https://doi.org/10.56093/ijas.v90i11.108590

Indian Journal of Agricultural Sciences **90** (11): 2174–9, November 2020/Article

Enhancing cane and sugar productivity applying variable modes of plant growth regulators in sugarcane (*Saccharum* sp. complex) cultivation under coastal climatic conditions of India

J R PATNAIK[1] and P K NAYAK[2]

Sugarcane Research Station, Odisha University of Agriculture and Technology, Nayagarh, Odisha 752 070, India

Received: 11 February 2020; Accepted: 9 March 2020

ABSTRACT

A field experiment was carried out for three crop seasons at Sugarcane Research Station, Nayagarh (Odisha) during spring seasons of 2015-16, 2016-17 and 2017-18 to assess the effect of ethrel and gibberellic acid on growth, yield attributing characters, yield and quality of sugarcane (*Saccharum* sp. complex). Pooled data of three years study indicated that different treatments with plant growth regulators had significant effect on growth, yield and quality parameters of sugarcane. Germination percent of cane buds was the highest in the treatment involving planting of sugarcane setts after overnight soaking in 100 ppm ethrel solution followed by foliar application of gibberellic acid @35 ppm at 90,120 and 150 days after planting (DAP). Other sugarcane growth parameters, *viz.* number of tillers and plant heights were significantly higher with the application of growth regulators which produced higher number of millable canes (at harvest) than that of other treatments in the test. Overnight soaking of cane setts in 100 ppm ethrel solution followed by foliar application of gibberellic acid @35 ppm at 90,120 and 150 days after planting also produced significantly higher yield parameters, viz. number of millable cane (84.26’ 000 ha^{-1}), cane length (313.6 cm), cane girth (2.94 cm) and single cane weight (1.64 kg) as compared to conventionally planted sugarcane crop. There was no significant influence on juice quality parameters due to various treatments in this study. However, overnight soaking of setts with 100 ppm ethrel solution followed by foliar application of gibberellic acid @ 35 ppm at 90, 120 and 150 days after planting showed comparatively higher values in all the juice quality parameters. Significantly higher cane and sugar yields of 116.14 t/ha and 12.82 t/ha, respectively were obtained with planting of sugarcane after overnight soaking in 100 ppm ethrel solution followed by gibberellic acid spray @ 35 ppm at 90, 120 and 150 days after planting. The above higher yields were attributed mainly to marked improvement in growth and yield attributes in response to application of plant growth regulators. Therefore, it can be concluded that combined application of ethrel and gibberellic acid had the positive effect to improve the growth parameters, yield and quality of sugarcane.

Key words: Growth and yield of sugarcane, Juice quality, Plant growth regulators, Water soaking

Sugarcane (*Saccharum* sp. complex) is an efficient converter of solar energy into sugars and other renewable forms of energy involving various by-products of high economic importance to sugar industry and farmers as well. It is an important agro-based commercial crop which is cultivated, both in tropical and sub-tropical climatic conditions in India. It is cultivated approximately in 101 countries globally, and produces 178 million tonnes of sugar, which is about 80% of the total sugar production in the world. In India, its acreage is about 2.53% (4.9 million ha) of the gross cropped area of the country with an annual production of 303.6 million tonnes (Anonymous 2017). After Brazil, India is the second largest producer of sugarcane and sugar to the tune of 15 and 25% of the total global production, respectively (Mohan and Kanaujia 2017). Moreover, India is the top most consumer of sugar in the world with a total sugar consumption of 24.85 million tonnes per year. The requirement of sugar in the country will go up from 24.85 million tonnes to 48 million tonnes by 2050. The increased production of sugarcane and sugar will have to be achieved from the existing cane area through the vertical improvement in productivity of sugarcane and sugar since further expansion in cane area is not practically possible (Anonymous 2015). Sugarcane cultivation in India particularly in east coast climatic conditions severely faces numerous problems, such as weeds, diseases, pests, and/or several abiotic stresses, such as prolonged water stagnation in cane fields, which lead to yield declines, both in cane and sugar (Tew and Cobill 2008). Apart from this, the lower sugar content of cane sometimes causes lower procurement prices by sugar mills in light of Fair and Remunerative Price

[1]Junior Scientist (Agronomy) (jrpatnaik117@gmail.com), [2]OIC and Senior Scientist (Plant Breeding) (pknpbg@gmail.com)

(FRP) structure being operated by the Govt. of India on regular basis. Now, there is an utmost need to improve the productivity of both cane and sugar vertically by planting location specific high cane and sugar yielding varieties of sugarcane with the adoption of efficient crop management practices besides applying various plant growth regulators. Plant growth regulators (PGRs) are organic compounds, other than nutrients, that promote plant physiological processes. PGRs, called biostimulants or bioinhibitors, act inside plant cells to stimulate or inhibit specific enzymes or enzyme systems and help regulate plant metabolism. They are active normally at very low concentrations in plants. Sugarcane crop is propagated vegetatively through cane setts of varying length or stalk cuttings which require large quantities of seed cane about 6 to 8 t/ha (nearly 10% of total produce). Since, sugarcane crop is generally kept for ratooning purpose too, so it is important to insure a good initial stand establishment of plant population. Therefore, growers need to plant a very high rate of seed cane as planting material for ensuring a good field establishment. In conventional method of sugarcane planting, initial sprouting of cane setts is poor (35-40%) and scanty, therefore, a heavy input of seed cane material is required which could have been used for sugar recovery otherwise. Due to late planting of sugarcane, the initial growth (germination and tillering) is drastically affected due to high temperature and low humidity during early phase of the crop. The poor sprouting and initial growth of ratoon crop during winter months also affect sugarcane and sugar productivity in many areas.

Therefore, an agro-technique pertaining to improvement in germination of cane buds along with higher tiller production is of utmost requirement to obtain higher number of millable canes (NMC) and ultimately to both high cane and sugar yield. Moreover, plant growth regulators have been found to act on sugarcane by improving or retarding some of the physiological constraints of cane growth (Alexander 1973). Application of plant growth regulators like ethrel and gibberellic acid (GA_3) to sugarcane have been found to be quite effective in increasing germination, growth processes and thus improving productivity of sugarcane. Ethrel application has been found to enhance sprouting of seed cane setts under normal and late-planting situations besides inducing tiller development in many genotypes. It also helps in sprouting of underground stubble buds and can prevent flowering which is detrimental in commercial sugarcane plantation (Li and Solomon 2003). External application of GA_3 remarkably increases internodal length in sugarcane (Moore 1980 and Pribil *et al*. 2007). Foliar application of GA_3 has been found to be much effective in improving height, thickness and number of cane stalks per ha (El-Lattief and Bekheet 2012). Therefore, a field experiment was carried out with objectives to study the combined application of ethrel and gibberellic acid at different growth stages for improving sprouting, enhancing shoot numbers, yield attributes and yield of sugarcane by sett treatment with ethrel and foliar application of gibberellic acid in east coast climatic conditions of Odisha.

MATERIALS AND METHODS

A field experiment was carried out consecutively for three crop seasons at Sugarcane Research Station, Nayagarh (Odisha) (19°54'- 20°32' N latitude and 84°29' - 85°27' E longitude) during spring season of 2015-16, 2016-17 and 2017-18. The experimental site falls under the East and South Eastern Coastal Plain Agro-climatic Zone of Odisha having sub-humid climate with unimodel rainfall pattern. The objective of the study was to find out the effect of plant growth regulators on growth, yield and quality of sugarcane. The soil of the experimental field was sandy loam in texture, with low in organic carbon (0.48 %), medium in available phosphorus (11.2 kg/ha) and exchangeable potassium (137 kg/ha).The experiment was laid out in a randomized block design replicated thrice. An early maturing sugarcane variety, Co Or 03151 was planted at 80 cm apart with eight different treatment combinations which were allocated randomly. Thus, there were altogether 24 plots. The treatments were: T_1 – Conventional planting/farmers practice (3 bud setts), T_2 – Planting of setts after overnight soaking in water, T_3 – Planting of setts after overnight soaking in 50 ppm ethrel solution, T_4 – Planting of setts after overnight soaking in 100 ppm ethrel solution, T_5 – T_1 + gibberellic acid (GA_3) spray (35 ppm) at 90, 120 and 150 DAP (days after planting), T_6 – T_2 + GA_3 spray (35 ppm) at 90, 120 and 150 DAP, T_7 – T_3 + GA_3 spray (35 ppm) at 90, 120 and 150 DAP and T_8 – T_4 + GA_3 spray (35 ppm) at 90, 120 and 150 DAP. Healthy cane setts having viable buds were planted after above sett treatments in different experimental plots. The crop was uniformly fertilized with recommended doses of 250 kg N, 100 kg P_2O_5 and 60 kg K_2O ha^{-1} besides 10 t/ha well decomposed FYM. Urea, single super phosphate and muriate of potash were taken as sources of nitrogen, phosphorus and potassium, respectively. 100% recommended dose of P_2O_5 and K_2O was applied at the time of planting, while nitrogen 100% (250 kg ha^{-1}) applied in three equal splits, *i.e.* 33% each at 30, 60 and 90 days after planting, respectively. In each year, the crop was grown as per standard agronomical practices followed in the region. The crop was planted in spring season and harvested in next early spring season during all the three years of experimentation. The observations on germination percentage, plant height, number of shoots, yield attributes and cane yield were recorded at their respective growth and harvesting stages. Juice quality parameters were also determined at the time of harvesting. CCS (commercial cane sugar) percent in cane was calculated according to the formula given by Parthasarathy (1977). Statistical analysis of experimental data was done using analysis of variance technique prescribed for randomized block design, and to test difference among treatments means by the 'F-test' (Gomez and Gomez 1984).

RESULTS AND DISCUSSION

Germination percentage

Experimental data on germination percentage were recorded at 20, 30 and 40 days after planting of sugarcane in the experimental plots. The pooled data of three years on germination is presented in Table 1. Results indicated that the germination percent of cane buds under various treatments differed significantly at all the three stages. The higher germination per cent was observed when cane setts were planted after overnight soaking of cane setts in 100 ppm ethrel solution. Overnight soaking of cane setts with 50 ppm ethrel solution was also found equally effective over other treatments in the study. At 40 DAP, all the treatments were quite effective in improving the germination percentage of cane buds, however, maximum germination (60.56%) was observed in the treatment wherein cane setts were planted after overnight soaking with 100 ppm ethrel solution, and it was at par with the treatment involving cane setts planting after overnight soaking with 50 ppm ethrel (57.87%) solution. The improvement in germination was apparently due to ethrel treatment which might have increased the enzyme activity of acid invertase and ATPase activity during bud sprouting by growth promoting hormones (Jain *et al.* 2007). Cane sett soaking with 100 ppm ethrel solution recorded 29 per cent higher germination over conventionally planted sugarcane. Improvement in germination due to ethrel treatment has also been reported by many workers (Li and Solomon 2003, Jain *et al.* 2011). Cane setts treated with overnight soaking of water also improved germination percent. Improvement in germination under water soaking treatment might be due to faster conversion of sucrose to reducing sugars. Higher bud sprouting due to soaking of setts in water has also been reported by Tudu *et al.* (2007) and Rai *et al.* (2008). They reported that ethrel treated cane setts improved bud sprouting owing to a change in the membrane permeability, increase in moisture content, uptake of electrolytes in buds and induction of nitrate reductase, acid invertase and peroxidase activities in sugarcane cultivars.

Observations recorded on plant height at 120 and 180 DAP (133.32 cm and 242.3 cm, respectively) was comparatively higher at planting of setts after overnight soaking in 100 ppm ethrel solution + GA_3 spray @ 35 ppm at 90, 120 and 150 DAP. Improvement in stalk height due to foliar application of GA_3 was also reported by El-Lattief and Bekheet (2012) and Jain *et al.* (2013). They noticed that GA_3 promotes stem elongation by enhancing invertase activity in apical portion of the sugarcane stalks.

Moreover, higher tillers production of 85.67 and 88.56' 000 ha^{-1} at 120 and 180 DAP, respectively was recorded with overnight cane setts soaking in 100 ppm ethrel solution along with GA_3 spray at 90, 120 and 150 DAP which was significantly higher with that obtained under conventional method of planting (73.9 and 83.16 '000 ha^{-1}, respectively) at the same growth stages. However, all the treatments consisting of various growth promoting hormones were almost similar in producing at par results with respect to germination per cent of cane buds. Higher germination per cent of cane buds due to ethrel treatment was possibly due to strengthening of root activity and effective utilization of the nitrate- nitrogen for proper tiller growth. Rao *et al.*(2005) reported that exogenous application of ethrel has the ability to promote the axillary bud break and increases initial shoot numbers in several species. Higher tiller production due to ethrel treatment has also been reported by several workers (Li and Solomon 2003). Foliar application of GA_3 at 90 days after planting showed its positive impact on tillers

Table 1 Effect of plant growth regulators on germination, plant height and shoot count at various stages of sugarcane growth

Treatment		Germination%			Plant height (cm)		No. of shoots ('000 ha^{-1})	
		20 DAP	30 DAP	40 DAP	120 DAP	180 DAP	120 DAP	180 DAP
T_1	Conventional planting/Farmers practice (3 bud setts)	11.27	29.52	46.91	123.46	223.40	78.90	83.16
T_2	Planting of setts after overnight soaking in water	14.11	32.34	52.10	121.40	225.02	80.03	82.90
T_3	Planting of setts after overnight soaking in 50 ppm ethrel solution	24.46	45.76	57.67	125.83	229.19	82.42	85.23
T_4	Planting of setts after overnight soaking in 100 ppm ethrel solution	27.06	48.64	59.54	130.62	233.99	83.62	85.10
T_5	T_1 + GA_3 spray @35 ppm at 90, 120 & 150 DAP	11.23	30.02	44.80	126.18	237.03	83.20	85.93
T_6	T_2 + GA_3 spray @35 ppm at 90, 120 & 150 DAP	11.43	31.22	51.33	125.82	239.67	84.27	87.10
T_7	T_3 + GA_3 spray @35 ppm at 90, 120 & 150 DAP	25.41	44.82	57.87	132.74	241.82	85.67	88.27
T_8	T_4 + GA_3 spray @35 ppm at 90, 120 & 150 DAP	28.21	48.74	60.56	133.32	242.30	85.17	88.56
SEm ($\pm$)		1.33	1.447	1.510	2.227	2.167	1.733	1.045
CD (5%)		5.02	6.38	4.581	6.753	6.572	5.257	3.171

Table 2 Effect of plant growth regulators on yield parameters of sugarcane

Treatment		Length of per cane (cm)	Girth of cane (cm)	Weight of per cane (kg)	NMC ('000 ha^{-1})
T_1	Conventional planting/ Farmers practice (3 bud setts)	279.21	2.50	1.31	74.63
T_2	Planting of setts after overnight soaking in water	280.43	2.52	1.36	75.39
T_3	Planting of setts after overnight soaking in 50 ppm ethrel solution	283.15	2.58	1.49	77.38
T_4	Planting of setts after overnight soaking in 100 ppm ethrel solution	288.40	2.63	1.52	78.04
T_5	T_1 + GA_3 spray @35 ppm at 90, 120 & 150 DAP	293.47	2.58	1.52	78.16
T_6	T_2 + GA_3 spray @35 ppm at 90, 120 & 150 DAP	294.30	2.58	1.54	79.37
T_7	T_3 + GA_3 spray @35 ppm at 90, 120 & 150 DAP	309.56	2.92	1.58	83.22
T_8	T_4 + GA_3 spray @35 ppm at 90, 120 & 150 DAP	313.60	2.94	1.64	84.26
SEm (±)		2.660	0.198	0.063	1.26
CD (5 %)		8.069	0.599	0.191	3.82

production at 120 and 180 DAP. Results of Rai *et al.* (2017) indicated that phasic application of gibberellic acid led to an increase in shoot numbers against control. This was due to a significant decrease in shoot mortality in case of conventionally planted crop of sugarcane. GA_3 application led to the development of robust root system which must have synergized the water and mineral nutrients absorption required for stimulated growth of the shoots.

Yield parameters

Experimental observations pertaining to yield parameters like length, girth and weight of cane play an important role in improving the yield of cane. Length and girth of cane were increased significantly in the treatment involving overnight soaking of cane setts in 100 ppm ethrel solution followed by foliar application of gibberellic acid @ 35 ppm at 90, 120 and 150 DAP over rest of the treatments in the test. In the above treatments, cane length and girth were improved by 12.3% and 17.6%, respectively over control. The improvement in shoot height and subsequent enhancement in cane length was possibly due to foliar application of gibberellic acid solution, which improved photosynthetic efficiency of plants through its influence on photosynthetic enzymes and improving nutrients use efficiency as well. The higher photosynthesis was also associated with higher leaf area index in this treatment, and accordingly enhanced the photosynthetic area of the plants of that particular treatment. Improving photosynthetic efficiency due to gibberellic acid solution application is also in conformity with the findings of Iqbal *et al.* (2011). Improvement in cane thickness due to gibberllic acid solution application in this case also confirms with the findings of El-lattief and Bekheet (2012).Weight of cane is decided by both length and girth of the cane. Individual cane weight (1.64 kg) was the highest in the treatment involving overnight soaking of ethrel solution @ 100 ppm followed by GA_3 spray @ 35 ppm at 90,120 and 150 DAP. Similar results have also been reported by Praharaj *et al.* (2016). Early and higher germination on account of sett treatment with ethrel, and better photosynthetic efficiency due to foliar application of gibberellic acid solution resulted in the production of higher number of tillers and their subsequent conversion into millable cane production at harvest of sugarcane. Maximum number of millable cane production was observed in T_8 (84.26'000 ha^{-1}), which was significantly higher over rest of the treatments in the test. Planting of setts after overnight soaking in 100 ppm ethrel solution + GA_3 spray @ 35 ppm at 90, 120 and 150

Table 3 Effect of plant growth regulators on juice quality and yield of sugarcane

Treatment		^{o}Brix	Sucrose (%)	Cane yield (t ha^{-1})	CCS (%)	CCS yield (t ha^{-1})
T_1	Conventional planting/ Farmers practice (3 bud setts)	18.03	16.8	94.52	10.98	11.76
T_2	Planting of setts after overnight soaking in water	18.09	17	95.50	10.81	11.54
T_3	Planting of setts after overnight soaking in 50 ppm ethrel solution	18.22	17.5	104.43	11.60	12.12
T_4	Planting of setts after overnight soaking in 100 ppm ethrel solution	17.69	17.6	107.31	11.14	12.28
T_5	T_1 + GA_3 spray @35 ppm at 90, 120 & 150 DAP	17.12	16.6	105.53	11.58	12.42
T_6	T_2 + GA_3 spray @35 ppm at 90, 120 & 150 DAP	18.18	16.8	107.77	11.42	12.18
T_7	T_3 + GA_3 spray @35 ppm at 90, 120 & 150 DAP	18.08	17.5	112.95	11.75	12.74
T_8	T_4 + GA_3 spray @35 ppm at 90, 120 & 150 DAP	18.64	17.7	116.14	11.79	12.82
SEm (±)		0.38	0.52	2.74	0.36	0.80
CD (5 %)		NS	NS	8.32	NS	2.44

DAP (T_8) increased millable canes by 9.63'000 ha^{-1} over conventionally planted crop of sugarcane in this study. Similar results were reported by El-Lattief and Bekheet (2012).

Yield and quality parameters

Cane quality data presented in Table 3 indicated that there was a significant difference among treatments with respect to yield of sugarcane. Among different treatments, planting of setts after overnight soaking in 100 ppm ethrel solution + GA_3 spray @ 35 ppm at 90, 120 and 150 DAP (T_8) produced the highest cane yield (116.14 t ha^{-1}), which was at par with planting of setts after overnight soaking in 50 ppm ethrel solution + GA_3 spray @ 35 ppm at 90, 120 and 150 DAP (112.95 ha^{-1}). Higher cane yield attributes observed in these treatments might be due to the combined effect of ethrel (resulted to higher germination and ultimately to high shoot count) and gibberellic acid solution (due to improvement in plant height and growth) applications. The cane yield thus obtained with the application of growth promoting hormones in all the treatments increased cane yield significantly over conventional method of sugarcane planting. The results are supported with the findings of Praharaj *et al.* (2016).

The effect of different treatments on cane juice quality parameters, *viz.* ^{0}brix, sucrose % and CCS % were found to be not significant (Table 3). From the data, it can be observed that ethrel as well as gibberellic acid solution treatments increased juice quality parameters. Overnight soaking of setts in 100 ppm ethrel solution along with spray of GA_3 @ 35 ppm at 90, 120 and 150 DAP exhibited the higher ^{0}brix (18.64), sucrose % (17.7) and CCS % (11.79) in all the three years of this study. Lu *et al*. (2010) found that spraying of gibberellic acid on sugarcane plants with its concentration of 30 g/667 M^2/year had positive effects on ^{0}brix value and sucrose percent as well.

The commercial cane sugar yield which is considered as recoverable sugar is directly affected by cane yield and CCS per cent in juice, which in turn, governed by its ^{0}brix and sucrose per cent values. Higher sucrose accumulation, higher will be the available sugar. It has been revealed that different treatments showed significant difference on sugar yield. Planting of setts after overnight soaking in 100 ppm ethrel solution followed by GA_3 spray @ 35 ppm at 90, 120 and 150 DAP (T_8) recorded significantly higher sugar yield (12.82 t ha^{-1}), which was at par with T_7 (12.73 t ha^{-1}). It has been observed that the CCS per cent did not affect due to different treatments in the study, however, the significant effect obtained in sugar yield was solely due to cane yield differences which led to such significant differences in different treatments. Xing *et al.* (2002) observed that ethrel promotes the differentiation and stimulates plant growth, and finally results to higher cane and sugar yields. Hence, overnight soaking of setts with 100 ppm ethrel followed by foliar application of gibberellic acid solution is useful for improving germination, subsequent growth and productivity of sugarcane and sugar as well.

REFERENCES

Alexander A G. 1973. A comprehensive study of the Saccharum source-to sinks system. *Sugarcane Physiology*, pp 443-464. Elsevier Scientific Publishing Co, Amsterdam.

Anonymous. 2015. *Vision 2050.* Sugarcane Breeding Institute, Coimbatore, India, pp 2–8.

Anonymous. 2017. Sugar Statistics. *Indian Sugar* **68**(9): 70–74.

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

Gomez K A and Gomez A A. 1984. *Statistical Procedures for Agricultural Research,* Second edition. Wiley-interscience Publication, Newyork.

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): 998–1007.

Jain R, Chandra A and Solomon S. 2013. Impact of exogenously applied enzymes effectors on sucrose metabolizing enzymes (SPS, SS and SAI) and sucrose content in sugarcane. *Sugar Tech* **15**(4): 370–378.

Jain R, Shrivastava A K, Solomon S and Yadav R L. 2007. Low temperature stress-induced biochemical changes in stubble bud sprouting in sugarcane (*Saccharum* sp. hybrid). *Plant Growth Regulation* **53**: 17–23.

Jain R, Solomon S and Chandra A. 2011. Some discernible physio-biochemical changes associated with improved sprouting of sugarcane setts treated with ethephon. *Sugar Tech* **13**(2): 123–128.

Li Y R, and Solomon S. 2003. Ethephon: A versatile growth regulator for sugarcane industry. *Sugar Tech* **5**(4): 213–223.

Lu J, Lei C, Zha L, Li X, Fang J and Zhuang W. 2010. A study on the application and residues of plant growth regulators in the fruit sugarcane grown in the sub-suitable region. *Journal of Agricultural Sciences* **2**(4): 254–256.

Mohan N and Kanaujia A K. 2017. Biomass energy for economic & environmental sustainability in India. *Sharkara* **48**(3): 24–26.

Moore P H. 1980. Additive and non-additive effects of serial applications of GA_3 on sugarcane internodal growth. *Physiol Plant* **49**:271–276.

Parthasarthy S V. 1979. *Sugarcane in India*, pp 634–653 KCP Ltd., Madras.

Praharaj S, Singh D and Guru S K. 2016. Effect of ethephon and gibberellic acid on emergence, yield attributes and yield of sugarcane. *Bioscan* **11**(4): 2675–2678.

Pribil M, Hermann S R and Dun G D. 2007. Altering sugarcane shoot architecture through genetic engineering: Prospects for increasing cane and sugar yield. *Proc Aust Soc Sugar Cane Technology* **29**:251–257

Rai R K, Singh P, Shrivastava A K and Suman A. 2008. Modulation of low-temperature-induced biochemical changes in bud and root band zones of sugar cane sets by potassium, zinc and ethrel for improving sprouting. *Journal of Agricultural and Food Chemistry* **56**: 11976–11982.

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.

Rao M S, Krishnamurthi M and Weerathaworn P. 2005. Beneficial effect of ethephon on yield and sucrose productivity of sugarcane cultivars in Thailand. *Sugar Tech* **7**(2 and 3):48–52.

Tew T L and Cobill R M. 2008. Genetic improvement of sugarcane (*Saccharum* spp.) as an energy crop. (*In*) *Genetic Improvement of Bioenergy Crops*, pp 273–294. Springer, New York, NY, USA.

Tudu S, Mandal D and De G C. 2007. Studies on sprouting and rooting of single budded sugarcane setts in seedbed. *Agric. Sci. Digest* **27**(3): 222-224.

Xing Y X, Yang L T and Li Y R. 2002. Effect of ethephon on respiratory exchange in different sugarcane varieties. *Chinese Journal of Tropical Crops* **23**(3): 66–72.