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Response of fertilizer treatments on agronomic and biochemical traits in main and ratoon crops of sweet sorghum (*Sorghum bicolor* (L.) Moench) cultivar ICSV 93046

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ABSTRACT:

The response of sweet sorghum cultivar ICSV 93046 to six fertilizer treatments viz., T1 (control - 80 Kg N ha^{-1} and 40 Kg P_2O_5 ha^{-1}); T2 (Designed fertilizer from a commercial source); T3 (N + P with Zn and B soil application); T4 (N + P with Zn and B soil application); T5 (N + P with foliar application of 0.1% sodium borate and T6 (N + P with foliar application of 0.5% $ZnSO_4$ and 0.1% sodium borate) was evaluated during the post-rainy season (December-March, 2009–10) as main (plant) crop and during summer season (April-July, 2010) as ratoon crop. The combined ANOVA showed that there was no significant crop (main and ratoon) and treatment interactions for the qualitative and quantitative component traits of sugar yield measured and also no significant differences for main and ratoon crop except for non-significant numerical differences giving a trend. The stalk yield was highest for treatments T5 and T6 in main crop and in the ratoon the treatment T4 recorded the highest.

Key words: Brix %, fertilizer treatments, ICSV 93046, sugar yield, sucrose, glucose and fructose

Abrevations: RCBD: Randamized complete block design, N: Nitrogen, P: Phosphorus, Zn: Zinc, B: Boron, $ZnSO_4$: Zinc sulphate, RE: Renewable energy, HPLC: High performance liquid chromatography.

INTRODUCTION:

Renewable energy from different sources has received a renewed interest in the recent past, as global fossil fuels are rapidly declining due to increased consumption demands and concerns over climate change. The demand for renewable energy (RE) has led to increased research on conversion of alternative (non-conventional) biomass to fuels, as RE contribution is predicted to increase from the current levels of 12.9% of global energy use to 27% by 2050 (Edenhofer *et al*., 2011). Sweet sorghum (*Sorghum bicolor* (L.) Moench) is a C4 plant with high photosynthetic efficiency and dry matter production and is considered an important energy crop for production of fuel bioethanol, due to high-yields, drought tolerance, relatively low input requirements in terms of water and fertilizer and its ability to grow under a wide range of agro-climatic conditions. It can yield significant amounts of readily soluble fermentable sugars (Reddy et al., 2005). Sugar stalk crops, such as sugarcane and sweet sorghum, offer more advantages than other crops since they produce a solid residue (bagasse) which can be used as a source of fuel to generate energy (Srinivasa Rao *et al*., 2009, Kumar *et al*., 2010), as animal feed (Blummel *et al*., 2009) or as soil fertilizer after composting with other agro-wastes (Srinivasa Rao *et al*., 2011). The utilization of bagasse has a most promising future for its bioconversion to cellulose-based ethanol, while the residual solids (mainly lignin) can be incinerated to co-generate heat and power (Srinivasa Rao *et al*., 2009). Besides, sweet sorghum has a panicle with grains that may be used either as food or feed (Blummel *et al*., 2009). Some recent research reports suggest that soluble sugars produced in sweet sorghum has a potential to yield up to 8000 L of ethanol per hectare or about twice the ethanol yield potential of maize grain and 30% greater than the average Brazilian sugarcane productivity of 6000 L/ha. Intensive research efforts are in progress in various countries viz., USA, China, India, Africa, Indonesia, Iran and Philippines in assessing the agro-industrial potential of sweet sorghum (Reddy *et al*., 2005; Ranola *et al*., 2007; Reddy *et al*., 2008; Tsuchihashi and Goto, 2008; Bennett and Anex, 2009; Pillay and Da Silva, 2009; Zhang *et al*., 2010; Srinivasa Rao *et al*., 2011). There are many sweet sorghum cultivars distributed throughout the world, providing a diverse genetic resource from which regionally specific, highly productive cultivars can be developed through diverse breeding approaches.

The biofuel distilleries need continuous supply of raw material, i.e. sweet stalks for major period of the year to be commercially viable. Since the sweet sorghum crop takes 3-4 months for reaching maturity, it is advantageous to explore the possibility of rationing not only to extend the raw material supply to the distillery but also for reducing the cost of feedstock production as well as to facilitate relay cropping to maximize the returns on land and labour (Srinivasa Rao *et al*., 2009; Tsuchihashi and Goto, 2008). Ratoon cropping, an additional double-cropping scheme can be adopted which involves the harvesting of the crop twice or more times from a single planting during the growing season (Duncan and Gardner, 1984). Further, to increase the yield, timely application of fertilizers in adequate quantities is required. It has been reported that sugarcane responds favourably for micronutrients like zinc, copper, iron and boron (Shinde *et al*., 1986; Nayyer *et al*.,1984). Improved biomass of sorghum by Zn application was reported in sorghum (Rego *et al*., 2003) and micronutrient response in semi-arid crops like chickpea, groundnut and chickpea is well reported in the literature (Rego *et al*., 2007; Srinivasarao *et al*., 2008). In forage sorghum, maximum green fodder yield (52.9 t/ha) was obtained from 100% recommended dose of fertilizer (RDF) + 25 kg $ZnSO_4$ /ha and significant positive response to Zn was established (AICSIP, 2009). Hence, a study was attempted with the twin objectives of possibility of ratooning sweet sorghum in tropical conditions and also to assess the response of sweet sorghum to micronutrients like zinc and boron, particularly on sugar yield and related traits.

MATERIALS AND METHODS

Experimental Design and Crop Management

The response of sweet sorghum cultivar, ICSV 93046, to six fertilizer treatments viz., T1 (control -80 Kg N ha^{-1} and 40 Kg P_2O_5 ha^{-1}); T2 (Designed fertilizer from a commercial source); T3 (N+P with Zn and B soil application); T4 (N+P with Zn and B soil application); T5 (N+P with foliar application of 0.1% sodium borate and T6 (N+P with foliar application of 0.5% ZnSO4 and 0.1% sodium borate) was evaluated during post-rainy season (December-March, 2009–10) as main (plant) crop and during summer season (April-July, 2010) as ratoon crop in vertisols of the experimental farm of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), located in Patancheru, Andhra Pradesh, India (altitude 545 m above mean sea level, latitude**.** 17.53° N and longitude 78.27° E) . The experimental design consisted of a randomized complete block design (RCBD) with four replications and a treatment plot size of 3 m wide and 4 m long, i.e. six rows of nine meters long spaced at 75 cm × 15 cm.

The planting was done on ridges with a plant stand of about 100,000 ha^{-1}. Sweet sorghum was initially planted dense but later (15 days after seedling emergence, DAS) thinned to one plant in each hill. Hand weeding was done following by two inter-cultivations. Surface irrigation was applied in furrows to the crop to maintain proper growth. Standard agronomic package of practices and plant protection measures were followed throughout the crop growth period in all the plots. At flowering, sorghum heads were covered with fine mesh bags for protection against bird damage on the developing grain. Four central rows, leaving the two guard rows were harvested at physiological maturity (when hilum turns black). The stalks were squeezed once to extract the juice on a three-roller cane press mill. The juice was collected into sterile sample bottles and then transported under cold ice-jacketed conditions to the laboratory for further analysis. Data on juice yield (t ha^{-1}), pH and the stalk yield (t ha^{-1}) were collected following standard procedures for each plot. Approximate sugar yield (t ha^{-1}) is estimated as the product of Brix % and juice yield (t ha^{-1}).

Chemical analysis

Sugar concentration in the stems was estimated in terms of Brix (%) using a hand-held pocket refractometer (Atago, Japan) based on the extracted juice samples taken from each plot. The contents of hexose sugars i.e., glucose, fructose and sucrose in the extracted juice were analyzed on a HPLC system (Shimadzu, Kyoto, Japan) equipped with a Luna 5 µm NH_2 100R column (4.6 × 250 mm, 5 µm particle size, Phenomenex, Inc., USA). The detection of the separated sugars was carried out with a refractive index detector (Model RID-10A, Shimadzu, Kyoto, Japan) using a mobile phase of acetonitrile-water (80:20, v/v) at a flow rate of 1.0 ml min^{-1} in isocratic mode and the column temperature was maintained at 40ºC. All solvents for mobile phase optimization were degassed before use. Standard stock solution (1000 µg/ml) of different sugars was prepared in Milli-Q distilled water as diluent was used for calibrating the HPLC system. The juice sample analysis was carried out by manual injection of 20 µl of pre-filtered sample. The data acquisition and analysis was carried out using LC solutions software (version 1.24 SP2) (Shimadzu, Kyoto, Japan). The concentration of each sugar in the juice was determined using peak area from the chromatograms and expressed in terms of percentage of total sugars (Kumar *et al*., 2010).

Statistical analysis

General linear model (GLM) was used for analysis of variance and to calculate significant differences among improved varieties using SAS software (SAS Institute Inc., 1991) GraphPad Prism (GraphPad Software Inc., San Diego, CA, USA) software version 2.0 (Motulsky, 1999) was used for simple linear regression analysis between traits. The statistical significance of the differences between the means was estimated by the least significant difference and all significant results were reported at the $P \leq 0.05$ levels.

RESULTS AND DISCUSSION:

ANOVA for agronomic and biochemical traits:

The combined ANOVA (Table.1) reveals that there is no significant differences among the treatments and the interaction of treatments with cropping (main and ratoon). However, significant differences were observed for all the traits except for bagasse yield and sucrose levels in the main and ratoon crop interaction. This explains the reason for reduced sugar yield in ratoon crop and the component traits influenced in the ratoon.

The mean performance of fertilizer treatments on agronomic and biochemical traits of main and ratoon crops of sweet sorghum cultivar, ICSV 93046 for stalk yield, juice yield, bagasse yield, Brix%, sugar yield, fructose, glucose, sucrose and pH are presented in Table.2. The average stalk yield for the main crop is 29.4 t ha^{-1} while the ratoon has recorded 25.2 t ha^{-1}. The stalk yield in the ratoon was lower than that of plant crop, but not significant. The highest stalk yield was recorded for fertilizer treatments T5 and T6 in the main crop (31.4 t ha^{-1}) and in the ratoon crop fertilizer treatment T4 recorded the highest stalk yield (28.9 t ha^{-1}). The lowest stalk yield was realized in T2 treatment both in the main/plant and ratoon crop. The juice yield is significantly lower in the ratoon crop as it was grown in summer season, coinciding with higher temperatures. These findings are in tune with the earlier reports (Tsuchihashi and Goto, 2008 and Srinivasarao et al, 2009). The highest Brix% was recorded for fertilizer treatments T5 (16.9 %) and T6 (16.8 %) in the main crop and in the ratoon crop fertilizer treatment T1 recorded the highest Brix % (20.8%). The variation is probably due to low temperature differential during post-flowering stage in the postrainy season while higher temperature differences in summer ratoon crop (Srinivasarao et al, 2009, Kumar et al, 2010 and Srinivasarao et al, 2011). The average sugar yield in the main crop is 1.5 t ha^{-1} while the ratoon sugar yield is 1.2 t ha^{-1}. This reduced sugar yield in ratoon crop *vis a vis* main crop conforms to the earlier report of Tsuchihashi and Goto, 2008. The lower mean sugar yield in summer ratoon crop is attributed to reduced stalk yield and juice recovery, inspite of the higher Brix% in ratoon summer crop. The highest sugar yield was recorded for fertilizer treatments T5 (1.74 t ha^{-1}) and T6 (1.67 t ha^{-1}) in the main crop and in the ratoon crop fertilizer treatment T4 recorded the highest sugar yield (1.49 t ha^{-1}). In case of sucrose levels, the ratoon crop recorded higher sucrose 7.05% compared to the main crop's level of 6.95%. The highest sucrose % was recorded for fertilizer treatments T5 (7.5%) and T6 (7.7%) in the main crop and in the ratoon crop fertilizer treatment T4 recorded the highest sucrose % (7.6 %). However, the glucose and fructose levels in ratoon crop are considerably lower in comparison to those of main crop. Surprisingly the pH content was significantly lower in the ratoon crop compared to that in main crop.

CONCLUSION:

Main and ratoon cropping pattern of sweet sorghum is provides double-cropping option for farmers to achieve maximum benefits of their resources and also helps for the extended period of functioning of the biofuel distillers. The application of micronutrients (Zn and B) at Patancheru location did not yield significant gains in productivity. The decline in ratoon crop productivity in is due to reduction in stalk yield, juice yield, glucose and fructose levels as reflected in the final sugar yield. In future, the breeding programs should address these traits for sustained ratoon crop yield.

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Table -1: Combined ANOVA table for response of fertilizer treatments on agronomic and biochemical traits of main and ratoon crops of sweet sorghum cultivar ICSV 93046

Source of variation	df.	Stalk weight (t ha^{-1})	Juice weight (t ha^{-1})	Bagasse weight (t ha^{-1})	Brix %	Sugar yield (t ha^{-1})	Fructose %	Glucose %	Sucorse %	pH
Replication	3	85.73	24.20	20.41	12.54	0.73	1.00	0.68	5.53	0.01
Treatments	5	31.20	6.23	9.89	4.14	0.11	0.17	0.22	0.36	0.00
Main *vs* ratoon crop	1	194.67 **	171.04 **	16.33	63.03 **	0.97 *	4.8324 **	6.64 **	0.20	0.39 **
Treatments x Cropping	5	23.49	4.79	5.82	8.88	0.19	0.62	0.45	3.02	0.01
Pooled Residual	15	17.66	4.22	7.34	3.38	0.13	0.31	0.25	1.61	0.01

** df = degrees of freedom*

Table-2: Mean performance table for response of fertilizer treatments on agronomic and biochemical traits of main and ratoon crops of sweet sorghum cultivar ICSV 93046

Treatments	Stalk yield ($t\ ha^{-1}$)		Juice yield ($t\ ha^{-1}$)		Bagasse yield ($t\ ha^{-1}$)		Brix (%)		Sugar yield ($t\ ha^{-1}$)		Fructose %		Glucose%		Sucrose %		P^H	
	Main crop	**Ratoon crop**	**Main crop**	**Ratoon crop**	**Main crop**	**Ratoon crop**	**Main crop**	**Ratoon crop**	**Main crop**	**Ratoon crop**	**Main crop**	**Ratoon crop**	**Main crop**	**Ratoon crop**	**Main crop**	**Ratoon crop**	**Main crop**	**Ratoon crop**
T1	30.56	26.45	13.22	8.89	17.08	16.48	15.9	20.8	1.59	1.40	2.42	1.81	2.17	1.53	6.46	7.11	5.76	5.58
T2	23.91	22.36	10.61	8.02	13.25	14.19	15.9	18.1	1.27	1.09	2.73	1.83	2.57	1.53	7.52	7.08	5.79	5.59
T3	29.56	26.73	12.08	9.83	17.16	15.60	15.7	19.1	1.44	1.43	2.09	2.00	1.97	1.65	6.34	7.47	5.73	5.63
T4	29.51	28.95	13.28	10.82	16.22	16.57	14.5	18.1	1.48	1.49	1.87	2.00	1.70	1.62	5.88	7.61	5.70	5.61
T5	31.44	23.98	13.77	7.97	17.54	14.75	16.9	17.2	1.74	1.08	2.80	1.76	2.60	1.50	7.54	6.68	5.82	5.57
T6	31.43	22.77	13.20	7.98	17.94	14.61	16.8	16.2	1.67	0.99	2.92	1.63	2.69	1.44	7.78	6.36	5.82	5.55
Minimum	23.91	22.36	10.61	7.97	13.25	14.19	14.50	16.19	1.27	0.99	1.87	1.63	1.70	1.44	5.88	6.36	5.70	5.55
Maximum	31.44	28.95	13.77	10.82	17.94	16.57	16.88	20.76	1.74	1.49	2.92	2.00	2.69	1.65	7.78	7.61	5.82	5.63
Mean	29.40	25.21	12.69	8.92	16.53	15.37	16.0	18.2	1.53	1.25	2.47	1.84	2.28	1.54	6.92	7.05	5.77	5.59
LSD **($p<0.005$)**	6.33		3.09		4.08		2.76		0.542		0.834		0.753		1.91		0.113	
CV %	7.2		8.2		7		4.2		8.6		6.8		8.7		3.1		0.3	

LSD: Least significant difference; CV %: Coefficient of variation

T1	Control (N+P)
T2	Designed fertilizer from TCL as per their recommendation
T3	N+P with Zn and B soil application
T4	N+P with foliar application of 0.5% ZnSO4
T5	N+P with foliar application of 0.1% sodium borate
T6	N +P with foliar application of 0.5% ZnSO4 and 0.1% sodium borate