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**Research Paper**

# Effect of planting method on productivity and economics of sugarcane (*Saccharum* spp. hybrid complex) varieties under waterlogged condition

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## ABSTRACT

A field experiment was conducted during 2013–14, 2014–15 and 2015–16 at Pusa, Bihar, to evaluate planting options (conventional and trench method) and sugarcane (*Saccharum* spp. hybrid complex) varieties ('BO 91', 'BO 137', 'BO 141', 'BO 154' and 'CoP 2061') for higher growth, yield and quality of sugarcane under waterlogged conditions. Significantly higher germination (33.2%), plant population (179,600/ha), plant height (294 cm), total dry-matter accumulation (28.9 t/ha) and leaf-area index (4.38) were observed with trench method of planting than conventional method of planting. However, significantly higher number of nodes having aerial roots (8.1) and cane lodging (48.5%) were observed with conventional method of planting. The maximum cane diameter (2.07 cm), millabe canes (107,600/ha), cane yield (78.1 t/ha), gross returns (₹199,100/ha), net returns (₹114,000/ha) and benefit: cost ratio (1.34) were obtained with trench method of planting, being higher by 13.7, 18.9, 19.2, 19.2, 22.8 and 7.2%, respectively, over that of furrow planting respectively. Similarly, trench planted canes exhibited significantly higher brix (19.1%), pol (16.93%), commercial cane sugar (11.72%) and sugar yield (9.2 t/ha) than that of conventional method. Among the varieties, 'CoP 2061' showed better performance under waterlogged conditions with higher germination (37.8%), plant population (1,87,500/ha), plant height (296 cm), total dry matter accumulation (30.2 t/ha), LAI (4.60), cane diameter (2.06 cm) and millable canes (1,09,700/ha). Significantly higher cane yield (80.9 t/ha) and gross returns (₹2,06,300/ha) was obtained with the variety 'CoP 2061' which was statistically comparable to 'BO 137' (77.9 t/ha) and 'BO 154' (74.1 t/ha). Similarly, higher net returns (₹126,700/ha) and benefit: cost ratio (1.59) were obtained with 'CoP 2061'. However, higher brix content (19.1%) was noticed with 'BO 154'. There were no significant varietal differences for pol and purity per cent juice. Thus, sugarcane should be planted with trench method and varieties 'CoP 2061' and 'BO 137' may be adopted to enhance productivity of sugarcane under waterlogged conditions.

***Key words*** **:** Crop productivity, Economics, Planting method, Sugarcane varieties, Waterlogged conditions

Sugarcane (*Saccharum* spp. hybrid complex) is one of the most important commercial crops of India and known to be cultivated since pre-historic periods. In India, it is cultivated in an area of 5.3 million ha, of which Bihar shares only 0.28 million ha concentrated in north Bihar. The sugarcane productivity of the state is 50.0 t/ha, which is also low as compared to national average yield of 63.7 t/ha (ISMA, 2017). Low productivity of sugarcane in state is linked to the biotic and abiotic stresses. Waterlogging among other abiotic stresses is a major concern, as 30–35% sugarcane area in Bihar is under waterlogged conditions. The reduction in yield and quality due to waterlogging happens primarily due to creation of anaerobic condition in the soil which results in poor root respiration, root growth and nutrient uptake. If waterlogging occurs during July–September which is the grand growth period of crop, adverse effect is reported on growth, yield and quality of sugarcane (Kumar, 2009; Kumar *et al*., 2013). Crop yield losses due to waterlogging mainly depend on depth and duration of waterlogging and stage of crop growth. Apart from this, the lodging of cane and formation of aerial roots impair movement of nutrients leading to emergence of new shoots which drain out the food reserves. Kumar *et al*. (2015) reported that, higher water stagnation during grand growth phase (July– September) reduced plant height by 9.4%, cane diameter by 13.4%, millable canes by 13.8% and single cane weight by 15.7% compared with normal condition. Loss of yield and quality in waterlogged condition mainly starts with lodging of canes. Lodging of canes largely depends upon the method of planting, which could be minimized mainly through appropriate planting method

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and cultivation of suitable varieties. Conventional method of sugarcane planting at 15 cm depth restricts the cane yield and quality to a considerable extent owing to excessive lodging of canes under waterlogged conditions. Trench method of sugarcane planting is becoming popular due to availability of tractor-drawn trencher; higher germination and plant population that might help in minimizing the lodging to some extent since the depth of planting in trench method is greater (30 cm) to that of conventional method (15 cm). Choice of suitable variety is another factor of prime importance to increase productivity. Growing of sugarcane varieties with no waterlogging tolerance pulls down the average productivity of state. The present investigation was therefore conducted to study the response of sugarcane varieties to planting methods under waterlogged conditions.

## MATERIALS AND METHODS

A field experiment was conducted during 2013–14, 2014–15 and 2015–16 at Sugarcane Research Institute, Dr Rajendra Prasad Central Agricultural University, Pusa (Samastipur), Bihar under waterlogged conditions. The soil was sandy loam and alkaline (*p*H 8.2). It contained 0.44% organic carbon, 29.8% free $CaCO_3$ and was low in nitrogen (203 kg/ha), medium in phosphorus (19.4 kg/ha) and poor in potassium (102 kg/ha). The experiment comprised 2 planting methods, viz. conventional and trench method with furrow and trench depth of 15 and 30 cm, respectively, and 5 sugarcane varieties ('BO 91', 'BO 137', 'BO 141', 'BO 154' and 'CoP 2061'). The experiment was conducted in randomized block design with 3 replications during the spring season. Crop was planted in the second week of February at 90 cm row spacing and harvested in the last week of January during all the years. Recommended doses of N, P and K (150, 37.1 and 49.8 kg/ha) were applied. Urea, diammonium phosphate and muriate of potash were taken as sources of nitrogen, phosphorus and potassium respectively. Full dose of P and K and half the dose of N were applied basal at the time of planting and the rest of N in 2 equal splits–after first irrigation and at the time of earthing up–in each year. The total rainfall received was 980.8, 1,112.5 and 932.6 mm during 2013–14, 2014–15 and 2015–16 respectively. The experiment was conducted under irrigated condition as per recommended packages of practice. The average depth of water in the crop field during the month of July, August, September and October was 60, 105, 115 and 35 cm, respectively, during 2013–14, 2014–15 and 2015–16. The data were recorded on growth, yield attributes, yield and quality of sugarcane following the standard procedures. Whole cane samples were taken at the time of harvesting and cane juice was extracted with power crusher and juice quality was estimated as per method given by Spencer and Meade (1955). Sugar yield was calculated as: sugar yield (t/ha) = [S – 0.4 (B - S) × 0.73] × cane yield (t/ha)/100; where S and B are sucrose and brix in cane juice respectively. Fibre per cent cane was estimated by rapi-pol extractor. Economic analysis was done based on pooled yield data and considering price of input and output of the last year of study. The net realization was calculated by deducting the total cost of cultivation from the gross realization. The benefit: cost ratio was calculated as ratio of net realization to cost of cultivation. Finally the data were analysed as per the standard statistical methods.

## RESULTS AND DISCUSSION

### *Growth*

The data revealed that the method of planting produced marked variation in growth of sugarcane (Table 1). Trench method of planting recorded the highest germination percentage (33.2%) at 45 days after planting (DAP), plant population (179,600/ha) at 125 DAP, leaf-area index (4.38) at 240 DAP and plant height (294 cm) and dry-matter accumulation (28.9 t/ha) at harvesting. However, this was statistically at par with conventional method of planting in respect of tillers mortality. The better growth and development characters of plants in case of trench method over conventional method of planting could be attributed to availability of optimum moisture at greater depth. Singh *et al.* (2012) and Kumar *et al.* (2014) also reported such results. Trench method of planting decreased the number of nodes having aerial roots by 14.8% compared with conventional planting. Cane lodging percentage was also low by 33.8 with trench method. The reduction in number of nodes having aerial roots and cane lodging percentage with trench planted canes might be ascribed to extra strength to roots due to deep placement of setts which leads to emergence of shoots from deeper layers which resists lodging as lodging is the main cause of aerial root formation. All the growth characters were significantly influenced by sugarcane varieties (Table 1). It was observed that 'CoP 2061' being at par with 'BO 154' recorded significantly higher germination (37.8%) and plant population (187,500/ha) than 'BO 91', 'BO 137' and 'BO 141'. Higher germination and plant population might be owing to the chemical composition of soluble solids in juice as well as enzymes and hormones present in cell-sap, which differ from variety to variety. Variety 'CoP 2061' recorded taller plants (296 cm), higher dry-matter accumulation (30.2 t/ha) and leaf area index (4.60). Though it was at par with 'BO 154' and 'BO 91' in respect of plant height and 'BO 154' and 'BO 137' in case of dry-matter accumulation. It was mainly due to its fast growth over other varieties. Kumar *et al.* (2013) also observed

marked variation in dry-matter accumulation, plant height and leaf-area index due to different varieties under waterlogged conditions. The highest tillers mortality of 43.6% was recorded with 'BO 141' which was statistically comparable with 'CoP 2061' (41.5%) and 'BO 154' (40.7%), while the lowest tillers mortality of 34.1% was recorded under 'BO 91'. This indicated that, 'BO 141' is more susceptible to waterlogging. Similar results were also reported by Kumar (2009). Significant variation was observed among the varieties in terms of number of nodes having aerial roots and cane lodging percentage, and the variety 'BO 137' recorded the minimum number of nodes having aerial roots (6.1) and cane lodging (26.7%). The minimum number of nodes having aerial roots and lower lodging percentage was mainly due to erect growth habit of 'BO 137'.

### *Yield attributes and cane yield*

Cane diameter, millable canes and cane yield varied significantly due to planting method, but failed to exert significant influence on single cane weight (Table 2). The trench method of planting registered a 13.7, 18.9 and 19.2% higher cane diameter, millable canes and cane yield over conventional method. Higher cane diameter, millable canes and cane yield under trench method of planting could be attributed to better soil environment and growth

**Table 1.** Effect of planting methods and variety on growth of sugarcane under waterlogged condition (pooled data of 3 years)

| Treatment | Germination (%) at 45 DAP | Plant population at 125 DAP ($\times 10^3$/ha) | Plant height at harvest (cm) | Total DMA* at harvest (t/ha) | LAI at 240 DAP | Tillers mortality (%) | Number of nodes having aerial roots | Cane lodging (%) |
|---|---|---|---|---|---|---|---|---|
| *Planting method* | | | | | | | | |
| Conventional | 30.2 | 147.9 | 254 | 24.7 | 3.68 | 38.8 | 8.1 | 48.5 |
| Trench | 33.2 | 179.6 | 294 | 28.9 | 4.38 | 40.1 | 6.9 | 32.1 |
| SEm± | 0.67 | 4.43 | 6.2 | 0.51 | 0.079 | 0.88 | 0.15 | 0.88 |
| CD (P=0.05) | 2.0 | 12.5 | 18 | 1.5 | 0.23 | NS | 0.4 | 2.6 |
| *Variety* | | | | | | | | |
| 'BO 91' | 31.3 | 158.0 | 282 | 26.3 | 4.06 | 34.1 | 8.0 | 45.2 |
| 'BO 137' | 28.7 | 156.6 | 265 | 28.9 | 3.91 | 37.5 | 6.1 | 26.7 |
| 'BO 141' | 25.2 | 145.0 | 247 | 20.7 | 3.56 | 43.6 | 8.3 | 58.5 |
| 'BO 154' | 35.5 | 171.8 | 280 | 27.8 | 4.01 | 40.7 | 7.5 | 32.7 |
| 'CoP 2061' | 37.8 | 187.5 | 296 | 30.2 | 4.60 | 41.5 | 7.6 | 38.8 |
| SEm± | 1.05 | 7.01 | 9.8 | 0.81 | 0.124 | 1.40 | 0.24 | 1.39 |
| CD (P=0.05) | 3.1 | 19.8 | 29 | 2.4 | 0.37 | 4.2 | 0.7 | 4.1 |

DAP, Days after planting; DMA*, dry-matter accumulation; LAI, leaf-area index

**Table 2.** Effect of planting methods and variety on yield attributes, cane yield and economics of sugarcane under waterlogged condition (pooled data of 3 years)

| Treatment | Cane diameter (cm) | Millable canes ($\times 10^3$/ha) | Single cane weight (g) | Cane yield (t/ha) | Gross returns ($\times 10^3$₹/ha) | Cost of cultivation ($\times 10^3$₹/ha) | Net returns ($\times 10^3$₹/ha) | Benefit: cost ratio |
|---|---|---|---|---|---|---|---|---|
| *Planting method* | | | | | | | | |
| Conventional | 1.82 | 90.5 | 726 | 65.5 | 167.0 | 74.2 | 92.8 | 1.25 |
| Trench | 2.07 | 107.6 | 735 | 78.1 | 199.1 | 85.1 | 114.0 | 1.34 |
| SEm± | 0.047 | 2.44 | 14.3 | 1.82 | 4.49 | - | 3.09 | 0.029 |
| CD (P=0.05) | 0.14 | 6.9 | NS | 5.2 | 13.4 | - | 9.2 | 0.08 |
| *Variety* | | | | | | | | |
| 'BO 91' | 1.78 | 104.2 | 685 | 70.7 | 180.3 | 79.7 | 100.7 | 1.26 |
| 'BO 137' | 2.09 | 97.8 | 802 | 77.9 | 198.6 | 79.7 | 118.9 | 1.49 |
| 'BO 141' | 1.77 | 81.8 | 684 | 55.4 | 141.2 | 79.7 | 61.5 | 0.77 |
| 'BO 154' | 2.02 | 101.9 | 736 | 74.1 | 189.0 | 79.7 | 109.3 | 1.37 |
| 'CoP 2061' | 2.06 | 109.7 | 745 | 80.9 | 206.3 | 79.7 | 126.7 | 1.59 |
| SEm± | 0.074 | 3.86 | 22.6 | 2.88 | 7.10 | - | 4.89 | 0.045 |
| CD (P=0.05) | 0.22 | 10.9 | 67 | 8.2 | 21.1 | - | 14.5 | 0.13 |

attributes. Prem Guru *et al*. (2017) and Katiyar *et al*. (2013) also reported similar results.

Among the varieties, 'BO 137' recorded higher cane diameter (2.09 cm) and was significantly superior to 'BO 91' and 'BO 141'. Significantly more millable canes (109,700/ha) were recorded with 'CoP 2061', at par with 'BO 91' and 'BO 154'. It was mainly owing to pre-monsoon period higher plant population of these varieties than the others which led to higher number of millable canes at harvesting. These results confirm the findings of Shukla (2007) and Chakrawal and Kumar (2014). 'BO 137' produced thicker canes (802 g/plant) which were significantly superior to 'BO 91' and 'BO 141' and at par with 'CoP 2061' and 'BO 154'. Kumar (2009) also noticed significant variation in aforesaid attributes among different sugarcane varieties in waterlogged conditions. Significantly higher cane yield was recorded with the variety 'CoP 2061' (80.9 t/ha) than 'BO 91' (70.7 t/ha) and 'BO 141' (55.4 t/ha), being statistically similar with 'BO 137' and 'BO 154', owing to higher number of millable canes with moderate cane thickness and weight. Kumar (2009), Kumar *et al.* (2015), and Gulati *et al.* (2015) also reported similar yield variation under waterlogged conditions.

### *Economics*

Trench method of planting recorded significantly higher gross returns (₹199,100/ha), net returns (₹114,000/ha) and benefit: cost ratio (1.34) (Table 2). The magnitude of increase in gross returns, net returns and benefit: cost ratio by trench method of planting over conventional method was 9.2, 22.8 and 7.2% respectively. This was primarily owing to higher cane yield under trench method of planting. The cost of cultivation for all the varieties was similar. It was because of similar seed cost of all the varieties. Varieties differed significantly for gross returns, net returns and benefit: cost ratio (Table 2). 'CoP 2061' recorded the highest gross returns (₹206,300/ha) though it was at par with 'BO 137' (₹198,600/ha) and 'BO 154' (₹189,000/ha). Based on cost analysis variety 'CoP 2061' gave the maximum net returns (₹126,700/ha) which was statistically comparable to 'BO 137' (₹118,900/ha) and significantly superior to rest of the varieties. Similar was the trend in respect of benefit: cost ratio.

### *Quality*

The results indicated that except for purity per cent planting methods had significant impact on quality parameters of sugarcane (Table 3). Significantly higher brix (19.1%), pol (16.93%) and CCS (11.72%) were recorded with trench method of planting. The magnitude of increase in brix, pol and CCS percentage over conventional method was 2.1, 2.9 and 3.2% respectively. Purity per cent juice was not significantly influenced by planting methods; however, it improved in trench method. Significantly lower cane fibre content (13.5%) was noticed with trench method of planting which reduced by 5.6% against that of conventional method. This might be due to lower lodging percentage in trench-planted canes. Trench method of planting gave significantly higher sugar yield (9.2%) which was 24.3% higher than conventional method. The increase in sugar yield was owing to increase in CCS% and cane yield under trench method of planting.

Among the varieties, significant variation in brix, CCS%, cane fibre and sugar yield was noticed, while the effect on pol and purity was non-significant (Table 3). Sig-

**Table 3.** Effect of planting methods and variety on quality parameters of sugarcane under waterlogged condition (pooled data of 3 years)

| Treatment | Brix (%) | Pol (%) | Purity (%) | CCS (%) | Cane fibre (%) | Sugar yield (t/ha) |
|---|---|---|---|---|---|---|
| *Planting method* | | | | | | |
| Conventional | 18.7 | 16.45 | 88.0 | 11.36 | 14.3 | 7.4 |
| Trench | 19.1 | 16.93 | 88.6 | 11.72 | 13.5 | 9.2 |
| SEm± | 0.10 | 0.120 | 0.32 | 0.056 | 0.08 | 0.15 |
| CD (P=0.05) | 0.3 | 0.35 | NS | 0.17 | 0.2 | 0.5 |
| *Variety* | | | | | | |
| 'BO 91' | 18.9 | 16.74 | 88.6 | 11.59 | 13.7 | 8.3 |
| 'BO 137' | 19.0 | 16.92 | 89.1 | 11.75 | 14.0 | 9.2 |
| 'BO 141' | 18.5 | 16.20 | 87.6 | 11.16 | 13.3 | 6.2 |
| 'BO 154' | 19.1 | 16.85 | 88.2 | 11.65 | 14.1 | 8.6 |
| 'CoP 2061' | 19.0 | 16.76 | 88.2 | 11.58 | 14.5 | 9.4 |
| SEm± | 0.15 | 0.197 | 0.50 | 0.089 | 0.12 | 0.24 |
| CD (P=0.05) | 0.4 | NS | NS | 0.26 | 0.4 | 0.7 |

CCS, Commercial cane sugar

nificantly higher brix (19.1%) was recorded with the variety 'BO 154' which was significantly superior to 'BO 141' (18.5%) and statistically comparable to rest of the varieties. Variety 'BO 137' exhibited significantly higher CCS% juice (11.75%) when compared to 'BO 141' (11.16%). Significantly higher cane fibre (14.5%) was recorded for 'CoP 2061' being statistically similar to 'BO 154' (14.1%). Higher sugar yield (9.4 t/ha) was obtained with 'CoP 2061' which was statistically comparable to 'BO 137' and significantly superior to rest of the varieties. The higher cane yield contributed greater extent in enhancing sugar yield than other quality parameters (Table 3).

Based on the study, it may be concluded that trench method of sugarcane planting under waterlogged conditions is more productive, profitable and lodging resistant compared to conventional planting method. Among the varieties tested, 'CoP 2061' and 'BO 137' have a great promise for increased productivity, profitability and sugar yield of sugarcane under waterlogged conditions.

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