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Research Paper

Effect of ethrel and gibbrellic acid on bio-chemical changes and productivity of sugarcane (*Saccharum* species hybrid complex)

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ABSTRACT

The present study was conducted during the spring seasons of 2015–16 to 2017–18 to investigate the effects of application of *ethrel* and gibbrellic acid on growth, yield and sucrose content of spring planted sugarcane in order to work out its potential to be used as germination and growth enhancer in subtropical region. The treatments viz., planting of setts after overnight soaking in water, T_2; planting of setts after overnight soaking in 50 ppm ethrel solution, T_3; planting of setts after overnight soaking in 100 ppm ethrel solution, T_4; T_1 + GA_3 spray @ 35 ppm at 90, 120 and 150 DAP, T_5; T_2 + GA_3 spray @ 35 ppm at 90, 120 and 150 DAP, T_6; T_3 + GA_3 spray @ 35 ppm at 90, 120 and 150 DAP, T_7 and T_4 + GA_3 spray @ 35 ppm at 90, 120 and 150 DAP, T_8 were compared with T_1 (conventional planting/farmers practice treatment). Sugarcane growth, yield, and quality parameters were significantly influenced by various treatments. Owing to enhanced reducing sugars, acid invertase (AI), indole acetic acid oxidase (IAAO) and superoxide dismutase (SOD) activity in treated setts, planting of setts after overnight soaking in 50 ppm ethrel solution resulted in higher germination count at 10, 20, 30, 40 and 50 days after planting (DAP). Planting of setts after overnight soaking in 50 ppm ethrel solution + GA_3 spray @ 35 ppm at 90, 120, and 150 DAP resulted in a greater plant population at all stages of growth, which was responsible for a higher number of millable canes at harvesting. Treatment planting of setts after overnight soaking in 50 ppm ethrel solution + GA_3 spray @ 35 ppm at 90, 120 and 150 DAP recorded higher leaf area index at 180 and 240 DAP. Similarly, treatment (T_7) also recorded higher shoot and root dry weight at 120, 180, 240 and 300 DAP. Net assimilation rate during 120–180 DAP (5.78 g/m^2/day) and 180–240 DAP (3.95/m^2/day) were also recorded highest in treatment T_7. Similarly, planting of setts after overnight soaking in 50 ppm ethrel solution + GA_3 spray @ 35 ppm at 90, 120 and 150 DAP recorded higher cane yield (101.2 t/ha) and net returns (166.25 × 10^3 ₹/ha) with a benefit: cost ratio of 1.31 which was significantly higher than farmers practice and planting of setts after overnight soaking in water. Thus, planting of setts after overnight soaking in 50 ppm ethrel solution + GA_3 spray @ 35 ppm at 90, 120 and 150 DAP should be adopted to obtain the maximum productivity and profitability by spring sugarcane.

Key words: *Ethrel*, Germination, Gibbrellic acid, Growth, Sugarcane yield

Multi-purpose uses of sugarcane (*Saccharum* species hybrid complex) in various industries are driving up demand for enhanced production and long-term sustainability in the country. Sugar production fluctuates year to year, which affects the production of highly sensitive sugar commodity. Due to the extreme temperatures and the adoption of suboptimal agro-technologies, sugarcane productivity in the subtropical zone is significantly lower than that in tropical region. Tillers are used to harvest 60–70% of millable canes in sub-tropical India, whereas only 20–30% are harvested in tropical India. In spring-planted sugarcane, several attempts have been made to improve germination and shoot counts under sub-tropical condition. Irrigation between planting and germination has been attempted to improve setts and buds moisture but it causes crust formation in the upper layer of the soil, which prevents the emergence of settlings. In sugarcane, studies are available that exogenous application of plant-growth regulators (PGRs), which have improved the sprouting and growth processes. Plant-growth regulators have been recognized for their importance in raising germination count, improving mother shoot population, and promoting growth and yields. Ethephon is a flexible plant growth regulator that is rapidly metabolized by hydrolysis in plants, soils, and animals, creating ethylene gas, phosphoric acid, and hydrochloric

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acid, all of which is non-toxic and found naturally in all plants. It has the ability to improve photosynthesis and also important in abscission and lodging resistance (Ye *et al*., 2016). Physiological and biochemical studies have shown that ethylene is involved in the regulation of sugarcane growth and sucrose buildup. Through ethrel soaking and gibberellic acid (GA_3) treatments, higher shoot numbers, leaf area index, and stalk elongation can be achieved within a short growth period. The GA_3 boosts acid invertase activity, which increases the supply of hexoses (from sucrose cleavage), which are used by elongating cells for growth and metabolism. Previous research has proven the role of gibberellins in stimulating sugarcane stalk elongation (Upadhaya and Kumar, 2018). It is required to improve the germination rate and yield-attributing characters such as cane length, cane girth, individual cane weight, and quantity of millable canes in order to achieve targeted productivity. In this regard, PGRs such as ethephon and gibberellic acid, when used judiciously, have been proven to be efficient in alleviating these limitations and hence in enhancing productivity in sugarcane. Considering the above facts, the current study was conducted to determine the applicability of plant-growth regulators for improving sugarcane germination, growth, and yield in subtropical conditions.

MATERIALS AND METHODS

Three years field experiments were conducted during spring seasons of 2015–16 to 2017–18 at Sugarcane Research Institute, Dr. Rajendra Prasad Central Agricultural University, Pusa (25^0 59' N, 85^0 40' E, 52.1 m above mean sea level), Bihar. The climate of the experimental site was subhumid and subtropical, with moderate rainfall, hot dry summer and a cold winter. Total rainfall received was 914.8 mm in 2015–16, 760.6 mm in 2016–17, and 750 mm in 2017–18 during the cropping season. The soil had pH 8.2, 0.43% organic carbon, 0.28 dS/m electrical conductivity, 210 kg/ ha available N, 8 kg/ ha available P, and 102 kg/ ha available K. The recommended dose of fertilizers was 150 kg N + 37.1 kg P + 49.8 kg K/ ha. Half of the N, the entire dose of P, and the entire dose of K were applied as basal in the form of urea, diammonium phosphate and muriate of potash to the sugarcane crop. The remaining nitrogen was applied in 2 splits during the first and final stages of tillering. The study comprising 8 treatments, viz. conventional planting/farmers practice (T_1), planting of setts after overnight soaking in water (T_2), planting of setts after overnight soaking in 50 ppm ethrel solution (T_3), planting of setts after overnight soaking in 100 ppm ethrel solution (T_4), T_1 + GA_3 spray @ 35 ppm at 90, 120 and 150 DAP (T_5), T_2 + GA_3 spray @ 35 ppm at 90, 120 and 150 DAP (T_6), T_3 + GA_3 spray @ 35 ppm at 90, 120 and 150 DAP (T_7) and T_4 + GA_3 spray @ 35 ppm at 90, 120 and 150 DAP (T_8) were arranged in randomized block design with 3 replications. As per the treatment, setts were left overnight to soak the ethrel compound before being planted the next morning. Prior to planting in the furrows, they were dipped in 0.1% carbendazim solution for 10 minutes. The experimental crop was planted in the second fortnight of March and harvested in the first fortnight of January during all the 3 years. Standard agronomic cultivation techniques were used to raise the crop. In a cooled pestle and mortar with chilled distilled water, freshly sampled bud tissues were chopped and homogenized to make a 10% homogenate. After filtering the homogenate through 4 layers of cheese cloth, it was centrifuged at 8000 RPM for 20 minutes at 40°C. After centrifugation, the supernatant was utilized to calculate the amount of reducing sugars and sucrose. The number of germinated buds out of the total planted buds was used to compute the germination per cent. Sprouting was described as buds with an initial shoot protrusion of at least 2 mm in length. For the estimation of sugar in juice, 5 canes were chosen at random from each plot. Cane juice was extracted using a power crusher, and the quality of the juice was determined using Spencer and Meade's (1955) method.

RESULTS AND DISCUSSION

Biochemical changes during sprouting

An increase of 56.2, 58.0 and 54.3% in reducing sugar content and decrease in sucrose contents by 3.3, 25.9 and 29.2% were recorded in planting of setts after overnight soaking in 50 ppm ethrel solution at 20, 40 and 60 days after planting (DAP), respectively, against farmers practice (Table 1). Increment of reducing sugar content in setts by ethrel soaking was responsible for enhanced germination percentage in sugarcane. Significantly higher acid invertase (AI) activity at 20, 40 and 60 DAP was obtained with planting of setts after overnight soaking in 50 ppm ethrel solution which was followed by planting of setts after overnight soaking in 100 ppm ethrel solution. The magnitude of increase in AI activity with planting of setts after overnight soaking in 50 ppm ethrel solution over farmers practice at 20, 40 and 60 DAP was about 3 fold. Soaking of setts showed reverse trend in IAA contents at 20, 40 and 60 DAP. However, higher IAAO and SOD activities at 20, 40 and 60 DAP were recorded with planting of setts after overnight soaking in 50 ppm ethrel solution. The increase in IAA activity by planting of setts after overnight soaking in 50 ppm ethrel solution at 20, 40 and 60 DAP over farmers practice was 43.9, 59.9 and 54.2%, respectively. The corresponding values for SOD activity was 36.4, 46.6 and 51.7%, respectively (Table 2). It might be attributed to significantly higher germination percentage, tillers, millable

Table 1. Effect of ethrel on biochemical changes during sprouting (data pooled over 3 years)

Treatment	Reducing sugars (mg/ g (fresh weight)				Sucrose (mg/ g fresh weight)				Acid invertase activity (mmolmin/mg/ protein)			
	0 DAP	20 DAP	40 DAP	60 DAP	0 DAP	20 DAP	40 DAP	60 DAP	0 DAP	20 DAP	40 DAP	60 DAP
Unsoaked	8.6a	8.9c	10.0c	11.6c	34c	30a	27a	24a	0.12a	0.18d	0.23d	0.25d
Planting of setts after overnight soaking in water	8.6a	11.8b	12.5b	14.2b	39a	28a	25a	21b	0.12a	0.24c	0.34c	0.42c
Planting of setts after overnight soaking in 50 ppm ethrel solution	8.8a	13.9a	15.8a	17.9a	37ab	29a	20b	17c	0.14a	0.56a	0.68a	0.73a
Planting of setts after overnight soaking in 100 ppm ethrel solution	8.7a	13.6a	15.5a	17.6a	36bc	24b	21b	18c	0.13a	0.50b	0.62b	0.66b
CD (P=0.05)	NS	1.2	1.2	1.7	2	2	2	2	NS	0.04	0.4	0.4

[1]Numbers followed by different alphabets are significantly ($p = 0.05$) different.

Table 2. Effect of ethrel on stress- induced biochemical changes during sprouting to 60 days after planting (data pooled over 3 years)

Treatment	IAA (µg/ g fresh weight)				IAAO activity (µg IAA oxidized/ mg protein)				SOD activity (EU/ mg protein)			
	0 DAP	20 DAP	40 DAP	60 DAP	0 DAP	20 DAP	40 DAP	60 DAP	0 DAP	20 DAP	40 DAP	60 DAP
Unsoaked	0.83a	0.79a	0.76a	0.72a	9.12a	9.44b	9.72c	9.78c	0.40a	0.55c	0.58c	0.60c
Planting of setts after overnight soaking in water	0.83a	0.60b	0.54b	0.50b	9.12a	10.14b	12.25b	12.32b	0.40a	0.62b	0.66b	0.70b
Planting of setts after overnight soaking in 50 ppm ethrel solution	0.78a	0.40c	0.35c	0.32c	9.14a	13.58a	14.96a	15.08a	0.42a	0.75a	0.85a	0.91a
Planting of setts after overnight soaking in 100 ppm ethrel solution	0.80a	0.42c	0.38c	0.35c	9.13a	13.50a	14.90a	14.98a	0.42a	0.72a	0.81a	0.85a
CD (P=0.05)	NS	0.04	0.04	0.04	NS	0.98	1.23	1.23	NS	0.06	0.06	0.08

[1]Numbers followed by different alphabets are significantly ($p = 0.05$) different.

canes and enhanced translocation of photosynthates which led to higher cane yield.

Growth parameters and yield attributes

The data on germination (%) were recorded between 10 to 50 days after planting. Significant improvement in germination at all the stages of observations was noticed with the application of ethrel. Diverse treatments resulted in a considerable increase in sugarcane germination percentage (Fig. 1). At 10 DAP, the germination percentage ranged from 0.1 to 3.3%, 4.5 to 16.0% at 20 DAP, 18.2 to 30.4% at 30 DAP, 25.8 to 38.8% at 40 DAP, and 32.3 to 54.0% at 50 DAP. Planting of setts following overnight soaking in 50 ppm ethrel solution resulted in higher germination percentages at all stages (T_3). The increase in reducing sugars and 3 fold rise in acid invertase (AI) activity might have contributed to the improved germination in ethrel treatment's. Moisture is critical for cane sprouting, and it can be increased due to ethrel treatment, which reduces moisture loss in buds while maintaining the ideal moisture level required for sprouting.

Higher leaf-area index (LAI) was recorded with ethrel soaked setts and GA_3 application over farmers practice (Fig. 1). Leaf-area index enhanced by 28.9 and 30.6%, respectively at 180 and 240 DAP with the planting of setts after overnight soaking in 50 ppm ethrel solution and GA_3 spray at 90, 120 and 150 DAP over farmers' practice. The data showed that green leaf area expanded gradually from the initial stage of 120 DAP to 240 DAP, when it reached its maximum. Planting of setts after overnight soaking in 50 ppm ethrel solution + GA_3 spray @ 35 ppm at 90, 120, and 150 DAP resulted in a higher leaf area index at 180 and 240 DAP, followed by planting of setts after overnight soaking in 100 ppm ethrel solution + GA_3 spray @ 35 ppm at 90, 120, and 150 DAP. Higher ethylene evolution resulted in more leaf area, which caused in more light interception and photosynthesis. The increase in leaf-area index could be attributed to foliar application of GA_3, which improves the plant's photosynthetic efficiency by influencing photosynthetic enzymes and boosting nutrient-use efficiency, resulting in an increase in photosynthetic area. This could be because GA_3 causes cell elongation or cell-division, which leads to an increase in leaf area. Similarly, Chandra (2011) stated that, GA_3 exhibited early crop canopy coverage, resulting in a higher leaf-area index (LAI).

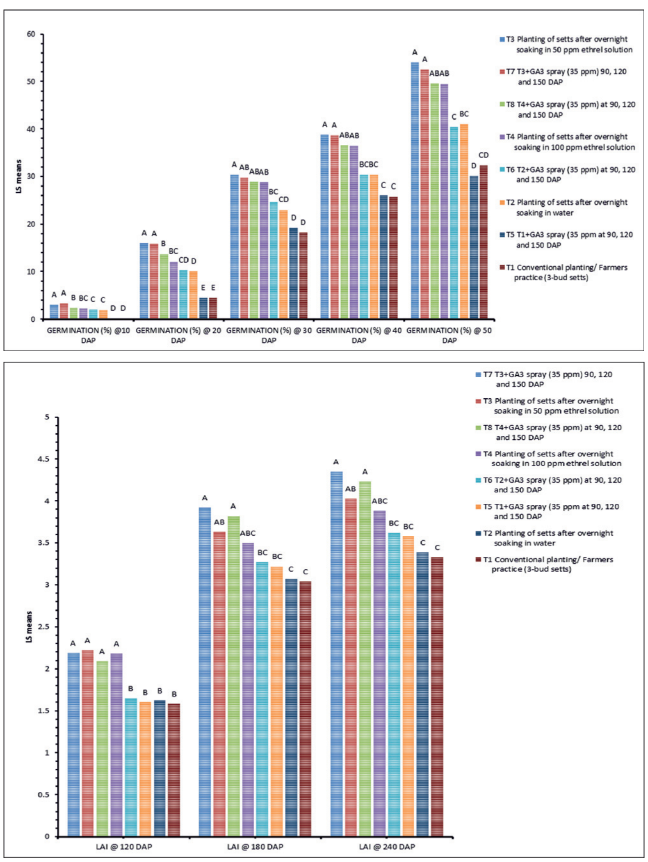

Fig. 1. Germination and leaf-area index of sugarcane as affected by plant growth regulators (data pooled over 3 years)

Maximum shoot and root dry-matter accumulation at 120, 180, 240 and 300 DAP obtained with the planting of setts after overnight soaking in 50 ppm ethrel solution and GA_3 application @ 35 ppm at 90, 120 and 150 DAP (Fig. 2). The data revealed that early stages have a low rate of dry-matter production due to the small size of the assimilatory (leaves) and absorbing (roots) apparatus. However, when the assimilatory and absorbing organs grew in volume with age, dry-matter production rose at a compound rate until the grand growth stage. The GA_3 also promotes phloem loading by stimulating fructose 1, 6-biphosphate and sucrose phosphate synthatase (Iqbal *et al.,* 2011).

Net assimilation rate (NAR), which indicates the rate of increase in biomass per unit leaf area per day, was greater in planting of setts after overnight soaking in 50 ppm ethrel solution and GA_3 spray @ 35 ppm at 90, 120 and 150 DAP (Fig. 3). However, it was found to be non-significant during 180–240 DAP. During 120–180 DAP, net assimilation rates, or the growth in plant dry weight per unit leaf area and unit time, varied considerably. Due to senescence of basal leaves, it tends to diminish with time during 180–240 DAP. Sugarcane has a high leaf area index and a high photosynthetic efficiency under full sunlight, greater than any other crop in the tropics; hence leaf-area index is particularly important in sugarcane yield estimation. The amount of intercepted radiation, which is mostly governed by the leaf area index, is closely related to variation in growth and productivity.

Use of plant growth regulators resulted in significant

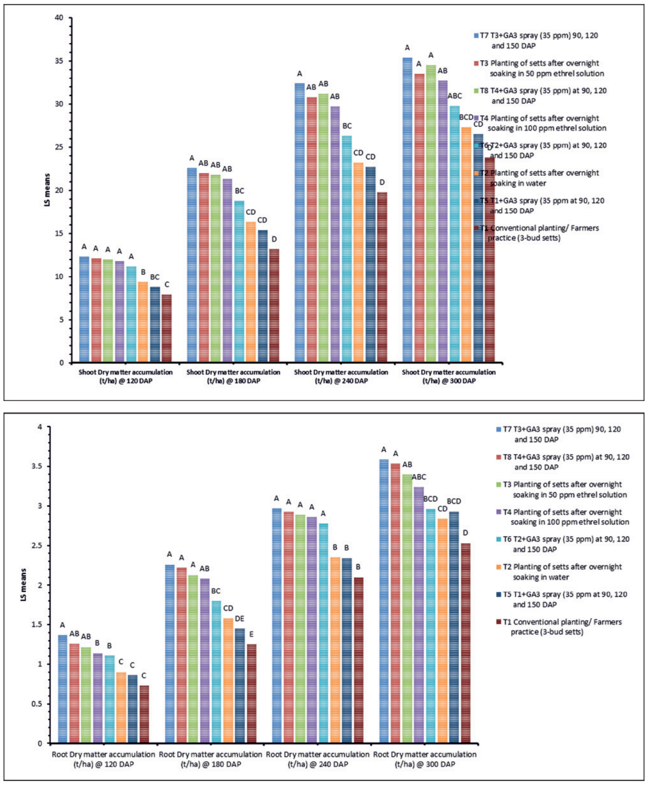

Fig. 2. Dry-matter accumulation (t/ ha) of sugarcane shoots and root as affected by plant growth regulators (data pooled over 3 years)

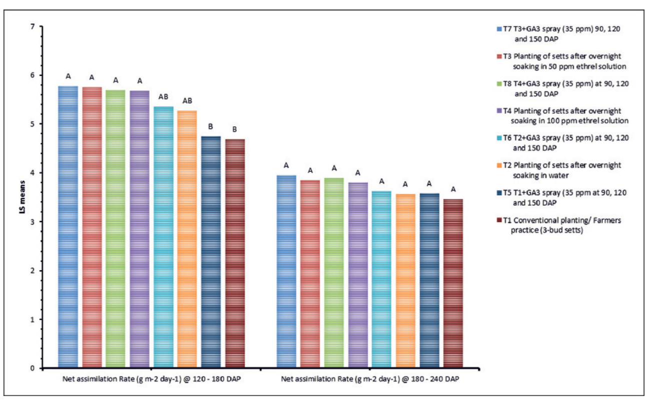

Fig. 3. Net assimilation rate of sugarcane as affected by plant growth regulators (data pooled over 3 years)

variation in the plant population at 90 and 120 DAP (Table 3). Plant population increased by 43.9 and 46.6% at 90 and 120 DAP with the planting of setts after overnight soaking in 50 ppm ethrel solution and GA_3 spray @ 35 ppm at 90, 120 and 150 DAP against farmers' practice. Reported increased tiller production as a result of ethrel treatment. The GA_3 spray was applied 90 days after planting and this might have influenced the plant population count at 120 DAP. Rai *et al*. (2017) found that, phasic application of gibberellic acid increased shoot counts when compared to the control. The reason for this was a considerable reduction in shoot mortality. The use of GA_3 resulted in the formation of a strong root system that synergizes the water and mineral nutrient absorption essential for the stimulation of shoot growth. Plant height of sugarcane did not vary significantly due to different treatments (Table 3). However, the plant height at harvesting in different treatments ranged from 265 to 327 cm. Planting of setts after overnight soaking in 50 ppm ethrel solution along with GA_3 spray @ 35 ppm at 90, 120 and 150 DAP produced significantly higher number of millable canes (153,900/ ha) as compared to farmers practice (118,300/ ha). The production of tillers alone, however, does not result in a higher yield. It is more vital to have optimum number of millable canes at harvesting. Early emergence and production of tillers were induced by ethrel in this experiment, resulting in a higher number of mature stalks. Planting setts after overnight soaking in 50 ppm ethrel solution + GA_3 application @ 35 ppm at 90, 120, and 150 DAP increased millable canes by 35600/ha compared to conventional planting. By treating setts with ethrel solution and foliar application of gibbrellic acid, early and higher emergence was achieved. As a result of higher emergence, and their subsequent conversion to tillers, led to higher number of millable canes. Our results confirm the findings of El-Lattief and Bekheet (2012).

Cane yield, sucrose content and economics

Data related to cane yield, sucrose content and economics are presented in Table 3. Cane yield varied significantly owing to different treatments. Treatments had a considerable effect on cane yield (Table 3). Planting of setts after overnight soaking in 50 ppm ethrel solution + GA_3 spray @ 35 ppm at 90, 120, and 150 DAP (T_7) resulted in the maximum cane yield (101.2 t/ ha), which was comparable to planting of setts after overnight soaking in 100 ppm ethrel solution + GA_3 spray @ 35 ppm at 90, 120, and 150 DAP (T_8), planting of setts after overnight soaking in 50 ppm ethrel solution (T_3), planting of setts after overnight soaking in 100 ppm ethrel solution (T_4) and significantly superior to rest of the treatments. The treatment (T_7) resulted in the maximum cane yield owing to higher number of tillers, millable canes and cane length and other growth and yield attributing characters. Cane yield was increased in all treatments when compared to conventional planting, though the response varied by treatment to treatment. Even soaking setts in water overnight before planting resulted in a 10.4% increase in cane yield compared to the conventional planting. Our findings confirm those of Praharaj *et al*. (2016) and Upadhaya and Kumar (2018a).

Sugarcane juice was analyzed for sucrose content at harvest (Table 3). The differences in per cent juice sucrose due to different treatments were found non-significant.

Table 3. Effect of plant growth regulators on growth, yield, quality and economics of sugarcane (data pooled over 3 years)

Treatment		Plant population ($\times 10^3$/ha) 90 DAP	Plant population ($\times 10^3$/ha) 120 DAP	Plant height at harvest (cm)	Millable canes ($\times 10^3$/ha)	Cane yield (t/ha)	Sucrose in juice (%)	Cost of cultivation ($\times 10^3$ ₹/ha)	Net returns ($\times 10^3$ ₹/ha)	B : C ratio
T_1	Conventional planting/ Farmers practice (3-bud setts)	148.4d	159.3e	265a	118.3d	74.8d	17.17a	121.38	95.54d	0.79d
T_2	Planting of setts after overnight soaking in water	173.9c	186.3cde	277a	127.3bcd	82.6bcd	17.10a	122.76	116.78cd	0.95cd
T_3	Planting of setts after overnight soaking in 50 ppm ethrel solution	205.5a	222.9ab	292a	147.1ab	94.4ab	17.53a	123.31	150.45ab	1.22a
T_4	Planting of setts after overnight soaking in 100 ppm ethrel solution	201.8ab	220.5abc	284a	145.1abc	92.6abc	17.24a	123.97	144.57ab	1.17ab
T_5	T_1+GA_3 spray (35 ppm) at 90, 120 and 150 DAP	156.9cd	168.6de	296a	123.6cd	80.5cd	17.01a	125.30	108.15cd	0.86cd
T_6	T_2+GA_3 spray (35 ppm) at 90, 120 and 150 DAP	178.9bc	194.6bcd	306a	129.7bcd	87.8bcd	17.15a	126.68	127.94bc	1.01bc
T_7	T_3+GA_3 spray (35 ppm) at 90, 120 and 150 DAP	213.5a	233.6a	327a	153.9a	101.2a	17.18a	127.23	166.25a	1.31a
T_8	T_4+GA_3 spray (35 ppm) at 90, 120 and 150 DAP	205.8a	225.9ab	317a	147.4ab	98.1a	17.08a	127.89	156.60a	1.22a
	CD (P=0.05)	24.9	35.1	NS	21.6	13.5	NS	-	22.83	0.17

[1]Different letters in columns indicate significant differences between mean values for treatments at the 0.05 probabilit

Among different treatments, average sucrose content in cane juice ranged from 17.01 to 17.53%. Net returns and benefit-cost ratio were realized maximum with the planting of setts after overnight soaking in water + GA_3 spray @ 35 ppm at 90, 120 and 150 DAP (T_7) which was statistically similar to T_8, T_3 and T_4 treatments. This was owing to maximum increase of cane yield and moderate cost of cultivation under the treatment.

Thus, out of the 8 treatments tested, planting of setts after overnight soaking in 50 ppm ethrel solution was found more suited in order to have enhanced reducing sugars, acid invertase activity, IAAO, SOD and reduced IAA activity which resulted in significantly higher rate and extent of sugarcane germination. Planting of setts after overnight soaking in 50 ppm ethrel solution, planting of setts after overnight soaking in 100 ppm ethrel solution, planting of setts after overnight soaking in 50 ppm ethrel solution + GA_3 spray @ 35 ppm at 90, 120 and 150 DAP and planting of setts after overnight soaking in 100 ppm ethrel solution + GA_3 spray @ 35 ppm at 90, 120 and 150 DAP were found equally effective as these have resulted in higher plant population of sugarcane and realizing higher millable canes at harvest, besides enhancing cane yield in the agro-climatic condition of Bihar. Thus, the results indicated a potential possibility of ethrel and gibberellic acid to be used as growth-enhancer which besides improving mother shoots can also solve the problem of lower germination of sugarcane in subtropical region.

REFERENCES

Chandra, A. 2011. Physio-biochemical and molecular approaches to enhance sucrose content in sugarcane: Indian initiatives. *Sugar Technology* **13**(4): 315–321.

El-Lattief, E.A.A. and Bekheet, M.A. 2012. Quantitative and qualitative attributes of three sugarcane varieties as inuenced by foliar spray of some growth regulators under Upper Egypt conditions. *Sugar Technology* **14**(4): 345–350.

Iqbal, N., Nazar, R., Khan, M.I.R., Masood, A. and Khan, N.A. 2011. Role of gibberellins in regulation of source sink relations under optimal and limiting environmental conditions. *Current Science* **100**(7): 998–1,007.

Praharaj, S., Singh, D. and Guru, S.K. 2016. Effect of ethephon and gibberellic acid on emergence, yield attributes and yield of sugarcane. *The Bioscan* **11**(4): 2,675–2,678.

Rai, R.K., Tripathi, N., Gautam, D. and Singh, P. 2017. Exogenous application of ethrel and gibberellic acid stimulates physiological growth of late planted sugarcane with short growth period in sub-tropical India. *Journal of Plant Growth Regulation* **36**: 472–486.

Spencer, G.L. and Meade, G.P. 1955. Cane Sugar Hand Book. John Wiley & Sons, New York, USA.

Upadhaya, B. and Kumar, N. 2018. Effect of plant growth regulators on germination and growth parameters of sugarcane (*Saccharum* spp. hybrid complex). *Journal of Pharmacognosy and Phytochemistry* **7**(4): 2,589–2,592.

Upadhaya, B. and Kumar, N. 2018a. Yield, quality and profitability of sugarcane (*Saccharum* spp. hybrid complex) as influenced by plant growth regulators in sub-tropical India. *International Journal of Chemical Studies* **6**(6): 802–805.

Ye, D.L., Zhang, Y.S., Alkaisi, M.M., Duan, L.S., Zhang, M.C. and Li, Z.H. 2016. Ethephon improved stalk strength associated with summer maize adaptations to environments differing in nitrogen availability in the North China Plain. *Journal of Agricultural Sciences* **154**(6): 960–977.