation was practiced and no planting materials were used, which ultimately contributed to a beneficial reduction in the overall costs of production.

4. Conclusion

Under the conditions of this work, instead of the conventional late planting of sugarcane in May by cane cutting, it was found that planting it using seedlings produced by bud chips technique can be recommended to get the highest cane and sugar yields. It also ensures the possibility of intercropping a winter crop preceding cane planting, which finally guarantees a satisfactory net return for growers.

Authors' Contributions

All authors are contributed in this research.

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Institutional Review Board Statement

All Institutional Review Board Statement are confirmed and approved.

Data Availability Statement

Data presented in this study are available on fair request from the respective author.

Ethics Approval and Consent to Participate

This work carried out at the Agriculture Research Station, Sugar Crops Research Institute, Agric. Res. Center.

Consent for Publication

Not applicable.

Conflicts of Interest

Declare no conflict of interest.

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