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EDITOR'S NOTE

It is with great pleasure that we present the **41st volume of the *Bangladesh Journal of Sugarcane (BJS)***—a distinguished platform dedicated to sharing sugarcrop research findings with the global scientific community. The publication of this journal not only broadens the perspectives and contributions of its authors but also fosters collaboration and engagement within the wider research network. Serving as a valuable resource, *BJS* continues to support researchers, academicians, and professionals involved in various aspects of sugarcane production, processing, and utilization.

The *Bangladesh Journal of Sugarcane* plays a pivotal role in articulating scientific ideas, communicating research outcomes, and translating findings into practical applications that enhance sugarcrop production systems. This volume features need-based research results and actionable recommendations designed to address the pressing challenges of sugarcrop cultivation in Bangladesh.

The contributions in this issue come from dedicated scientists committed to advancing the sugarcrop sector. Their studies were conducted at the **Bangladesh Sugarcrop Research Institute (BSRI), Ishwardi**, as well as its regional and sub-stations across the country. The information presented herein will undoubtedly enrich the existing knowledge base and provide practical insights and recommendations for researchers, development practitioners, and extension personnel working in this field.

The editorial team extends heartfelt appreciation to all authors, reviewers, and contributors for their dedication, scholarly rigor, and commitment to maintaining the academic excellence of this publication. We also express our sincere gratitude to the **Bangladesh Sugarcrop Research Institute (BSRI)** and other stakeholders for their continued encouragement and support in promoting research dissemination and scientific exchange.

Looking ahead, *BJS* remains steadfast in its commitment to upholding high editorial standards, fostering interdisciplinary collaboration, and contributing to the sustainable growth of the sugar industry both nationally and globally.

We warmly welcome constructive feedback from our readers and the broader scientific community to further enhance the quality, impact, and relevance of this journal.

Finally, I extend my deepest gratitude to all authors, reviewers, and members of the editorial board whose dedication and scholarly contributions have made this publication possible. I hope that this volume will inspire young and passionate scientists to develop innovative technologies that increase sugarcrop and sugar yields—ultimately contributing to self-sufficiency in sugar and *gur* production in Bangladesh.

Dr. Kabir Uddin Ahmed
Director General

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CONTENTS

Evaluation of Sugarcane Genotypes Based on Morphophysiological Traits under Drought Stress in Barind Tracts

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ABSTRACT

Drought stress is one of the limiting factors in many areas of Bangladesh especially Barind tracts for successful crop production and the development of drought tolerant crop varieties is essential for the drought prone areas. The experiments were conducted to evaluate the performance of eleven sugarcane genotypes (I 127-09, I 130-09 , I 85-10 , I 101-10 & I 103-10 under ZYT-III & I 7-11, I 111-11, I 198-11, I 230-11, I 118-10 & I 131-10 under ZYT II) and one standard variety (Isd 39) under induced drought stress during 2017-2018 cropping season at Physiology and Sugar Chemistry Division yard of Bangladesh Sugarcrop Research Institute, Ishwardi, Pabna, and in some farmers field under natural drought stress situated on drought prone areas like Rajshahi and thakurgaon of Bangladesh to select drought tolerant genotypes of sugarcane. Under drought stress greenness of plants, number of tillers, millable canes and yield were strongly correlated, indicating usefulness of these parameters in identifying drought tolerant genotypes. The genotypes I 127-09 (green leaf 59.26%, Chl. 45.8 at 90d, pol % 14.75) & I 101-10 (green leaf 56.04%, Chl. 43.4 at 90d, pol % 14.79) under ZYT III and genotypes I 7-11 (green leaf 59.19%, Chl. 47.55 at 90d, pol % 14.66) & I 118-10 (green leaf 48.85%, Chl. 46.8 at 90d, pol % 15.17) under ZYT II showed better performance under induced drought stress . Genotypes I 127-09 and I 7-11 produced higher level of proline during the stress period. Genotypes I 127-09, I 85-10 & I 103-10 under ZYT III were recorded as highly tolerant against natural drought stress condition, and produced 106.39, 101.57 and 127.85 t ha^{-1} yield at Godagari (Rajshahi) location while those genotypes showed lower performance under farmer's field drought stress condition at Patuadangi (Thakurgaon) with cane yield 34.54, 49.11, and 56.32 t ha^{-1} respectively due to poor soil condition at Thakurgaon location. Genotypes I 7-11 and I 198-11 under ZYT-II performed better at Godagari, Rajshahi location having cane yield 145.11 and 121.37 t ha^{-1} respectively. Those genotypes showed comparatively better performance in Thakurgaon location having cane yield 59.16 and 63.88 t ha^{-1}. Results indicated strong possibilities of present technique to screen sugarcane genotypes for superior tolerance to drought.

Key words: Drought stress, Chlorophyll, Green leaf, Dry leaf, Pol% and Proline content

INTRODUCTION

Drought is the most important limiting factor for crop production and it is becoming an increasingly severe problem in many regions of the world (Passioura, 1996, 2007). According to statistics, the percentage of drought affected land areas more than doubled from the 1970s to the early 2000s in the world (Isendahl and Schmidt, 2006). For sugarcane, researches have concentrated on agronomic and physiological traits,

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which could lead to adaptation to these conditions or be correlated to drought tolerance and could be used for development of new varieties (Domaingue, 1995). One of the main problems associated with the development of drought tolerant varieties is the difficulty to identify single traits that can be used for selection (Quizenberry, 1982). Apart from that, the information on drought response among cultivars is generally gained after they have been released for commercial production (Inman-Bamber *et al.*, 2005), and only a few genotypes are compared (Domaingue, 1995).

Drought induced osmotic stress triggers a wide range of perturbations ranging from growth and water status disruption to the modification of ion transport and uptake systems (Lutts *et al.*, 1996; Bajji *et al.*, 2000). Upon exposure to water deficit plants exhibit physiological, biochemical and molecular responses at both the cellular and whole plant levels (Greenway and Munns, 1980; Hasegawa *et al.*, 2000). Vendruscolo *et al.* (2007) suggested that proline plays an important role in water stress tolerance mechanism(s) in plants due to its ability in opposing oxidative stress; and considered this as the most important strategy in plants to overcome water deficit effects. Moisture stress at tillering, and grand growth phase during March to June is one of the important constraint which limit millable canes production, cane height and unit stalk weight, and these yield contributing characters have affects on yield. Apart from low management with unavailable modern cultivars drought stress due to high evaporative demand during crops canopy development and reproductive phase is conceived as the most dominant factor for low yield. Due to rapidly declining aquifer and rising cost of irrigation, development of modern drought resistant variety could be the most alternative solution of achieving higher yield of this crop. Sugarcane varieties show inherent differences in their yield potential under different degrees of stress condition (Bamber,1982; Humbert, 1963). The performance of sugarcane varieties is mostly dependent on climatological factors during different growth phases along with soil conditions and agronomical management. Thus, varieties performing best at one location may not have been same performance at another location. It is, therefore, highly essential to test some promising sugarcane varieties under a given set of agronomic condition. (Joshi *et al.,*1994). Direct screening in the field conditions is, therefore, very difficult, and in many cases, doubtful. Johnson (1980) suggested that a suitable screening technique should be rapid, should require small quantities of plant material and be capable of screening large population. The present work was, therefore, carried out to gain information on performance of some sugarcane clones grown under drought stress condition.

MATERIALS AND METHODS

The BSRI bred genotypes were included in the study to conduct in the following phases:

i. Testing under induced drought stress condition
ii. Testing under natural drought stress condition at farmer's field
iii. Testing under induced drought stress condition

In this case Single-budded setts of different test genotypes were planted in to 60×10 cm PVC pipes each containing 6 kg soil. Four months after planting the PVC pipes containing plants subjected to artificially made drought stress by using 2% PEG

(Polyethylene Glycol 6000). Normal intercultural operations including fertilization, weeding etc. were done. Sugarcane genotypes under ZYT III and other selected genotypes were used for this purpose.
iv. Testing under natural drought stress condition at farmer's field.

Same experiments were conducted in the farmer's field under natural drought prone areas using double-bedded setts and the plot size were 6m×6m. The experiments were conducted at drought prone locations such as Godagari (Rajshahi) and Patuadangi farm, RSRS (Thakurgaon). Eleven promising genotypes were tested at all the locations. The experiments were laid out in RCB design with three replications. The experiment was set up on 1st November at Godagari (Rajshahi) and 3rd November at RSRS (Thakurgaon) locations. Two budded setts were planted at trenches following end to end method of planting. NPKS fertilizers were applied @ 325 kg urea, 250 kg TSP, 190 kg MP, 180 kg Gypsum and 9 kg $ZnSo_4$ per hectare. Urea was application in 3 splits and MOP was applied in two splits. All necessary cultural practices were done as and when required. Data were recorded on tolerance rating at 15 days interval during drought period, tiller count, millable canes and yield. Tolerance rating scale were recorded on greenness of leaves and other factors recorded. Soil pH, Organic carbon (%), N (%), P (ppm), K (meq) and S(ppm) were 7.2, 0.66, 0.06, 11.0, 0.20 and 17.0 at Godagari (Rajshahi) location and 5.3, 1.15, 0.08, 20.0, 0.12 and 18.0 at Patuadangi farm, RSRS (Thakurgaon) location respectively. Due to low pH nutrients availability was lower at Patuadangi farm, RSRS (Thakurgaon) location. So, the soil was recorded as poor at Patuadangi farm, RSRS (Thakurgaon) location than Godagari (Rajshahi) location.

Data collection

Under field condition data were recorded on tolerance rating at 15 days interval during drought period, tiller count, millable canes and yield. Tolerance rating scales were recorded on greenness of leaves and other factors recorded.

Under induced drought stress chlorophyll level were determined as SPAD unit using Chlorophyll meter (SPAD 502 Plus). Green and dry leaves were collected at different days and root volumes were collected after harvesting the plants.

For proline measurement, 3rd leaf from top was randomly collected from 2 months-old-grown plants in PVC pipes under stress and soon after collection proline content was determine following the procedure of Bates *et al.* (1973).

Chemical analysis of sugarcane juice

Randomly selected sample cane stalks/genotypes were crushed with a mini power crusher to get juice for analysis. Brix was determined by Brix hydrometer standardized at 20°C and sucrose determination was done using automatic Polarimeter (ADP-220) by Horne's dry lead method. Pol% cane was calculated by the method prescribed in Queensland Laboratory Manual (Anon, 1970), while reducing sugars were measured by

Lanc and Eynon method (Chen, 1985).

Brix (%): Percentage of total soluble solids present in solution (juice)

Purity (%): Percentage of pure sucrose in cane juice = $\frac{Pol}{Brix} \times 100$

Pol % cane: Percentage of sucrose content in whole cane.

Statistical analysis was performed using CRD with three replications and mean values were compared using LSD at 5% level of significance (Gomez and Gomez, 1984).

REULTS AND DISCUSSION

Morpho physiological characters like green leaf percentage, root wt. were collected from twelve sugarcane genotypes from the expt. conducted under induced drought stress condition at BSRI (yard) (Table 1 & 2). Juice quality was also determined from the expt. conducted under induced drought stress (Table 3 & 4). Under ZYT III I 127-09 (59.26) produced highest green leaf percentage at 90 days followed by I 130-09 (47.46) & I 103-10 (46.04) like the standard var. Isd 39 (51.02). Genotypes I 85-10 produced highest root (153.5g) followed by I 130-09 (100g). After combination of these data I 127-09, I 130-09 & I 103-10 got 1 according to tolerance rating scale like the standard var. Isd 39. Under ZYT II genotype I 7-11, I 131-10 and I 118-10 got 1 according to tolerance rating scale on the basis of green leaf content at 90 days and root wt.

On the basis of chlorophyll content and juice quality I 127-09 (45.8 SPAD unit, pol% 14.75) and I 101-10 (43.4 SPAD unit, pol% 14.79) got 1 under ZYT III. Under ZYT II, I 7-11 (Chl. 37.55 SPAD, pol% 14.66) & I 118-10 (Chl. 46.8 SPAD, pol% 15.17) got 1 on the basis of chlorophyll content and sucrose content. Genotypes I 127-09 and I 7-11 produced remarkable amount of proline under stress condition than the other genotypes (Table 5). Our findings are in agreement with Silva *et al.* (2007) who found that drought caused a decline in sugarcane leaf chlorophyll level, but this reduction varied among genotypes. Drought tolerant sugarcane cultivars have higher level of chlorophyll than drought susceptible cultivars (Jangpromma *et al.*, 2010). For instance, water deficit reduced leaf chlorophyll content of field grown soybean (Paknejad *et al.*, 2009) chlorophyll degradation as a consequence of drought stress may result in photo-inhibition and photo-bleaching (Long *et al.*, 1994).

Kumar *et al.* (1972) observed quantitative correlations between chlorophyll content and the levels of sucrose, amylase, ATPase and acid phosphate in detached sugarcane blades (variety P. R. 980). Wardlaw (1968) notes that photosynthesis, translocation of sugars, and growth have been designated as the first process to be affected by water stress.

Sucrose formation is directly related with Photosynthesis. The genotypes which produce more chlorophyll under stress condition can perform more photosynthesis resulting more formation of sucrose which is measured by pol (%). In this study we found that the genotype I 127-09, I 7-11 and Isd 39 showed better chlorophyll, green leaves resulting better formation of Brix (%), pol (%), & purity (%). Under stress condition disaccharide sucrose converted into monosaccharide glucose & fructose which is measured by RS (%). Stress tolerant genotypes produce relatively less RS (%) than susceptible genotype. The genotype Isd 39 produced lowest RS (%).

Table 1. Performance of BSRI bred genotypes grown in PVC pipes under induced drought stress conditions

Varieties / clones ZYT - III	Drought (days)				Air dry weight of root/ plant (g)	Volume of root	Tolerance rating scale (1-5)*
	60		90				
	Dry leaf (%)	Green leaf (%)	Dry leaf (%)	Green leaf (%			
I 127-09	29.83 b	37.18 b	40.75 b	59.26 a	48.0 bc	135 c	1
I 130-09	38.67 ab	61.34 a	52.55 ab	47.46 ab	100 b	237.5 b	1
I 85-10	56.46 a	43.54 ab	67.22 a	32.78 b	153.5 a	395.0 a	2
I 101-10	37.98 ab	62.02 a	65.63 a	34.38 b	35.0 c	40 d	2
I 103-10	55.13 a	44.88 ab	53.97 ab	46.04 ab	20.0 c	160 c	1
Isd 39	38.53 ab	61.47 a	48.98 ab	51.02 ab	33.5 c	165 c	1

Values with different letters within the column are significantly different at 5% level of significance

Figure 1. (a) Early stage and (b) harvesting stage of the experiment conducted under induced drought stress

Table 2. Performance of BSRI bred genotypes grown in PVC pipes under induced drought stress conditions

Varieties / genotypes ZYT - II	Drought (days)				Air dry weight of Root/ plant (g)	Volume of Root	Tolerance rating scale (1-5)*
	60		90				
	Dry leaf (%)	Green leaf (%)	Dry leaf (%)	Green leaf (%			
I 7-11	43.94 b	56.06 a	60.82 ab	59.19 a	23.5 abc	75.0 ab	1
I 111-11	57.22 ab	42.79 ab	76.27 ab	23.74 ab	38.5 abc	112.5 ab	2
I 198-11	65.2 a	34.80 b	83.75 a	16.25 b	0 c	0 b	2
I 230-11	57.62 ab	42.39 ab	67.06 ab	32.94 ab	11.0 bc	26.0 b	2
I 118-10	38.18 b	61.82 a	51.15 ab	48.85 ab	52.0 ab	162.5 a	1
I 131-10	49.17 ab	50.84 ab	58.85 ab	41.16 ab	62.0 a	185.0 a	1
Isd 39	38.53 b	61.47 a	48.98 b	51.02 ab	33.5 abc	165.0 a	1

Values with different letters within the column are significantly different at 5% level of significance

Table 3. Performance of BSRI bred genotypes grown in PVC pipes under induced drought stress conditions

Varieties/ genotypes	Chlorophyll (SPAD)	Brix %	Purity %	Pol % cane	R.S. %	Grading (1-5)*
ZYT III	90 days					
I 127-09	45.8 a	21.0	88.89	14.75	0.84	1
I 130-09	35.7 ab	19.6	86.36	13.37	1.30	2
I 85-10	45.8 a	19.2	86.14	13.07	1.24	2
I 101-10	43.4 a	21.0	89.17	14.79	0.50	1
I 103-10	28.95 b	19.6	73.55	12.74	2.60	2
Isd 39	40.55 ab	21.6	89.06	15.20	0.29	1

Values with different letters within the column are significantly different at 5% level of significance

Table 4. Performance of BSRI bred genotypes under induced drought stress conditions. (PVC pipe)

Varieties/ genotypes	Chlorophyll (SPAD)		Brix %	Purity %	Pol % cane	R.S. %	Grading (1-5)*
ZYT II	30 days	90 days					
I 7-11	70 .8 a	37.55 b	20.6	90.10	14.66	1.30	1
I 111-11	47.65 b	37.7 b	19.8	88.78	13.89	1.37	2
I 198-11	56.1 ab	0 c	19.4	88.78	13.39	1.37	2
I 230-11	73.7 a	39.7 ab	19.5	88.78	13.59	1.37	2
I 118-10	59.05 ab	46.8 a	21.4	89.71	15.17	0.62	1
I 131-10	43.65 b	35.9 b	22.4	88.30	15.63	0.41	1

Values with different letters within the column are significantly different at 5% level of significance

Table 5. Proline content of the BSRI bred genotypes under induced drought stress conditions. (PVC pipe)

Name of the varieties	Proline (mg/g) in normal condition	Proline (mg/g) in stress condition
ZYT III		
I 127-09	0.211 g	0.541 b
I 130-09	0.215 e	0.399 d
I 85-10	0.197 j	0.280 j
I 101-10	0.195 k	0.277 j
I 103-10	0.201 i	0.361 f
ZYT II		
I 7-11	0.481 a	0.522 c
I 111-11	0.201 i	0.377 e
I 198-11	0.213 f	0.297 i
I 230-11	0.231 c	0.322 h
I 118-10	0.203 h	0.298 i
I 131-10	0.218 d	0.342 g
lsd 39	0.342 b	1.519 a

Values with different letters within the column are significantly different at 5% level of significance

Figure 2. (a, b). Late tillering stage of the experiment conducted under natural drought stress in some drought prone areas of Bangladesh. (Fig. a. Godagari, Rajshahi & Fig. b. Thakurgaon)

Table 6. Performance of BSRI bred genotypes under drought stress at different location of farmers' field condition

Varieties /genotypes ZYT-III	Rajshahi			Thakurgaon		
	Millable cane ($x10^3$ ha^{-1})	Yield (t ha^{-1})	Grading (1-5)*	Millable cane ($x10^3$ ha^{-1})	Yield (t ha^{-1})	Grading (1-5)*
I 127-09	89.4 c	106.39 bc	1	37.11 h-j	34.54 f	3
I 130-09	80.46 c	96.56 c	2	44.89 f-i	40.54 d-f	3
I 85-10	111.62 b	101.57 c	1	52.78 b-f	49.11 b-e	3
I 101-10	110.6 b	87.38 c	2	65.22 a	60.46 ab	2
I 103-10	118.66 a	97.85 a	1	56.78 a-e	56.32 a-c	2
Isd 39	133.08 a	123.76 ab	1	56.11 a-f	48.99 b-e	3

Values with different letters within the column are significantly different at 5% level of significance

Table 7. Performance of BSRI bred genotypes under drought stress at different location of farmers' field condition

Varieties /genotypes ZYT-II	Rajshahi			Thakurgaon		
	Millable cane ($x10^3$ ha^{-1})	Yield (t ha^{-1})	Grading (1-5)*	Millable cane ($x10^3$ ha^{-1})	Yield (t ha^{-1})	Grading (1-5)*
I 7-11	152.75 a	145.11 a	1	60.65 a-d	59.16 a-c	2
I 111-11	77.39 d	69.65 d	2	52.44 b-f	55.50 a-c	2
I 198-11	143.78 ab	121.37 b	1	61.22 a-c	63.88 a	2
I 230-11	121.33 bc	106.77 bc	2	48.55 e-h	45.95 c-f	3
I 118-10	116.73 c	87.54 cd	2	29.44 j	33.55 f	3
I 131-10	87.10 d	89.38 cd	2	36.44 ij	38.71 ef	3
Isd 39	133.08 abc	123.76 ab	1	56.11 a-f	48.99 b-e	3

Values with different letters within the column are significantly different at 5% level of significance

The results obtained on yield contributing characters such as tillers production, millable canes and yield of eleven promising sugarcane genotypes at drought prone Godagari (Rajshahi) and RSRS (Thakurgaon) locations have been presented in Tables 6 and 7. It is seen from the Table 6 & 7 that the genotypes I 127-09, I 85-10, I 103-10, I 7-11 and I 198-11 showed highly tolerant reaction having tolerance rating 1 against drought stress under farmer's field condition at Godagari (Rajshahi), and produced 106.39, 101.57, 97.85, 145.11 and 121.37 t ha^{-1} cane yield respectively. Genotypes I 130-09, I 101-10, I 111-11, I 230-11, I 118-10 and I 131-10 showed tolerant reaction having tolerance rating 2 against field drought stress, and produced 96.56, 87.38, 69.65, 106.77, 87.54 and 89.38 t ha^{-1} cane yield respectively in the same location.

Table 6 & 7 also shows that the genotypes I 101-10, I 103-10, I 7-11, I 111-11and

I 198-11 showed tolerant reaction at field drought stress test at Patuadangi farm, RSRS, Thakurgoan location having tolerance rating scale 2 and obtained cane yield of 60.46, 56.32, 59.16, 55.50 and 63.88 t ha^{-1} respectively. It is seen from the tables 6 & 7 that there is no consistency in cane yield between highly tolerant and tolerant genotypes, and in several cases tolerant genotypes produced higher cane yield compared to highly tolerant genotypes. This indicates that stress tolerance is not the only factor for cane yield, and stress level was not too long to cause severe damage. It is also seen that clone I 101-10 & I 111-11 performed equally good under both poor and fertile soils conditions, while the other genotypes did much better under fertile soils of Godagari (Rajshahi) compared to poor soils of Patuadangi farm of RSRS (Thakurgoan). From the above facts it is seen that the genotypes which give highly tolerant reaction according to tolerance rating scale give better yield than other genotypes. Those genotypes which showed more freshness and greenness in stress period produced more photosynthate, and gave higher yield. According to Malik *et al.* (1992) photosynthesis may be reduced 90% when leaves are wilted. Varieties show different behavior of growth and plant survival during moisture stress. Drought tolerant genotypes maintain near optimum growth for longer period of time show lesser yield reduction under moisture stress condition. This varietal adaptability is due to morphological and anatomical modification of plant parts and tissue and some physiological traits associated with plant survival (Malik *et al.*, 1992). Tolerance rating 2, genotypes I 130-09 and I 101-10 produced cane yield 96.56 and 87.38 t ha^{-1} at Godagari (Rajshahi) and 40.54 & 60.46 t ha^{-1} at RSRS (Thakurgaon) locations. Joshi *et al.* (1994) reported that the performance of sugarcane varieties is mostly dependent on climatological factors during different growth phases along with soil conditions and agronomical management. Thus the varieties/genotypes performing better at one location may not be equally good at another location which is in agreement with our findings. Anon (2003) obtained average yield 94.9, 94.2 and 92.8 t ha^{-1} for the clone I 142-98, I 137-97 and I 202-97 respectively in different location. The variations might be due to some other factors like climate, soil condition, weather, fertilizer and drought stress condition etc. Cane planted in poor soil face severe stress than organic matter rich soils (Malik *et al.*, 1992). The results of this study will help the breeders to improve drought resistant varieties, and might be recommended for release for cultivation in drought prone areas.

Despite the complexity of the interaction between the effects of water stress on a number of physiological and juice quality parameters in twelve sugarcane genotypes, we can conclude from the above results that Isd 39, I 127-09 & I 7-11 was the most drought tolerant sugarcane genotypes.

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REFERENCES

Anonymous, 1970. Laboratory Manual for Queensland Sugar Mills (5th edition). Published by Watwon,Ferguson and Co. Brisbane. pp.107–108..

Annonymous, 2003. BSRI. Annual Report 2003-2004. Bangladesh Sugarcane Research Institute, Ishwardi, Pabna, Bangladesh. pp.28–29.

Bajji, M.S.; Lutts and Kinet, J.M. 2000. Physiological changes after exposure to and recovery from polyethylene glycol-induced water deficit in callus cultures issued from durum wheat (*Triticum durum* Desf.) cultivars differing in drought resistance. *J. Plant Physiol.*, **156**: 75–83

Bamber, N.G.I. 1982. Drought tolerance of commercial varieties in South Africa. *Proc. Ann. Congress. S. Africa Sugar Tech. Assoc.*, **56**: 112-117.

Bates, L.S.; Waldren, R.P. & Teare, I.D. 1973. Rapid determination of free proline for water-stress studies. *Plant Soil,* **39**: 205–207.

Chen, J.C.P. 1985. Cane sugar handbook, 11th ed. 1101–1103. New York: Wiley.

Domaingue, R. 1995. Family and varietal adaptation of sugarcane to dry conditions and relevance to selection procedures. In: International society of Sugar Cane Technologists Congress, 21. Bangkok,Proceedings. Bangkok: ISSCT. pp. 418-435.

Gomez, K.A. and Gomez, A.A.1984. Statistical procedures for agricultural research (2nd Ed.). A Wiley Interscience Publication, NY, USA.

Greenway, H. and Munns, R. 1980. Mechanisms of salt tolerance in nonhalophytes. *Ann. Rev. Plant Physiol.*, **31**: 149–190.

Hasegawa, P.; Bressan, R.A.; Zhu, J.K. and Bohnert, H.J. 2000. Plant cellular and molecular responses to high salinity. *Ann. Rev. Plant Mol. Biol.*, **51**: 463–499.

Humbert, R.P. 1963. The growing of sugarcane. Elsevier Publishing Co. Amsterdam, London, New York. pp. 312-351.

Inman-Bamber, N.G., G.D. Bonnett, D.M. Smith and Thorburn, P.J. 2005. Sugarcane physiology: Integrating from cell to crop to advance sugarcane production. *Field Crops Res.*, **92**: 115–117.

Isendahl, N. and Schmidt, G. 2006. Drought in the mediterranean-WWF policy proposals. In A, edited by W. Report. Madrid.

Jangpromma, N.; Kitthaisong, K.S.; Lomthaisong, S.; Daduang and Jaisil, P. 2010. A proteomics analysis of drought stress-responsive proteins as biomarker for drought-tolerant sugarcane cultivars. *Am. J. Biochem. Biotechnol.*, **6**: 89–102.

Johnson, D.A. 1980. Improvement of Perennial herbaceous plants for drought stressed western range lands. In: Adoption to water and high temperature stress. N. C. Turnen and P. J. Knamer (Ed.) Wiley Interscience, New York. pp. 419–435.

Joshi, S.; Bendigeri, A.V. and Hapase, D.G. 1994. Studies on some physiological parameters in six varieties of sugarcane. *SISSTA Sugar J.*, **20** (1): 168–171.

Kumar, A.; Acin, N.M. and Alexander, A.G., 1972. Relationships of chlorophyll and enzyme gradients to sucrose content of sugarcane leaves. *Annu. Ret. Agric. Exp. Sta. Univ.* P. R. (1970–1971).

Lutts, S.; Bouharmont, J. and Kinet, J.M. 1996. Physiological characterization of salt-resistant rice (Oryza sativa) somaclones. *Aust .J. Bot.*, **47**:835–849.

Long, S.P.; Humphries, S. and Falkowski, P.G. 1994. Photoinhibition of photosynthesis in nature. *Annu. Rev. Plant Physiol. Plant Mol. Biol.*, **45**: 633–662.

Malik, B.K. 1992. Effect of drought stress on the yield and recovery of sugarcane. *Pak. Sugar J.*, **6** (1):17–23.

Paknejad, F.; Mirakhori, M.; Jami Al-Ahmadi, M. and Nazeri, P. 2009. *Amer. J. Agric. Biol Sci.*, **4** (4): 311-318.

Passioura, J.B.; 1996. Drought and drought tolerance. *Plant Growth Regul.*, **20** (2): 79–83.

Passioura, J.B. 2007. The drought environment: physical, biological and agricultural perspectives. *J. Exp. Bot.*, **58** (2): 113–117.

Quizenberry, J.E. 1982. Breeding plants for drought tolerance and plant water use efficiency. In: Christiansen, M.N., Lewis, C.F. (Ed.) Breeding plants for less favorable environments.

Silva, M.D.A.; Jifon, J.L.; De Silva, J.A.G and Sharma, V. 2007. Use of physiological parameters as fast tools to screen for drought tolerance in sugarcane. *Braz. J. Plant Physiol.*, **19**: 193–201.

Vendruscolo, A.C.G.; Schuster, M.I.; Pileggi, C.A.; Scapim, H.B.C.; Molinari, C.J.; Marur and. Vieira, L.G.C. 2007. Stress-induced synthesis of Proline confers tolerance to water deficit in transgenic wheat. *J. Plant Physiol.*, **164**: 1367–1376.

Wardlaw, I.F. 1968. The control and pattern of movement of carbohydrates in plants. *Bot. Re.*, **34**: 79–105.

Phenotypic Diversity of Some Locally Collected Sugarcane Germplasm

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ABSTRACT

Success of breeding program depends on wider variability and gene pool among utilized germplasm. Variance components with heritability refer to selection intensity. Agglomerative clustering and principal component analysis helps to select desired genotypes for varietal improvement program. Twenty eight locally collected genotypes of sugarcane (*Saccharum officinarum* L.) were investigated for determining genetic diversity based on 12 quantitative traits using variance components. High variation was observed for most of the characters. Based on Euclidean distance, the accessions were grouped into four different clusters consists of 6, 5, 8 and 9 genotypes respectively. The genotypes with high index scores can be crossed to have maximum variability of good combinations of characters. Though cluster analyses grouped genotypes with greater similarity for agronomic traits, they did not necessarily include the genotypes from the same source or origin. The first four components cumulatively explained about 77.63% of the total variation among the accessions. All of the studied characters showed higher heritability, high genetic advance and were responsible for high variation which explained over two-third variations in first four principal components. So that, selection based on these traits will be suitable for variety improvement program.

Key words: Sugarcane, germplasm, morphology, genetic diversity

INTRODUCTION

Sugarcane (*Saccharum* spp. complex) is an important industrial crop growing in about 90 countries in tropical and sub-tropical regions of the world (Andreoli and Souza, 2007).Its major use in primitive human societies was restricted to chewing or occasional manufacture of raw sugar by boiling the juice. A wide variety of sweet cane types existed from which the early people selected thick barreled, high sucrose soft sticks and this crude method of selection eventually produced better cane types. Sugarcane produces numerous valuable by-products like alcohol used by pharmaceutical industry, ethanol used as a fuel, bagasse used for manufacturing paper and chipboard and press mud used as a rich source of organic matter and nutrients for crop production.

Modern sugarcane varieties that are cultivated for sugar production are complex interspecific hybrids (*Saccharum* spp.) that have arisen through intensive selective breeding of species within the *Saccharum* genus primarily involving crosses between the species *Saccharum officinarum* L. and *S. spontaneum* L. (Cox *et al.*, 2000).

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An essential first step in varietal development program is to come up with sugarcane germplasm which has sufficient genetic variability. Evaluation of genetic diversity is important for the improvement of sugarcane genotypes since parents with diverse genetic materials could be utilized in hybridization for developing viable superior progenies (Hamrick, 2004). Accurate assessment of genetic diversity is very important in crop breeding as it helps in the selection of desirable genotypes, identifying diverse parental combination for further improvement through selection in the segregating populations, and introgressing desirable genes from diverse germplasm into the available genetic base (Mohammadi *et al.*, 2003). Therefore, genetically diverse germplasm is needed in breeding programs to enhance the productivity and diversity of cultivars. Utilization of introduced germplasm and the knowledge of genetic remoteness among them are vital for their manipulation in crop improvement program (Malik *et al.*, 2010).

In order to obtain the wide spectrum of variation among the segregants the genotypes belonging to the distant clusters could be incorporated in hybridization program. Therefore, keeping in view, the importance of sugarcane in the country and use of genetic diversity in crop improvement, 28 genotypes were investigated for determining genetic diversity based on quantitative traits for planning future germplasm management and utilization.

MATERIALS AND METHODS

Especially collecting local germplasm would be crucial as they provide locally adapted genes for better crop improvement. Towards this effort, an exploration and collection of local sugarcane germplasm in different geographic regions of Bangladesh has been conducted and 28 materials were collected. In 2018-19, the collected genotypes were planted in a triplicate RCBD under field conditions at BSRI, Ishurdi, Pabna. Each entity was planted in 6 pits of one meter lengths. All the agronomic practices were kept normal for all the genotypes as per BSRI recommendations. Ten plants from each replication were randomly selected for recording data on Number of millable cane, Length of leaf blade (cm), Width of leaf blade (cm), Length of bud (mm), Width of bud (mm), Plant height (cm), Stalk length (cm), Number of internode, Internode length (cm), Internode diameter (cm), Single cane weight (kg) and Brix (%).

Table 1. List of germplasm characterized morphologically

Sl. No.	Cultivar/Local name	Collecting site		Geographical position
		Upazilla	District	
1	Modhumala	Babugonj	Barishal	90.633330°E/23.400000°N
2	Babulal	Shibgonj	Chapainawabganj	88.597868°E/24.365876°N
3	Chandpuri Gandary	Matlab Uttor	Chandpur	90.706997°E/23.348592°N
4	Bonpara Gandary	Boraigram	Natore	88.954490°E/25.503090°N
5	Tangail Gandary	Matlab Uttor	Chandpur	91.893042°E/21.480697°N
6	Juamoti	Bandarban Sadar	Bandarban	92.191670°E/22.233330°N
7	Cheuric	Bandarban Sadar	Bandarban	92.191673°E/22.233330°N
8	Bhulong	Khagrachari sadar	Khagrachari	90.124020°E/22.145540°N
9	Kali kushal	Khagrachari sadar	Khagrachari	92.384070°E/22.668810°N
10	Misrimala	Babugonj	Barisal	90.633330°E/23.400000°N
11	Dhonupodi	Dighinala	Khagrachari	91.993922°E/23.116819°N
12	Domba Kusail	Dighinala	Khagrachari	91.993922°E/23.116819°N
13	Black Ruby	Savar	Dhaka	90.247872°E/23.838665°N
14	Malaysia	Kustia sadar	Kustia	90.247340°E/24.817050°N
15	Misridana	Babugonj	Barisal	90.633330°E/23.400000°N
16	Senegal	QS, Gazipur Sadar	Gazipur	89.500000°E/25.250000°N
17	Kaptai-3	Kaptai	Rangamati	92.232575°E/22.493963°N
18	Baskusal Kaptai	Kaptai	Rangamati	92.232575°E/22.493963°N
19	Turag	Shibgonj	Chapainawabganj	88.597868°E/24.365876°N
20	Huleykhali-2	Terokhada	Khulna	89.558060°E/22.841930°N
21	CO 527	Kaliganj	Satkhira	89.0706474°E/22.711188°N
22	Kali kushal-2	Khagrachari sadar	Khagrachari	92.384070°E/22.668810°N
23	Shung	Kalapara	Patuakhali	90.223218°E/21.986005°N
24	Q 69	Mohasthan	Bogura	89.352338°E/24.954024°N
25	Atkushail	Sadar	Rangamati	92.191860°E/22.643170°N
26	Raujan	Dighinala	Khagrachari	91.993922°E/23.116819°N
27	Chitra	QS, Gazipur Sadar	Gazipur	89.500000°E/25.250000°N
28	Kharki	Khagrachari sadar	Khagrachari	92.384070°E/22.668810°N

Analysis of the information/data

Estimation of Genotypic and Phenotypic Variances: Genotypic and phenotypic variances were calculated using the following formula

Genotypic variance ($\sigma^2 g$) = GMS – EMS/r

where GMS is genotypic mean square, EMS is error mean square, r is number of replication, and phenotypic variance is ($\sigma^2 p$) = $\sigma^2 g + \sigma^2 e$.

Estimation of Genotypic Coefficient of Variation (GCV) and Phenotypic Coefficient of Variation (PCV) Phenotypic (PCV) and genotypic (GCV) coefficients of variation were evaluated according to the methods as follows

Genotypic coefficient of variation (GCV) = $\sigma^2 g/\bar{X} \times 100$
where $\sigma^2 g$ is genotypic variance and $\bar{X}$ is population mean.
Phenotypic coefficient of variation (PCV) = $\sigma^2 \mathrm{p}/\bar{X} \times 100$
where $\sigma^2 \mathrm{p}$ is phenotypic variance and $\bar{X}$ is population mean.

Estimation of Heritability: Broad-sense heritability ($h^2 \mathrm{b}$) for mean values was calculated using following the formula
Heritability ($h^2 \mathrm{b}$) =$\sigma^2 g$ / $\sigma^2 \mathrm{p} \times 100$
where $\sigma^2 g$ is genotypic variance and $\sigma^2 \mathrm{p}$ is phenotypic variance.

Estimation of Genetic Advance: Genetic advance (GA) was estimated accordance to the methods illustrated
Genetic advance (GA) = $h^2 \mathrm{b} \cdot K \cdot \sigma p$
where $h^2 \mathrm{b}$ is heritability in broad sense,$K$is the selection differential value which is 2.06 at 5% selection intensity, and σp is phenotypic standard deviation.

The analysis of variance, clustering and principal component were statistically analyzed as randomized complete block design using the R-software. Characters with count data (random variable) were log transformed before analysis. All the genotypes were clustered on the basis of agglomerative cluster analysis, where specifications were made based on Euclidean distance.

RESULTS AND DISCUSSION

The analysis of variance for all the characters studied showed highly significant differences among the genotypes. Similar results also found by Chaudhary, R.R. (2001) in case of number of millable canes, individual cane weight, cane height and sucrose%. These results indicated that there have been greater variations among the studied genotypes that might support the plan of breeding target for improvement of sugarcane. All the characters except internode diameter, single cane weight, width of bud and number of millable cane showed high genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV). The estimated PCV were more or less similar to GCV for all the traits indicating very little environmental influences on these traits for total variation. High GCV and PCV indicated that selection may be effective based on these characters and their phenotypic expression would be good indication of the genotypic potential (Singh *et al.*, 1994). Mean performance of different genotypes had wider variation in performance values for different traits. The entire trait showed high heritability indicated that selection based on phenotype for these traits might be effective method for sugarcane improvement. The highest genetic advance was found in stalk length followed by plant height (Table 2).

Table 2. Components of variances, heritability in broad sense and genetic advance for 12 characters of 28 sugarcane genotype

Characters	GV	EV	PV	GCV	PCV	Heritability	GA
Number of millable cane (NMC)	0.92	0.23	1.15	19.15	23.86	80.28	1.77
Length of leaf blade (cm)	223.07	2.50	225.57	155.84	157.59	98.89	30.60
Width of leaf blade (cm)	2.05	0.01	2.06	35.16	35.24	99.76	2.95
Length of bud (mm)	2.80	0.14	2.94	27.90	29.30	95.24	3.36
Width of bud (mm)	1.29	0.14	1.43	15.26	16.95	90.00	2.22
Plant height (cm)	2712.67	59.00	2771.67	627.90	641.55	97.87	106.14
Stalk length (cm)	2961.33	77.00	3038.33	1107.81	1136.62	97.47	110.67
Number of Internode	17.51	3.04	20.55	61.83	72.57	85.21	7.96
Internode length (cm)	2.21	0.24	2.45	22.65	25.08	90.28	2.91
Internode dia (cm)	0.26	0.01	0.28	9.48	9.97	95.11	1.03
Single cane weight (kg)	0.23	0.05	0.28	14.02	17.28	81.09	0.89
Brix (%)	10.98	0.06	11.04	67.93	68.30	99.46	6.81

Note: GV = genotypic variance, EV = error variance, PV = phenotypic variance, GCV = genotypic coefficient of variation, PCV = phenotypic coefficient of variation and GA=genetic advance

Cluster analysis

Cluster (segmentation) analysis for phenotypic traits showed a clear demarcation between sugarcane accessions. Cluster differences were observed by summarizing cluster means for the 12 quantitative traits. All the genotypes were clustered on the basis of agglomerative cluster analysis, where specifications were made based on Euclidean distance and grouping was made on average clustering method. Based on these traits, the accessions were grouped into four different clusters. The dendogram divided the accessions into four different clusters consists of 6, 5, 8 and 9 genotypes respectively (Table 3, Fig. 1). Though cluster analyses grouped genotypes with greater similarity for agronomic trait, they did not necessarily include the genotypes from the same source of origin as well as collection site. In most of the germplasm resources lack of accessions between agronomic traits and origin has been reported (Ghafoor *et al.*, 2005 and Perera *et al.*, 2012). This information will be helpful to use in crop breeding through identification of parents. Crosses involving parents from these genetically divergent clusters are expected to manifest maximum heterosis and generate wide variability in genetic architecture. These are also likely to produce potential recombinants with desired traits (Singh and Singh, 1989).

Table 3. Clustering of 28 sugarcane genotypes using mean of 12 quantitative characters

Cluster	No. of genotypes	Genotypes	Location
C_1	6	2, 3, 4, 9, 12, 22	Chapai Nawabganj, Chandpur, Natore and Khagrachari
C_2	5	17, 18, 19, 21, 24	Rangamati, Chapai Nawabganj, Satkhira and Bogura
C_3	8	14, 16, 20, 23, 25, 26, 27, 28	Kustia, Gazipur, Khulna, Patuakhali, Rangamati and Khagrachari
C_4	9	1, 5, 6, 7, 8, 10, 11, 13, 15	Barishal, Chandpur, Bandarban, Khagrachari and Dhaka

Note: Numbers refers to code of genotypes

Table 4. Differences among four clusters of 28 sugarcane genotypes for mean performance of 12 quantitative characters

Characters	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Grand mean
Number of millable cane	4.86	5.07	4.54	5.28	4.94
Length of leaf blade (cm)	148.46	142.61	140.95	142.41	143.61
Width of leaf blade (cm)	5.52	5.97	6.11	5.27	5.72
Length of bud (mm)	10.75	10.12	9.45	10.55	10.22
Width of bud (mm)	7.87	7.92	8.74	9.18	8.43
Plant height (cm)	357.68	500.42	442.69	408.97	427.44
Stalk length (cm)	186.90	339.74	279.79	241.86	262.07
Number of Internode	22.51	30.39	30.87	26.32	27.52
Internode length (cm)	8.57	11.52	9.56	9.53	9.80
Internode dia (cm)	2.91	2.83	2.76	2.52	2.76
Single cane weight (kg)	1.53	1.92	1.67	1.27	1.60
Brix %	14.40	15.67	17.29	16.20	15.89

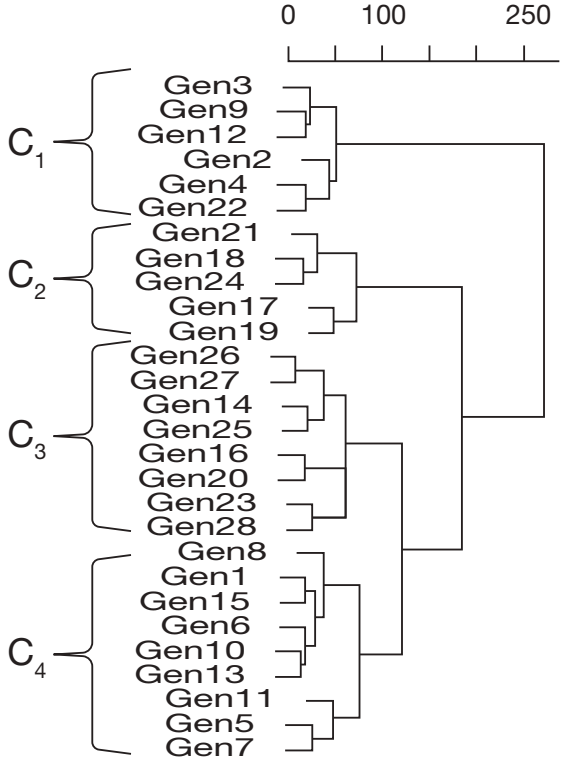

Figure 1. Dendogram based on mean performance of variables among 28 sugarcane genotypes

Principal component analysis

In the present study the PCA grouped the 12 phenotypic characters into 12 components, which accounted for the entire (100%) variability among the studied accessions. As Chatfield *et al.* (1980) stated, components with an Eigen value of less than 1 should be eliminated so that fewer components are dealt with. Furthermore, Hair *et al.* (1998) suggested that Eigen values greater than one are considered significant and component loadings greater than ±0.3 were considered to be meaningful. Hence, from this study, only the first four components which had Eigen values greater than one and cumulatively explained about 77.63% of the total variation among the accessions. The variation attributes of first four PCs are shown in table 5. The first principal component (PC1) alone explained 30.98% of the total variation. These were mainly due to length of leaf blade (cm), width of leaf blade (cm), length of bud (mm), internode diameter (cm) and single cane weight (kg). Characters which contributed more to the second PC accounted for 25.76% of the total variation, which were due to plant height (cm), stalk length (cm), number of internode and internode length (cm). The third and fourth PC expressed 12.4% and 8.5% of the variation. The variation of third PC composed of number of millable cane, length of bud (mm), width of bud (mm) and brix (%). Width of bud (mm) and number of internode contribute to the variation in fourth PC.

Table 5. Principal component analysis of 12 quantitative characters in 28 sugarcane genotypes

Characters	Eigenvectors			
	PC1	PC2	PC3	PC4
Number of millable cane	-0.26	-0.08	0.46	-0.50
Length of leaf blade (cm)	0.27	-0.04	-0.20	-0.50
Width of leaf blade (cm)	0.38	0.21	0.17	0.07
Length of bud (mm)	0.19	-0.08	0.45	0.05
Width of bud (mm)	0.09	-0.05	0.59	0.39
Plant height (cm)	-0.11	0.53	0.01	-0.12
Stalk length (cm)	-0.17	0.52	0.02	0.03
Number of internode	0.03	0.46	-0.08	0.37
Internode length (cm)	-0.36	0.26	0.07	-0.24
Internode dia (cm)	0.46	0.12	0.16	-0.16
Single cane weight (kg)	0.35	0.30	0.15	-0.31
Brix (%)	-0.40	-0.01	0.32	-0.03
Proportion of variance	0.31	0.26	0.12	0.08
Cumulative proportion	0.31	0.57	0.69	0.78

The PCA biplots provide an overview of the similarities and differences between the quantitative traits of different accessions and of the interrelationships between the measured variables. The biplot demarcated the accessions with characteristics most explained by the first two dimensions. The first and second PCs explained the most variation among the accessions, revealing a high degree of association among the characters studied.

In the biplot (Fig 2), the axes represent the PC scores. Taking the projection of PC1 axis, it indicated that ID, WLB, SCW, LLB being positively correlated with PC1 and ID had the highest PC1 score, while variables PH, SL, NMC, IL, and BR had a negative association with PC1. Variables such as PH, SL and IN had a positive association with PC2. Genotype 17 and 19 had high association with PH and NI. Genotype 14 and 16 had higher SCW. On the other hand, PH had a positive association with SL but weak association with BR & NMC as revealed by the acute angles between the vectors of these traits.

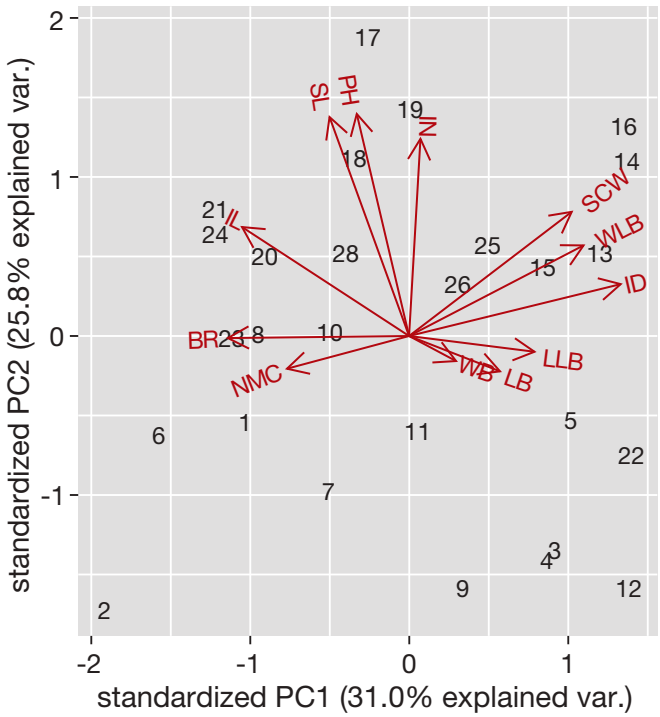

Figure 2. Genotype by trait (GT) biplot of 28 sugarcane genotypes

N.B.: NMC=Number of millable cane, LLB=Length of leaf blade (cm), WLB=Width of leaf blade (cm), LB=Length of bud (mm), WB=Width of bud (mm), PH=Plant height (cm), SL=Stalk length (cm), NI=Number of internode, IL=Internode length (cm), ID=Internode diameter (cm), SCW=Single cane weight (kg), BR=Brix percentage

This study indicated that there is wide genetic variability among the tested genotypes for yield and yield contributing characters. The genotypes showed high GCV expressed their genetic background of variation. High PCV over GCV indicating greater environmental influences on studied characters for total variation (Table 2). All the traits showed high heritability with environmental influence at measurable extent leads to single selection based on these phenotypic characters might be effective for sugarcane variety improvement breeding program. Agglomerative cluster analysis based on Euclidean distance produce meaningful grouping facilitates selection of parents for target breeding program (Figure 1). Upon principal component analysis, the first four components explain around 78% of total variation among studied characters (Table 5). It depicts the relationship among genotypes thus supports grouping of genotypes obtain through cluster analysis. The characters like stalk length, plant height, number of internode, length of leaf blade, length of bud, internode length, internode diameter etc. showed higher heritability, high genetic advance and were responsible for high variation in first two principal components. So that, selection based on these traits will be suitable for variety improvement program.

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REFERENCES

Anonymous. 1998. *Sugar and Sweetener*. FAO Production Year Book.

Chatfield, C. and Collin, A.J. 1980. Introduction to Multivariate Analysis. Chapman and Hall, Methuen, Inc., New York. http://dx.doi.org/10.1007/s10681-012-0661-9.

Chaudhary, R.R. 2001. Genetic variability and heritability in sugarcane. *J. Nep. Agric. Res.*, **4**(5):56–59.

Cox, M.; Hogarth, M. and Smith, G. 2000. Cane breeding and improvement. *In* "Manual of cane growing", M Hogarth, P Allsopp, (eds). Bureau of Sugar Experimental Stations, Indooroopilly. Australia. pp. 91-108.

Ghafoor, A.; Ahmad, Z. and Anwar, R. 2005. Genetic Diversity in *Pisum sativum* and a Strategy for Indigenous Biodiversity Conservation. *Pak. J. Bot.*, **37**:71-77.

Hair, J.F.; Andrson, J.R.; Tatham, R.E. and Black, W.C. 1998. Multivariate Data Analysis. 5th Edition, Prentice-Hall International Inc., London.

Malik, S.R.; Bakhsh, A.; Asif, M.A.; Iqbal, U. and Iqbal, S.M. 2010. Assessment of genetic variability and interrelationship among some agronomic traits in chickpea. *Int. J. Agric. Biol.*, **12**:81–85.

Mohammadi, S.A. and Prasanna, B.M. 2003. Analysis of genetic diversity in crop plants-salient statistical tools and considerations. *Crop Sci.*, **43**(4):1235-1248.

Perera, M.; Arias, M.; Costilla, D.; Luque, A.; García, M. and Romero, C. 2012. Genetic Diversity Assessment and Genotype Identification in Sugarcane Based on DNA Markers and Morphological Traits. *Euphytica*, **185**:491-514. http://dx.doi.org/10.1007/s10681-012-0661-9.

Singh, R.K.; Singh, D.N.; Singh, S.K. and Singh, H.N. 1994. Genetic variability and correlation studies in foreign commercial hybrids of sugarcane. *Agric. Sci. Dig.*, **14**:103–107.

Singh, V. and Singh, F. 1989. Genetic Diversity and Stability in Chickpea. *Indian J. of Genet.*, **49**:349-353.

Productivity of Sugarcane with Maize as Intercrop in Single and Paired Row Planting Systems

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ABSTRACT

An experiment was conducted during 2014-2015 and 2015-2016 cropping seasons at Regional Sugarcrop Research Station, Thakurgaon to study the productivity, profitability and suitability of sugarcane (cv. Isd 39) cultivation with different maize varieties as intercrop. Under this experiment eleven treatment combinations viz. T_1: Single row cane (SRC) sole , T_2: Paired row cane (PRC) sole, T_3: SRC + 1 line maize (NK-40), T_4: PRC + 2 lines maize (NK-40), T_5: PRC + 3 lines maize (NK-40), T_6: SRC + 1 line maize (Sunshine), T_7: PRC + 2 lines maize (Sunshine), T_8: PRC + 3 line maize (Sunshine), T_9: SRC + 1 line maize (VA-786), T_{10}: PRC + 2 lines maize (VA-786), T_{11}: PRC + 3 lines maize (VA-786) were tested. Sole sugarcane in single row cane performed better than the other treatment combinations. Significant differences were found among all the observed parameters except brix (%) in both seasons. Sole sugarcane in single row cane performed better than the other treatment combination. Significant differences were found among all the observed perameters except brix in both seasons. Sole sugarcane in single row planting system gave the highest stalk height (3.52 m and 3.43 m), cane diameter (2.22 cm), number of tillers (193 x 10^3 ha^{-1} and 201 x 10^3 ha^{-1}) number of millable cane (92.22 x 10^3 ha^{-1} and 108 x 10^3 ha^{-1}), unit stalk weight (0.90 kg and 0.88 kg), total adjusted cane yield (81.68 tha^{-1} and 94.64 tha^{-1}) and BCR (1.91 and 2.17) which were followed by sole sugarcane in paired row planting system in both seasons. Cane yield loss (%) was observed in all maize intercropped plots compared to sole sugarcane plots where the maximum loss 44.3% was in treatment T_8 paired row cane with three lines maize (Sunshine) in cropping season 2014-2015 and loss 50.00% wass in treatment T_{11} paired row cane with three lines maize (VA-786) in cropping seasons 2015-2016. The overall results under this study revealed that maize as first intercrop affected sugarcane productivity and profitability. Thus, more study is needed on how maize as intercrop could be suitable in Bangladesh aspect.

Key words: Sugarcane, maize, intercropping, yield loss (%), BCR

INTRODUCTION

Sugarcane (*Saccharum officinarum* L.) is a vegetative propagated perennial crop. It is one of the most important food-cum-cash-cum-industrial and main sugar producing crop in Bangladesh (Junejo *et al.*, 2010). It is grown in tropical and sub-tropical regions of the world in a range of climates from hot dry environment near sea level to cool and moist environment at higher elevations (Mehareb, 2015). Sugarcane is cultivated in many of the world countries with Brazil as a major producer followed by Brazil (829.74 million tons), India (446.89 million tons), Thailand (144.41 million tons), China (121.21

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million tons), Pakistan (77.72 million tons) and Mexico (65.40 million tons), (FAOSTAT. 2019). In Bangladesh sugarcane was grown under many diverse agro-ecological conditions on an area of about 0.16 million hectares. It is a long duration crop that takes about 12-14 months from planting to harvesting which decreases economic return to farmers (Islam *et al.*, 2016).

To get higher economic return from sugarcane cultivation appropriate intercropping practices with short duration crops will be alternative way to increase total yield, interim and higher monetary return. It helps diversification of crop production as per need of farmers (Singh *et al.*, 1986). The initial growth of the cane is slow and thus inter row spaces is not covered by sugarcane leaf canopy for the first 120-50 days. So, the vacant space can be used for intercrop cultivation. Several studies have shown the importance of the cereal and legume intercropping system, which is considered as an old practice in tropical agriculture (Ghanbari *et al.*, 2010; Waddington *et al.*, 2007). Intercropping is an important agronomic strategy that involves the growing of two or more crops simultaneously of the same piece of land per year. The opposite of intercropping is growing one crop alone in pure stands; this known as sole cropping (synonymous with pure stand cropping and mono cropping) (Katyayan, 2005). Intercropping has many advantages over sole cropping. These include increased enhancement of efficient use of environmental factors (e.g., light, nutrient and soil moisture) and labors, reduces the adverse effect of various biotic and abiotic stress, provides the diversity of food, generates more income, offers insurance against crop failure, higher return and total productivity per unit area (Farhad *et al.*, 2014).

Maize (*Zea mays*) belongs to the grass family (Gramineae) with a long, tall annual plant, extensive fibrous root system and cross pollinating species. Maize is cultivated in more than 160 countries under different agro-climatic conditions and has wider adaptability and acceptability. Among leading maize growing countries viz. USA, China, Brazil, Mexico, Argentina, India, Canada and Indonesia; USA ranks first in production contributing nearly 35% of the total production in the world (Kumar *et al.*, 2013). In Bangladesh, it occupied 3rd position after rice and wheat as cash crops (Alam *et al.*, 2016). It is one of the most versatile and multi utility crops, having wider adaptability in diverse ecologies. Globally, it is known as queen of cereals because of its highest genetic potential. It is the major source of protein, food, feed, fodder, fuel and industrial raw material industry for production of starch for textile, pharmaceutical, cosmetic industries, high quality corn oil, protein, alcoholic beverages, food sweeteners etc and provides enormous opportunity for crop diversification, value addition and employment generation. It is also grown for many other special purposes viz. quality protein maize, sweet corn, baby corn, pop corn, waxy corn, high oil and high amylase corn (Kumar *et al*., 2013). Now a day`s maize cultivation has become popular and farmers are showing interest to cultivate maize because lower cost of production and higher yield as compared to that of rice and wheat (Ahammed and Haque, 2002). On the other hand In Bangladesh is in an increasing trend with the increasing in poultry industry as well as increasing in maize price (Moniruzzaman *et al.*, 2009). In the spring season, the growth of sugarcane almost remains stunted up to 3- months and this situation could be taken advantage of by planting maize in between two rows of sugarcane beneficially (Shamsi *et al.*, 2003). Considering the fact, this study was undertaken to find out the suitability of maize intercropping with sugarcane for increasing productivity and interim economic benefit of sugarcane cultivation in Bangladesh.

MATERIALS AND METHODS

The experiment was conducted at the experimental farm of Regional Sugarcrop Research Station (in between 25°40´ and 26°12´ north latitudes and 88°05´ and 88°39´ east longitudes) Thakurgaon, Bangladesh, during 2014-15 and 2015-16 cropping season under irrigated conditions. The site represents the Old Himalayan Piedmont Plain Soil (Agro Ecological Zone 1) with medium high land of typical sandy loam soil having PH 5.5. Three selected maize hybrid varieties NK 40, Sunshine and VA-786 were grown as an intercrop with sugarcane (cv. Isd 39) in a single and paired row planting systems. The experiment was laid out in a Randomized Complete Block Design with three replications. The unit plot size was 8.0 m x 6.0 m with the following treatment combinations.

T_1: Single row cane (SRC) sole	T_7: PRC + 2 lines maize (Sunshine)
T_2: Paired row cane (PRC) sole	T_8: PRC + 3 lines maize (Sunshine)
T_3: SRC + 1 line maize (NK-40)	T_9: SRC + 1 line maize (VA-786)
T_4: PRC + 2 lines maize (NK-40)	T_{10}: PRC + 2 lines maize (VA-786)
T_5: PRC + 3 lines maize (NK-40)	T_{11}: PRC + 3 lines maize (VA-786)
T_6: SRC + 1 line maize (Sunshine)	

Previously raised two budded soil bed sugarcane settlings were transplanted in each plot in the 2nd December of both the cropping seasons of 2014-15 and 2015-16, maintaining 100cm x 45cm spacing in single row planting system and 140cm+60cm x 45 cm in paired row planting system. The intercrop maize was sown on the same date of sugarcane transplantation. Fertilizers were applied following the recommended rate (BARC, 2012). N, P, K, S and Zn for sugarcane @ 165, 55, 120, 30 and 2.5 kg ha^{-1}, respectively and 128, 38, 40, 18 and 1 kg ha^{-1} for maize as intercrop, respectively. Pest and disease management and necessary intercultural operations like weeding, mulching, gap filling, irrigation, earthing up and tying etc. were done according to the proper time. The tiller population of sugarcane was recorded at 90 DAT, 120 DAT, 150 DAT. Millable cane, stalk height, stalk diameter, individual cane yield and brix (%) of cane were recorded at harvest. Maize grown as intercrop was harvested at 125 DAS and yield data was recorded properly. Sugarcane was harvested in Mid December of 2015 and 2016 for both the cropping seasons. Cane equivalent yield of intercrop, total adjusted cane yield, yield loss of cane due to maize intercropping were calculated and economic analysis was done after harvesting of both the crops. Fisher's analysis of variance (ANOVA) was used for statistical analysis of collected data and for comparison of differences among treatment means. Least significant difference (LSD) test was done at 5% level of probability (Steel *et al.*, 1996). Statistix 10 (Tallahassee FL 32317) was used for the determination of statistical differences.

The benefit cost ratio (BCR) indicated whether the cultivation was profitable or not, which was calculated as follows (CIMMYT, 1988):

$$BCR = \frac{\text{Gross return (Tk.ha}^{-1})}{\text{Cost of production (Tk.ha}^{-1})}$$

Gross return = Value of cane

Cost of production = The sum of the cost of the resources.

RESULTS AND DISTCUSSION

Responses of maize intercropping and its effect on stalk height (m), stalk diameter (cm) and brix (%) of sugarcane were represented in Table 1.

Stalk height

Environmental factors and genetic characteristics of plants play an important role in determining plant height. Among different treatment combination the highest stalk height of 3.52m and 3.43m were found from sole sugarcane following SRC planting system in both the seasons of 2014-15 and 2015-16, respectively which were followed by sole sugarcane of PRC (3.43 m and 3.35m) in both the seasons. The lowest stalk height of 2.98 and 2.85 m were found from T_{11} in both the seasons of 2014-15 and 2015-16, respectively. This observation was with the agreement of Zarekar *et al.* (2017). They observed that sole sugarcane stalk height (1.78 m) was higher than (1.69 m) sugarcane intercrop with sweet corn.

Stalk diameter and Brix (%)

The highest cane diameter (2.22 cm) was recorded from the sole sugarcane at SRC Sole (T_1) which was at par with the treatments of T_2, T_7 and T_{10} but the lowest cane diameter (1.91 cm) was found in the treatment of T_{11} which was statistically similar with T_5 and T_8 in 2014-15 season. In the 2015-16, the highest cane diameter (2.19 cm) was found from the sole sugarcane at SRC only which was statistically similar with T_2, T_4, T_7, T_9 and T_{10} but the lowest cane diameter was found from T_{11} (1.89 cm) which was statistically similar with T_5 and T_8. Brix (%) readings obtained from all the treatments were not affected significantly but it were numerically different. Similar findings recorded by Zarekar *et al.* (2017).

Table 1. Effect of maize intercropping on height, diameter and brix (%) of sugarcane in 2014-15 and 2015-16 cropping seasons

Treatments	Stalk height (m)		Stalk Diameter (cm)		Brix (%)	
	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
T_1 : SRC sole	3.52 a	3.43 a	2.22 a	2.19 a	20.16	20.43
T_2 : PRC sole	3.43 a	3.35 a	2.16 ab	2.15 ab	20.21	20.50
T_3 : SRC + 1 line maize (NK-40)	3.23 b	3.15 b	2.08 bc	2.05 bc	20.00	20.17
T_4 : PRC + 2 lines maize (NK-40)	3.21 b	3.23b	2.10 bc	2.09 ab	19.77	20.33
T_5 : PRC + 3 lines maize (NK-40)	3.00c	2.91 de	1.95 d	1.91 d	20.23	19.93
T_6: SRC + 1 line maize (Sunshaine)	3.22 b	3.18 b	2.07 bc	2.05 bc	19.93	20.15
T_7 : PRC + 2 lines maize (Sunshine)	3.17 b	3.15 b	2.12 ab	2.08 a-c	20.16	20.17
T_8 : PRC + 3 lines maize (Sunshine)	2.98c	3.00 cd	2.00 cd	1.95 cd	19.83	20.17
T_9 : SRC + 1 line maize (VA-786)	3.21b	3.18 b	2.10 bc	2.10 ab	19.87	20.33
T_{10}: PRC + 2 lines maize (VA-786)	3.15 b	3.12 bc	2.13 ab	2.06 a-c	20.13	20.17
T_{11}: PRC + 3 lines maize (VA-786)	2.96 c	2.85 e	1.91 d	1.89 d	20.10	20.50
LSD (0.05)	0.12	0.12	0.11	0.13	NS	NS

Tiller population

Significant variation of tiller formation in sugarcane was found among different treatments at 90 DAT, 120 DAT and 150 DAT in both seasons 2014-15 and 2015-16. Figure 1 and Figure 2 shows that in sole sugarcane was given higher tiller number that was 137.44 x 10^3 ha^{-1}, 185.22 x 10^3 ha^{-1} and 193 x 10^3 ha^{-1} cropping season 2014-15 and 128.06 x 10^3 ha^{-1}, 191.24 x 10^3 ha^{-1} and 201 x 10^3 ha^{-1} cropping season 2015-16 at 90 DAT, 120 DAT and 150 DAT, respectively. Data showed that in sole sugarcane tiller formation gradually increased up to 90 DAT but rapidly increase at 90 DAT to 120 DAT, after that the tiller formation slowly increased up to 150 days. In the intercropping condition, maize was highly affected on sugarcane tiller formation up to 90 DAT, then tiller formation increases gradually up to 90-120 DAT but it was very slow. After maize harvest tiller formation increased up to 150 DAT. Similar result was found by Zarekar *et al.* (2017).

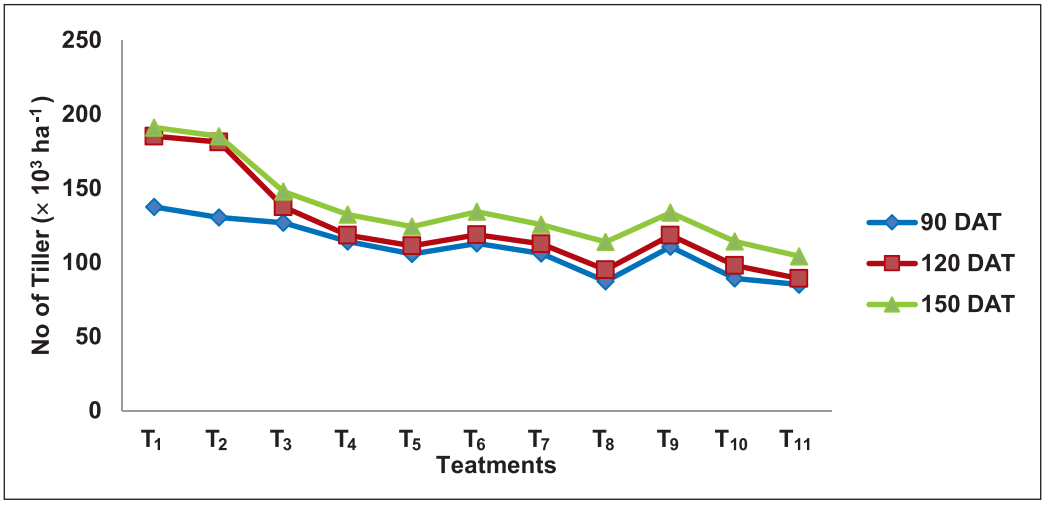


Figure 1. Effect of maize intercropping with sugarcane on tiller formation in cropping season 2014-15

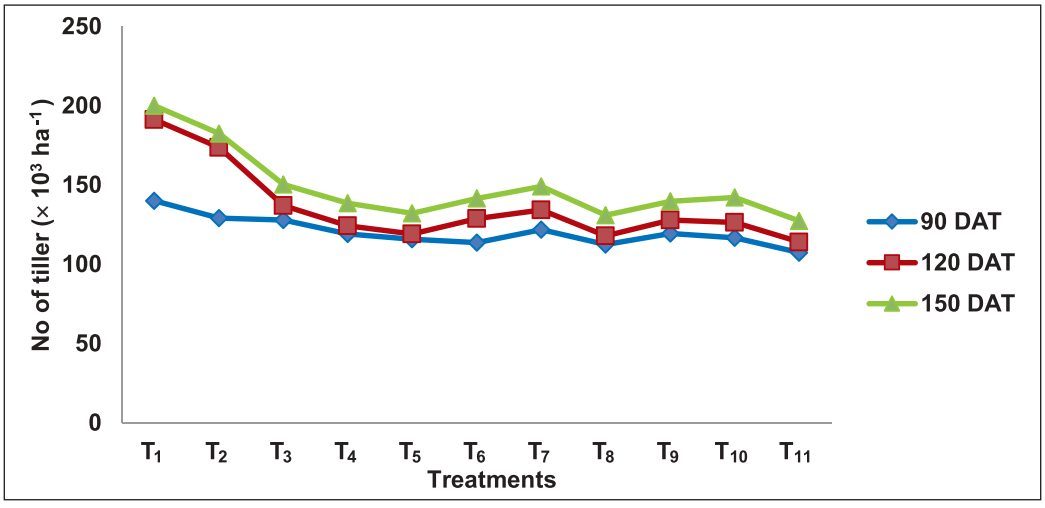


Figure 2. Effect of maize intercropping with sugarcane on tiller formation in cropping seasons 2015-16

Results revealed that all the treatments exerted significant influence on the yield and others yield attributes viz. millable cane, unit stalk weight of cane presented in Table 2.

Millable cane

The number of millable cane directly influences cane yield. The highest number of millable cane of 92.22 × 10^3 ha^{-1} and 108.00 × 10^3 ha^{-1} were found from the T_1: SRC sole in both seasons. The lowest number of millable cane of 56.38 × 10^3 ha^{-1} and 62.97 × 10^3 ha^{-1} were recorded from the treatment T_{11} in both cropping seasons. Millable cane obtained in both seasons was significantly similar with the treatments of T_4, T_5, T_7, T_8, T_9 and T_{10} in 2014-15 and T_5 and T_8, in 2015-16 seasons (Table 2). The similar result was observed by Zarekar *et al.* (2018). They observed that minimum number of millable cane (66.95 × 10^3 ha^{-1}) in paired row planted sugarcane intercropped with sweet corn that was lower than sole paired row planting sugarcane (73328.67 × 10^3 ha^{-1}).

Unit stalk weight

The highest unit stalk weight was obtained from T_1: SRC sole 0.90 kg and 0.88kg in both seasons. The lowest unit stalk weight of 0.76 kg was observed from T_7 in 2014-15 season and 0.75 kg from the treatment T_{11} in 2015-16 season which was significantly similar to the other treatments except T_1 and T_2. The same observations were mentioned by Li *et al*. (2014).

Cane yield

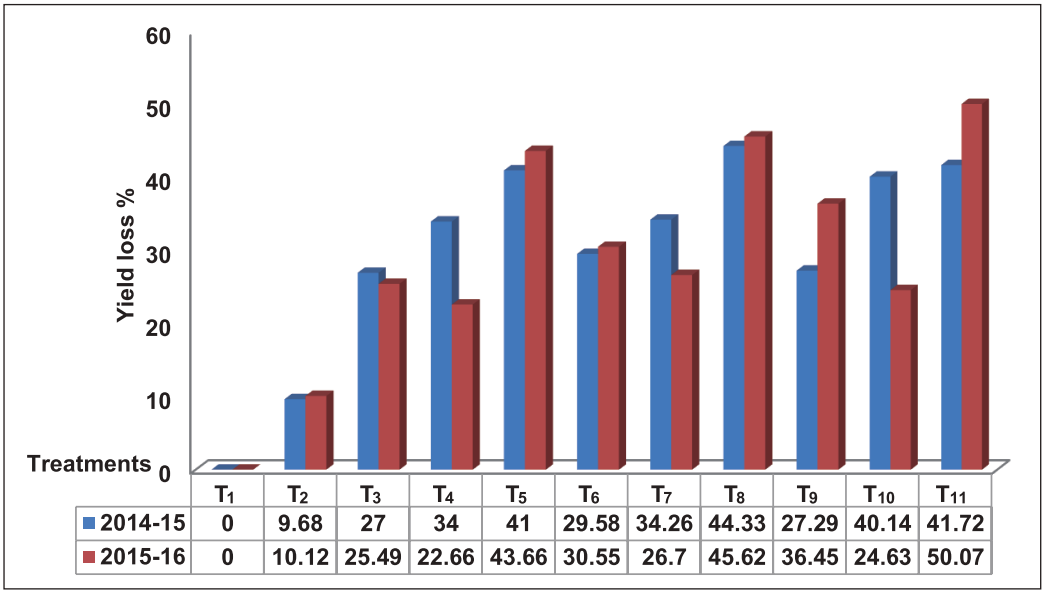
The highest cane yield 81.68 t ha^{-1} and 94.64 t ha^{-1} were found from T_1: SRC sole in both seasons which were statistically similar with the yield 73.77 tha^{-1} from T_2: PRC sole in cropping season 2014-15. The lowest cane yield 45.47 t ha^{-1} was found from T_8 in the cropping season 2014-15 which was statistically similar with T_5, T_6, T_7, T_8, T_9 and T_{10} in 2014-15 season. In the season of 2015-16, the lowest cane yield (47.25 t ha^{-1}) was found from T_{11} which was statistically similar with T_5 and T_8. Similar results were reported by Li *et al.* (2014). They reported that in the sugarcane-maize intercropping system, the yield of intercropped sugarcane was 9. 72% -33.17% lower than that of monoculture.

Table 2. Effect of maize intercropping on yield and yield attributes of sugarcane in 2014-15 and 2015-16 cropping seasons

Treatments	Millable cane (×10^3 ha^{-1})		Unit stalk weight (kg)		Cane yield (tha^{-1})	
	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
T_1 : SRC sole	92.22 a	108.00 a	0.90 a	0.88 a	81.68 a	94.64 a
T_2: PRC sole	85.55 ab	97.29 b	0.86 ab	0.87 a	73.77 ab	85.06 b
T_3 : SRC + 1 line maize (NK-40)	74.72 a-c	85.79 c	0.80 bc	0.82 ab	59.55 c-e	70.52 c
T_4 : PRC + 2 lines maize (NK-40)	62.70 de	87.92 c	0.85 ab	0.84 ab	53.49 e	73.19 c
T_5 : PRC + 3 lines maize (NK-40)	57.34 de	67.20 d	0.79 bc	0.79 ab	48.01 f	53.24 ef
T_6 : SRC + 1 line maize (Sunshaine)	67.56 b-d	81.15 c	0.85 a-c	0.81 ab	57.52 ef	65.73 cd
T_7 : PRC + 2 lines maize (Sunshine)	68.31 de	83.90 c	0.76 c	0.83 ab	53.70 d-f	69.37 c
T_8 : PRC + 3 lines maize (Sunshine)	56.38 e	65.57 d	0.81 bc	0.77 b	45.47 f	50.52 f
T_9 : SRC + 1 line maize (VA-786)	73.88 c-e	79.34 c	0.80 bc	0.76 b	59.39 ef	60.14 de
T_{10}: PRC + 2 lines maize (VA-786)	59.34 e	88.74 bc	0.82 a-c	0.79 ab	48.89 f	71.33 c
T_{11}: PRC + 3 lines maize (VA-786)	57.13 de	62.97 d	0.80 bc	0.75 b	47.60 f	47.25 f
LSD (0.05)	10.45	9.78	0.09	0.09	10.04	8.40

Cane yield loss (%) due to maize intercropping

Figure 3 shows that the yield loss (%) was found due to maize intercropping compared to sole sugarcane in a single row planting system in both seasons. The maximum yield loss percent (44.03%) was found from T_8 paired row cane with three lines maize (Sunshine) compared to sole sugarcane in a single row planting system in the cropping season 2015-16. On the other hand cropping season 2015-16, maximum yield loss (50%) was found from T_{11} paired row cane with three lines maize (VA-786) compared to sole sugarcane in a single row planting system. The minimum yield loss percent 9.68 and 10.10 were found from T_2 compared to sole sugarcane in a single row planting system in both the cropping seasons.



Treatments	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}
2014-15	0	9.68	27	34	41	29.58	34.26	44.33	27.29	40.14	41.72
2015-16	0	10.12	25.49	22.66	43.66	30.55	26.7	45.62	36.45	24.63	50.07

Figure 3. Yield loss (%) due to intercrop and PRC planting system in cropping season 2014-15 and 2015-16

Here, T_1: Single row cane (SRC) sole, T_2: Paired row cane (PRC) sole, T_3: SRC + 1 line maize (NK-40), T_4: PRC + 2 lines maize (NK-40), T_5: PRC + 3 lines maize (NK-40), T_6: SRC + 1 line maize (Sunshine), T_7: PRC + 2 lines maize (Sunshine), T_8: PRC + 3 lines maize (Sunshine), T_9: SRC + 1 line maize (VA-786), T_{10}: PRC + 2 lines maize (VA-786) and T_{11}: PRC + 3 lines maize (VA-786)

Results indicated that all the treatment combinations exerted significant influence by the intercropping on cane yield, equivalent cane yield of intercrop and total adjusted cane yield presented in Table 3.

Intercrop yield, equivalent cane yield of intercrop and adjusted cane yield

The yield of maize as an intercrop was significantly different among the different treatment combinations. Paired row cane with maize combinations was produced the higher yield where single row cane with one line maize combinations given the lowest maize yield in both seasons. The highest equivalent cane yield of intercrop 17 tha^{-1} was calculated from T_{11} in cropping season 2014-15 and 18.62 tha^{-1} was calculated from T_8 in cropping season 2015-16. The lowest equivalent cane yield of intercrop 10.68 tha^{-1} and 12.67 tha^{-1} were calculated from T_9 in both cropping seasons 2014-15 and 2015-16. The highest total adjusted cane of 81.68 tha^{-1} and 94.64 tha^{-1} were found in T_1: SRC sole and the lowest of 61.90 tha^{-1} were found from treatment T_8 in 2014-15 season and 65.04 tha^{-1} was found from T_{11} in cropping season 2015-16. The similar result was found by Saini *et al.* (2000). They found that intercrop yield, equivalent cane yield of intercrop and adjusted cane yield of sugarcane with okra intercropping was higher than intercropping sugarcane with maize.

Table 3. Intercrop yield, equivalent cane yield of intercrop and total adjusted cane yield as affected by maize intercropping with sugarcane in 2014-15 and 2015-16 cropping seasons

Treatments	Intercropped yield (tha^{-1})		Equivalent cane yield of intercrop (tha^{-1})		Total adjusted cane yield (tha^{-1})	
	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
T_1	-	-	-	-	81.68	94.64
T_2	-	-	-	-	73.77	85.06
T_3	4.09 d	4.10 c	12.92	14.16	72.47	84.68
T_4	4.72 bc	4.65 b	14.91	16.06	68.40	89.25
T_5	5.13 ab	5.48 a	16.21	18.93	64.22	72.17
T_6	4.02 d	3.95 c	12.70	13.65	70.22	69.68
T_7	4.42 cd	4.49 bc	13.96	15.51	67.66	84.88
T_8	5.20 a	5.39 a	16.43	18.62	61.90	69.14
T_9	3.38 e	3.67 d	10.68	12.67	70.00	72.81
T_{10}	4.35 cd	4.38 bc	13.74	15.13	62.63	86.46
T_{11}	5.41 a	5.15 a	17.00	17.79	64.60	65.04
LSD (0.05)	7.20	0.52	-	-	-	-

Price of crops (2014-15): Sugarcane: 2690 Tk. t^{-1}, Maize: 8500 Tk. t^{-1}
Price of crops (2015-16): Sugarcane: 2750 Tk. t^{-1}, Maize: 9500 Tk. t^{-1}

Cost and benefit

The economic analysis of the experiment under different treatment combinations is presented in Table 4. Among the different treatments the highest gross return 219719.00 $Tk.ha^{-1}$ and 260260.00 $Tk.ha^{-1}$ were achieved from T_1: Single row cane sole in both seasons. The lowest of gross return 166511.00 $Tk.ha^{-1}$ was obtained from T_8: PRC + 3

lines Sunshine in 2014-15 season and 178860.00 Tk.ha^{-1} was achieved from T_{11}: PRC + 3 lines VA-786 in 2015-16 season. The highest net returns of 104719.00 Tk.ha^{-1} and 140260.00 Tk.ha^{-1} was obtained from T_1: Single row cane sole in both seasons. The lowest of net return 30511.00 Tk.ha^{-1} was obtained from T_8: PRC + 3 lines Sunshine in 2014-15 season and 39860.00 Tk.ha^{-1} were obtained in T_{11}: PRC + 3 lines VA-786 in 2015-16 season. The treatment T_1: Single row cane only gave the highest BCR of 1.91 and 2.17 in both the seasons and the lowest BCR of 1.22 was found from the treatment T_8 : PRC + 3 lines Sunshine in 2014-15 cropping season and BCR 1.29 was obtained from T_{11} : PRC + 3 lines VA-786 in 2015-16 cropping season. The similar result was found by Saini *et al.* (2000).

Table 4. Total cost of production, grows return, net return and benefit cost ratio as affected by maize intercropping with sugarcane in 2014-15 and 2015-16 cropping seasons

Treatments	Cost of production (Tk.ha^{-1})		Gross return (Tk.ha^{-1})		Net return (Tk.ha^{-1})		BCR	
	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
T_1	115000	120000	219719	260260	104719	140260	1.91	2.17
T_2	125000	128000	198441	233915	73441	105915	1.59	1.83
T_3	124000	129000	194944	232870	70944	103870	1.57	1.81
T_4	134000	137000	183996	245437	49996	108437	1.37	1.79
T_5	136000	139000	172751	198467	36751	59467	1.27	1.43
T_6	124000	129000	188890	191620	64890	62620	1.52	1.49
T_7	134000	137000	182005	233420	48005	96420	1.36	1.70
T_8	136000	139000	166511	190135	30511	51135	1.22	1.37
T_9	124000	129000	188300	200227	64300	71227	1.52	1.55
T_{10}	134000	137000	168474	237765	34474	100765	1.22	1.74
T_{11}	136000	139000	173774	178860	37774	39860	1.28	1.29

Price of crops (2014-15): Sugarcane : 2690 Tk. t^{-1}, Maize : 8500 Tk. t^{-1}
Price of crops (2015-16): Sugarcane : 2750 Tk. t^{-1}, Maize : 9500 Tk. t^{-1}

The overall result of this experiment shows that intercropping of irrespective maize varieties with sugarcane affected all the yield attributes and economic return. The highest yield and maximum BCR were achieved from sole single row sugarcane planting then the sole paired row sugarcane planting. It can be concluded that intercropping maize with sugarcane is not appropriate as followed in this study. Further and different studies to be needed on this how it could be suitable in the aspect of Bangladesh.

REFERENCES

Ahammed, A. and Haque, M.A. 2002. Bangladesh a bhuttarutpadon o babohar (In Bangla), Bangladesh Agricultural Research Institute and Co-ordinated Maize Development Project, DAE, pp 23-28.

Alam, S.; Kowsari, M.S.; Chowdhury, N.Y.; Islam, M.M. and Haque, S. 2016. Factors affecting land allocation for maize cultivars in Lalmonirhat District of Bangladesh. *Progress. Agric.*, **27** (3): 346-354.

BARC(Bangladesh Agricultural Research Council). 2012. Fertilizer Recommendation Guide. Bangladesh Agri. Res.Coun., New Airport Road, Farm gate, Dhaka-1225. pp. 191.

CIMMYT. 1988. From Agronomic Data to Farmers Recommendations: An Economics Training Manual. Completely revised edition. Mexico. D.F. pp. 31-45.

FAOSTAT, 2019. Report, Food and Agriculture Organization of the United Nations: Economic and Social Department, The Statistical division FAOSTAT, http://faostat3.fao.org/home/index.html# Download.

Farhad, I.S.M.; Chowdhury, M.M.U.; Bhowal, S.K.; Choudhury, A.K. and Khan A.S.M.M.R. 2014. Chilli - Garlic intercropping system in coastal saline area. *Appl. Sci. Rep.*, **6** (2): 47-50.

Ghanbari, A.; Dahmardeh, M.; Siahsar, B.A. & Ramroudi, M. 2010. Effect of maize (*Zea mays* L.) cowpea (*Vigna unguiculata* L.) intercropping on light distribution, soil temperature and soil moisture in arid environment. *J. of Food, Agric. Environ.*, **8** : 102–108.

Islam, M.S.; Alam, M.J.; Hossain, M.S.; Rashid, M.M. and Rahman M.K. 2016. Productivity and Profitability of Flowers - Mungbean Sequential Intercropping with Sugarcane. *Bangladesh J. Sugarcane.* **37**:83-92.

Junejo, S.; Kaloi, G.M..; Panhwar, R.N.; Chohan, M. and Soomro, A.F. 2010. Performance of some newly developed sugarcane genotypes for some quantitative and qualitative traits under Thatta conditions. *J. Ani & Plant Sci.*, **20**(1): 40-43.

Katyayan, A. 2005. Fundamentals of agriculture. Varanasi, Uttar Pradesh: Kushal Publications & Distributors. pp. 10-12.

Kumar, A.; Jat, S.L.; Kumar, R.; and Yadav, O.P. 2013. Maize production systems for improving resource-use efficiency and livelihood security. Directorate of Maize Research, Pusa Campus, New Delhi-pp.123.

Li, Z.X.; Yang, W.T. and Wang J.W. 2014. Effect of Sugarcane-Sweet Corn Intercropping on Yield, Quality and Economic Benefit of Sugarcane. *Chinese J. Ecol.*, **33**(1) 98-104.

Mehareb E.M.; Elwafa, S.F.A. and Galal, M.O.A. 2015. Comparative Performance of Sugarcane Genotypes for Ratoon Ability in Early Clonal Selection Stages. *J. Sugarcane Res.*, **5** (2): 11 – 21.

Moniruzzaman, M.; Rahman, M.S.; Karim, M.K. and Alam, Q.M. 2009. Agro-Economic Analysis of Maize Production in Bangladesh: A Farm Level Study. *Bangladesh J. Agri. Res.*, **34** (1): 15-24.

Parsons, M. J. 1999. Intercropping with sugarcane. *Proc. S. Afr. Sug. Technol. Ass.*, **73**: 58-65.

Saini, L.K.; Kapur, M.L. ; Singh ; Makhan, S. and Garcha, A.I.S. 2000.Productivity and profitability of intercropping in spring sugarcane. *Indian Sugar*, **50** (3):157-160.

Shamsi, I.H.; Shah, W.A.; Bakht, J. and Masood, M. 2003. Effect of Maize Population (As Intercrop) on the growth of Ratoon Sugarcane and Maize Yield. *Asian J. Plant Sci.*, **2** (7): 532-534.

Singh, V.; Kothari, S.K. and Tripathi, H.N. 1986. Studies on Intercropping in sugarcane in Central Uttar Pradesh. *Indian Sugarcane J.*, **35**: 559-562.

Steel RGD, Torrie JH and Dicky DA. 1996. Principles and Procedures of Statistics, A Biometrical Approach, 3rd ed.; McGraw Hill, Inc. Book Co.: New York, NY, USA.

Waddington, S.; Mekuria, M.; Siziba, S. and Karigwindi, J. 2007. Long-term yield sustainability and financial returns from grain legume–Maize intercrops on a sandy soil in subhumid north central Zimbabwe. *Exp. Agric.*, **43**: 489–503.

Zarekar, V.V.; Kapse V.D.; Chavan, A.R. and Gangawane S.B. 2018. Effect of intercropping and planting methods on yield, nutrient content and uptake by sugarcane under lateritic soil of Konkan region. *J. Pharmacogn. Phytochem.*, **7**(1):135-139.

Zarekar, V.V.; Pati, I.H.M.; Game, V.N. and Gangawane, S.B. 2017. Effect of intercropping and planting methods on yield, quality and economics of sugarcane under lateritic soil condition. *Int. J. Chem. Stud.*, **5**(4): 1895-1900.

Performance of Some Winter Crops-Mungbean Intercropping with Sugarcane under Old Himalayan Piedmont Plain Soils in Bangladesh

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ABSTRACT

An experiment was conducted in farmers' field at two locations (Thakurgaon and Dinajpur) of Old Himalayan Piedmont Plain Soils (AEZ 1) in Bangladesh during 2011-2012 cropping season to know the performance of some high value winter crops viz; potato, onion, garlic, coriander, bushbean and tomato as first intercrop and mungbean as second intercrop with sugarcane under paired row planting system. The study included seven sequential intercrop treatment combinations viz T_1: Paired row cane (PRC) sole, T_2: PRC + potato - mungbean, T_3: PRC + onion - mungbean, T_4: PRC + garlic - mungbean, T_5: PRC + coriander - mungbean, T_6: PRC + bush bean - mungbean and T_7: PRC + tomato - mungbean in a randomized complete block design with three replications. Sugarcane variety Isd 37 was used in the trial. Most of the observed parameters showed significant differences except number of internode, unit stalk weight and Brix (%) in both the locations. Paired row cane + potato - mungbean gave the highest tiller population (246.11 x 10^3 ha^{-1} and 275.00 x 10^3 ha^{-1}), millable cane (115.00 x 10^3 ha^{-1} and 99.17 x 10^3 ha^{-1}), stalk height (3.46 m and 3.41 m), stalk diameter (2.39 cm and 2.42 cm), cane yield (113.22 t ha^{-1} and 99.10 t ha^{-1}), total adjusted cane yield (180.86 ha^{-1} and 160.50 ha^{-1}) and benefit cost ratio (2.96 and 2.62) in both the locations. The overall results under this study indicated that intercropping have a positive impact on cane yield and other yield contributing components and found profitable compare to sole sugarcane cultivation. Considering the total cost and economic return, different factors associated with production system and farmers' liking, growing potato as first and mungbean as second intercrop with sugarcane in paired row planting system might be a profitable package at Old Himalayan Piedmont Plain Soils.

Key words: Performance, sugarcane, intercropping, benefit cost ratio

INTRODUCTION

Sugarcane (*Saccharum Officinarum* L.) is one of the major sugarcrop in Bangladesh. It is one of the most important food-cum-cash-cum-industrial crops in Bangladesh and cultivating in more than 90 countries of the tropical and Sub-tropical regions of the world (FAO, 2011). Brazil is a major sugarcane producer followed by India,

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China, Pakistan, Thailand and Mexico (FAO, 2010). It covers 2.05% of the total cultivable land. Currently, on average sugarcane is grown on 160 thousand hectares of land annually of which almost 50% area is located within the sugar mills zone, and the remaining in the non-mills zone (Hussain, 2011). It is mainly grown in high and medium high land under rainfed condition mostly in the north-west and south-west regions of the country. The soil and climate of Bangladesh is very much congenial for sugarcane production but the average sugarcane yield is around 44 tha^{-1} (BBS, 2011). It is one of the important crops in contributing to the country's economy and farmer's livelihood development and the second largest contributor (10–12%) of dietary carbohydrate to human after the cereals. It is a commercially important crop that accounts for approximately 65% of global sugar production (Deho *et al.*, 2002). Besides sugar production, it also produces numerous valuable by-products like alcohol, used in pharmaceutical products; ethanol, used as a fuel; bagasse, used for paper and chipboard manufacturing and used as a rich source of organic matter as well as nutrients for sustainable crop production (Majid, 2007). Though having a high importance and prosperity, the acreage of sugarcane cultivation is decreasing because of pressure for cultivation of more food grains and utilization of crop lands for more roads, housing, industries etc. In this situation there is a little scope to increase both cane yield and sugarcane acreage to meet the higher demand of sugar or gur for the ever increasing population. Day by day the population is rapidly increasing which is decreasing the area under crop production. The prerequisite is to increase the production and income per unit area by developing such planting techniques and practices, which may help in maintaining proper plant population and intercropping (Hussain *et al.*, 2008). In this situation there are many ways to sustain sugarcane farming and boost the per unit yield in different farming systems. Among those intercropping can be a viable option which is more efficient and eco-friendly method that results in enhanced production. It is an important agronomic strategy that involves the growing of two or more crops simultaneously of the same piece of land per year (Katyayan, 2005) and have many advantages over sole cropping. These include increased yield and income, the provision of a more varied diet, more stable production, less problems with pests, diseases and weeds, a better spread of family labour, the control of soil erosion and a host of other minor benefits, all of which have been reviewed (Willey, 1979). Intercropping also uses the practice of sowing a fast-growing crop with a slow-growing crop, so that the first crop is harvested before the second crop starts to mature (Lithourgidis *et al.*, 2011). In early stage of growth, some short duration crops viz., vegetables, pulses, oil seeds and spices can be grown as intercrop in the vacant spaces between two rows of sugarcane. In paired rows system of sugarcane planting, two rows of cane are planted at 60 cm apart in a trench leaving 120-140 cm vacant space between two paired rows of cane (Alam *et al.*, 2008). It has been reported that farmers grow a large number of winter vegetables like potato, tomato, cauliflower, onion, carrot etc. as first intercrop with sugarcane profitably (Matin *et al.*, 2001). Besides, after harvesting of first intercrop, there is possibility of growing some short duration crops such as leafy vegetables, mungbean and dhaincha successfully as second intercrop with sugarcane. Many reports suggest that mungbean can be used as the second intercrop (Hossain *et al.*, 1995). Benefits of intercropping legumes like mungbean,

soybean, sunhemp and cowpea in sugarcane is improved the soil properties, sustain the sugarcane yield and increases the total productivity of the system (Khandagave *et al.*, 2010). Intercropping results in an increased farm income and better utilization of resources. The farming community can get inspiration and higher net returns from this system (Akhtar *et al.*, 2010). Economic benefits of first and second intercrop production in sugarcane with paired row planting system have been reported elsewhere (Islam *et al.*, 2009). The production of intercrop with sugarcane in Bangladesh is localized depending on the soil, environment and market in Bangladesh. In view of the above circumstances, an experiment was undertaken to find out performance of some selected intercrops as first followed by summer mungbean as second intercrop with sugarcane following paired rows planting system in Old Himalayan Piedmont Plan Soils.

MATERIALS AND METHODS

The experiment was conducted at farmers' field at Thakurgaon and Dinajpur of Bangladesh during 2011-2012 cropping season under irrigated condition. The site represents the Old Himalayan Piedmont Plain Soil (Agro Ecological Zone 1) with medium high land of typical sandy loam soil having PH 5.5. Six selected winter crops viz, potato, onion, garlic, coriander, bush bean and tomato were grown as first intercrop followed by summer mungbean as the second intercrop with sugarcane in paired row planting system where sugarcane variety was Isd 37. The experiment was laid out in a Randomized Complete Block Design with three replications. The unit plot size was 8m x 6m with the following treatments were used in the trial.

T_1: Paired row cane (PRC) sole
T_2: PRC + potato - mungbean
T_3: PRC + onion - mungbean
T_4: PRC + garlic - mungbean
T_5: PRC + coriander - mungbean
T_6: PRC + bushbean - mungbean
T_7: PRC + tomato - mungbean

Table 1. Fertilizer, seed rate and spacing of different crops

Crops	Cowdung, N, P, K kg ha^{-1}	Seed rate ha^{-1}	Spacing
Sugarcane	10000:150:50:100	33333 settlings	140cm + 60 cm × 30cm
Potato	500:70:25:60	800 kg	50 cm × 10 cm
Onion	5000:75:30:75	5 lak seedlings	15 cm × 7.5 cm
Garlic	2000:60:30:60	250 kg	10 cm × 10 cm
Coriandar	2000:60:24:40	6 kg	line sowing
Bushbean	2000:60:20:30	60 kg	30 cm × 10 cm
Tomato	2000:75:24:50	35000 seedling	50 cm × 40 cm
Mungbean	2000:15:18:14	10 kg	line sowing

Fertilizer recommendation guide (BARC, 2005), Krishi projukti hat boi (BARI, 2011) and Hossain *et al.* (2008)

Crop Management

Previously raised two budded soil bed sugarcane settlings were transplanted in each plot in the 15th November 2011 of both locations maintaining 140cm + 60cm x 45 cm in paired row planting system. All the first intercrops were planted in the same date of sugarcane plantation. Mungbean was sown as second intercrop in 17th March after harvesting of first intercrops. Fertilizer application, sett/seed rate and spacing were maintained as mentioned in Table 1. Pest and disease management and necessary intercultural operations like weeding, mulching, gap filling, irrigation, earthing up, tying etc. were done accordingly in proper time. Yield and other necessary data of all intercrops were recorded properly at harvest. Tiller population, millable cane, stalk height, stalk diameter, number of internodes per stalk, cane yield and brix (%) of cane were recorded properly. Sugarcane was harvested in 20 December of 2012 in both the locations. Cane equivalent yield of intercrop and total adjusted cane yield were calculated and economic analysis was done with the current market price of the crops. Fisher's analysis of variance (ANOVA) was used for statistical analysis of collected data and for comparison of differences among treatment means. Least significant difference (LSD) test was done at 5% level of probability (Steel *et al.*, 1996). Statistix 10 (Tallahassee FL 32317) was used for the determination of statistical differences.

Benefit cost ratio was calculated as follows (CIMMYT, 1988):

$$BCR = \frac{\text{Gross return (Tk.ha}^{-1})}{\text{Cost of production (Tk.ha}^{-1})}$$

Gross return = Value of cane
Cost of production = Sum of the cost of the resources.

RESULTS AND DISTCUSSION

Results presented in Table 2 illustrated that tiller population, stalk diameter (cm) and number of internode of sugarcane.

Tiller population

Tiller production was significantly affected by different intercrops. The highest tiller population of 246.11 x 10^3 ha^{-1} was found from the treatment T_2 (PRC + potato - mungbean) at Dinajpur which was statistically at par with T_1 and T_7. In Thakurgaon, the highest number of tillers (246.11 x 10^3 ha^{-1}) was found from the same treatment. The minimum number of tiller (254 x 10^3 ha^{-1}) at Dinajpur location was found from T_6: (PRC + bush bean - mungbean) treatment where as at Thakurgaon location it was 179.15 x 10^3 ha^{-1} recorded from T_7: (PRC + tomato - mungbean). Similar result was observed by Ahmed *et al.* (2007). They observed that PRC + potato - mungbean was given highest number of tiller (207.22 x 10^3 ha^{-1}) than other treatment combinations. The findings of the present experiment were in consent with Singh *et al.* (2010) where they realized that variation in tiller formation of cane among different treatment combination as inter-cropping condition because differences in growth habit, canopy structure and duration of intercrops resulted in differential competition for resources.

Stalk diameter and number of internode

At Dinajpur location stalk diameter was not significantly different but it was significantly different at Thakurgaon location. The highest cane diameter of 2.39 cm was recorded from T_2: (PRC + potato - mungbean) which was statistically similar with the values found from others treatments except T_7, which gave the lowest stalk diameter of 2.18 cm. The similar result was observed by Kabiraj *et al.* (2008). They observed that there was no Significant Difference in case of internode per stalk but it was numerically varied in both locations.

Table 2. Tiller, stalk diameter and number of internode of sugarcane at Thakurgaon and Dinajpur locations

Treatments	Tiller ($\times 10^3$ ha^{-1})		Stalk Diameter (cm)		No. of Internode (stalk^{-1})	
	Thakurgaon	Dinajpur	Thakurgaon	Dinajpur	Thakurgaon	Dinajpur
T_1	237.00 ab	265.00 ab	2.33 ab	2.35	26	25
T_2	246.11 a	275.00 a	2.39 a	2.40	28	27
T_3	201.00 cd	260.00 b	2.31 ab	2.38	27	26
T_4	218.37 bc	264.00 bc	2.29 ab	2.42	27	27
T_5	195.00 de	257.00 bc	2.25 ab	2.27	25	25
T_6	209.15 cd	254.00 c	2.24 ab	2.30	26	25
T_7	179.15 e	265.00 ab	2.18 b	2.32	24	23
LSD (0.05)	20.76	10.64	0.2	NS	NS	NS

In a column, figures with similar letters do not differ significantly at 5% level
Legends: T_1: Paired row cane (PRC) sole, T_2: PRC + potato - mungbean, T_3: PRC + onion - mungbean, T_4: PRC + garlic - mungbean, T_5: PRC + coriander - mungbean, T_6: PRC + bushbean - mungbean, T_7: PRC + tomato - mungbean

Stalk height

Environmental factors and genetic characteristics of plants play an important role in determining the plant height. Among different treatment combinations stalk height was significantly affected in both locations (Figure 1). The highest stalk height of 3.46 m and 3.41m were found from the treatment T_2: (PRC + potato - mungbean) in the both locations. The lowest stalk height of 3.20 m and 3.10 m were found from the treatment T_7: PRC + tomato - mungbean in the both locations. Similar result was assent by Bhullar *et al.* (2006). They realized that sugarcane with potato intercrop was given highest stalk height (1.63 m) than other intercropping combinations.

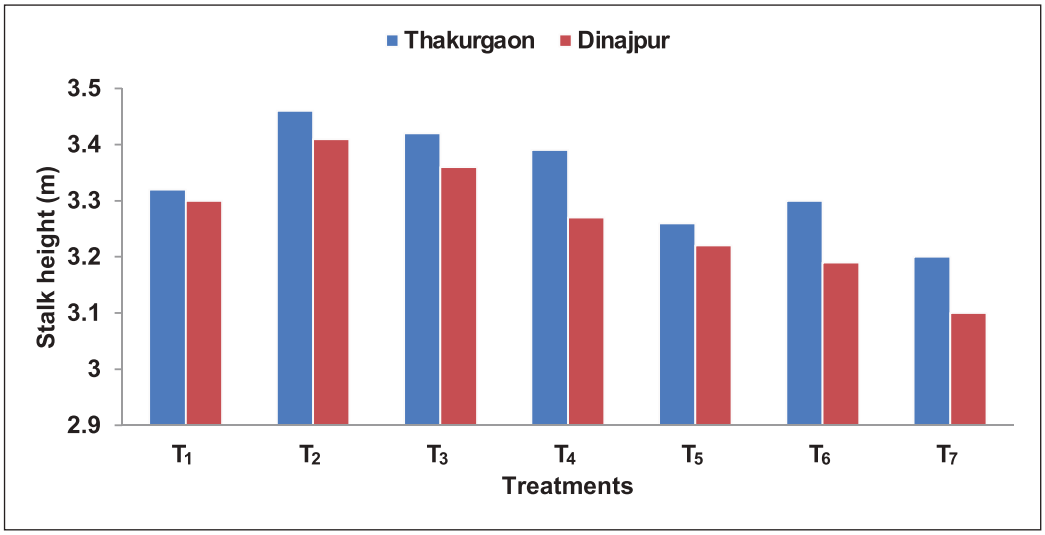

Figure 1. Effect of intercropping with sugarcane on stalk height at Thakurgaon and Dinajpur locations

Legends: T_1: Paired row cane (PRC) sole, T_2: PRC + potato - mungbean, T_3: PRC + onion - mungbean, T_4: PRC + garlic - mungbean, T_5: PRC + coriander - mungbean, T_6: PRC + bushbean - mungbean, T_7: PRC + tomato - mungbean

Results from this study further indicated that all the treatments exerted significant influence on the yield and others yield attributes viz. millable cane, unit stalk weight and of cane yield presented in Table 3.

Millable cane

The number of millable cane directly influences cane yield. The highest number of millable cane 115 × 10^3 ha^{-1} and 99.17 × 10^3 ha^{-1} were found from the treatment T_2: (PRC + potato - mungbean) in the both locations. The lowest millable cane 91.52 x 10^3 ha^{-1} was found from the T_7: (PRC + tomato - mungbean) at Thakurgaon location and 89.52 x 10^3 ha^{-1} was found from the T_6: (PRC + bushbean - mungbean) at Dinajpur location. The similar result was observed by Kabiraj *et al.* (2008) and Matin *et al.* (2001).

Unit stalk weight

Unit stalk weight was not significantly different in both locations but the range was 0.93 kg to 0.98 kg $stalk^{-1}$ and 0.86 kg to 1.02 kg $stalk^{-1}$ at Thakurgaon and Dinajpur locations, respectively.

Cane yield

Higher yield of sugarcane with different intercropping systems (spices, vegetables and pulse) were attributed to higher population of shoots and millable canes, tiller and heavier stalk (Lawande *et al.*, 2008). The highest cane yield of 113.22 tha^{-1} and 99.10

tha^{-1} were found from the treatment T_2: PRC + potato - mungbean in both the locations But the lowest cane yields of 85.49 tha^{-1} and 80.90 tha^{-1} were found from the T_7: (PRC + tomato - mungbean) at both locations. Similar result was reported by (Verma *et al.*, 1985, Imam *et al.*, 1990, Porwal *et al.*, 1994 and Matin *et al.*, 2001). Verma *et al.* (1985) reported that growing potato as an intercrop with sugarcane decreased soil bulk density and increased its available nitrogen content so, it enhanced cane yield. Porwal *et al.* (1994) also described that short statured crop than onion, garlic, bushbean and tomato, so it did not smother the sugarcane plants and thus tillering of sugarcane was not affected and the crop produced higher cane yield. On the other hand Imam *et al.* (1990) reported that intercropping of potato with sugarcane enhanced cane yield and net returns than sole cane due to better use of residual P, K and to a lesser extent of N. Matin *et al.* (2001) attained that PRC + potato - mungbean was given the highest cane yield (175.7 tha^{-1}) than other treatments.

Table 3. Yield and yield attributes of sugarcane at Thakurgaon and Dinajpur locations

Treatments	Millable cane ($\times 10^3$ ha^{-1})		Unit stalk weight (Kg $Stalk^{-1}$)		Cane yield (tha^{-1})	
	Thakurgaon	Dinajpur	Thakurgaon	Dinajpur	Thakurgaon	Dinajpur
T_1	110.67 ab	95.00 ab	0.95	0.99	104.42 ab	95.59 ab
T_2	115.00 a	99.17 a	0.98	1.02	113.22 a	99.10a
T_3	104.00 abc	94.76 abc	0.96	0.99	100.44 bc	94.42 ab
T_4	99.37 cd	93.00 ab	0.97	1.00	96.00 bc	92.76 b
T_5	100.00 bcd	97.18 ab	0.93	0.86	93.42 cd	85.32 cd
T_6	98.48 cd	89.52 d	0.93	0.97	91.44 cd	86.66 c
T_7	91.52 d	90.21 cd	0.93	0.90	85.49 d	80.90 d
LSD (0.05)	11.28	3.85	NS	NS	10.25	4.83

In a column, figures with similar letters do not differ significantly at 5% level

Legends: T_1: Paired row cane (PRC) sole, T_2: PRC + potato - mungbean, T_3: PRC + onion - mungbean, T_4: PRC + garlic - mungbean, T_5: PRC + coriander - mungbean, T_6: PRC + bushbean - mungbean, T_7: PRC + tomato - mungbean

Brix (%)

Brix readings obtained from all the treatments were not affected significantly but it were numerically different (Figure 1). The highest Brix (20.07 %) and (20%) were obtained in the treatments T_4 and T_1 respectively. The lowest Brix (18.93%) and (18.95%) were obtained in the treatment T_6. Similar result was agreement with Kashem *et al.* (2007).

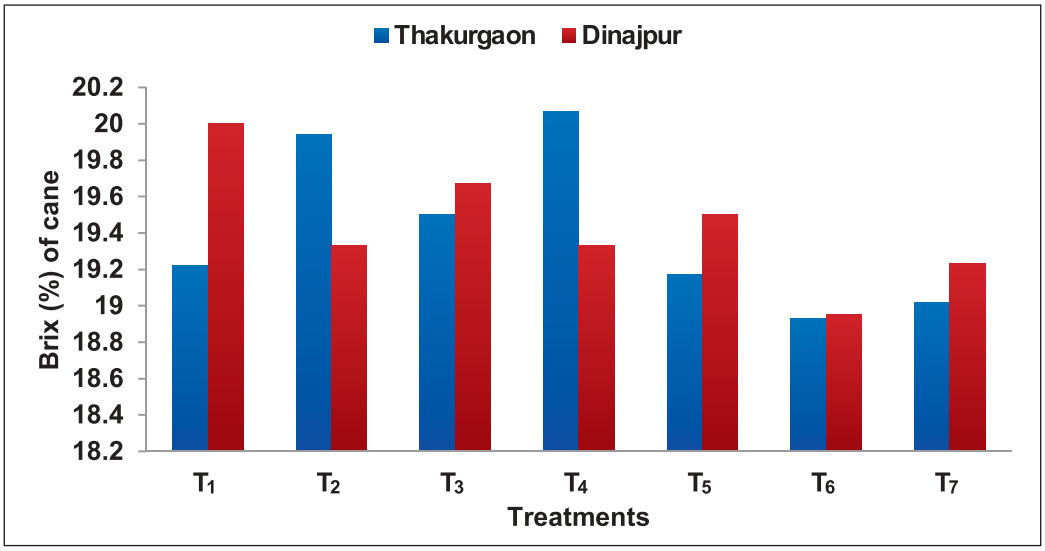

Figure 2. Effect of intercropping with sugarcane on Brix (%) of cane at Thakurgaon and Dinajpur locations

Legends: T_1: Paired row cane (PRC) sole, T_2: PRC + potato - mungbean, T_3: PRC + onion - mungbean, T_4: PRC + garlic - mungbean, T_5: PRC + coriander - mungbean, T_6: PRC + bushbean - mungbean, T_7: PRC + tomato - mungbean

Results from our study intercrop yield, equivalent cane yield of intercrop and total adjusted cane yield presented in Table 4.

Intercrop yield

The overall yield performance of the first intercrops (Potato, onion, garlic, coriander, bushbean and tomato) was found satisfactory (Table 4). Summer mungbean also performed better yield response as second intercrop for all of the combinations. The highest yield of second intercrop mungbean was obtained from T_2 treatment (0.53 tha^{-1} and 0.55 tha^{-1}) in both locations which were followed T_3 treatment 0.46 and 0.45 tha^{-1} in both locations. The lowest mugnbean intercrop yield 0.35 and 0.33 tha^{-1} was found from T_7 treatment in both locations. The data showed that under intercropping condition, the type of first intercrop influence on the yield of second intercrop (mungbean). The similar result was observed by Ahmed *et al.* (2007).

Adjusted cane yield

Adjusted cane yield is an important parameter for determining the total yield potentials of intercropped plot over the sole cane plot (Alam *et al.*, 2000). From the table 4, the highest total adjusted cane yield of 180.86 tha^{-1} and 160.50 tha^{-1} were found from T_2: (PRC + potato - mungbean) in both locations and the lowest total adjusted cane yield 104.42 tha^{-1} and 93.59 tha^{-1} were found from the treatment T_1: Paired row cane (PRC) sole in both locations. The similar result was observed by Ahmed *et al.* (2007).

Table 4. Intercrop yield, equivalent cane yield of intercrop and total adjusted cane yield of sugarcane at Thakurgaon and Dinajpur locations

Treatments	1st intercrop yield (tha^{-1})		2nd intercrop yield (tha^{-1})		Equivalent cane yield of intercrop (tha^{-1})		Total adjusted cane yield (tha^{-1})	
	Thakurgaon	Dinajpur	Thakurgaon	Dinajpur	Thakurgaon	Dinajpur	Thakurgaon	Dinajpur
T_1	-	-	-	-	-	-	104.42	93.59
T_2	13.20	11.50	0.53	0.55	67.64	61.40	180.86	160.50
T_3	6.71	5.78	0.46	0.45	53.14	47.28	153.58	141.70
T_4	2.75	2.45	0.42	0.40	55.76	50.40	151.76	143.16
T_5	0.65	0.58	0.43	0.41	32.84	30.04	126.26	115.36
T_6	5.30	4.93	0.40	0.42	43.00	41.34	134.44	128.00
T_7	13.5	12.97	0.33	0.35	63.24	57.80	148.73	142.58

Price of crops: Sugarcane: 2500 Tk. t^{-1}, Potato: 10 Tk. kg^{-1}, Onion: 15 Tk. kg^{-1}, Garlic: 40 Tk. kg^{-1}, Coriander: 80 Tk. kg^{-1}, Bushbean: 15 Tk. kg^{-1}, Tomato: 10 Tk. kg^{-1} and Mungbean 70 Tk. kg^{-1}

Legends: T_1: Paired row cane (PRC) sole, T_2: PRC + potato - mungbean, T_3: PRC + onion - mungbean, T_4: PRC + garlic - mungbean, T_5: PRC + coriander - mungbean, T_6: PRC + bushbean - mungbean, T_7: PRC + tomato - mungbean

Cost and return

The economic analyses of the experiment under different treatment combinations are present in Table 5. Among the different treatments the highest gross return (452150.00 $Tk.ha^{-1}$) and (401250.00 $Tk.ha^{-1}$) were achieved from T_2: PRC + potato - mungbean in both locations. The lowest of gross return of 261050.00 $Tk.ha^{-1}$ and 233975 were found from the treatment T_1: Paired row cane (PRC) sole in both locations. The highest net return (299150.00 $Tk.ha^{-1}$) and (248250.00 $Tk.ha^{-1}$) were achieved from T_2: (PRC + potato - mungbean) in both locations. The lowest of net return of 151050 $Tk.ha^{-1}$ and 123975 were found from the treatment T_1: Paired row cane (PRC) sole in both locations. The treatment T_2: (PRC + potato - mungbean) was given the highest BCR of 2.96 and 2.62 in both locations and the lowest BCR of 2.37 and 2.13 were given the treatment T_1: Paired row cane (PRC) sole in both locations. The similar report was reported by Kashem *et al.* (2007) and Alam *et al.* (2000).

Table 5. Total cost of production, gross return, net return and benefit cost ratio of sugarcane at Thakurgaon and Dinajpur locations

Treatments	Total cost of production cost (Tk.ha^{-1})		Gross return (Tk.ha^{-1})		Net return (Tk.ha^{-1})		Benefit cost ratio (BCR)	
	Thakurgaon	Dinajpur	Thakurgaon	Dinajpur	Thakurgaon	Dinajpur	Thakurgaon	Dinajpur
T_1	1,10,000	1,10,000	261050	233975	151050	123975	2.37	2.13
T_2	1,53,000	1,53,000	452150	401250	299150	248250	2.96	2.62
T_3	1,48,000	1,48,000	383950	354250	235950	206250	2.59	2.39
T_4	1,43,000	1,43,000	379400	357900	236400	214900	2.65	2.50
T_5	1,23,000	1,23,000	315650	288400	192650	165400	2.57	2.34
T_6	1,32,000	1,32,000	336100	320000	204100	188000	2.55	2.42
T_7	1,43,000	1,43,000	371825	356450	228825	213450	2.60	2.49

Price of crops: Sugarcane: 2500 Tk. t^{-1}, Potato: 10 Tk. kg^{-1}, Onion: 15 Tk. kg^{-1}, Garlic: 40 Tk. kg^{-1}, Coriander: 80 Tk. kg^{-1}, Bushbean: 15 Tk. kg^{-1}, Tomato: 10 Tk. kg^{-1} and Mungbean 70 Tk. kg^{-1}.

Legends: T_1: Paired row cane (PRC) sole, T_2: PRC + potato - mungbean, T_3: PRC + onion - mungbean, T_4: PRC + garlic - mungbean, T_5: PRC + coriander - mungbean, T_6: PRC + bushbean - mungbean, T_7: PRC + tomato - mungbean

The study shows that intercropping of winter crops with sugarcane affected on all the yield attributes and economic return of sugarcane. The highest yield and maximum BCR were achieved from potato - mungbean in paired row sugarcane planting which was followed by garlic - mungbean and tomato - mungbean paired row sugarcane planting. It can be concluded that growing potato, garlic and tomato as first and mungbean as second intercrop with paired row sugarcane might be recommended at old Himalayan piedmont plain soils.

REFERENCES

Ahmed, T.; Bashar, M.K.; Biswas, M.M.; Abdullah, M.; M.; Kashem, M.N. and Rahman, M.K. 2007. Performance of sugarcane with double intercrops in Tista Meander Flood Plain Soils. *Bangldesh J. Sugarcane*, **29:** 56-59.

Akhtar, M.; Yaqub, M.; Iqbal, Z.; Ashraf, M.Y.; Akhter, J. and Hussain, F. 2010.Improvement in yield and nutrient up take by co-cropping of wheat and chickpea. *Pak. J. Bot.*, **42:** 4043-4049.

Alam, M.J.; Hossain, M.S.; Islam, A.K.M.R.; Rahman, M.K. and Kabir, M.L. 2008. Performance of jute varieties for seed production as first and mungbean as second intercrop under transplanted cane in paired row. *Bangladesh J. Sugarcane*, **30:** 116-121.

Alam, M.J.; Islam, M.A.; Rahaman, M.M. and Zaman, A.K.M.M. 2000. Impact of paired row sugarcane with double intercrops. *Bangladesh J. Sugarcane*, **22:** 1-9.

BARC (Bangladesh Agricultural Research Council). 2005. Fertilizer Recommendation Guide. Bangladesh Agri. Res.Coun., New Airport Road, Farm gate, Dhaka-1225. pp.147-233.

BARI (Bangladesh Agricultural Research Institute). 2011. Krishi projukti hat boi Khondo-1, Joydebpur, Gazipur.

BBS. 2011. Statistical Year Book of Agricultural Statistics of Bangladesh. Planning Division, Ministry of Planning.Government of the Peoples Republic of Bangladesh. pp.122.

BBS (2013). www.bbs.gov.bd/home.aspx. Bangladesh Bureau of Statistics. Ministry of Planning. Government of the Peoples Republic of Bangladesh. Dhaka, Bangladesh.

Bhullar M.S.; Kamhoj, A.; Singh, G.P. and Uppaji, S.K. 2006. Nutrient Requirement of Autumn Sugarcane Based Intercropping Systems. *J. Res. Punjab agric. Univ.*, **43** (3): 176-78.

CIMMYT. 1988. From Agronomic Data to Farmers Recommendations: An Economics Training Manual. Completely revised edition. Mexico. D.F.pp. 31-45.

Deho, Z.A., Tunio, S.D., Minhas, Y.J. and Majeedano, H.I. 2002. Effect of mulching technique on the growth and yield of sugarcane. *Pakistan Sugarcane J.*, **17:** 22-26.

FAO (Food and Agriculture Organization). 2011. Economic and Social Department. The Statistical Division, p. 567.

FAO. 2010. Crop production. Food and Agriculture Organization of the United Nations, Retrieved, 17-06-2010.

Hossain, A.H.M.D.; Rahman, M.K.; Kabir, M.L.; Matin, M.A. and Alam, M.J. 1995. Performance of soybean and some other crops as intercrops with paired row transplanted sugarcane. *Bangladesh J. Sugarcane*, **17:** 119-122.

Hossain, M.S.; Alam, M.J.; Rahman, M.K.; Kabir, M.L. and Islam, A.K.M.R.2008. Effect of row and plant spacing on growth, yield and quality of sugarcane and intercrops. *Bangladesh J. Sugarcane*, **30:** 104-110.

Hussain, M.; Farooq, M.; Jabran, K. and Rehman, H. 2008. Exogenous glycine betaine application improves yield under water limited conditions in hybrid sunflower. *Arch. Agron. Soil Sci.*, **54:** 557-567.

Hussain, S.k.G. and Iqbal, A. 2011. Research Priorities in Bangladesh Agriculture. Bangladesh Agri. Res. Coun., New Airport Road, Farmgate, Dhaka-1225. pp.43-44.

Imam, S.A.; Hossain, A.H.M.D.; Sikka, L.C. and Midmore, D.J. 1990. Agronomic management of potato/sugarcane intercropping and its economic implications. *Field Crops Res.*, **25:** 111–122.

Islam, M.A.; Miah, M.N.A.; Rahman, M.A.; Kader, M.A. and Karim, K.M.R. 2009. Performance of Sugarcane with different planting methods and Intercrops in old Himalayan Piedmont Plain Soils. *Int. J. Sustain. Crop Prod.*, **4**(1): 55-57.

Kabiraj, R.C.; Bashar, M.K.; Rahaman, M.K.; Hossain, M.S. and Islam, A.K.M.R. 2008. Performance of some selected intercrops as first and green manuring crop as second intercrop with paired row sugarcane. *Bangladesh J. Sugarcane*, **30**: 91-97.

Kailasam, C. 2008. Crops suitable for intercropping in sugarcane. In: Intercropping with Sugarcane Manual. (T Rajula Shanty and D Puthira Prathap, Eds.) ICAR-Sugarcane Breeding Institute, Coimbatore., pp. 25-33.

Kashem, M.N.; Hossain, G.M.A.; Kanner, M.A.; Basher, M.K. and Alam, K.S. 2007. Performance of selected winter vegetables as first and sunhemp as second intercrop with paired row sugarcane. *Bangladesh J. Sugarcane*, **29**:68-73.

Khandgave, R.B. 2010. Agronomic management of intercropping in sugar cane and its economic implications. *Proc-Int. Sugarcane Technol.*, **27**:1-4.

Katyayan, A. 2005. Fundamentals of agriculture. pp. 10–11. Varanasi, Uttar Pradesh: Kushal Publications & Distributors.

Lithourgidis, A.S.; Dordas, C.A.; Damalas, C.A. and Vlachostergios, D.N. 2001). Annual intercrops: an alternative pathway for sustainable agriculture. *Australian J. Crop Sci.*, **5**(4): 396-410.

Majid, M.A. 2007. Sugarcane variety composition in Pakistan. *Pakistan Sugarcane J.*, **22**(1): 2-23.

Matin, M.A.; Kabir, M.L.; Alam, M.J. and Zaman, A.K.M.M. 2001. Performance of winter vegetable and summer mungbean as intercrops with paired row transplanted sugarcane. *Bangladesh J. Sugarcane*, **23**: 7-14.

Porwal, N.K. and Kumperwat, B.S. 1985. Studies on the effect of intercropping with and without fertilizer on the yield of spring planted sugarcane. *Indian Sug.*, **35** (5):309-313.

Singh, K.; Gumber, R.K.; Bhullar M.S. and Singh, R.S. 2008. Yield, quality and economics of chickpea (*Cicer arietinum*) intercropped autumn sugarcane. *Indian Sugar.*, **58**: 37-40.

Singh, K.; Singh, A.; Gill, M.S.; Singh, D.; Uppal, S.K. and Bhullar, M.S. 2010. Intercropping in single bud vertical planted sugarcane. *J. Res. Punjab Agric. Univ.*, **47** (3 & 4): 138-42.

Steel RGD, Torrie JH and Dicky DA. 1996. Principles and Procedures of Statistics, A Biometrical Approach, 3rd ed.; McGraw Hill, Inc. Book Co.: New York, NY, USA.

Verma, R.S.; Chauhan, R.S. and Singh, R.N. 1985. Studies on Row Arrangement and Population Densities of Potato Cultivars in a Sugarcane and Potato Intercropping System in North Central India, **21** (4): 321-327.

Willey, R. W. 1979. Intercropping – its importance and research needs. Part 2. Agronomy and research approaches. *Field Crop Abst.*, **32** (2): 73-85.

Efficacy of New Insecticides Against White Grub in Sugarcane and their Effects on Yield

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ABSTRACT

A field experiment comprised of seven treatments was conducted at Patuadangi Farm, RSRS, Thakurgaon, and Sultanpur farm under STSM, Dinajpur, Bangladesh during 2017-18 and 2018-19. The application of newer insecticides (Setup 22WDG & Fiphos 45SE) was done by drenching and the granules were applied along with soil.Soil drenching of Setup 22WDG @ 75.0gm a.i ha^{-1} and Fiphos 45SE @ 1.8 L a.i ha^{-1} at March + April were found to be most effective new insecticides to reduce the population of white grubs compared to check plots. Application of Setup 22WDG @75.0 gm a.i ha^{-1} reached the efficacy of 83.33 and 81.85% during 2017-18 and 2018-19 at Patuadangi farm while 81.82 and 80.79% during 2017-18 and 2018-19 at Sultanpur farm, STSM respectively. Similarly Fiphos 45 SE @ 1.8 L a.i ha^{-1} gave 88.89 and 8376% efficacy during 2017-18 and 2018-19 respectively at Patuadangi farm while 81.82% and 82.12% effectiveness were recorded in Sultanpur farm respectively during 2017-18 and 2018-19. Increased cane yield over control was recorded among the treatments at both the locations which ranges from 25.41-55.03% in Patuadangi farm and 24.30-54.25% Sultanpur farm during 2017-2018 and 20.00-47.37% in Patuadangi farm and 23.59-47.34% yield increase was recorded in Sultanpur farm during 2018-2019 cropping season.

Key words: Sugarcane, white grubs, lufenuron, chlorpyriphos, yield

INTRODUCTION

White grubs are immature stages of scarabid beetles. Different species of white grubs in recent years destroy the crop seriously in different sugarcane tracts in the country. They are highly polyphagus pest. White grubs have been considered as major pest causing serious problem to sugarcane production in Bangladesh (SRTI, 1979).

Different species of white grubs attack sugarcane and cause severe damage resulting loss in yield. Its attack is mainly confined to the non-flooded sandy and sandy loam soils of northern cane growing areas of Bangladesh particularly STSM, TSM & PSM areas. Seventeen species of white grubs have so far been recorded in Bangladesh causing damage every year (SRTI, 1981 and 1984). But all of them are not equally important in respect of damage. Among these, *Brahmina* sp., *Holotrichia* sp., *Anomala* sp. and *Adoretus versutus* are most damaging. Heavy infestation may cause 50-60% damages, even total loss of canes. The grubs feed on the roots and underground portion of stalks rendering the plants looking pale and sickly, ultimately the affected

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shoot/cane dries up which can easily be pulled out. The canes from affected clumps become unfit for crushing and as seed materials. The yield loss due to white grubs was found to be 23.07 to 38.17 t ha^{-1} (Miah *et al., 1*983).

The incidence of *Leucopholis* reduces 40 per cent germination of the cane and causes 40 to 60 per cent reduction in cane yield and 78 units reduction in sugar recovery in heavily infested sugarcane fields. The yield loss due to white grubs was reported to be as high as 100 percent (Thamarai Chelvi *et al.*, 2010; Patil and Hapse, 1981). Several tactics have been adopted for the management of white grubs including cultural, mechanical, biological, chemical and integrated methods suggested by various workers (Srikanth and Singaravelu, 2011).

The period of attack by white grubs is found in the months of March to September but severe in March to April targeting sugarcane roots in the soil. Miah *et al.* (1986) reported that among different chemicals Furadan (Carbofuran) and Ekalux (Quinalfos) at 2.00 kg ai ha^{-1} effectively controlled white grubs. Mostafa *et al.* (1986) reported carbofuran (2,3-dihydro-2, 2-dimethyl benzofuran-7yl methylcarbamate) is a broad-spectrum systemic insecticide. The carbamate insecticides have both properties of killing insects by contact as well as systemic actions. The short life of carbofuran in soil is supported by Chowdhury *et al.* (2002) who reported that carbofuran after 30 days of application left no residues in soil indicating complete degradation of the pesticides. Wenchlor 15G applied @ 2.25 kg ai ha^{-1} and rest insecticides applied @ 2.00 kg ai ha^{-1} in March and April significantly reduced the population of white grubs compared to check plots (BSRI, 2016).

The grubs are subterranean having complex life cycle and actively feed on living roots, therefore, the control of this pest becomes difficult. Adult collection and insecticidal applications are the major tactics of management followed against all the white grub species (Veeresh, 1974 and Raodeo *et al.*, 1976). Development of high level of resistance to the white grub demands the necessity of implementation of alternative options, such as the performance of new group of insecticides which change insect plant environment interaction with specific and novel mode of action, less hazardous eco-friendly and compatible with eco-friendly pest management programs.Now-a-days large numbers of newer insecticidal formulations in the form of ready-made individual are also available in market. Attempt was, therefore, made to test the efficacy of those against white grub in sugarcane crop.

MATERIALS AND METHODS

The experiment was set up at Patuadangi Farm, RSRS, Thakurgaon and Sultanpur farm under STSM, Dinajpur, Bangladesh during the cropping season 2017-18 and 2018-19. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. There were 7 treatments including one control. The treatment Furadan 5G (March + April) was considered as standard. The plot size was 6m x 6m. Block to block distance was 2m and plot to plot distance was 1m. The variety lsd 35 was

used as planting material and planting was done through conventional sett placement (end to end) in the trenches. The tested insecticide Setup 22WDG (Lufenuron 20% + Emamectin Benzoate 2%) and standard insecticide (Furadan 5G) granular in formulation used @ 2.0 kg a.i ha^{-1} was used in different doses. Fiphos 45SE (Chlorpyriphos 40% + Fipronil 5%) was used @ 1.8 L a.i ha^{-1}. The application of insecticides was done twice, one in March and the other in April. Before irrigation, soil ridges surrounding individual plots were made to protect the inflow of water from one plot to another. The fertilizer application, weeding, mulching and earthing up were done as normal cultural practices. For application of insecticides furrows were made on both sides of cane rows and then insecticides (granular) were applied at the base of the plants and in the space between furrows and mixed with soils followed by irrigation. Setup and Fiphos were applied in the soil to the bottom of the plants through drenching. Data were taken from 5 randomly selected clumps per plot. An area of 60 cm x 60 cm was dug up from a depth of 40 cm with spade. Larval population was counted in roots and in soils of these pits. Data were taken twice in a year, one in April and the other in June. The yield of canes per plot was recorded at harvest in February 2018 and 2019.

RESULTS AND DISCUSSION

Efficacy of newer molecules of insecticides against white grub under field condition during 2017-2018 cropping session

In a field experiment during 2017-2018 cropping season the efficacy of newer insecticides against white grub were evaluated in Patuadangi Farm, RSRS, Thakurgaon and Sultanpur farm, STSM, Dinajpur. The results of the experiments are presented in Table 1 and 2 respectively. Treatments were given during first week of March and April of both locations.

In Patuadangi Farm, RSRS, Thakurgaon, it was observed that all the test insecticides significantly reduced white grub population over control in 2017-2018 cropping season. Data collected in April showed that white grub population ranged from 1.00 to 4.00 among the plots treated with insecticides whereas control plot had a population of 10.00 per 5 clumps (Table 1). After two application of insecticides (March and April), data collected in June showed that white grub population varied from 1.00 to 2.33 among the insecticide treated plots whereas in control plot the population was 8.00 per 5 clumps (Table 1). In case of Sultanpur farm, STSM, Dinajpur April data showed that white grub population ranged from 2.00 to 4.67 among the plots treated with insecticides whereas control plot had a population of 12.00 per 5 clumps (Table 2). After two application of insecticides (March and April), data collected in June showed that white grub population varied from 2.33 to 4.00 among the insecticide treated plots whereas in control plot the population was 13.67 per 5 clumps (Table 2). New insecticides, Setup 22WDG @ 75.0 gm ai ha^{-1} and Fiphos 45SE @ 1.8 L ai ha^{-1} treated plots showed above 80% efficacy over control, which ranged from 83.33 and 88.89% respectively at Patuadangi Farm, RSRS (Table 1) where as 81.82 and 81.82% efficacy were observed respectively at Sultanpur farm, STSM, Dinajpur in 2017-18 season (Table 2).

Efficacy of newer molecules of insecticides against white grub under field condition during 2018-2019 cropping session

The efficacy of newer insecticides against white grub were evaluated in Patuadangi Farm, RSRS, Thakurgaon and Sultanpur farm, STSM, Dinajpur during 2018-2019 cropping season. The results of the experiments are presented in Table 3 and Table 4 respectively. Treatments were given during first week of March and April in both locations.

All the test insecticides significantly reduced white grub population over control in Patuadangi Farm, RSRS, Thakurgaon, during the cropping season 2018-2019. From the collected data in April showed that white grub population ranged from 0.67 to 1.49 among the plots treated with insecticides whereas control plot had a population of 6.00 per 5 clumps (Table 3). The white grub population varied from 1.67 to 4.07 among the insecticide treated plots after two application of insecticides (March and April), whereas in control plot the population was 8.67 per 5 clumps in June (Table 3). April data showed that white grub population ranged from 3.00 to 6.48 among the plots treated with insecticides whereas control plot had a population of 23.67 per 5 clumps in Sultanpur farm, STSM, Dinajpur (Table 4). After two application of insecticides (March and April), data collected in June showed that white grub population varied from 4.33 to 8.33 among the insecticide treated plots whereas in control plot the population was 26.67 per 5 clumps (Table 4). The tested insecticides (Setup 22WDG @ 75.0 gm a.i ha^{-1} and Fiphos 45SE @ 1.8 L a.i ha^{-1}) treated plot showed above 80% efficacy over control, which ranged from 81.85 to 83.76% at Patuadangi Farm, RSRS (Table 3) where as 80.79 and 82.12% efficacy were observed respectively at Sultanpur farm, STSM, Dinajpur in 2018-19 cropping season (Table 4).

Miah *et al.* (1986) reported the effects of different chemicals on white grubs, among those chemicals Furadan (Carbofuran) and Ekalux (Quinalfos) both at 2.0 kg ai ha^{-1} significantly controlled the white grub. Abdullah *et al.* (1998) reported, Rugby 10G @ 2.00 kg ai ha^{-1} effectively controlled white grub population (over 80%) compared to untreated plots which have similarities with the present study. Corosulfan 6G, Edfuran 5G, Pillar 5G, Krishan 5G, Amcofuran 5G, Q-furan 5G Adfuran 5G, Nokoban 15G and Pyriban 15G @ 2.0 kg a.i ha^{-1} gave 81.00 - 97.43% efficacy in controlling white grub (Rahman *et al.,* 2005).Mane and Mohite (2014) reported that imidacloprid 40% + fipronil 40% 80WG @ 300 g ha^{-1} applied along with dry soil or sand in equal proportions at the time of planting and 75 days after planting gave most effective control of white grub. All these reports support the efficacy of test insecticides of the present findings in controlling white grubs of sugarcane. The effectiveness of any insecticide showing mortality of pests or reduction of pest infestation should reach 80% or above is a precondition set by Pesticide Technical Advisory Committee (PTAC, 1980), a government body and hopefully the present research result achieved the desired level of efficacy.

Data collected at harvest during 2017-2018 season showed that cane yield varied from 56.47 to 69.81 among the treatments at Patuadangi farm giving the increased yield over Control ranges from 25.41- 55.03% while at Sultanpur farmcane yield among the treatments ranged from 54.73 to 67.92 ton ha^{-1} which is indicated increased cane yield

ranged from 24.30 54.25% over control (Table 5). Data collected in 2018-2019 cropping season showed same increased yield over control which had similar response among the treatments in Patuadangi farm, highest yield of 68.72 ton ha^{-1} was recorded following the application of Fiphos 45 SE @ 1.8 L a.i ha^{-1} and yield increased among the treatments ranges from 20.00 to 47.37%. At Sultanpur all the treatments had statistically significant response over control in producing caneyield that ranges from 54.64-64.14 ton ha^{-1} photo showing the increased yield ranges from 23.59-47.34% (Table 6). Results obtained in 2017-2018 and 2018- 2019 it is observed that set up 22 WDG @ 75.00 gm a.i ha^{-1} and Fiphos 45SE @ 1.8 L a.i ha^{-1} showed similar trend of cane yield at both locations.

Upon the satisfactory result from the present study it might be concluded that application of Setup 22WDG @ 75.0 gm ai ha^{-1} and Fiphos 45SE @ 1.8 L a.i ha^{-1} applied in March and April might be recommended for the control of white grubs in the white grub prone areas of the country.

Table 1. Efficacy of some new insecticides against White grubs, Patuadangi farm, RSRS, Thakurgaon, 2017-2018

Treatments (Insecticides)	Dose a.i. ha^{-1}	WG Population (5 clumps/plot)		Mean population	Percent Effectiveness over control
		1st data	2nd data		
T_1 -Setup 22WDG	17.0 gm a.i ha^{-1} at March +April	3.67 bc	2.33 b	3.00	66.67
T_2 -Setup 22WDG	22.0 gm a.i ha^{-1} at March +April	4.00 b	1.67 b	2.84	68.50
T_3 -Setup 22WDG	33.0 gm a.i ha^{-1} at March +April	2.33 cd	1.67 b	2.00	77.78
T_4 -Setup 22WDG	75.0 gm a.i ha^{-1} at March +April	2.00 d	1.00 b	1.50	83.33
T_5 - Fiphos 45SE	1.8 L a.i ha^{-1}at March +April	1.00 d	1.00 b	1.00	88.89
T_6 - Furadan 5G	2.0 kg a.i ha^{-1}at March +April	1.33 d	1.00 b	1.17	87.04
T_0 - Control	-	10.00 a	8.00 a	9.00	-
LSD (0.05)		1.59	1.66	-	-

Table 2. Efficacy of some new insecticides against White grubs, Sultanpur farm, STSM, Dinajpur, 2017-2018

Treatments (Insecticides)	Dose a.i. ha^{-1}	WG Population (5 clumps/plot)		Mean population	Percent Effectiveness over control
		1st data	2nd data		
T_1 -Setup 22WDG	17.0 gm a.i ha^{-1} at March +April	4.33 bc	4.00 b	4.17	67.53
T_2 -Setup 22WDG	22.0 gm a.i ha^{-1} at March +April	4.67 b	3.33 b	4.00	68.83
T_3 -Setup 22WDG	33.0 gm a.i ha^{-1} at March +April	4.00 bc	3.00 b	3.50	72.73
T_4 -Setup 22WDG	75.0 gm a.i ha^{-1} at March +April	2.00 c	2.67 b	2.33	81.82
T_5 - Fiphos 45SE	1.8 L a.i ha^{-1}at March +April	2.33 bc	2.33 b	2.33	81.82
T_6 - Furadan 5G	2.0 kg a.i ha^{-1}at March +April	2.33 bc	2.67 b	2.50	80.52
T_0 - Control (untreated)	-	12.00 a	13.67 a	12.83	-
LSD (0.05)		2.47	1.98	-	-

Design: RCBD, Replication: 3, Treatments: 7, Variety: Isd 35

Table 3. Efficacy of some new insecticides against White grubs, Patuadangi farm, RSRS, Thakurgaon, 2018-2019

Treatments (Insecticides)	Dose a.i. ha^{-1}	WG Population (5 clumps/plot)		Mean population	Percent Effectiveness over control
		1st data	2nd data		
T_1 -Setup 22WDG	17.0 gm a.i ha^{-1} at March +April	1.49 b	4.07 bc	2.78	62.07
T_2 -Setup 22WDG	22.0 gm a.i ha^{-1} at March +April	1.33 b	3.67 b	2.50	65.89
T_3 -Setup 22WDG	33.0 gm a.i ha^{-1} at March +April	1.08 b	4.00 c	2.54	69.30
T_4 -Setup 22WDG	75.0 gm a.i ha^{-1} at March +April	1.00 b	1.67 bc	1.33	81.85
T_5 - Fiphos 45SE	1.8 L a.i ha^{-1} at March +April	0.69 b	1.77 bc	1.19	83.76
T_6 - Furadan 5G	2.0 kg a.i ha^{-1}at March +April	0.67 b	1.67 bc	1.17	84.04
T_0 - Control	-	6.00 a	8.67 a	7.33	-
LSD (0.05)		1.06	2.52	-	-

Table 4. Efficacy of some new insecticides against White grubs, Sultanpur farm, STSM, Dinajpur, 2018-2019

Treatments (Insecticides)	Dose a.i. ha^{-1}	WG Population (5 clumps/plot)		Mean population	Percent Effectiveness over control
		1st data	2nd data		
T_1 -Setup 22WDG	17.0 gm a.i ha^{-1} at March +April	6.48 b	8.04 b	7.26	71.16
T_2 -Setup 22WDG	22.0 gm a.i ha^{-1} at March +April	5.67 b	8.33 b	7.00	72.19
T_3 -Setup 22WDG	33.0 gm a.i ha^{-1} at March +April	5.33 b	6.69 c	6.01	76.12
T_4 -Setup 22WDG	75.0 gm a.i ha^{-1} at March +April	4.67 b	5.00 c	4.83	80.79
T_5 - Fiphos 45SE	1.8 L a.i ha^{-1}at March +April	4.67 b	4.33 c	4.50	82.12
T_6 - Furadan 5G	2.0 kg a.i ha^{-1}at March +April	3.00 b	4.67 c	3.83	84.77
T_0 - Control	-	23.67 a	26.67 a	25.17	-
LSD (0.05)		1.06	2.52	-	-

Table 5. Effect of different Insecticides on yield of sugarcane at Patuadangi farm, RSRS, Thakurgaon and Sultanpur farm, STSM, Dinajpur, 2017-2018

Treatments (Insecticides)	Dose a.i. ha^{-1}	Yield M.ton ha^{-1} (December/2018)			
		Patuadangi farm, RSRS, Thakurgaon		Sultanpur farm, STSM, Dinajpur	
		Mean	% increase over control	Mean	% increase over control
T_1 -Setup 22WDG	17.0 gm a.i ha^{-1} at March +April	56.47 ab	25.41	55.97 ab	27.12
T_2 -Setup 22WDG	22.0 gm a.i ha^{-1} at March +April	59.43 ab	31.98	54.73 ab	24.30
T_3 -Setup 22WDG	33.0 gm a.i ha^{-1} at March +April	61.25 ab	36.07	59.56 ab	35.27
T_4 -Setup 22WDG	75.0 gm a.i ha^{-1} at March +April	67.51 a	49.92	65.13 a	47.92
T_5 - Fiphos 45SE	1.8 L a.i ha^{-1} at March +April	69.81 a	55.03	67.92 a	54.25
T_6 - Furadan 5G	2.0 kg a.i ha^{-1}at March +April	65.19 a	44.77	64.85 a	47.29
T_0 - Control	-	45.03 c	-	44.03 c	-
LSD (0.05)		4.122		4.023	

Table 6. Effect of different insecticides on yield of sugarcane at Patuadangi farm, RSRS, Thakurgaon and Sultanpur farm, STSM, Dinajpur, 2018-2019

Treatments (Insecticides)	Dose a.i. ha^{-1}	Yield M.ton ha^{-1} (December/2019)			
		Patuadangi farm, RSRS, Thakurgaon		Sultanpur farm STSM, Dinajpur	
		Mean	% increase over control	Mean	% increase over control
T_1 -Setup 22WDG	17.0 gm a.i ha^{-1} at March +April	55.96 ab	20.00	54.64 ab	23.59
T_2 -Setup 22WDG	22.0 gm a.i ha^{-1} at March +April	58.64 ab	25.75	56.36 ab	27.48
T_3 -Setup 22WDG	33.0 gm a.i ha^{-1} at March +April	61.77 ab	32.47	59.81ab	35.29
T_4 -Setup 22WDG	75.0 gm a.i ha^{-1} at March +April	66.63 a	42.89	63.33 a	43.25
T_5 - Fiphos 45SE	1.8 L a.i ha^{-1} at March +April	68.72 a	47.37	65.14 a	47.34
T_6 - Furadan 5G	2.0 kg a.i ha^{-1} at March +April	66.17 a	41.90	65.05 a	47.14
T_0 - Control	-	46.63 c	-	44.21 c	-
LSD (0.05)		3.910		3.914	

REFERENCES

Abdullah, M; Biswas, M.M; kundu, R. and Alam, M.A. 1998. Efficacy of some insecticides against White Grubs of Sugarcane. *Bangladesh J. Sugarcane*, **18-20**: 138-140.

BSRI, Annual Report, 2015-16. Bangladesh Sugarcrop Research Institute, Ishwardi, Pabna, Bangladesh. pp. 116-117.

Choudhury, N.; Malek, M.A.; Ullah, S.M. and Rahman, M. 2002. Fate of Carbofuran Pesticides studied in a sandy loam soil in laboratory conditions. *J. Asiatic Soc. Bangladesh, Sci.*, **28** (1): 19-26.

Mane, P.B. and Mohite, P.B. 2014. Efficacy of newer molecules of insecticides against white grub in sugarcane. *Asian J. Bio. Sci.*, **9** (2): 173-177.

Miah, M.A.H.; Khuda, A.K.M.Q.E.; Alam, M.A.; Biswas, M.M. and Shahjahan, M. 1983. Chemical control of white grubs. *Bangladesh J. Sugarcane*, **5**: 1-7.

Miah, M.A.H.; Biswas, M.M. and Mannan, M.A. 1986. Effect of some insecticides on white grub control and yield of Sugarcane. *Tropical Pest Management*, **32**: 338-340.

Mostafa, I.Y.; Fakhr, I.M.I.; Bahig, M.R.E. and El-Zawahry, Y.A. 1986. Metabolism of organophosphorus insecticides. Archives of Microbiology, **86**: 221-224.

PTAC, 1980. Standards for Selection for Pesticides for Registration in Bangladesh, PTAC, Ministry of Agriculture, Bangladesh, BGP-80/81-5151B-100, p 2.

Patil, A.S. and Hapase, D.G. 1981. Research on sugarcane borers in Maharashtra State. Proceedings. national symposium on stalk borer. pp. 165-175.

Raodeo, A.K.; Deshapande, S.V.; Deshpande, A.D.; Puri, S.N. and Bilapate. 1976. A large scale compaign for the control of white grub *Holotrichia serrata* F. in Maharashtra state, *PANS.*, **4**: 223-228.

Rahman, M.A.; Biswas, M.M.; Alam, M.A. and Abdullah, M. 2005. Efficacy of Some New Organocarbamate and Chlorpyrifos in Controlling White Grubs of Sugarcane. *Bangladesh. J. Sugarcane*, **24-27**: 161-163.

Srikanth, J. and Singaravelu, N. 2011. Advances in transgenic research for insect resistance in sugarcane. *Trop. Plant Biol.*, **4**: 52-61.

SRTI, 1979. Annual Report (Special issue), 1973-78. Sugarcane Research and Training Institute, Ishwardi, Pabna, Bangladesh. pp. 143.

SRTI, Annual Report, 1981. Sugarcane Research and Training Institute, Ishwardi, Pabna, Bangladesh. pp. 67-79.

SRTI, Annual Report, 1984. Sugarcane Research and Training Institute, Ishwardi, Pabna, Bangladesh. pp. 79-94.

Thamarai, Selvi C.; Rhichard, Thilaga, Raj, W. and Kandasamy, R. 2010. Laboratory culture and virulence of *Beauveria brongniarti* isolates on sugarcane white grub, *Holotrichia Serrata F. J. Biopestici.*, **3** (1): 177-179.

Veeresh, G.K. 1974. Root grub control, campaign in Karnataka. *White Grubs Newsletter*, **1**: 17-18.

Effects of Different Management Practices in Controlling Sugarcane Scale Insect

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ABSTRACT

The experiment was conducted at Faridpur Sugar Mills Experimental Farm, Faridpur for two consecutive years 2013-2014 and 2014-2015 to find out the effective management practice for sugarcane scale insect Melanaspis glomerata Green in sugarcane cultivation. The experiment was laid out in a Randomized Complete Block Design with three replications and comprised of eight treatments combinations viz., T_1: Planting scale insect free setts, T_2: Setts dipping in Malathion/Folithion for 15 minutes before planting, T_3: Detrashing of older leaves at 30 days intervals (July - October), T_4: T_2 + T_3, T_5 : Application of malathion 57 EC @ 3.5 L ha^{-1} (July + August +Sept.), T_6 :T_4 + Application of Chlorpyrofos + Cypermethrin (Nitro 55 EC) @ 4.0 L ha^{-1}, T_7 : Application of Imidachloprid 20 SL @ 1.0 L ha^{-1}, T_8: Application of Cypermethrin 10EC @ 2.0 L ha^{-1} and T_0: Control (untreated) against sugarcane scale insect. The highest efficacy 88.79% and the highest yield 78.79 t ha^{-1} was observed in T_6 : T_4 + Application of Chlorpyrofos (Nitro 55 EC) @ 4.0 L ha^{-1} (July + August + September) treated plot in the cropping season 2013-14. Similarly, in the cropping season 2014-15, the highest efficacy (80.63%) and the highest yield 65.04 t ha^{-1} was observed in same treatment T_6 : T_4 + Application of Chlorpyrofos + Cypermethrin (Nitro 55 EC) @ 4.0 L ha^{-1} (July + August + September) treated plot. The percent infestation of sugarcane scale insect was significantly reduced over the control due to detrashing and gave 49.39 and 47.50 efficacy during the both cropping seasons. On other hand the average lowest percent scale insect was found in T_6 treatment at 1.3 and 7.50 during reporting period 2013-14 and 2014-15. This study revealed that application of insecticides preceded by detrashing of older leaves was diminishing sharply percent infestation of scale insect and increasing the yield of cane significantly over the control.

Key words: Sugarcane, scale insect, detrashing, insecticides, effective control, yield of cane

INTRODUCTION

Sugarcane scale insect *Melanaspis glomerata* Green is an important pest of sugarcane in tropical and sub-tropical parts of India. The infestation of scale insect poses a potential economic impact to sugar industries in Bangladesh. Its infestation has increased to an alarming position in the districts like Faridpur, Nator, Panchagar, Thakurgaon, Dinajpur and western part of Bangladesh. Scale insect infestation is being reported to new sugarcane growing areas regularly. The pest survives in the underground stubble after harvest of the main crop and serves as a primary source of

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infestation in ratoon crops. It is known for its adaption to a wide range of climatic conditions, varying from high temperatures and humidity to moderately warm and humid conditions. Infestations commence prior to monsoons in early plantings and ratoons. It builds up mainly from July onwards until harvest. Sugarcane is damaged by thirty five species of scale insects belonging to Aclerdidae, Asterolecaniidae, Coccidae and Diaspidae in different countries (Rao and Sankaran,1969). Among the different species, *Melanaspis glomerata* Green, the native armoured scale insect is economically important.

The reproduction is generally by fertilization and occasionally by parthenogenesis. The scale insect make the appearance in 5-6 months old crop after the formation a new internodes of sugarcane (Agarwal, 1960). Eggs are laid under the females scale. Upon hatching the crawlers (young immature mobile stage) wander looking for a feeding site. They insert their needle-like mouthparts and suck plant sap and do not move again. They then develop a thick, waxy scale cover. This may coincide with the onset of monsoon, the scale insect damage the cane crop in several ways (Khanna, 1957). Its infestation reduces germination, inhibits cane growth, reduces cane yield, percentage of juice extraction, juice quality and jaggery production. Germination of buds in infested setts is much delayed and reduced to 33.30 percent compared to 81.40 percent in healthy setts (Tripathy and Shukla, 1982). The percent germination is inversely proportional to the percent intensity of scale insect infestation. In the variety Co 775, the sacle insect infestation caused 29 percent reduction in height and 18 percent relative reduction in the height of millable portion of cane (Moholkar *et al.*, 1973). Thontadarya and Govindo (1976) observed that the loss in cane yield to be more in light soil (33% in Co 740 and 17% in Co 774) as compared to heavy soil (11.4% in Co 740 and 8% in Co 774). The constant desapping of canes results in the reduction of juice content from 0.3% (Moholkar *et al.*, 1973) to as high as 41.1% (Prabhakara Rao *et al.*, 1976). The sugar recovery is reduced by 1.7, 2.3, 3.3 and 9.1 units under varying levels scale insect infestation (Shukla and Tripathy, 1980). The syrup prepared from the juice of scale insect infested canes does not set properly (Prabhakara Rao *et al.*, 1976). According to Moholkar and Ranadive (1973), there is reduction in gur production and the jaggery in dark colour with high reducing sugars (more than 10%), that reduces its market value. Bhavani (2013) mentioned the effect of detrashing and chemical treatment in controlling scale insect infestation. The comparative efficacy of different management tactics including some non-chemical and selected insecticides for development of suitable management package using safer components are not properly reported in Bangladesh. Therefore, this study aims at developing appropriate management package(s) to control sugarcane scale insect to ensure high sugar and goor production from sugarcane.

MATERIALS AND METHODS

The field experiment was conducted in two consecutive years during the cropping season 2013-2014 and 2014- 2015 at Faridpur Sugar Mills experimental Farm, Faridpur. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The plot size was 6m × 6m with six sugarcane lines. The sugarcane variety Isd 37 was conventionally planted in December 2013 and 2014 respectively. Forty (40)

two eye budded setts were placed per line. Total 240 setts were placed per plot. Intercultural operations weeding, mulching, detrashing, earthing up etc. were done as and when required (Rahman and Pal, 2003). Fertilizers were applied as per recommended dose, method and time (FRG, 2012) use fertilizer dose. There were eight (8) treatments including one control.

Detrashing and application of liquid insecticides :

The scale insect makes its appearance in 5-6 months old crop after the formation of a new internodes of sugarcane therefore detrashing was started from the month of June and continued to October. The insecticides of the treatments were sprayed by a Knap-sac sprayer after detrashining the crop. Fertilizer application, irrigation, weeding, mulching and earthing-up were done as per normal cultural practices (Anon.,1998). The following are the treatment combinations in two consecutive seasons:

Treatments in cropping season 2013-2014:
T_1 – Plantation with scale insect free setts
T_2 – Sett dipping in Malathion/Folithion for 15 minutes before plantation
T_3 – Detrashing of older leaves at 30 days intervals (July - October)
T_4 – T_2 + T_3
T_5 – T_4 + Application of Malathion 57 EC @ 3.5 L ha^{-1} (July + August + September)
T_6 – T_4 + Application of Chlorpyrofos + Cypermetrin (Nitro 55 EC) @ 4.0 L ha^{-1} (July + August + September)
T_7 – Application of Chlorpyrofos + Cypermethrin (Nitro 55 EC) @ 4.0 L ha^{-1} (July + August + September)
T_0 – Control

Treatments in cropping season 2014-2015:
T_1 – Plantation with scale insect free setts
T_2 – Sett dipping in Malathion/Folithion for 15 minutes before plantation
T_3 – Detrashing of older leaves at 30 days intervals (July - October)
T_4 – T_2 + T_3
T_5 – Application of malathion 57 EC @ 3.5 L ha^{-1} (July + August +Sept.)
T_6 – T_4 + Application of Chlorpyrofos + Cypermethrin (Nitro 55 EC) @ 4.0 L ha^{-1} (July + August + Sept.)
T_7 – Application of Imidachloprid 20 SL @ 1.0 L ha^{-1} (July + August + Sept.)
T_8 – Application of Cypermethrin 10EC @ 2.0 L ha^{-1} (July + August + Sept.)
T_0 – Control (Untreated)

Data on the incidence of scale insect was recorded on nodal basis in the month of August and November. The yield of sugarcane was also recorded at harvest. The collected data were converted to percent infestation to measure the level of incidence and analyzed for comparison by using LSD at 0.05 levels interpretation. For efficiency study, percent infestation was computed by total and infested canes for individual plot and percent infestation was computed by using the following formula:

$$\% \text{ Scale insect Infestation} = \frac{\text{Number of infested canes}}{\text{Total number of canes}} \times 100$$

Plate 1: Sugarcane scale insect *Melanaspis glomerata* Green infested plant.

RESULTS AND DISCUSSION

The infestation of sugarcane scale insect among the treatments during August and November 2014 at Faridpur Sugar Mill Farm, Faridpur was significantly different. The lowest infestation of 1.16% and 1.44% percent was found in T_6 treatment in August and November respectively during 2013-14 (table 1). In August data the treatment T_6 with sett dipping in Malathion for 15 minutes before planting + detrashing older leaves at 30 days intervals once in a month (July-October) + Chlorpyrifos (Nitro 55 EC) @ 4.0 L ha^{-1} applied in July + August + September gave the highest 81.47 percent efficacy followed by T_5 treatment with Malathion 57 EC for 15 minutes before planting + detrashing older leaves at 30 days intervals once a month (July-October) + Malathion 57 EC @ 3.5 L ha^{-1} at 76.68% against scale insect during 1st data collection on August 2014. In November data, significant difference was observed where the T_6 setts dipping in Malathion 57 EC for 15 minutes before planting + detrashing older leaves at 30 days interval once in a month (July-October) + Chlopyrifos with Cypermethrin (Nitro 55 EC) @ 4.0 L ha^{-1} applied in July + August + September provided the highest (96.10%) efficacy followed by T_7 treatment with (Nitro 55 EC) @ 4.0 L ha^{-1} showing similar efficacy of 95.42%. Treatment T_5 - setts dipping in Malathion 57 EC for 15 minutes before planting + detrashing older leaves once a month (July- October) + application of Malathion 57 EC @ 3.5 L ha^{-1} (July+ August +September) showed 88.63% efficacy. The results indicated that T_6 treatment showed more than 80% efficacy both in August and November 2014 whereas T_5 and T_7 exhibited more than 80% efficacy only in November.

Table 1. Effects of detrashing and insecticides in management of sugarcane scale insect at Faridpur Sugar Mill farm in 2014

Treatments	Percent Scale insect infestation		Pool data
	August data	November data	
T_1 – Plantation with scale insect free setts	6.04 ab (3.51)	19.76 b (46.43)	12.87 (24.94)
T_2 – Sett dipping in Malathion/Folithion for 15 minutes before plantation	4.87 ab (22.20)	12.62 bc (65.89)	8.74 (44.04)
T_3 – Detrashing of older leaves at 30 days intervals (July - October)	4.50 d (28.12)	18.69 b (49.39)	11.59 (38.75)
T_4 – T_2 + T_3	2.84 c (54.63)	11.19 bc (69.70)	7.01 (62.16)
T_5 – T_4 + Application of malathion 57 EC @ 3.50 L ha^{-1} (July + August + September)	1.46 cd (76.68)	4.20 c (88.63)	2.83 (82.66)
T_6 – T_4 + Application of (Nitro 55 EC) @ 4.0 L ha^{-1} (July + August + September)	1.16 d (81.47)	1.44 c (96.10)	1.3 (88.78)
T_7 – Application of Chlorpyrofos (Nitro 55EC) @ 4.0 L ha^{-1} (July + Aug. + Sept.)	1.66 cd (73.48)	1.63 c (95.42)	1.65 (84.45)
T_0 – Control (untreated)	6.26 a	36.93 a	21.59
LSD (0.05)	1.5408	12.297	-

Means within the same column followed by the same letter(s) are not significantly different at 5% level of LSD.
Figures in parenthesis are percent effectiveness over control.

In cropping season 2013-14 the data revealed that the yield of sugarcane was significantly different among the treatments. The highest sugarcane yield 78.79 t ha^{-1} was observed in T_6 where Chlorpyrofos + Cypermethrin (Nitro 55 EC) was applied with the treatment T_4 followed by T_7 : application of Nitro 55 EC at 75.74 t ha^{-1}, the treatment T_5 where malathion 57 EC was applied with T_4 showed the yield of 71.20 t ha^{-1} and T_4 provided 67.68 t ha^{-1} whereas lowest yield 43.05 t ha^{-1} was obtained in control plot. The yield of sugarcane in all treatment was increased over control treatment and ranged from 8.32-83.02 t ha^{-1}. The highest percent cane yield increased over control was 83.02 t ha^{-1} found in Nitro treatment together wither with T_4 followed by 75.93 t ha^{-1} when only Nitro 55 EC was applied. The lowest yield increase over control was 8.32 t ha^{-1} recorded in T_1 treatment (planting scale insect free setts plot) (table 2).

Table 2. Effects of detrashing and insecticides in management of sugarcane scale insect yield at Faridpur Sugar Mill farm in 2014

Treatments	Yield (t ha^{-1})	% Yield increase over control (t ha^{-1})
T_1 – Plantation with scale insect free setts	46.63 e	8.32
T_2 – Sett dipping in Malathion/Folithion for 15 minutes before plantation	59.17 d	37.44
T_3 – Detrashing of older leaves at 30 days intervals (July - October)	47.87 e	11.20
T_4 – T_2 + T_3	67.68 c	57.21
T_5 – T_4 + Application of malathion 57 EC @ 3.50 L ha^{-1} (July + August + September)	71.20 bc	65.39
T_6 – T_4 + Application of Nitro 55 EC @ 4.0 L ha^{-1} (July + August + September)	78.79 a	83.02
T_7 – Application of Nitro 55 EC @ 4.0 L ha^{-1} (July + August + September)	75.74 ab	75.93
T_0 – Control (untreated)	43.05 e	-
LSD (0.05)	5.81	

Means within the same column followed by the same letter(s) are not significantly different at 5% level of LSD.

During cropping season 2014-15 in August 2015 data, it was observed that there was a statistically significant difference among the treatments (table 3). The treatment (T_6 - sett treatment with Malathion 57 EC for 15 minutes + detrashing older leaves at 30 days intervals once in a month (July- October) + Nitro 55 EC @ 4.0 L ha^{-1} applied in July + August + September gave the highest (80.65%) efficacy that reached the desired level (80% and above) followed by T_8 - Cypermethrin 10 EC @ 2.0 L ha^{-1} applied in July + August + September at 70.79% efficacy against scale insect of sugarcane. Similarly in October data, The treatment T_6 - sett treatment with Malathion 57 EC for 15 minutes + detrashing older leaves at 30 days intervals once in a month (July- October) + Nitro 55 EC @ 4.0 L ha^{-1} applied in July + August + September gave the highest (80.61%) efficacy that was reached the desired level 80% and above followed by T_8 - Cypermethrin 10 EC @ 2 L ha^{-1} applied in July + August + September showed 71.78% efficacy against scale insect of sugarcane. T_6 treatment was statistically insignificant difference with T_5, T_7 and T_8 but significant with other treatments.

Table 3. Effects of detrashing and insecticides in management of sugarcane scale insect at Faridpur Sugar Mill farm, Faridpur in 2015

Treatments	Percent Scale insect infestation (mean)		Pool data
	August data	November data	
T_1 – Plantation with scale insect free setts	28.19 a (9.82)	33.55 b (27.30)	30.87 (18.56)
T_2 – Sett dipping in Malathion/Folithion for 15 minutes before plantation	16.43 b (47.44)	26.60 bc (42.36)	21.52 (44.90)
T_3 – Detrashing of older leaves at 30 days intervals (July - October)	16.84 b (46.13)*	23.60 cd (48.86)	20.22 (47.50)
T_4 – T_2 + T_3	15.51 bc (50.38)	20.25 cde (56.12)	17.88 (53.25)
T_5 – Application of malathion 57 EC @ 3.5 L ha^{-1} (July + August +Sept.)	9.13 bc (55.02)	14.14 ef (69.36)	11.64 (62.19)
T_6 – T_4 + Application of Chlorpyrofos and Cypermethrin (Nitro 55 EC) @ 4.0 L ha^{-1}(July + Aug. + Sept.)	6.05 c (80.65)	8.95 f (80.61)	7.50 (80.63)
T_7 – Application of Imidachloprid 20 SL @ 1.0 L ha^{-1} (July + August + Sept.)	11.74 bc (62.44)	16.72 def (63.77)	14.23 (63.11)
T_8 – Application of Cypermethrin 10EC @ 2.0 L ha^{-1} (July + August + Sept.)	14.06 bc (70.79)	18.10 cdef (71.78)	16.08 (71.29)
T_0 – Control (Untreated)	31.26 a	46.15 a	38.71
LSD (0.05)	9.7330	9.2712	-

Means within the same column followed by the same letter (s) are not significantly different at 5% level according to LSD test.
Figures in parenthesis are percent effectiveness over control.

The yield of cane in treated plots increased significantly compared to control (untreated) plots. Yield increase over control ranged from 17.75–29.69% (table 4). The highest yield increase of cane was 29.69% in treatment T_6 (T_4 +Application of Nitro 55EC @ 4.0 L ha^{-1}. The highest cane yield (65.04 t ha^{-1}) was obtained in treatment T_6 followed by T_8: Application of Cypermethrin 10EC @ 2.0 L ha^{-1}, T_7: Application of Imidachloprid 20 SL @ 1.0 L ha^{-1}, T_5 : Application of malathion 57 EC @ 3.5 L ha^{-1} and T_2: Sett dipping in Malathion (Fifanon) for 15 minutes before planting as 63.89, 62.43, 61.95 and 59.32 t ha^{-1} respectively. T_6 treatment was statistically insignificant with T_8: (Cypermethrin 10EC), T_7 (Imidachloprid 20 SL), T_5 (Malathion 57 EC) and T_2 (Sett dipping in Malathion) Fifanon for 15 minutes before planting treated plots but significantly difference with control (untreated plot). Whereas rest of the agronomical treatment showed T_1 (Plantation with scale insect free setts), T_3 (Detrashing of leaves at 30 days intervals) and T_4 (T_2: Sett dipping in Malathion (Fifanon) for 15 minutes before planting + T_3: Detrashing of older leaves at 30 days intervals in July + August +September) gave 61.07 t ha^{-1}, 59.19 t ha^{-1} and 59.05 t ha^{-1} respectively (table 4).

Table 4. Effects of detrashing and insecticides in management of sugarcane scale insect yield at Faridpur Sugar Mill farm, Faridpur in 2015

Treatments	Yield (t ha^{-1})	% increase over control (t ha^{-1})
T_1 – Plantation with scale insect free setts	61.07 ab	21.77
T_2 – Sett dipping in Malathion/Folithion for 15 minutes before plantation	59.32 ab	18.29
T_3 – Detrashing of older leaves at 30 days intervals (July - October)	59.19 ab	18.03
T_4 – T_2 + T_3	59.05 ab	17.75
T_5 – Application of malathion 57 EC @ 3.5 L ha^{-1} (July + August +September)	61.95 ab	23.53
T_6 – T_4 + Application of Chlorpyrofos (Nitro 55 EC) @ 4.0 L ha^{-1} (July + August +September)	65.04 a	29.69
T_7 – Application of Imidachloprid 20 SL @ 1.0 L ha^{-1} (July + August +September)	62.34 ab	24.31
T_8 – Application of Cypermethrin 10EC @ 2.0 L ha^{-1} (July + August +September)	63.89 a	27.40
T_0 – Control (Untreated)	50.15b	-
LSD (0.05)	12.212	

Means within the same column followed by the same letter(s) are not significantly different at 5% level of LSD.

Relationship between sugarcane scale insect infestations with cane yield

A positive linear relationship was obtained between percent sugarcane scale insect infestation and cane yield in the cropping season of 2013-14 (Figure 1). This suggests that cane yield is affected by scale insect infestation. Variation of more than 0.81% (R^2 = 0.813) cane yield can be explained by the level of scale insect infestation. So, it indicates that the yield of sugarcane is decreasing with increasing the scale insect infestation.

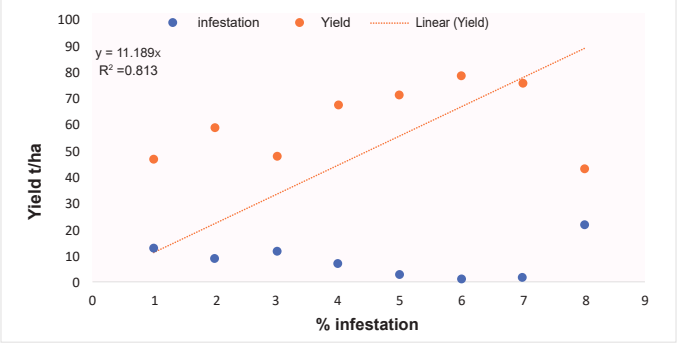

Figure 1. Relationship between sugarcane scale insect infestations and cane yield, during cropping season 2013-14

Similarly during cropping season of 2014-15 there was a positive linear relationship between the degree of scale insect infestation and the yield of sugarcane (Figure 2) indicating that the total cane yield is dependent on scale insect infestation. A variation of 0.78% (R^2 = 0.776) in the sugarcane scale insect infestation could be explained for the variation of cane yield. So, it is clear that the cane yield was decreased with the increasing infestation of sugarcane scale insect.

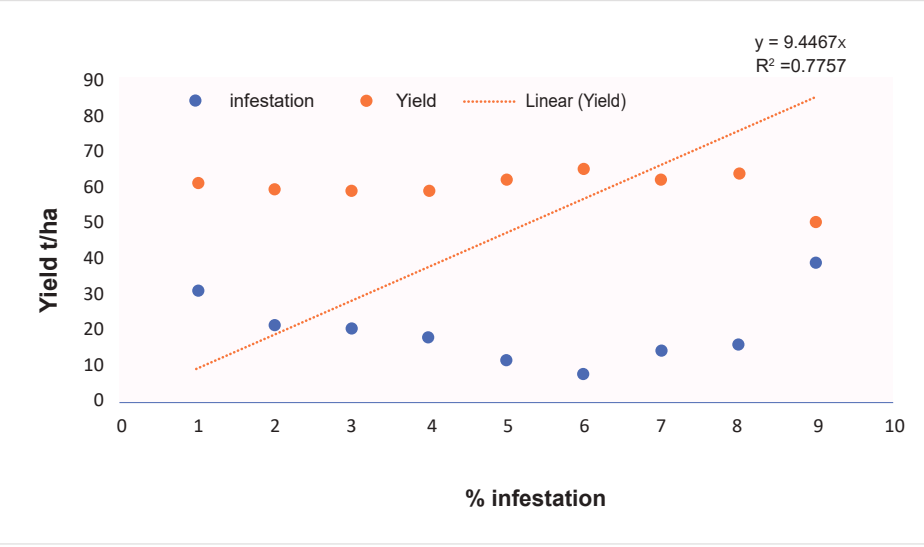

Figure 2. Relationship between sugarcane scale insect infestations and cane yield, during cropping season 2014-15

The findings of this experiment clearly establishes that application of insecticides preceded by detrashing is more effective than individual treatment in controlling of sugarcane scale insect. Sett treatment with Malathion 57 EC for 15 minutes + detrashing older leaves at 30 days intervals during (July - October) + application of Chlorpyrofos 20EC @ 4.0 L ha^{-1}/ Nitro 505 EC @ 4 L ha^{-1} in July + August + September showed more than 80% effectiveness against scale insect in both cropping season 2013-14 and 2014-15. The pooled data also revealed that this treatment provided the highest effectiveness of 88.78% and 80.63% in cropping season 2013-14 and 2014-15, respectively. The yield of sugarcane was also found as 78.79 t ha^{-1} and 65.04 t ha^{-1} in both cropping season 2013-14 and 2014-15. Bhavani (2013) mentioned that detrashing and chemical treatment combined controlled scale insect infestation effectively and increased the yield of sugarcane. This result is also in conformity with the findings of Bhavani *et al.* (2011) showing that application of insecticides preceded by detrashing older leaves in reduced the percent of scale insect infestation and increased the yield of sugarcane over control treatment From above discussion it was concluded that combined approach of mechanical and chemical should be needed for effective control the scale insect of sugarcane in the field.

REFERENCES

Agarwall, R.A.1960.The sugarcane scale, *Melanaspis glomerata* (Green), its biology and control. *Indian sug.*, **8**: 253-260 and 533-545.

Anonymous.1998. Sugarcane cultivation: Transferable Improved Technologies (in Bengali). Bangladesh Sugarcane Research Institute, Ishwardi, Pabna. Publication No. 74, p 34.

Bhavani, B. 2013. Management of sugarcane scale insect (*Melanaspis glomerata* Green) in North Coastal Region of Andhra Pradesh, *India. Int. Sugar J.*, 714-717.

Bhavani, B.; Rao, N.V.; Rao, CH.V.N. and Naidu, N.V. 2011. Integrated management of scale insect (*Melanaspis glomerata* Green) in sugarcane. Pestology, **4**: 26-29.

FRG. 2012. Fertilizer Recommendation Guide, Bangladesh Agricultural Research Council (BARC), Farmgate, Dhaka-1215. pp 172.

Khanna, K.L. 1957. On the coccid, *Melanaspis glomerata* (Green), on sugarcane in Bihar. *Indian J. Sug. Cane Res. Div.*, **11**: 19-22.

Moholkar, P.R. and Ranadive, S.J. 1973. Carryover of scale insect, *Melanaspis glomerata* G., and white grub (*Holotricha serrata* F.) in sugarcane field. *Proc. A. Conv. Deccan. Sug. Technol. Assoc.*, **25**: 45-51.

Moholkar, P.R.; Ranadive, S.J. and Jawalekar, D.V. 1973. Effects of scale insect of sugarcane on the quality and recovery of jaggery (gur). *Proc. Annu. Conv. Deccan. Sugar Technol. Assoc.*, **25**:41-44.

Prabhakara Rao K.K.; Seshagiri Rao, C.C. and Venkateswara Rao, S. 1976. Sugarcane scale, *Melanaspis glomerata* (Green), its control measures. *All India Sem. Sug. Cane Scale insect, Nidadavole.* pp. 68-73.

Rahman, A.B.M. and Pal, S.K. 2003. Sugarcane Production Technologies in Bangladesh: A Hand Book. Bangladesh Sugarcane Research Institute. Ishurdi, Pabna. pp. 54-56.

Rao, P.V. and Sankaran, T. 1969.The scale insect of sugarcane. In "Pest of sugarcane" (Williams, J.R., J.R. Metcalf. R.W. Mungomery and R. Mathes, eds.). Elsevier Publ. Co., Amsterdam. pp. 325-340.

Shukla, G.S. and. Tripathi, N.1980. Estimation of losses caused by sugarcane scale insect, *Melanaspis glomerata* (Green) (Hemiptera: Coccidae) in eastern Uttar Pradesh. *Co-or. Sug.*, **12**: 189-191.

Thontadary, T.S. and Govindan, R. 1976. Status of sugarcane scale, *Melanaspis glomerata* (Green) in northern Karnataka. *Proc. All India Sem. Sug. Cane Scale insect, Nidadavole.* pp. 42-43.

Tripathi, N. and Shukla, G.S. 1982. Effects of sugarcane scale insect, *Melanaspis glomerata* (Green) attack on the growth and diameter of sugarcane plants. *Co-op. Sug.*, **13**: 583-584.

Response of Some Sugarcane Genotypes Against Wilt Disease

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ABSTRACT

Wilt (*Cephalosporium sacchari* Butler) is one of the most destructive diseases of sugarcane in Bangladesh. Cultivation of wilt resistant varieties is only effective and economic method to control the disease. A field trial was conducted to screen 27 sugarcane genotypes against the disease in the experimental farm of Bangladesh Sugarcrop Research Institute (BSRI), Ishwardi, Pabna during the cropping season 2016-17 and 2017-18. Before planting, two budded setts were inoculated with mixed inocula of 6 different isolates of wilt pathogen following hypodermic syringe method. Among the tested genotypes 4 were grades as resistant, 17 as moderately resistant, another 4 as moderately susceptible, 1 (Isd 28) was susceptible and another 1 (Isd 18) as highly susceptible to wilt disease. The genotypes showing resistant or moderately resistant reaction to wilt disease were selected for further evaluation to develop commercial varieties.

Key words: Screening, sugarcane genotype, wilt disease

INTRODUCTION

Sugarcane is one of the most important industrial cash crops in Bangladesh. Among many causes disease play a significant role to decline the yield of sugarcane as well as sugar content. So far 40 sugarcane diseases have been recorded in Bangladesh of which wilt is considered as major one (Talukder *et al.*, 2010). There is hardly an area in Bangladesh free from wilt disease (Malek *et al.*, 1982). Its causal agent, *Cephalosporium sacchari* Butler occurs alone or frequently in association with the red rot pathogen (*Colletotichum falcatum* Went.) and hastens the deterioration of the affected canes (Ganguly, 1964). Depending on incidence of wilt, the yield reduction may go as high as 65% (Sharma, 1976). In Bangladesh Iqbal *et al.* (1988) reported that, mean reduction of nine clones on germination, millable cane and weight of canes were 12.8, 19.0 and 23.0% respectively due to wilt disease. Ratoon cane generally, ratoon cane is more vulnerable to damage by the disease compared to plant cane. The wilt disease not only reduces yield but also impairs juice quality (Anon. 1959). Wilt is mainly sett transmissible but the fungus can survive in the soil for 27-31 months (Ganguly and Chand, 1963). Since the fungus is soil and sett borne in nature, it is very difficult to control. Planting of resistant varieties instead of susceptible varieties is the most successful and reliable method to control the disease (Antoine, 1961). With this view in mind BSRI screens sugarcane genotypes regularly to develop resistant varieties for commercial cultivation. The present paper reported the results of a field trial conducted during 2016-17 and 2017-18 to develop wilt resistant sugarcane varieties for commercial cultivation.

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MATERIALS AND METHODS

A total of 27 sugarcane genotypes comprising commercial varieties, clones under zonal yield trial (ZYT) III, II, and I were tested for wilt resistance during 2016-17 and 2017-18 at BSRI farm, Ishwardi, Pabna. Apparently healthy two budded setts of each genotype were planted in single rows of 20 m length. Row to row distance was 1 m. A mixture of spore suspension (106/ml) of 6 isolates of *Cephalosporium sacchari* Butler collected from different cane growing areas of the country were used as inocula. The collected isolates were grown on Oat Meal Agar (OMA) medium for 12 days to sporulate and mixed inoculum was prepared from the fresh culture. Inoculation was done at the age of 8 months of plant in the month of September. Fifteen canes of each clone were inoculated in the middle of the third internode above the ground level following hypodermic syringe method (Hossain *et al.*, 2017). The punctured point (done by special inoculating needle, 2 cm long and 2 mm dia. was covered and wrapped by insulating tape in order to keep away from oxidation and contamination. The inoculated canes were examined by splitting longitudinally after three months of inoculation and graded according to symptomatic method for calculating disease index (Table 1).

Table 1. Criteria for determination of disease index for screening sugarcane genotypes to wilt

Sl. No.	Criteria/Characters	Numerical rating/score
1.	Lesions width above the inoculated internode (0-3)	
	a) very rare lesion or no lesion developed	0
	b) Rare lesion (1/3 or less spread of full width)	1
	c) Medium lesion (1/3rd to 2/3rd spread of full width)	2
	d) High lesion (coved the full width)	3
2.	Nodal transgression (0–3)	
	a) Lesion restricted in the inoculated internode	0
	b) One node crossed	1
	c) Two nodes crossed	2
	d) Three or more nodes crossed	3
3.	Presence of pith (0–2)	
	a) Pith/holo absent	0
	b) Pith/holo restricted	1
	c) Pith/holo progressive	2
4.	Condition of top (0–1)	
	a) Green	0
	b) Yellow/dry	1

The mean of the total numerical ratings/scores of 15 canes were taken for assessing disease index and reaction of each genotype against wilt disease was done based on following scale:

Table 2. Scoring index for determining disease reaction for screening sugarcane genotypes to wilt

Disease index (score)	Disease reaction (Grade)
0.00-2.00	Resistant (R)
2.10-4.00	Moderately Resistant (MR)
4.10-6.00	Moderately Susceptible (MS)
6.10-8.00	Susceptible (S)
Above 8.10	Highly Susceptible (HS)

RESULTS AND DISCUSSION

The results of different sugarcane genotypes in respect of their resistance/ susceptibility against wilt pathogen during the cropping season of 2016-17 and 2017-18 are presented in the Table 3. Out of 27 sugarcane genotypes, 4 were graded as resistant, 17 as moderately resistant, another 4 as moderately susceptible, 1 (Isd 28) as susceptible and another 1 (Isd 18) as highly susceptible to wilt disease. Among the 18 varieties prevailing under commercial cultivation, Isd 2-54, Isd 19, Isd 32, Isd 34, Isd 36, Isd 38, Isd 39, Isd 40, BSRI Akh 43, BSRI Akh 44, BSRI Akh 45 and BSRI Akh 46 showed resistant to moderately resistant reaction. Similar results were also reported by Hossain *et al.* (2017) and Uddin *et al.* (2013). Out of 9 clones Under ZYT III and ZYT II, 8 clones viz. I 103-10, I 7-11, I 111-11, I 230-11, I 143-12, GT-11, GT-17 showed resistant to moderately resistant reaction. During release of varieties for commercial cultivation all the varieties like Isd 16, Isd 18, Isd 28, Isd 33 and BSRI Akh 41 showed resistant to moderately resistant (MR) reaction. Presently, these are showing resistant to moderately susceptible to highly susceptible reaction. Such break down of resistance may be due to change in pathotypes (races) of the wilt pathogen and environmental factor (Hossain *et al.*, 2017 and Begum *et al.,* 2007). Similar results were also reported by Hossain *et al.* (2017), Begum *et al.* (2007), Rahman *et al.* (1984) and Malek *et al.* (1982). To cope up with this problem it is important to undertake research programmes regularly for breeding and selection of wilt resistant sugarcane varieties.

Table 3. Reaction of different sugarcane genotypes against mixed isolates of wilt pathogen causing wilt disease at BSRI farm, Ishwardi during the cropping season 2016-17 and 2017-18

Sl. No.	Varieties/Strains	Disease index against wilt pathogen at BSRI farm, Ishwardi during		Average of two years (Mean)	Disease Reaction
		2016-17	2017-18		
1.	Isd 2-54	3.30	1.80	2.55	MR
2.	Isd 16	6.30	2.70	4.50	MS
3.	Isd 18	8.90	7.40	8.15	HS
4.	Isd 19	3.70	1.60	2.65	MR
5.	Isd 28	8.70	6.70	7.70	S
6.	Isd 32	0.90	0.80	0.85	R
7.	Isd 33	6.00	3.70	4.85	MS
8.	Isd 34	2.40	2.80	2.60	MR
9.	Isd 36	3.12	2.20	2.66	MR
10.	Isd 37	3.38	2.10	2.74	MR
11.	Isd 38	5.58	2.40	3.99	MR
12.	Isd 39	1.80	1.20	1.50	R
13.	Isd 40	4.20	1.90	3.05	MR
14.	BSRI Akh 41	5.10	3.40	4.25	MS
15.	BSRI Akh 43	2.30	2.20	2.25	MR
16.	BSRI Akh 44	2.50	2.60	2.55	MR
17.	BSRI Akh 45	2.70	0.60	1.65	R
18.	BSRI Akh 46	3.00	1.30	2.15	MR
19.	I 103-10	3.60	1.40	2.50	MR
20.	I 7-11	2.70	1.90	2.30	MR
21.	I 111-11	0.51	2.00	1.26	R
22.	I 230-11	6.50	0.60	3.55	MR
23.	I 36-12	7.80	3.60	5.70	MS
24.	I 143-12	4.90	3.00	3.95	MR
25.	I 146-12	4.90	2.20	3.55	MR
26.	GT -11	5.60	2.40	4.00	MR
27.	GT-17	3.55	3.90	3.73	MR

REFERENCES

Anonymous, 1959. Ad-hoc Expert Sub-Committee of the I. C.S. C. Sugarcane Research in India. *Jour. Sug. Res. and Dev.*, **3**: 180-181.

Antoine, R. 1961. Sugarcane Disease of the world. Vol. 1 Eds. by Martin, J.P., E.V. Abott and C.G., Hughes. Elsevier Publication Co., Amsterdam. p. 326.

Begum, F.; Talukder, M.I.; Iqbal, M. and Rahman, M.A. 2007. Comparative Resistance of Thirty Sugarcane Clones to wilt Disease of Sugarcane. *Bangladesh J. Sugarcane*, **29**: 137-139.

Ganguly, A. and Chand, J.N. 1963. Longevity of *Cephalosporium sacchari* Butler causing wilt disease of sugarcane. *Sci. & Cult.*, **29**: 347-348.

Hossain, M.I.; Rahman, M.S.; Reza M.E. and Khaiyam, M.O. 2017. Screening of Some Sugarcane Genotypes to Wilt. Am. J. Plant Biol., **3** (4): 125-128.

Iqbal, M.; Rahman, S.; Nahar, S.M.N. and Kabir, A.K.M. 1988. Assessment of losses due to wilt (*Cephalosporium sacchari* Butler) in sugarcane. *Bangladesh J. Sugarcane.* **10**:55-58.

Malek, M.A.; Rahman, S. and Kamal, M.M. 1982. Relative resistance of some sugarcane varieties to wilt. *Bangladesh J. Sugarcane*, **4**: 71-74.

Rahman, S.; Malek, M.A.; Kamal, M.; S.M.N.; Talukder, I. and Kalimuddin. 1984. Resistance of Some Foreign Varietiesto Wilt of Sugarcane. *Bangladesh J. Sugarcane*, **6**: 63-64.

Sharma, M.N. 1976. Wilt disease of sugarcane. *Sugarcane Pathol. Newsl*, **15-16**: 30-33.

Talukder, M.I.; Kamal, M.M.; Iqbal, M.; Rahman, S. and Rahman, M.S. 2010.Bangladeshe Akher Rog-Balaisomuho O Tar Protikar (First Edition). A booklet in Bangla published by BSRI, Ishurdi, Pabna.

Uddin, M.J.; Talukder, M.I. and Rahman, M.S. 2013. Screening of some sugarcane genotypes to wilt. *Bangladesh J. Sugarcane*, **33-34**: 49-53.

Performance of Different Chewing cane in Selected Region of Bangladesh

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ABSTRACT

An Experiment was conducted under farmer's field at Rajshahi and Gaibandha with four chewing cane varieties genotypes namely BSRI Akh 41, BSRI Akh 42, Co 208 and local variety Turag and Q 69 during 2017-18 and 2018-19 cropping season to evaluate the performance of chewing cane. The experiment was laid out in a randomized complete block design (RCBD) with three replications. The result revealed that variety and location had a significant effect on tiller population, chewable cane, yield and brix%. At Rajshahi location among the four varieties BSRI Akh 41 and BSRI Akh 42 gave the highest number of chewable cane and yield but net return and BCR was obtained from BSRI Akh 42 and Co 208 during both years. At Gaibandha location the highest number of chewable cane was observed from Q 69 but highest yield was obtained from BSRI Akh 42. In case of economic return highest net return and BCR was obtained from BSRI Akh 42 and Q 69 at Gaibandha.

Key words: Chewing cane, yield, net return, and benefit cost ratio

INTRODUCTION

Sugarcane is a food crop as well as industrial cash crop in Bangladesh. It covers 0.18 million hectares of land with a total annual production of 3.09 million metric ton (BBS, 2022). It is the principal raw material of sugar industry and the major source of white sugar and gur (jaggery) production and chewing purposes in Bangladesh. Currently, on an average, sugarcane is grown in 0.10 million hectare of land of which almost 50% is located in the mill zones, where sugarcane is mostly utilized for sugar production and remaining 50% is situated in the non-mill zone, which is used for gur and chewing purpose (Rahman, *et al.*, 2016). The highest contribution comes from jaggary sector (0.39%) followed by sugar (0.15%), chewing and juice (0.04%), seed (0.03%), cattle feed and fuel (0.03%) and by-product (0.03%) respectively (Rahman and Mondal, 2010).

In 2018-19 on an average 3.92 million metric tons (MMT) of sugarcane is being produced in Bangladesh. Out of it 1.18 (30.11%) MMT are used by sugar mills to produce 0.068 MMT of sugar and 2.11 (53.83) MMT are used to produce 0.21 MMT of gur and remaining 0.63 (16.06%) MMT are used for seed and chewing purposes (Anonymous, 2019). Sugarcane is a long duration crop which requires 12-14 months to maturing

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(Yadava, 1993). Sugarcane was originally grown for the sole purpose of chewing in southern Asia and Pacific. Naidu (1987) reported that sugarcane was primarily grown for chewing and livestock feed. Most of the farmers of Bangladesh are marginal and they deserve economic return from their crop within short period. BSRI developed latest cane varieties demonstrates short duration, better yield and high market value which may result in encouraging economic benefit for the farmers. As the demand of chewing cane is increasing day by day so, there is huge scope to expand the area under chewing cane cultivation in Bangladesh particularly in the non-mill zone area.

Development of high yielding varieties and their performance evaluation at farmer's field is a continuous process for greater adoption and increasing sugarcane production in the country. In Rajshahi and Gaibandha region there is a scope for up scaling sugarcane production with BSRI developed short duration and high yielding cane varieties. Regarding these contexts the present study was undertaken to find out the location specific suitable chewing cane varieties for wide scale cultivation in different region of Bangladesh.

MATERIALS AND METHODS

The experiment was conducted in farmer's field at Rajshahi and Gaibandha during the cropping season 2017-18 and 2018-19 respectively. The experimental plot represents the High Ganges River Floodplain and Active Brahmaputra-Jamuna Floodplain under Agro Ecological Zones 11 and 7 with medium high land of sandy loam soil with pH 7.2-7.6. The experiment comprised of four treatments i.e. four varieties of chewing sugarcane viz. BSRI Akh 41, BSRI Akh 42, Co 208 and local variety Turag and Q 69. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Conventional two budded sett was used as planting material for each variety in this experiment. Row to row distance was 150 cm and sett placement method was end to end. Fertilizers were applied @ 340, 250, 290, 190 and 10 kg ha^{-1} as Urea, TSP, MoP, Gypsum and Zinc Sulphate respectively. One third Urea and MoP and full quantity of other fertilizers were applied in trench during the time of plantation. The remaining Urea and MoP were applied in two equal splits at 90 and 135 days after planting. Irrigation was applied 5 times at germination, tillering and stem elongation stage. Other intercultural operations (weeding, mulching, earthing up, tying etc) were done as and when required. No. of tiller of chewing cane was recorded at 90, 120 and 150 days after planting. Number of chewable cane ha^{-1} stalk height, number of internodes $stalk^{-1}$, stalk diameter, single cane weight, yield and brix % were recorded at harvest. In 2017-18 cropping season, cane was harvested on 20 and 26 September 2018 at Rajshahi and Gaibandha respectively. In 2018-19 cropping season, cane was harvested on 23 and 28 August 2019 at Rajshahi and Gaibandha respectively. The collected data were analyzed by using the analysis of variance (ANOVA) technique with Statistic 10 software package and the mean differences were compared by least significant differences (LSD) at 5% Level of probability (Gomez and Gomez, 1984).

For estimating Gross Return, Net Return, Benefit Cost Ratio (BCR) the following formula were used (CIMMYT,1998).

Gross Return = Yield x Sale price

Net Return = Gross Return – Total cost

$$\text{Benefit Cost Ratio (BCR)} = \frac{\text{Gross return}}{\text{Total Cost}}$$

RESULTS AND DISCUSSION

Growth parameters of chewing cane

The growth parameters of different chewing cane varieties such as stalk height (m), cane diameter (cm), no. of internodes stalk^{-1}, single cane weights (kg) at Rajshahi and Gaibandha location during two consecutive years (2017-18 and 2018-19) are presented in Table 1 & Table 2. The highest stalk height was found from BSRI Akh 41 (3.28 and 3.13 m) which was statistically similar with BSRI Akh 42 (3.17 and 3.18 m) at Rajshahi during two consecutive years. The lowest stalk height was observed in Co 208 (2.97 and 2.90 m) and local variety Turag (2.93 and 2.78 m). The highest cane diameter (2.78 and 2.70 cm) was found in BSRI Akh 42 which was significantly higher than other varieties and the lowest cane diameter (2.23 and 2.13 cm) was observed in local variety Turag. The highest no. of internodes stalk^{-1} was recorded from BSRI Akh 41 (25.33) which was statistically similar with BSRI Akh 42 (25.00). The lowest no. of internodes stalk^{-1} was noted in Co 208 (20.00). The variety BSRI Akh 42 exhibited significantly higher single cane weight (2.65 and 2.52 kg) during the studied years while the lowest single cane weight (1.77 and 1.60 kg) was measured from local variety Turag which was statistically similar with BSRI Akh 41 and Co 208.

The results showed that BSRI Akh 42 demonstrated the highest cane weight during the successive years at Rajshahi might be the reason of the cumulative positive effect of yield contributing traits like stalk height, cane diameter and no. internode stalk^{-1}. The results are in agreement with the findings of Khan *el al.* (2003) who reported that increase in cane yield might due to maximum plant height, weight per stool and cane girth. Javed *et al.* (2002) also expressed that cane yield per hectare depend upon number of stalks per hectare and weight per stalk. Weight per stalk consequently depends upon stalk length and stalk girth.

Table 1. Growth attributes of different chewing varieties at Rajshahi during 2017-18 and 2018-19 cropping season

Treatments	Stalk Height (m)		Cane diameter (cm)		No. of internode stalk^{-1} (no.)		Single cane weight (kg)	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
BSRI Akh 41	3.28 a	3.13 a	2.50 b	2.55 b	25.33 a	25.00 a	1.90 b	1.97 b
BSRI Akh 42	3.17 a	3.18 a	2.78 a	2.70 a	25.00 a	24.33 a	2.65 a	2.52 a
Co 208	2.97 b	2.90 b	2.43 b	2.38 c	20.00 c	19.67 c	1.87 b	1.83 bc
Turag (Local variety)	2.93 b	2.78 b	2.23 c	2.13 d	22.00 b	21.67 b	1.77 b	1.60 c
LSD (0.05)	0.05	0.07	0.07	0.04	0.78	0.61	0.22	0.13
CV %	0.12	0.18	0.17	0.12	1.91	1.49	0.54	0.31

At Gaibandha location the highest stalk height was found from BSRI Akh 41 (2.92 and 3.00 m) which was statistically similar with BSRI Akh 42 (2.82 and 3.03 m) during two consecutive years. The lowest stalk height was observed in Co 208 (2.23 and 2.50 m). The highest cane diameter (2.57 and 2.68 cm) was attained from BSRI Akh 42 which was significantly different from the other varieties. However the result indicated that though popular varieties BSRI Akh 41 and BSRI Akh 42 showed similar stalk height, BSRI Akh 42 showed relatively higher cane diameter as compared to BSRI Akh 41. The lowest cane diameter (2.07 and 1.97 cm) was recorded in Co 208. BSRI Akh 41 showed maximum no. of internodes stalk^{-1} (23.33 and 25.33) which was more or less similar to BSRI Akh 42 (21.67 and 24.00) during two successive years. The lowest no. of internodes stalk^{-1} was found from Co 208 (18.33 and 20.00). The maximum single cane weight (2.52 and 2.63 Kg) was attained from BSRI Akh 42 which was significantly higher than other studied varieties. However, BSRI Akh 41 was also showed better single cane weight (2.02 and 2.10 kg) next to BSRI Akh 42. The lowest single cane weight was found in Co 208 (1.20 and 1.53 kg).

Table 2. Growth attributes of different chewing varieties at Gaibandha during 2017-18 and 2018-19 cropping season

Treatments	Stalk Height (m)		Cane diameter (cm)		No. of internode stalk^{-1} (no.)		Single cane weight (kg)	
	2017-18	2018-19	2017-18	2018-19	23.33 a	2018-19	2017-18	2018-19
BSRI Akh 41	2.92 a	3.00 a	2.37 b	2.47 b	21.67 b	25.33 a	2.02 b	2.1 b
BSRI Akh 42	2.82 ab	3.03 a	2.57 a	2.68 a	18.33 c	24.00 a	2.52 a	2.63 a
Co 208	2.23 c	2.50 c	2.07 d	1.97 c	21.00 b	20.00 c	1.20 d	1.53 c
Q 69 (Local variety)	2.75 b	2.70 b	2.23 c	2.13 c	0.65	22.00 b	1.60 c	1.70 c
LSD (0.05)	0.06	0.07	0.05	0.08	1.60	0.78	0.08	0.16
CV %	0.15	0.17	0.12	0.20	23.33 a	1.91	0.20	0.38

Yield and yield attributes of sugarcane

Yield and yield contributing characters of chewing cane at Rajshahi and Gaibandha location during two successive years (2017-18 and 2018-19) are presented in Table 3 and Table 4.

During 2017-18 cropping season at Rajshahi the highest number of tiller was obtained from BSRI Akh 41 (175.89 $\times 10^3$ ha^{-1}) followed by local variety turag (173.09$\times 10^3$ ha^{-1}), BSRI Akh 42 (172.39$\times 10^3$ ha^{-1}) and the lowest number of tiller was obtained from Co 208 (161.93$\times 10^3$ ha^{-1}). Alam *et al.* (2006) and Rashid *et al.* (2001) reported that there was a variation in tiller population among different varieties. The highest number of chewable cane was observed from BSRI Akh 41 (82.03 $\times 10^3$ ha^{-1}) which was statistically similar with BSRI Akh 42 (80.72 $\times 10^3$ ha^{-1}) and lowest number of chewable cane was observed in Co 208 (67.56 $\times 10^3$ ha^{-1}). The highest cane yield was recorded from BSRI Akh 42 (172.39 tha^{-1}) which was statistically different from others and the lowest cane yield was recorded from local variety Turag (109.04 tha^{-1}). Variation among the sugarcane varieties in respect of cane yield have also been reported by Singh *et al.* (1999), Bahadar *et al.* (2001) and Jamil *et al.* (2007). The highest Brix (%) was found from BSRI Akh 42 (15.20) which was statistically different from others and the lowest Brix (%) was found from Co 208 (13.53) which was statistically similar with local variety turag (13.7).

In 2018-19 cropping season at Rajshahi the highest number of tiller was obtained from BSRI Akh 41 (180.98 $\times 10^3$ ha^{-1}) followed by BSRI Akh 42 (173.41$\times 10^3$ ha^{-1}), local variety Turag (168.45$\times 10^3$ ha^{-1}) and the lowest number of tiller was obtained from Co 208 (163.21$\times 10^3$ ha^{-1}) which was statistically different from others. The highest number of chewable cane was observed from BSRI Akh 41 (82.04$\times 10^3$ ha^{-1}) which was statistically similar with BSRI Akh 42 (81.08$\times 10^3$ ha^{-1}). The lowest number of chewable cane was observed in Co 208 (68.26$\times 10^3$ ha^{-1}). The highest cane yield was recorded from BSRI Akh 42 (170.27 tha^{-1}) which was significantly different from others varieties/line. The lowest cane yield was attain from Turag (111.65 tha^{-1}). The similar result was demonstrated by Alam *et al.* (2011) in their study. The highest Brix (%) was found from BSRI Akh 42 (14.97) which was significantly different from others and the lowest Brix(%) was found from Co 208 (13.53) which was statistically similar with local variety turag (13.90). The similar result was reported by Sohel *et al.* (2009).

Table 3. Effect of varieties on tiller, chewable cane, yield, return and brix % at Rajshahi during 2017-18 and 2018-19 cropping season

Treatments	Tiller ($\times10^3$ ha^{-1})		Chewable cane ($\times10^3$ ha^{-1})		Yield (t ha^{-1})		Brix %	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
BSRI Akh 41	175.89 a	180.98 a	82.03 a	82.04 a	143.51 b	147.68 b	14.47 b	14.43 b
BSRI Akh 42	172.39 b	173.41 b	80.72 a	81.08 a	169.52 a	170.27 a	15.20 a	14.97 a
Co 208	161.93 c	163.21 d	67.56 c	68.26 c	121.61 c	122.87 c	13.53 c	13.53 c
Turag (Local variety)	173.09 b	168.45 c	72.69 b	72.03 b	109.04 d	111.65 d	13.70 c	13.90 c
LSD (0.05)	1.14	1.66	0.92	1.29	1.58	2.37	0.30	0.16
CV %	2.79	4.07	2.24	3.16	3.87	5.80	0.73	0.39

During 2017-18 cropping season at Gaiandha, the highest number of tiller was obtained from local variety Q 69 (186.33 $\times10^3$ ha^{-1}) which was followed by BSRI Akh 41 (173.67 $\times10^3$ ha^{-1}), BSRI Akh 42 (167.67$\times10^3$ ha^{-1}) and the lowest number of tiller was obtained from Co 208 (159.00 $\times10^3$ ha^{-1}). The highest number of chewable cane was obtained from local variety Q 69 (93.67 $\times10^3$ ha^{-1}) which was followed by BSRI Akh 41 (84.00 $\times10^3$ ha^{-1}), BSRI Akh 42 (76.67 $\times10^3$ ha^{-1}) and the lowest number of chewable cane was observed from Co 208 (65.33 $\times10^3$ ha^{-1}). The highest cane yield was recorded from BSRI Akh 42 (145.67 $\times10^3$ ha^{-1}) followed by BSRI Akh 41 (134.40 $\times10^3$ ha^{-1}), Q 69 (117.08 $\times10^3$ ha^{-1}) and the lowest cane yield was recorded from Co 208 (78.40 $\times10^3$ ha^{-1}). The highest Brix (%) was found from Q 69 (15.83) followed by BSRI Akh 42 (14.30), BSRI Akh 41 (13.23) and the lowest Brix (%) was found from Co 208 (12.10).

In 2018-19 cropping season at Gaiandha the highest number of tiller was obtained from local variety Q 69 (188.58 $\times10^3$ ha^{-1}) which was statistically different from others followed by BSRI Akh 41 (173.00 $\times10^3$ ha^{-1}), BSRI Akh 42 (165.33 $\times10^3$ ha^{-1}) and the lowest number of tiller was obtained from Co 208 (150.67 $\times10^3$ ha^{-1}). The highest number of chewable cane was observed from local variety Q 69 (94.77 $\times10^3$ ha^{-1}) which was statistically different from others followed by BSRI Akh 41 (84.07 $\times10^3$ ha^{-1}), BSRI Akh 42 (77.90 $\times10^3$ ha^{-1}) and lowest number of chewable cane was observed in Co 208 (65.79 $\times10^3$ ha^{-1}). The highest cane yield was recorded from BSRI Akh 42 (155.81 $\times10^3$ ha^{-1}) followed by BSRI Akh 41 (142.92 $\times10^3$ ha^{-1}), Q 69 (118.47 $\times10^3$ ha^{-1}) and the lowest cane yield was noted in Co 208 (82.65 $\times10^3$ ha^{-1}). The similar result was demonstrated by Alam *et al.* (2011) in their study. The highest Brix (%) was found from Q 69 (15.97) followed by BSRI Akh 41 (14.20), BSRI Akh 42 (14.10) and the lowest Brix (%) was found from Co 208 (12.17). The result is in agreement with the findings of Sohel *et al.* (2009).

Table 4. Effect of varieties on tiller, chewable cane, yield, return and brix % at Gaibanda during 2017-18 and 2018-19 cropping seasons

Treatments	Tiller ($\times10^3$ ha^{-1})		Chewable cane ($\times10^3$ ha^{-1})		Yield (t ha^{-1})		Brix %	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
BSRI Akh 41	173.67 b	173.00 b	84.00 b	84.07 b	134.40 b	142.92 b	13.23 c	14.20 b
BSRI Akh 42	167.67 c	165.33 c	76.67 c	77.90 c	145.67 a	155.81 a	14.30 b	14.10 b
Co 208	159.00 d	150.67 d	65.33 d	65.79 d	78.40 d	82.65 d	12.10 d	12.17 b
Turag (Local variety)	186.33 a	188.58 a	93.67 a	94.77 a	117.08 c	118.47	15.8 a	15.97 a
LSD (0.05)	2.34	2.83	1.73	2.00	2.64	3.02	0.26	0.20
CV %	5.59	6.91	4.23	4.90	6.46	7.39	0.63	0.50

Table 5. Economic return of chewing cane at Rajshahi during 2017-18 & 2018-19 cropping season

Treatments	Chewable cane ($\times10^3$ ha^{-1})		Cost of production (Tk. $\times10^3$ ha^{-1})		Gross Return (Tk $\times10^3$ ha^{-1})		Net Return (Tk $\times10^3$ ha^{-1})		BCR	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
BSRI Akh 41	82.03	82.04	310.00	310.00	820.0	825.35	510.00	510.4	2.64	2.66
BSRI Akh 42	80.72	81.08	375.00	375.00	1291.52	1297.28	916.52	922.28	3.44	3.46
Co 208	67.56	68.26	310.00	310.00	878.28	887.38	568.28	577.38	2.83	2.86
Q 69 (Local variety)	72.69	72.03	285.00	285.00	581.52	576.24	296.52	291.24	2.04	2.02

Single stalk price: BSRI Akh 41= 10 Tk, BSRI Akh 42= 16 Tk, Co 208= 13 Tk, Turag = 08 Tk

The cost and return analysis of chewing cane was calculated and presented in Table 5 & 6. During 2017-18 cropping season at Rajshahi the highest net return (916.52×10^3 Tk. ha^{-1}) and BCR (3.44) was obtained from BSRI Akh 42 followed by Co 208 with net return (568.28×10^3 Tk. ha^{-1}) and BCR (2.83) and BSRI Akh 41 with net return (510×10^3 Tk. ha^{-1}) and BCR (2.64). The lowest net return (296.52×10^3 Tk. ha^{-1}) and BCR (2.04) was recorded from local variety Turag.

During 2018-19 cropping season at same location the highest net return (922.28×10^3 Tk. ha^{-1}) and BCR (3.46) was obtained also from BSRI Akh 42 followed by Co 208 with net return (577.38×10^3 Tk. ha^{-1}) and BCR (2.86) and BSRI Akh 41 with net return (510.4×10^3 Tk. ha^{-1}) and BCR (2.66). The lowest net return (296.52×10^3 Tk. ha^{-1}) and BCR (2.02) was recorded from local variety Turag. The similar result was observed by Rashid *et al.* (2017).

Table 6. Economic return of chewing cane at Gaibandha during 2017-18 & 2018-19 cropping season

Treatments	Chewable cane ($\times 10^3$ ha^{-1})		Cost of production (Tk. $\times 10^3$ ha^{-1})		Gross Return (Tk $\times 10^3$ ha^{-1})		Net Return (Tk $\times 10^3$ ha^{-1})		BCR	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
BSRI Akh 41	84.00 b	83.50	290.00	290.00	588.00	584.5	298.00	294.5	2.03	2.01
BSRI Akh 42	76.67 c	73.55	330.00	330.00	1150.05	1103.25	820.05	773.25	3.48	3.34
Co 208	65.33 d	66.48	290.00	290.00	522.64	531.84	232.64	241.84	1.80	1.83
Q 69(Local variety)	93.67 a	95.89	295.00	295.00	655.69	671.23	360.69	376.23	2.22	2.28

Single stalk price: BSRI Akh 41= 07 Tk, BSRI Akh 42 =15 Tk, Co 208= 08 Tk, Q 69= 07 Tk

During 2017-18 cropping season at Gaibandha the highest net return (820.0 $\times 10^3$ Tk. ha^{-1}) and BCR (3.48) was obtained from BSRI Akh 42 followed by local variety Q 69 with net return (360.69 $\times 10^3$ Tk. ha^{-1}) and BCR (2.22) and BSRI Akh 41 with net return (298.00 $\times 10^3$ Tk. ha^{-1}) and BCR (2.03). The lowest net return (2$\times 10^3$ Tk. ha^{-1}) and BCR (1.8) was recorded from Co 208.

During 2018-19 cropping season at same location the highest net return (773.25$\times 10^3$ Tk. ha^{-1}) and BCR (3.34 $\times 10^3$ Tk. ha^{-1}) was obtained also from BSRI Akh 42 followed by local variety Q 69 with net return (376.23$\times 10^3$ Tk. ha^{-1}) and BCR (2.28) and BSRI Akh 41 with net return (294.5$\times 10^3$ Tk. ha^{-1}) and BCR (2.01). The lowest net return (241.84 $\times 10^3$ Tk. ha^{-1}) and BCR (1.83) was recorded from Co 208. The similar result was observed by Rashid *et al.* (2017).

The results revealed that var. BSRI Akh 42 performed better performance regarding yield and economic return in both locations during two consecutive years. At Rajshahi, BSRI Akh 42, Co 208 and BSRI Akh 41 performed better during 2017-18 and 2018-19 cropping seasons. At Gaibandha, BSRI Akh 42 and local variety Q 69 gave highest net return and BCR during both the years.

REFERENCES

Alam, M.J.; Rahman, M.K.; Kabir, M.L.; Hossain, M.S. and Islam, A.K.M.R. 2006. Comparative performance of newly released sugarcane varieties in southern region of Bangladesh. *Bangladesh J. Sugarcane*, **28**: 14-18.

Alam, M.N.; Rashid, M.A.; Akter S.; Sohel, M.A.T. and Islam, N. 2011. Selection of sugarcane clone as chewing cane. *Bangladesh J. Sugarcane*, **32**: 93-97.

Anonymous. 2019. Unpublished report of Department of Agricultural Extension (DAE), Dhaka.

Bahadar, K.; Baloch, M.S.; Suleman, H. and Aminullah, K. 2001. Ratooning capacity in some promising sugarcane genotypes, *Pak. J. Bio. Sci.*, **6**: 425-426.

BBS. 2022. Year Book of Agricultural Statistics of Bangladesh, Ministry of Planning, Government of the People's of Bangladesh. Dhaka, Bangladesh.

CIMMYT. 1988. From Agronomic Data to Farmers Recommendations: An Economics Training Manual. Completely revised edition. Mexico.D.F.

FAOSTAT. 2013. Food and Agricultural Organization of the United Nations: Economics and Social Department: The Statistical Division.

Gomez, K.A. and Gomez, A.A. 1984. Statistical procedure for agricultural research. International Rice Research Institute. John Wiley and Sons. New York Chickester, Brisane, Toronto, Singapur. pp. 1-340.

Jamil, M.; Afgan, S.; Majid, M.A. and Rasool, A. 2007. Ratooning performance of different sugarcane varieties. *Pak. Sugar J.*, **22** (3): 38-47.

Javed, M.A.; Khatri, A.A.; Khan, I.A.; Ansari, R.; Siddiqui, M.A.; Bahar, N.A.; Khanzada, M.H. and Khan, R. 2002. Comparative performance of elite sugarcane clones for yield and quality characteristics. *Pakistan Sugar J.*, **17**: 71-75

Khan, M.A.; Keerio, H.K.; Junejo, S.; Panhwar, R.N.; Rajput, M.A.; Memon, Y.M. and Qazi, B.R. 2003. Evaluation of new sugarcane genotypes developed through fuzz. Correlation of cane yield and yield components. *Pak. J. Applied Sci.*, **3** (4): 270-273.

Naidu, K.M. 1987. Potential yield in sugarcane and it's realization through variety improvement. pp.1-17 in sugarcane varietal improvement (M.K. Naidu, J.V. Shreenivasan and M.N. Premachandran, eds.). Sugarcane Breeding Institute, Coimatore, India.

Rahman, M.M. and Mondal, M.R.I. 2010. Agricultural Research Priority: Vision-2030 and Beyond. Final Report, Bangladesh Agricultural Research Council, New Airport Road, Farmgate, Dhaka-1215, Bangladesh.

Rahman, M.S.; Khatun, S. and Rahman, M.K. 2016. Sugarcane and sugar industry in Bangladesh: An overview. *Sugar Tech.*, **18** (6): 627-635.

Rashid, M.H.; Quddus, M.A.; Rashid, M.A. and Elahi, N.E. 2001. Performance of modern sugarcane varieties for gur production in Modhupur Tract Soils. *Bangladesh J. Sugarcane*, **23** : 57-60.

Rashid, M.A.; Akter S.; Sohel, M.A.T. and Islam, N. 2011. Selection of sugarcane clone as chewing cane. *Bangladesh J. Sugarcane*, **32**: 93-97.

Rashid, M.M.; Alam, M.J.; Islam, M.S.; Hossain, M.S. and Islam, M.R. 2017. Performance of chewing sugarcane genotypes in old Himalayan piedmont plain soil. *Bangladesh J. Sugarcane*, **38**: 80-85.

Singh, J.P.R.; Singh, U.P. and Kumar, S. 1999. Performance of mid late sugarcane varieties of north central zone in Calciorthents soil of Bihar. *Indian Sugar*, **49** (6): 411-413.

Sohel, M.A.T.; Rashid, M.A.; Alam, M.N.; Karim, K.M.R and Podder, B.P. 2009. Performance of chewing type sugarcane genotypes under AEZ 28. *Bangladesh J. Sugarcane*, **31**: 65-68.

Yadava, R.L. 1993. Agronomy of Sugarcane. International Book.

Performance of Promising Sugarcane Clones in Different Agro-Ecological Zones under Farmers' Condition

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ABSTRACT

Quality of genotype has pivotal role in determining the cane and sugar yield of sugarcane. The inherent yield potential of a genotype is of prime importance for sustaining higher production. An experiment was conducted under farmer's field at Thakurgaon, Rajshahi, Chuadanga, Jamalpur and Joypurhat during 2017-2018 cropping season to evaluate the performance of promising sugarcane clones in different Agro-Ecological Zones (AEZ) under farmer's field. Four sugarcane clones viz. I 07-11, I 111-11, I 85-10 and I 118-10 along with variety Isd 39 as check were included as factor one and five different locations were considered as factor two. The experiment was laid out in a randomized complete block design (RCBD) with three replications. The result revealed that both clones/variety and different locations had a significant effect on all parameters like tiller population, millable cane, yield and Brix (%). Among the clones and variety the highest millable cane (113.44x10^3 ha^{-1}) and Brix (%) (20.13) was obtained from variety Isd 39 which was significantly higher than the clones employed in the study. The highest number of tiller (208.18 x 10^3 ha^{-1}) was found from clone I 111-11 which was statistically at par with other clones and variety except I 07-11. Among the five different locations, the highest number of tiller (274.47 x 10^3 ha^{-1}), millable cane (136.90 x 10^3 ha^{-1}) and yield (103.43 t ha^{-1}) was found at Chuadanga where as the highest Brix % (20.15) was observed at Thakurgaon. Considering the yield attributes and yield variety Isd 39 exhibited better performance as compared to the tested clones.

Key words: Sugarcane, Clone, Performance, Farmers' Condition

INTRODUCTION

Sugarcane is an important cash crop in Bangladesh. In 2016-2017 season 3.86 million metric tons of sugarcane was produced from 0.092 million hectares of land in Bangladesh (BBS, 2017). The total production of sugar was 0.07 million tons and *gur* was about 0.4 million tons in 2010-2011 and the country imported 1.35 million tons of sugar (Patil and Patil, 2011). The minimum per capita consumption of sugar should be 13.0 kg or its equivalent quantity of 17.0 kg 'jaggery'. The total requirement of sugar is 1.95 million tons or 2.55 million tons of jaggery based on 150 million populations in the country (Patil and Patil, 2011). Our total production of sugar/jaggery is only 0.70 million ton (Patil and Patil, 2011). Therefore, there is a big gap of 1.25 million tons of sugar/jaggery in the country. In addition, presently average cane yield in Bangladesh is

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around 46 t ha^{-1} with average recovery of sugar is around 7.0 %, which is quite low in comparison to other sugarcane growing countries. To fulfill the requirements, the country needs to import 1.3 million metric tons of sugar at the cost of hard earned foreign exchange. Development of location specific variety is useful tool for increasing sugarcane production as well as sugar yield. The varieties developed by Bangladesh Sugarcrop Research Institute do not perform equally in all agro-ecological zones (Miah *et al.*, 1994). The sugarcane yield of a particular variety depends upon the heredity potential of the genotype and the environment where it is exposed during the course of its life cycle. Variety of a crop plays an important role as regards to the yield and quality, sugarcane is no exception (Anon. 1978).

Sugar industries in Bangladesh continuously searching for high yielding and high sugar content varieties. After a considerable period of cultivation sugarcane varieties show a tendency to decline in yield and vigor (Barnes, 1954 and Humbert, 1959). The solution to the problem of low sugarcane yield and sugar recovery can be resolved to some extent by planting newly developed advanced sugarcane varieties (Chattha *et al.*, 2006). Significant efforts are being made to increase the cane production by introducing high yielding varieties along with the adoption of improved crop production techniques (Gill, 1995). Similarly, selection of a proper variety to be planted in a particular agro-ecological zone is prerequisite to explore its quantitative and qualitative characteristics (Hassan *et al.*, 2017). So, the evaluation of the yield and quality performance of promising sugarcane varieties/clones under the agro-climatic conditions of sugarcane growing zone in Bangladesh is deemed imperative. To maintain high yielding, it is necessary to replace varieties every few years with new clones (Poehlman and Barthakur, 1959). Yield trial of newly developed promising clones in the different agro-ecological zones especially in the farmer's field before releasing as varieties for commercially cultivation is very essential. So it is necessary to ensure the performance of a promising clone in particular locations before recommendation. Performance of promising clones under farmers condition is required to be submitted the National Seed Board (NSB) for approval as variety and eventual commercial cultivation. So, the present study was undertaken to ascertain the performance of promising clones as per requirement of NSB for releasing a new variety which will mitigate the need of farmers and sugar industry.

MATERIALS AND METHODS

The experiment was conducted at five locations viz. Thakurgaon (AEZ 1), Jamalpur (AEZ 9), Chuadanga (AEZ 11), Rajshahi (Barind Tract, AEZ 26) and Joypurhat (AEZ 3) during the cropping season 2017-2018. It was factorial experiment. Four sugarcane clones along with one standard variety (check) were included as factor one and five different locations were considered as factor two. The treatments were composed as below:

T_1: I 07-11
T_2: I 111-11
T_3: I 85-10
T_4: I 118-10
T_5: Isd 39 (standard)

The experiment was laid out in a randomized complete block design (RCBD) with three replications. Each location was divided into 15 unit plots where the treatment combinations were allocated at random. There were altogether 75 plots in the experiment. The unit plot size was 8m x 6m where row-to-row distance maintained 1 meter. The experiment was established from first week to fourth week of November 2017 in all the locations following STP (Poly bag settling) method. Urea, Triple Super Phosphate (TSP), Muriate of Potash (MoP) and Gypsum were used as the source of N, P, K and S, respectively. All fertilizers were applied as per BARC fertilizer recommendation guide, 2012. Full amount of TSP, Gypsum and one third of MoP were applied in trenches and thoroughly mixed with soil prior to settlings plantation. One third of Urea was applied as side dressing at 21 days after transplanting. The rest of MoP and Urea were applied in two equal splits at early tillering stage and late tillering phase of sugarcane. Intercultural operations were done when required. Data on different parameters were taken in the month of February, March, May, September, December and January. The cane at different locations was harvested from December 2018 to January 2019. Statistical analysis were done with Statistix 10 software and mean values were compared using Least Significant Difference (LSD) at 5% level of probability (Gomez and Gomez,1984).

RESULTS AND DISCUSSION

Number of Tillers

Tillering is one of the most fundamental characters of sugarcane which is widely admired by the farmers. Increased number of tillers leads to obtain enhanced cane yield and better ratooning ability of the crop (Islam *et al.*, 2016). Significant difference in tiller population was observed among the clones and variety. From table 1 it was observed that the highest tiller population was obtained from clone I 111-11 (208.18 x 10^3 ha^{-1}) which was significantly different from clone I 07-11. The lowest tiller population was observed from clone I 07-11 (190.30 x 10^3 ha^{-1}), which was statistically similar with clone I 85-10 (199.49 x 10^3 ha^{-1}) and clone I 118-10 (197.68 x 10^3 ha^{-1}). Variation in tiller production among the different clones/varieties was reported by Miah *et al.* (1994) and Rashid *et al.* (2001).

Table 1. Effect of clones/varieties on tiller, millable cane, yield and brix % of sugarcane

Clones/Variety	Tiller (x 10^3 ha^{-1})	Millable Cane (x 10^3 ha^{-1})	Yield (tha^{-1})	Brix (%)
T_1: I 07-11	190.30 b	97.41 c	83.18 b	19.19 b
T_2: I 111-11	208.18 a	102.74 b	97.01 a	19.03 bc
T_3: I 85-10	199.49 ab	101.36 bc	96.76 a	19.30 b
T_4: I 118-10	197.68 ab	105.15 b	94.10 a	18.33 c
T_5: Isd 39	202.31 a	113.44 a	99.60 a	20.13 a
LSD (0.05)	11.07	5.25	5.66	0.77

Figures in a column having the same letter do not differed significantly as per LSD.

A significant difference in tiller population was observed in different locations (Table 2). The highest tiller was found at Chuadanga (274.47 x 10^3 ha^{-1}), which was statistically different from other locations and followed by Thakurgaon (223.40 x 10^3 ha^{-1}), Joypurhat (216.19 x 10^3 ha^{-1}) and Rajshahi (164.46 x 10^3 ha^{-1}), while the lowest tiller population was obtained at Jamalpur (119.44 x 10^3 ha^{-1}) which was also statistically different with other location.

Table 2. Effect of different locations on tiller, millable cane, yield and brix % of sugarcane

Locations	Tiller (x 10^3 ha^{-1})	Millable Cane (x 10^3 ha^{-1})	Yield (tha^{-1})	Brix (%)
Rajshahi	164.46 c	83.66 bc	89.28 cd	19.11 b
Jamalpur	119.44 d	80.61 c	84.77 d	18.89 b
Thakurgaon	223.40 b	131.87 a	93.81 bc	20.15 a
Chuadanga	274.47 a	136.90 a	103.43 a	17.89 c
Joypurhat	216.19 b	87.04 b	99.43 a	19.93 a
LSD (0.05)	11.07	5.25	5.66	0.77

Figures in a column having the same letter do not differed significantly as per LSD.

Tiller population was significantly influenced by the interaction effect of clones/variety and different locations. The highest tiller population was observed from clone I 118-10 at Chuadanga (292.11x 10^3 ha^{-1}), which was statistically at par with clone I 111-11, I 07-11 and variety Isd 39 at the same location. Clone I 85-10, I 118-10 and I 111-11 performed better in most of the I location. Clone I 07-11 produced the lowest tiller (Table 3) almost all locations-Jamalpur (102 x 10^3 ha^{-1}), Thakurgaon (197.52 x 10^3 ha^{-1}) and Joypurhat (206.39 x 10^3 ha^{-1}). So, the result indicated that clone I 85-10, I 118-10 and I 111-11 had higher tiller producing capacity and Chuadanga was the highest tiller producing area.

Table 3. Combined effect of clones/varieties and locations on tiller, millable cane, yield and brix % of sugarcane

Locations	Clone/Variety	Tiller (x 10^3 ha^{-1})	Millable Cane (x 10^3 ha^{-1})	Yield (tha^{-1})	Brix (%)
Rajshahi	T_1: I 07-11	169.23 gh	84.22 h-k	82.61 hij	18.17 c-f
	T_2: I 111-11	181.79 e-h	86.29 h-k	109.87 abc	19.83 bc
	T_3: I 85-10	173.84 f-h	83.47 kl	84.30 g-j	19.00 b-f
	T_4: I 118-10	136.92 ij	82.56 jkl	87.91 f-i	18.87 b-f
	T_5: Isd 39	160.50 hi	82.78 i-l	81.73 hij	19.70 bcd
Jamalpur	T_1: I 07-11	102.00 l	69.92 m	82.00 hij	19.60 b-e
	T_2: I 111-11	127.77 jk	88.07 h-k	92.21 e-h	17.53 fg
	T_3: I 85-10	137.38 ij	94.24 g-j	91.00 e-i	20.20 ab
	T_4: I 118-10	105.00 kl	71.56 lm	74.01 j	17.93 efg
	T_5: Isd 39	125.07 jkl	79.38 klm	84.62 g-j	19.20 b-f
Thakurgaon	T_1: I 07-11	197.52 def	102.68 fg	82.37 hij	20.17 ab
	T_2: I 111-11	210.00 d	108.57 f	78.57 ij	21.83 a
	T_3: I 85-10	207.62 d	124.32 e	100.48 b-f	19.17 b-f
	T_4: I 118-10	248.10 c	148.57 bc	101.42 b-e	19.17 b-f
	T_5: Isd 39	253.75 bc	175.23 a	106.18 a-d	20.40 ab
Chuadanga	T_1: I 07-11	276.39 ab	141.50 cd	73.51 j	16.43 g
	T_2: I 111-11	283.29 a	159.19 b	116.27 a	16.40 g
	T_3: I 85-10	236.81 c	111.23 f	106.19 a-d	19.13 b-f
	T_4: I 118-10	292.11 a	138.36 cd	108.86 abc	18.03 d-g
	T_5: Isd 39	283.76 a	134.24 de	112.32 ab	19.47 b-e
Joypurhat	T_1: I 07-11	206.39 de	88.75 h-k	95.04 d-g	21.56 a
	T_2: I 111-11	238.05 c	71.60 lm	88.15 f-i	19.55 b-e
	T_3: I 85-10	241.78 c	94.51 ghi	101.83 b-e	19.00 b-f
	T_4: I 118-10	206.25 de	84.79 h-k	98.26 c-f	17.67 fg
	T_5: Isd 39	188.47 d-g	88.75 h-k	113.13 ab	21.89 a
LSD (0.05)	-	24.74	11.74	12.66	1.72

Figures in a column having the same letter do not differed significantly as per LSD.

Number of Millable cane

Cane count or millable cane is a yield contributing factor (Junejo *et al.*, 2010) because more the number of canes in a field more will be the yield obtained from that specific field. Significant difference was observed in case of millable cane production among the clones and variety (Table 1). The highest number of millable cane was recorded from variety Isd 39 (113.44 x 10^3 ha^{-1}), which was significantly different from other clones. The lowest millable cane was observed from clone I 07-11 (97.41 x 10^3 ha^{-1}), which was statistically similar with clone I 85-10 (101.36 x 10^3 ha^{-1}) and significantly different from clone I 111-11 (101.36 x 10^3 ha^{-1}) and I 118-10 (105.15 x 10^3 ha^{-1}). The result correlated with the findings of Miah *et al.* (1986) who found variation in number of millable cane

production while studied the performance of some promising clones/varieties.

A significant difference in millable cane was aslo found in different locations (Table 2). The highest millable cane was found at Chuadanga (136.90 x 10^3 ha^{-1}) followed by Thakurgaon (131.87 x 10^3 ha^{-1}) and Rajshahi (83.66 x 10^3 ha^{-1}), while the lowest millable cane was observed at Jamalpur (80.61 x 10^3 ha^{-1}).

Significant variation was observed in millable cane with the interaction effect of clones/variety and different locations. The highest millable cane was obtained from variety Isd 39 (175.23 x 10^3 ha^{-1}) at Thakurgaon and followed by clone I 111-11 at Chuadanga (159.19 x 10^3 ha^{-1}) and I 118-10 at Thakurgaon (148.57 x 10^3 ha^{-1}). The lowest millable cane was found from clone I 07-11 (69.92 x 10^3 ha^{-1}) at Jamalpur which was statistically similar with clone I 118-10 (71.56 x 10^3 ha^{-1}) at the same location. So, the results suggest that variety Isd 39 had high millable cane producing potentiality and Thakurgaon was demonstrated high millable cane producing area.

Yield (t ha^{-1})

All the scientific developments in the agriculture and its sub-sectors are primarily focused on enhancing the obtained farm yield which eventually benefits the farmers as well as the economy of a country. From the observed data (Table 1), it was evident that clones and variety had significant influence on yield. The highest cane yield was observed from the variety Isd 39 (99.60 t ha^{-1}) followed by clone I 111-11 (97.01 t ha^{-1}), clone I 85-10 (96.76 t ha^{-1}) and clone I 118-10 (94.10 t ha^{-1}). The lowest cane yield was obtained from clone I 07-11 (83.18 t ha^{-1}), which was statistically different from other clones/variety. The variation in cane yield among the clones and varieties was due to the cumulative effect of yield contributing attributes. The findings of the present experiment was in agreement with Singh *et al.* (1999) and Arvind *et al.* (1997) where they found variation in cane yield among different varieties.

A significant difference in yield of cane was found in different locations (Table 2). The highest cane yield was recorded at Chuadanga (103.43 t ha^{-1}) followed by Joypurhat (99.43 t ha^{-1}), Thakurgaon (93.81 t ha^{-1}) and Rajshahi (89.28 t ha^{-1}), while the lowest cane yield was found at Jamalpur (84,77 t ha^{-1}) which was significantly different from other locations. All promising clones and variety showed better performance at Chuadanga and Joypurhat as compared to other locations. From the above findings it can be concluded that varietal yield potentiality depends on the agro-climatic condition of the specific location.

Significant variation was observed in yield of cane with the interaction effect of clones/variety and different locations. The highest cane yield was obtained from clone I 111-11 (116.27 t ha^{-1}) at Chuadanga, which was statistically similar with variety Isd 39 (112.32 t ha^{-1}) at Chuadanga, clone I 118-10 (108.86 t ha^{-1}) and clone I 85-10 (106.19 t ha^{-1}) at the same location followed by variety Isd 39 (113.13 t ha^{-1}) at Thakurgaon, clone I 85-10 (101.83 t ha^{-1}) at Joypurhat and clone I 118-10 (101.42 t ha^{-1}) at Thakurgaon. The lowest cane yield was recorded from clone I 07-10 (73.51 t ha^{-1}) at Chuadanga, which was statistically similar with clone I 118-10 (74.01 t ha^{-1}) at Jamalpur followed by clone I 111-11 (78.57 t ha^{-1}) at Thakurgaon and clone I 07-11 (82.37 t ha^{-1}) at the same location (Table 3). The genetically improved sugarcane clones may have ability to produce better results regarding cane yield and sugar contents under given set of environmental conditions (Arain *et al.*, 2011). So higher cane yield by variety Isd 39 and genotype I 111-11 may be attributed to its improved genetic makeup and its better adaptability

potential under the agro-ecological conditions of Chuadanga and Joypurhat.

Brix (%)

Sugar recovery and sugar yield are the principal attributes that make sugarcane a valuable crop. Higher Brix (%) of any variety/clone is an indication to produce higher sugar. Significant difference in Brix (%) was observed among the clones and variety (Table 1). The highest Brix (%) was recorded from variety Isd 39 (20.13), which was statistically different from other clones/variety and followed by clone I 85-10 (19.30 %) and I 07-11(19.19 %). The lowest Brix (%) was observed from the clone I 118-10 (18.83 %), which was statistically at par with clone I 111-11 (19.03 %).

A significant difference in Brix (%) was found in different locations (Table 2). The highest Brix (%) was observed at Thakurgaon (20.15), which was statistically similar with Joypurhat (19.93 %) followed by Rajshahi (19.11 %) and Jamalpur (18.89 %) while, the lowest Brix (%) was found at Chuadanga (17.89 %), which was significantly different.

Interaction effect of clones/variety and different locations exhibited significant variation on Brix (%). The highest Brix (%) was obtained from variety Isd 39 (21.89) at Joypurhat, which was statistically at par with clone I 111-11 (21.83) at Thakurgaon and followed by clone I 07-11 (21.56 %) at Joypurhat, variety Isd 39 (20.40) at Thakurgaon, clone I 85-10 (20.20 %) at Jamalpur and clone I 07-11 (20.17 %) at Thakurgaon. The lowest Brix (%) was found from clone I 111-11 (16.40) at Chuadanga which was statistically similar with clone I 07-11 (16.43 %) at the same location (Table 3).

The inherent genetic makeup of a genotype might have contributed towards higher and lower sugar contents. El-Geddaway *et al.* (2002) reported that sugarcane varieties are greatly affected by genetic makeup. According to Keerio *et al.* (2003) unless the genetic potential of a variety is not high, mere provisions of growing conditions such as fertilizer, irrigations etc. will not lead to the significant improvement in cane or sugar yield.

The results revealed that both clones/variety and different locations had a significant effect on all yield parameters like tiller population, millable cane, yield and Brix %. Among the clones and variety the highest number of millable cane (113.44 x 10^3 ha^{-1}), yield (99.60 t ha^{-1}) and Brix % (20.13) was obtained from variety Isd 39, where as the highest number of tiller (208.18 x 10^3 ha^{-1}) was observed from clone I 111-11. Among the five different locations, the highest number of tiller (274.47 x 10^3 ha^{-1}), millable cane (136.90 x 10^3 ha^{-1}) and yield (103.43 t ha^{-1}) was found at Chuadanga where as the highest Brix % (20.15) was observed at Thakurgaon.

The differences among clones/variety used in this study might be attributed to the differences in genetic constituents for each cultivar and their ability to benefit from the environmental factors which enabled it to adapt and achieve better yield and quality parameters. These results are in line with those obtained by Shehata *et al.* (2000), Gobarah and Mekki (2005) and Ismail (2002). The selection of better site specific genotype in terms of higher cane production along with higher sugar recovery might play vital role in prosperity of farmers as well as industrialists. This study provides sufficient information regarding the response of various sugarcane genotypes under agro-ecological conditions of different cane growing zone. Considering the all yield attributes variety Isd 39 performed better and clone I 111-11 was closely related to the variety Isd 39 considering yield attributes. From the above findings it may be concluded that no clone is superior over the standard variety.

REFERENCES

Anonymous.1978. The Sugar Commission Report of 1977-78, Dhaka. M.I.S. Department, Bangladesh Sugar and Food Industries Corporation. pp. 67-68.

Arain, M.Y.; Panhwar, R.N.; Gujar, N.; Chohan, M.; Rajput, M.A.; Soomro, A.F. and Junejo, S. 2011. Evaluation of new candidate sugarcane varieties for some qualitative and quantitative traits under Thatta agro-climatic conditions. *J. Anim. Plant Sci.*, **21**: 226-230.

Arvind, M.; Naidu, K.M. and Misra, A. 1997. Performance of promising mid late and late maturing sugarcane varieties under sub tropical conditions. *Agric. Sci. Digest J.*, **17**(2): 79-82.

Barnes, A.C. 1954. Agriculture of Sugarcane. Leonard Hill Ltd. 9 Eden Street, London. pp. 98-102.

BBS. 2017. Yearbook of Agricultural Statistics. Statistics and Informatics Division (SID), Ministry of Planning. Government of the People's Republic of Bangladesh. p.156.

Chattha, A.A.; Rafique, M.; Afzal, M.; Ahmed, F. and Bilal, M. 2006. Prospects of sugar industry & sugarcane cultivation in Punjab. Proceedings of 41st annual convention of Pakistan society of sugar technologists held at Rawalpindi on August 21-22, 2006. pp. 173-181.

El-Geddaway, I.H.; Darwesh, D.G.; Elsherbiny, A.A.; Eldin, E. and El-Hadi, A. 2002. Effect of row spacing and number of buds/seed setts on growth characters of ratoon crops for some sugarcane varieties. *Pak. Sugar. J.*, **17**: 7-14.

Gill, M.B. 1995. Physio agronomic studies on flat versus pit plantation of autumn and spring sugarcane (*Saccharum officinarum* L.). M.Sc. Thesis, Department of Agronomy, University of Agriculture, Faisalabad., pp. 49-89.

Gobarah, M.E. and Mekki, B.B. 2005. Influence of boron application on yield and juice quality of some sugarbeet cultivars grown under saline soil conditions. *J. Applied Sci. Res.*, **1**(5): 373-379.

Gomez, K.A. and Gomez, A. A. 1984. Statistical procedures for agricultural research (2nd Ed.) A Wiley Interscience Publication, NY, USA. p. 680.

Hassan, M.U.; Fiaz, N.; Mudassir, M.A. and Yasin, M. 2017. Exploring the ratooning potential of sugarcane (*Saccharum Officinarum* L.) genotypes under varying harvesting times of plant crop. *Pak. J. Agric. Res.*, **30**: 303-309.

Humbert, R.P. 1959. The growing of sugarcane. Amasterdam: Elsevier Publishing Company. pp. 2-6.

Islam, M.S.; Hussain, G.M.A.; Alam, K.M.; Islam, S. and Haque, M.A. 2016. Response of BSRI Akh 42 and soil properties to fertilizer doses in Chittagong Hill Tracts of Bangladesh. *Bangladesh J. Sugarcane*, **37**: 25-32.

Ismail, A.M.A. 2002. Evaluation of some sugarbeet varieties under different nitrogen levels in El-Fayium Egypt. *J. Applied Sci.*, **17**: 75-85.

Junejo, S.; Kaloi, G.M.; Panhwar, R.N.; Chohan, M.; Junejo, A.A. and Soomro, A.F. 2010. Performance of some newly developed sugarcane genotypes for some qualitative and quantitative traits under Thatta conditions. *J. Plant Anim. Sci.*, **20**(1): 40-43.

Keerio, H.K.; Panhwar, R.N.; Memon, Y.M.; Arain, M.Y.; Chohan, M. and Qazi, B.R. 2003. Qualitative and quantitative performance of some promising and commercial sugarcane varieties under agro-climatic conditions of Thatta. *Pak. J. Appl. Sci.*, **3**: 670-673.

Miah, M.A.; Awal, A.; Karim, M.A. and Azad, A.K.M. 1986. Performance of some varieties/Promising clones in the sandy soil of Setabganj Sugar Mills. *Bangladesh J. Sugarcane*, **8**: 61-63.

Miah, M.A.; Awal, A.; Nahar, S.M.N.; Mannan, Sk.A. and Ali, M.Y. 1994. Performance of some promising clones and varieties of sugarcane in Himalayan piedmont plain soils. *Bangladesh J. Sugarcane*, **16**: 116-119.

Patil, A.S. and Patil, K.A. 2011. Production consumption and deficit of sugar at global level in 2010-11 and 2011-2012, a forecast. www.ibap.

Poehlman, J.M. and Barthakur. D. 1959. Breeding Asian Field Crops. Mohan Primlan, Oxford & IBH Publishing Co. 66 Japath, New Delhi, 110001. pp. 238-255.

Rashid, M.H.; Quddus, M.A.; Rashid, M.A. and Elahi, N.E. 2001. Performance of modern sugarcane varieties for *gur* production in Modhupur Tract soils. *Bangladesh J. Sugarcane*, **23**: 57-60.

Shehata, M.M.; Azer, S.A. and Mustafa, S.N. 2000. The effect of soil moisture stress on some sugarbeet cultivars. *Egyptian J. Agril. Res.*, **78**: 1141-1160.

Singh, J.P.R.; Singh, U.P. and Kumar, S. 1999. Performance of mid late sugarcane varieties of north central zone in calciorthents soils of Bihar. *Indian Sugar*, **49**(6): 411-413.

Impact of Irrigation on Qualitative and Quantitative Yield of Sugarbeet in Bangladesh

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ABSTRACT

Efficient irrigation management is essential for the successful production of tropical sugarbeet under the agro-climatic condition of Bangladesh. The study aimed to find out the effect of irrigation management on yield and yield attribute of sugar beet. The experiment was conducted at the experimental farm in Bangladesh Sugarcrop Research Institute over two cropping seasons. Six irrigation treatments depending on pan evaporation for two sugarbeet varieties with three replications were organized in the experimental design. When irrigations were applied at 35 mm pan evaporation up to 50 DAS then at 50 mm pan evaporation, which was also suitable for the optimum birx content of sugarbeet under this agro-climatic condition, the highest yield in cropping seasons 2012-13 and 2013-14 were found to be 72.39 and 78.78 t/ha, respectively. This irrigation treatment had identified as the optimum level of irrigation for both varieties considering quantitative and qualitative yield of sugarbeet. Excessive or less irrigation both were responsible for reduced yield as well as brix of sugarbeet since optimum irrigation should ensure for effectual farming of sugarbeet.

Key words: Sugarbeet, irrigation, yield, brix

INTRODUCTION

Sugarbeet (*Beta vulgaris* L.), The family of the Chenopodiaceae, is a vegetal that's root contains a high concentration of sucrose (Hossain *et al.*, 2015). Sugarbeet growing season is 5-6 months and its sugar recovery rate is 12-14% which is also high in comparison to sugarcane (Paul *et al.*, 2019). Sugarbeet is mostly grown in temperate countries of the world that contributes about 30% of world sugar production (Bairagi *et al.*, 2013). Due to varietal development through genetical modification, there are some tropical sugarbeet varieties are available in the world which is suitable for agro-climatic condition of Bangladesh. As a new crop, it is essential to develop efficient management of different inputs during plantation to harvest as fertilization, water management, intercultural operations, etc. for successful production of beet. Sugarbeet is a plant with increased water requirements due to its long growing season and high yield potential. Irrigation water not only satisfies the demand of water but also facilitates to uptake of nutrients from the soil as well as maintain a suitable microclimate for the proper development of beet. On the other hand, excess water not only increases the production cost but also has a lot of negative impacts on yield.

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Sugarbeet most heavily depends on the soil type or location and above all, on the availability of water during the growing stage of the plants (Dziezyc *et al.*, 1987; Chmura *et al.,* 2009; Podlaski *et al.*, 2017). This water availability to plants is subject to the rainfall volume anddistribution during a growing season, or in the case of rainfall shortages, it relies on the use of irrigation if possible. Vamerali *et al.,* 2009, claimed that sugarbeet is a field crop well suited for deficit irrigation applications. However, the results of many study reports showed the yield losses under water deficit conditions. The optimum soil water content for maximum root yield and quality was 70% of the field capacity. Kiziloglu *et al.,* 2006, indicated that deficit irrigation practices significantly decreased the root, leaf, and total sugar yields of sugarbeet under semiarid and cool-season climatic conditions. Similarly, Topak *et al.,* 2011, found that root and white sugar yields of sugar beet significantly decreased by increasing the water deficit in a semiarid region. Okom *et al.,* 2017, indicated that the experimental implementation of a 16% water reduction applied to sugarbeet plants grown in a greenhouse implies that reduced summer rainfall will have a significant impact on soil moisture (12% decrease; $p < 0.05$) and wet sugar beet yield (11% decrease; $p < 0.05$).

The reduction of the sugarbeet yield occurs due to water scarcity, especially on light soils (Schindler *et al.*, 2007). Predicted climate change may be expected to reinforce this effect in the future (Okom *et al.*, 2017). According to the climate forecasts, the frequency of extreme weather conditions and hence the occurrence of rainfall shortages are expected to increase (Stocker *et al.*, 2013). Irrigation guarantees stability and mitigates problems of drought occurrence caused by climate change, as one can maximize yield quantity and the sugar content as well as achieve better uniformity of yield year after year. Sugarbeet is reputed to be a deep rooting crop and relatively insensitive to water stress because of the morphological and physiological characteristics of its root system (Doorenbos and Kasam, 1979). Sugarbeet has the ability to grow in a wide range of salinities and climatic conditions (Tognetti *et al.*, 2003), and Sugarbeet is resistant to drought and needs strategies to reduce the effects of drought stress so that it can achieve high yields (Hsiao, 2000). Sepaskhah (1996) reported that for plants like sugar beet (grown for their leaves or roots) shallow groundwater and alternate furrow irrigation led to high WUE, but deep groundwater might cause a substantial reduction in root yield if deficit irrigation was applied. One of the internal responses of sugar beet to water shortage, in addition to reduced growth, is increased sugar concentration in roots. In the several growth stages of sugarbeet, many researchers have investigated deficit irrigation management. Firoozabadi *et al.,* 2003, reported that they applied mild, moderate, and severe stress continuously on sugarbeet under normal conditions during the growing season, and achieved 58, 45, and 34 t/ha root yields, respectively. Bazza and Tayaa (1999) have reported that deficit irrigation by 25% in furrow irrigation led to a 21% reduction in root yield, but that water use efficiency would increase by 5% compared to the control that received full irrigation. In the study carried out by Rytter (2005), it has been reported that deficit irrigation by 40% reduced sugarbeet dry matter by 50% compared to the treatment that received full irrigation. Applying drought stress in the last growing season increased root impurities, especially

nitrogen, sodium, potassium and hence, increased molasses production. Therefore, water stress in the end period of sugarbeet season has an effect on the sugar concentration of the harvested crop (Clover *et al.*, 2001). Topak *et al.,* 2011, studied the effect of deficit irrigation on sugar beet in the semi-arid zone by the drip irrigation system and concluded that 25% and 50% saving in irrigation water caused 6.1 and 45.7% reduction, respectively, in the net income. Albayrak *et al.,* 2010 reported that total sugar yield in alternate furrow irrigation increased compared to conventional furrow irrigation and water use efficiency was 29% higher. Mohamoodi *et al.,* 2008 studied the relation to different irrigation regimes in 30, 50, 70 and 90% FC. Irrigation treatment showed that the optimum soil water content for root yield is at 70% field capacity with 78.5 tha^{-1} and maximum quality observed. In research carried out by Hassanli *et al.* (2010) it was shown that drip irrigation water management could lead to production of up to 79 tha^{-1} of sugar beet roots, with water use efficiency in root and sugar production being 9 and 1.26 kg/m^3, respectively. Government is giving much emphasis on growing sugarbeet. Due to climatic change the annual rainfall is varying year to year. So, it is essential to find out the irrigation scheduling of sugarbeet in Bangladesh. The objectives of this study were to evaluate the effect of irrigation management on the quality and quantity yield of sugarbeet. The research hypothesis assumed an increase in efficiency and quality improvement of sugarbeet root yield under the conditions of optimum irrigation.

MATERIALS AND METHODS

The field experiments were conducted at Bangladesh Sugarcrop Research Institute (BSRI) farm, Ishwardi, Pabna and repeated for two cropping seasons during 2012-13 to 2013-14 to find out optimum irrigation for two different sugarbeet varieties. The experimental site represents the High Ganges River Flood Plain soils of Bangladesh (Typic Eutrochrepts) under the AEZ 11. It is situated between 24°8′ North latitude and 89°4′ east longitude and situated about 15.5 m above the mean sea level.

Table 1. Seed sowing and harvest dates of sugarbeet

Cropping season	Seed sowing date	Harvest date
2012-13	8/12/12	08/05/13
2013-14	12/12/13	30/04/14

The design of the experiment was Spit Plot design for each cropping season. There were three replications withsix irrigation treatments depending on pan evaporation which were provided (Table 2) to two sugarbeet varieties as V_1=Cauvery and V_2=Shubrha. Subarbeet plantation and harvesting dates of 2012-13 and 2013-14 cropping seasons are given in table 1. Figure 1 shows the pictorial views of irrigation application in the experimental plot (A) furrow irrigation as live irrigation (B) furrow irrigation at growth stage.

Table 2. Number and time of irrigation applied at different treatments

Treatment	Treatment (Description)	No. of Irrigation		Days	
		Cropping Season 2012-13	Cropping Season 2013-14	Cropping Season 2012-13	Cropping Season 2013-14
I_1	25 mm Pan evaporation up to 50 DAS then at 50 mm Pan evaporation	7	6	0, 18, 32, 44, 63, 87, 102	0, 12, 27, 45, 92, 110
I_2	25 mm Pan evaporation up to 50 DAS then at 75 mm Pan evaporation	6	5	0, 18, 32, 44, 81, 102	0, 12, 27, 45, 99
I_3	35 mm Pan evaporation up to 50 DAS then at 50 mm Pan evaporation	6	5	0, 27, 46, 67, 91, 106	0, 17, 42, 92, 110
I_4	35 mm Pan evaporation up to 50 DAS then at 75 mm Pan evaporation	5	4	0, 27, 46, 83, 104	0, 17, 42, 99
I_5	45 mm Pan evaporation up to 50 DAS then at 50 mm Pan evaporation	6	5	0, 32, 42, 69, 84, 99	0, 23, 53, 92, 110,
I_6	45 mm Pan evaporation up to 50 DAS then at 75 mm Pan evaporation	5	4	0, 32, 42, 77, 99	0, 23, 53, 93

Since the root length was shorter during the early growth stage and could not draw water from the depth of the soil, irrigations were provided more frequently at the early stage (up to 50 days after planting) than at the later stage.

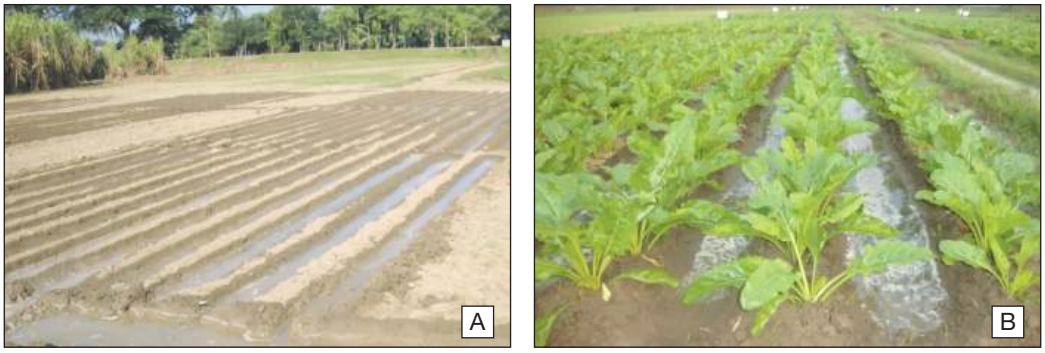

Figure 1. Irrigation applied to tropical sugarbeet (A) furrow irrigation as live irrigation (B) furrow irrigation at growth stage

Each plot was fertilized uniformly with Urea 260 kgha^{-1}, Triple Super Phosphate (TSP) 100 kgha^{-1} Muriate of Potash (MOP) 250 kgha^{-1}, Gypsum 100 kgha^{-1} Zinc Sulphate 10 kgha^{-1} and Boric Acid 7 kgha^{-1} (BSRI, 2011). All fertilizers were applied except Urea and MOP where as one-third of these two fertilizers were applied during land preparation and rest of these fertilizers were applied at 30 days and 60 days as topdressing equally. Necessary intercultural operations were done throughout the cropping season for proper growth and establishment of the crop as BSRI recommendation. Data of irrigation, beet yield and brix % were collected properly through the experimental period. Collected data were compiled and tabulated in proper form and subjected to statistical analysis by using statistix 10 software.

RESULTS AND DISCUSSION

Rainfall data was collected from BSRI weather station through the cropping season of the experiments. During experimental periods of 2012-13 and 2013-14 cropping season rainfall were 22 mm and 56 mm respectively (Figure 2).

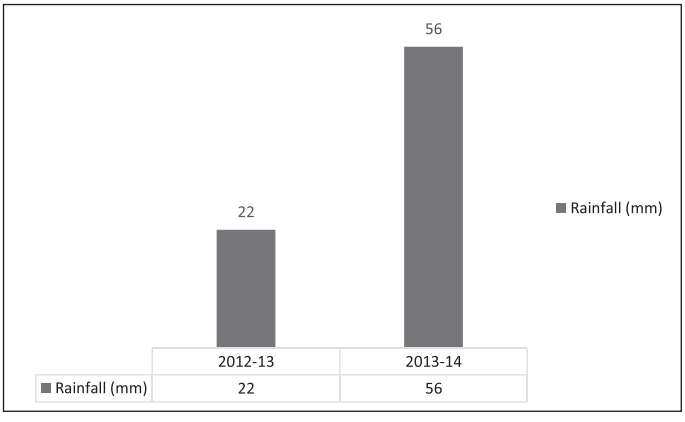

Figure 2. Rainfall during experiment periods

Irrigation has significant effect on yields of tropical sugarbeet in both cropping seasons (Table 3). According to table 3, the highest yield in both cropping season 2012-13 and 2013-14 were found for irrigation treatment I_3 (35 mm Pan Evaporation up to 50 DAS then at 50 mm Pan evaporation) and the values were 72.39 and 78.78 tha^{-1} respectively which indicate that excessive or less irrigation could reduce the yield of tropical sugarbeet. From table 3, it was also found that yield decreased significantly in treatment I_1 and I_2 in both cropping seasons due to more frequent irrigation at the early stage (Irrigation was applied at 25 mm pan evaporation up to 50 days after sowing). The yield had also decreased at treatments I_4, I_5 and I_6 because of drought stress at the early growth stage in cropping season 2012-2013. But that was not significant for the cropping season 2013-2014. It might cause for higher rainfall during that cropping season. Uçan and Gençoğlan (2004), reported that the root yield increased due to the application of irrigation water. Pidgeon *et al.,* 2001, also found that drought stress is an important factor in reducing yield which, depending on the climate under which it is grown, varies from 5 to 15 tha^{-1}.

Brix content had not affected significantly due to irrigation during cropping season 2012-2013 but that varied significantly during cropping season 2013-2014 (Table 3). It may due to lower rainfall during the cropping season 2012-2013 (Figure 2) and a higher number of irrigations at later growth stage than the cropping season 2013-2014 (Table 2). Lowest brix was found at irrigation treatment I_1 which had got highest number of irrigations in both cropping seasons. Which indicates that excessive irrigation reduces brix content of tropical sugarbeet also Abyaneha *et al.,* 2017 showed that irrigation treatments were significant for all quantitative and qualitative characteristics of sugarbeet. By increasing the amount of irrigation water, root and white sugar yields increased while the sugar content decreased. Mahmoodi *et al.,* 2008 showed that irrigation regimes had a significant effect on the sugar yield of sugarbeet and its quality. It demands further investigation to optimize irrigation scheduling for maximizing brix content of beet considering rainfall.

Table 3. Contribution of irrigation to yield and brix

Treatment	Yield (tha^{-1})		Brix (%)	
	Cropping Season 2012-13	Cropping Season 2013-14	Cropping Season 2012-13	Cropping Season 2013-14
I_1	63.22 ab	65.63 b	15.57	16.18 b
I_2	57.44 b	70.65 ab	15.90	16.70 ab
I_3	72.39 a	78.78 a	15.88	17.43 a
I_4	64.28 ab	77.31 a	16.58	16.70 ab
I_5	61.78 b	77.31 a	15.68	17.63 a
I_6	60.89 b	76.91 a	15.82	16.98 ab
LSD (0.05)	10.09	10.05	NS	1.082

Interaction effect of irrigation and variety

Both varieties are sensitive to irrigation considering yield and brix content of beet (Table 4). At irrigation treatment I_3 had identified as the optimum level of irrigation for both varieties considering beet yield. Excessive drought or less irrigation had also responsible to reduced yield of beet for both varieties. According to Table 4, both varieties showed nearly similar response to irrigation considering yield. Similar result was found by Abdelaty *et al.,* 2020.

The lowest brix content was found for I_1 irrigation for all cases which indicates that excessive irrigation had reduced brix content in both varieties at each year's significantly (Table 4). Besides that, brix content of beet also reduced due to drought water stress at maturity stage as when irrigation was not applied up to 75 mm pan evaporation during the later growth stage of beet. Though during 2013-14 cropping season, verity V_2 had not responded significantly considering brix content that might due to weather and varietal interaction.

Table 4. Interaction effect of irrigation and variety on yield and brix

Treatment	Yield (tha^{-1})		Brix (%)	
	Cropping Season 2012-13	Cropping Season 2013-14	Cropping Season 2012-13	Cropping Season 2013-14
V_1I_1	54.45 de	77.10 a-c	14.87 cd	15.17 c
V_1I_2	72.00 ab	80.43 a-c	15.77 bc	16.23 bc
V_1I_3	82.00 a	86.70 a	16.27 ab	18.03 a
V_1I_4	61.56 b-e	86.30 a	16.03 a-c	16.43 bc
V_1I_5	62.78 b-d	84.60 ab	15.93 a-c	18.03 a
V_1I_6	53.33 de	84.20 ab	15.83 bc	16.80 ab
V_2I_1	58.00 c-e	54.17 e	14.20 d	16.83 ab
V_2I_2	70.55 a-c	60.87 de	17.15 a	17.17 ab
V_2I_3	72.56 ab	73.37 a-d	16.93 ab	17.20 ab
V_2I_4	65.78 b-d	68.33 c-e	16.23 ab	16.97 ab
V_2I_5	57.78 c-e	70.03 b-d	15.83 bc	17.23 ab
V_2I_6	49.22 e	67.13 c-e	15.80 bc	17.17 ab
LSD (0.05)	12.98	14.85	1.304	1.53

From the results of the study, it can be said that significant differences in beet yields and brix % were noticeable due to differences in irrigation levels. Both that excess or little irrigation have a negative effect on the yield of sugar beet. Lack of proper irrigation and water management has severely hampered the yield of tropical sugarbeet.

REFERENCES

Abdelaty, M.D.;Elshafay, A.M. and Abu-Hussien, El.Kh. 2020. Evaluation of some sugar beet varieties under different irrigation intervals. *Am. J. Agric. Res.*, **79** (5):1-8.

Abyaneha, H.Z.; Jovzi, M. and Albaji, M.2017. Effect of regulated deficit irrigation, partial root drying and N-fertilizer levels on sugar beet crop (*Beta vulgaris* L.). *Agric. Water Manag.*, **194**: 13–23.

Albayrak, M.; Gunes, E. and Gulcubuk, B. 2010. The effects of irrigation methods on input use and productivities of sugar beet in Central Anatolia, *Turkey. Afr. J. Agric. Res.*, **5**(3): 188-195.

Bairagi, A.; Paul, S.K. and Kader, M.A. 2013. Yield of tropical sugarbeet as influenced by variety and rate of fertilizer application. *Pak. Sugar J.*, **28**(4): 13-20.

Bazza, M. and Tayaa, M.1999. Contribution to Improve Sugar Beet Deficit-Irrigation. In: Kirda, C., Moutonnet, P, Hera, C. and Nielson, D. R. (eds.) *Crop Yield Response to Deficit Irrigitation*. Kluwer, Dordrecht.

BSRI, 2011. Sugarbeet Cultivation in Bangladesh. Bangladesh Sugarcrop Research Institute. Ishwardi, Pabna, Bangladesh.

Chmura, K.; Chylińska, E.; Dmowski, Z. and Nowak, L. 2009. Role of the water factor in yield formation of chosen field crops. *Infrastruct. Ecol. Rural Areas*, **9**: 33–44.

Clover, G.R.G.;Jaggard, K.W.; Smith, H.G. and Azam-Ali, S.N. 2001. The use of radiation interception and transpiration to predict the yield of healthy, drought and virus-infected sugar beet. *J. Agric. Sci.*, **136**(2): 169-178.

Doorenbos, J. and Kassam, A.H. 1979. Yield response to water. FAO Irrigation and Drainage Paper 33.

Dzieżyc, J.; Nowak, L. and Panek, K. 1987. Ten-day indices of rainfall requirements of crops cultivated in Poland. *Zesz. Probl. Post. NaukRoln*, **314**: 11–33.

Firoozabadi, M., Abdollahian-Noghabi, M., Rahimzadeh, F., Moghadam M. and Parsaeyan, M. 2003. Effects of different levels of continuous water stress on the yield quality of three sugar beet lines. *Sugar Beet J. Iran*, **19** (2): 133-142.

Hossain, M.F.; Khaliq, Q.A. and Karim. A. 2015. Effect of sowing dates on growth and yield of tropical sugar beet. *IJAAR*, **7** (1): 53-60.

Hsiao, T. C. 2000. Leaf and root growth in relation to water status. *Hortic. Sci.*, **35** (6): 1051-1058.

Kiziloglu, F.M.; Sahin, U.; Angin, I. and Anapali, O. 2006. The effect of deficit irrigation on water-yield relationship of sugar beet (*Beta vulgaris* L.) under cool season and semi-arid climatic conditions. *Int. Sugar J.*, **108**: 90–94.

Mahmoodi, R.; Maralian, H. and Aghabarati, A. 2008. Effects of limited irrigation on root yield and quality of sugar beet *(Beta vulgaris* L.*). Afr. J. Biotechnol.*, **7**: 4475–4478.

Okom, S.; Russell, A.; Chaudhary, A.J.; Scrimshaw, M.D. and Francis, R.A. 2017. Impacts of projected precipitation changes on sugar beet yield in eastern England. *Meteorol. Appl.*, **24**: 52–61.

Paul, S.K., Joni, R.A., Sarkar. M.A.R., Hossain. M.S. and Paul. S.C. 2019. Performance of tropical sugar beet (*Beta vulgaris* L.) as influenced by date of harvesting. *AAES*, **4**(1): 19-26. https://doi.org/10.26832/24566632.2019.040103

Pidgeon, J.D.;Werker, A.R.;Jaggard, K.W.; Richter, G.M.; Lister, D.H. and Jones, P.D. 2001. Climatic impact on the productivity of sugar beet in Europe, 1961-1995. *Agric. For.*,**109**(1): 27-37.

Podlaski, S.; Chołuj, D. and Wiśniewska, A. 2017. Development of sugar beet yield in relation to selected environmental conditions Zesz. Probl. Post. *NaukRoln.*, **590**: 59–71.

Rytter, R. M. 2005. Water use efficiency, carbon isotope discrimination and biomass production of two sugar beet varieties under well-watered and dry conditions. *J. Agr.Cr.Sci.*, **191**(13): 426-438.

Studnicki, M.; Lenartowicz, T.; Noras, K.; Wójcik-Gront, E. and Wyszyński, Z. 2019. Assessment of stability and adaptation patterns of white sugar yield from sugar beet cultivars in temperate climate environments. *Agronomy*, **9**(7): 405 doi:10.3390/agronomy9070405.

Tarkalson, D.; Eujay, I.; Beyer, W. and King, B. 2014. A drought tolerance selection of sugarbeet hybrids. *J. Sugar Beet Res.*, **51**: 14–30.

Tognetti, R.; Palladino, M.;Minnocci, A.; Delfine, S. and Alvino, A. 2003. The response of sugar beet to drip and low-pressure sprinkler irrigation in southern Italy. *Agric. Water Manag.*, **60**(2): 135-155.

Topak, R.; Süheri, S. and Acar, B. 2011. Effect of different drip irrigation regimes on sugar beet (Beta vulgaris L.) yield, quality and water use efficiency in middle Anatolian, Turkey. *Irrig. Sci.*, **2**: 79–89.

Uçan, K. and Gençoğlan, C. 2004. The effect of water deficit on yield and yield components of sugar beet. *Turk J Agric.*, **28**(3): 163-172.

Vamerali, T.; Guarise, M.; Ganis, A. and Mosca, G. 2009. Effects of water and nitrogen management on fibrous root distribution and turnover in sugar beet. E*ur. J. Agron.*, **31**: 69–76.

Sugarcane *Gur* Production in Bangladesh: A Study on Farmers' Perception and Financial Profitability

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ABSTRACT

This study was undertaken to assess farmers' perception and to estimate the financial profitability of sugarcane *gur* production in Chapainawabganj and Sirajganj districts of Bangladesh. A total of 90 farmers were interviewed based on stratified random sampling technique using a structured questionnaire to collect primary data. A combination of descriptive, mathematical and statistical techniques was used to analyze the data. The study depicts that most of the sugarcane *gur* producers were small in farm size. They cultivated garlic and onion as the intercrops between the row of two lines of sugarcane. Intercrop practices, soil fertility and sugarcane gur price are the main factors influencing farmers' perception of sugarcane *gur* production. Financial profitability analysis shows that sugarcane *gur* production was highly profitable in the study areas. The study identified five significant factors, i.e., cultivating intercrops, sharing work among household members, owner of a crusher machine, income generation and access to training facilities which influence farmers positively to adopt sugarcane *gur* production. The study identified lack of clean seed, low output price and lack of knowledge on grading as the major input, production and marketing related problems, respectively. Based on the findings, the study recommended to develop high-yielding sugarcane variety and to ensure fair selling price as well as proper grading of the product. Moreover, government and non-government organizations should motivate farmers by providing modern crusher machines and clean seeds for producing sugarcane *gur* more profitable.

Key words: Sugarcane, *gur*, production practice, perception, profitability

INTRODUCTION

Sugarcane (*Saccharum officinarum*) is an important commercial crop used to manufacture sugar, jaggery and other products (Venkatesan *et al.*, 2022). In Bangladesh, the area under sugarcane production is about 44.28 thousand hectares of land, covering both mill and non-mill zones with an annual sugar production of about 21.31 thousand tons. It occupies an average of 1.17% of the country's total cultivable land and shares 0.81% of the total GDP in the national economy (BBS, 2022). More than 0.6 million farm families depend on sugarcane cultivation for their subsistence. The minimum per capita sugar consumption is 13.0 kg or its equivalent quantity of *gur* and it is 17.0 kg per year (Rahman *et al.*, 2016).

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Sugarcane is grown in the mill zone and non-mill zone areas of Bangladesh. In mill zone areas, it is mainly used for sugar production while in non-mill zone areas, it is for *gur* and juice production. In 2022-23, about 1.65 million tons of sugarcane were produced in our country. On average, 0.38 million tons of sugarcane were used by sugar mills to make sugar and 1.27 million tons were used to produce *gur* and chewing purposes (BSRI, 2022).

Sugarcane *gur* is an unrefined and non-centrifugal whole cane sugar eaten across the globe. *Gur* is a rich blend of minerals and vitamins, which makes it the healthiest sugar in the sweetener category (Gopalan *et al.*, 1991). Hence, it is digested slower than sugar and releases energy slowly and not spontaneously. This provides energy for a longer time and is not harmful for the body (Dutta D, 2015). Therefore, *gur* may be used as an essential ingredient for various sweeteners and sweetening components in a variety of products because of improvements in manufacturing, preservation and packaging methods.

Gur production is influenced by several factors, including the price of sugarcane that sugar mills can get throughout the crushing season, the price of sugar, the demand for *gur* in the market and the price of *gur*. In Bangladesh, most sugarcane growers manufacture *gur* with minimum capital investment, providing jobs to the unemployed rural people. The manufacturers are mostly small and marginal farmers relying on quick returns from *gur* (Khatun *et al.*, 2015).Improvement of access to markets is a key factor that will undoubtedly support small farmers because it could be a way to improve their incomes and hence, provide better conditions for producing *gur* of higher quality. Sugarcane *gur* is one of the significant agro-processing industries in our country's rural sector. Nearly 30-35% of total sugarcane production in the country is used to manufacture about 4.50 lac tonnes of *gur* (BSRI, 2022), known as the most nutritious agent among all sweeteners. Expanding this *gur* sector is imperative because it offers higher food value at a lower cost, boosts the rural economic system, incurs low transportation costs for raw materials, and requires minimal technical machinery and labor.

The present study is linked with other studies to some extent which are: Akter and Bonna (2022) conducted a study on the economic investigation of sugarcane production, processing and marketing: a case study of Fulbaria Upazila at Mymensingh district and found that human labor, irrigation, insecticides cost, transportation and seed cost were positively significant on gross return; Hoque *et al*. (2021) assessed problem confrontation of sugarcane farmers in Natore district of Bangladesh and identified that getting sugarcane setts was the most critical one. Stephen *et al*. (2021) conducted an inclusive study of *gur* marketing by sugarcane growers of the Sitapur district of Uttar Pradesh and suggested that there is scope to increase the producer’s share in consumer’s rupee by making the market more effective. Chouksey *et al*. (2019) conducted a study on the economic analysis of *gur* production in Narsinghpur district of Madhya Pradesh and revealed that *gur* manufacturing is a profitable business with much scope to improve the income under *gur* business in the study area.

It is evident from the above discussion that most of the studies were conducted on sugarcane and *gur* manufacturing. Still, no in-depth research has been conducted on farmers' attitudes, adoption strategies, and production methods on sugarcane *gur*, and numerous issues at the policy level remain untouched. Therefore, the study will depict production practices, farmers' perception, financial profitability, the factors affecting its adoption and the problems associated with sugarcane *gur* production in Bangladesh. The specific objectives are as follows:

i) To document the production practices and assess farmers' perceptions regarding sugarcane *gur* production;
ii) To estimate the financial profitability of sugarcane *gur* production;
iii) To explore the factors affecting adoption of sugarcane *gur* production by the farmers; and
iv) To identify the potential and the problems in the production and marketing of sugarcane *gur*.

MATERIALS AND METHODS

Study area and sample size

For collecting the required data, the study was conducted at different villages of Shibganj and Sirajganj Sadar upazilas in Chapainawabganj and Sirajganj districts, respectively. These two upazillas from two districts were selected as the study area because these are major sugarcane *gur* production areas in Bangladesh. So, it was easy to get the required and authentic information for completing the study successfully. The primary data were collected from a total of 90 farmers (60 from Chapainawabganj and 30 from Sirajganj district) (Table 1) using a structured questionnaire through direct interviews following a random sampling technique. Primary data were collected from November 2022 to March 2023. Focus group discussions (FGD) and key informant interviews (KII) were also performed for data collection. Secondary data sources relevant to this study, such as reports, publications, handouts, etc., were also examined.

Table 1. Sample size distribution in the study area

District	Upazilla	Union	Village	Total sample
Chapainawabganj	Shibganj	Mubarakpur	Mubarakpur	60
			Lahapur	
		Kansat	Debinagar	
			Lahapur	
			Bajitpur	
Sirajganj	Sadar	Baghbati	Baghbati	30
			Dattobari	
			Ghorabati	
		Khoksabari	Charpara	
		Total		90

Source: Field Survey, 2023.

Analytical techniques

A combination of descriptive, mathematical and statistical techniques was used to analyse the data to achieve the objectives and get meaningful results. In the present study, the following techniques were used:

Descriptive statistics were used to get the simple measures like average, percentage and ratio. It included the socioeconomic status of sugarcane *gur* producers, production practices and farmers' perception of its production in the study areas.

Per hectare profitability of sugarcane *gur* production from the view point of individual farmers was measured in terms of gross return, gross margin, net return and benefit-cost ratio (undiscounted) (Dillon and Hardaker, 1993). The formulas needed for the calculation of profitability are discussed below:

Total cost (TC) includes all variable and fixed cost items involved in the production process. The total cost was estimated as follows:

$$TC = TVC + TFC = \sum X_i \times P_{xi} + TFC$$

Where,

TC = Total cost (Tk./hectare); TVC = Total variable cost; X_i = Quantity of input (kg/hectare); Px_i =Per unit price of the i^{th} input (Tk./kg); and TFC = Total fixed cost includes cost of family labor, land use cost and the interest on operating capital.

Following Dillon and Hardaker (1993), the value of produced output (main product and by-products) of farm enterprises at actual farm gate prices and any in-kind gifts have been included as gross return. The following equation was used to estimate gross return (GR):

$$GR = \sum Q_y \,.\, P_y \; + \sum Q_b \,.\, P_b$$

Where,

GR= Gross return (Tk./hectare); Q_y = Total quantity of outputs (ton/ha); P_y = Per unit prices of the output (Tk./ton); Q_b = Total quantity of the intercrop (ton/ha); and P_b = Per unit prices of the intercrop (Tk./ton).

Gross margin was calculated by the difference between gross return and total variable cost, which is expressed as:

GM = GR-TVC

Where,

GM = Gross margin; GR = Gross return; and TVC = Total variable cost.

Net return was calculated by the difference between gross margin and total fixed costs, which is expressed as:

NR = GM-TFC
Where,
NR = Net return; GM = Gross margin; and TFC = Total fixed cost.

Profitability analysis was calculated by deducting all costs (variable and fixed costs) from gross return. To determine the net return for the crop, the following equation was used:

$$\prod = \sum Q_y \,.\, P_y \; + \sum Q_b . P_b \; - \sum_{i=1}^{n} (X_i . P_{xi}) - TFC$$

Where,
$\prod$= Net return (Tk./ha);
Q_y = Total quantity of the outputs (ton/ha);
P_y = Per unit prices of the output (Tk./ton);
Q_b = Total quantity of the by-product (ton/ha);
P_b = Per unit prices of the by-product (Tk./ton);
X_i = Quantity of the i^{th} inputs;
P_{xi} = Per unit price of the i^{th} inputs;
TFC= Total fixed cost involved in the production per hectare; and
i = 1, 2, 3, ..., n (Number of inputs).

The benefit-cost ratio (BCR) is a relative measure used to compare benefits per unit of cost. BCR was estimated as a ratio of gross return and total costs. The formula for calculating BCR (undiscounted) is as follows:

$$BCR = \frac{Gross\ return}{Total\ cost}$$

As there was variation in the same location among the farmers in terms of adoption of sugarcane *gur* production, the following dichotomous logistic regression analysis (i.e., logit model) was used to identify the factors affecting the adoption of sugarcane *gur* production (Gujarati, 2003):

$$\mathbf{K_i = ln\,[P_i \div (1 - P_i)]} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + E_i$$

Where,
P_i is the probability of adoption and non-adoption of sugarcane *gur* production (P_i = 1 for adoption and P_i = 0 for non-adoption);
Dependent variable (Binary):
K_i = Probability of adoption of sugarcane *gur* production of i^{th} farmer;
Independent variables:
X_1 = Farm size (ha);
X_2 = Intercrop practices (P_i = 1 having intercrop and P_i = 0 having no intercrop);

X_3 = Sharing work among household members (P_i = 1 sharing and P_i = 0 no sharing);
X_4 = Use of fallow land (P_i = 1 use of fallow and P_i = 0 no use of fallow);
X_5 = Risk minimization (P_i = 1 risk minimize and P_i = 0 no risk minimizes);
X_6 = Owner of a crusher machine (P_i = 1 owner of machine and P_i = 0 no owner of machine);
X_7 = Income generation (P_i = 1 generate income and P_i = 0 no generate income);
X_8 = Extension support (P_i = 1 having extension support and P_i = 0 having no support);
X_9 = Access to training (P_i = 1 having training access and P_i = 0 having no access);
β_0 = Intercept; β_1 to β_9 = Regression coefficient of the independent variables;
and E_i= Error term.

To address the problems about production, value addition and marketing of sugarcane *gur*, problem facing index (PFI) was calculated using the following formula (Uddin *et al.*, 2022):

$PFI = (P_s \times 3) + (P_m \times 2) + (P_l \times 1) + (P_n \times 0)$
Where,
P_s = Number of respondents facing the problems severely (weight assigned as 3);
P_m = Number of respondents facing the problems moderately (weight assigned as 2);
P_l = Number of respondents facing the problems at low level (weight assigned as 1); and
P_n = Number of respondents facing no problems (weight assigned as 0).

SWOT analysis was done to identify the prospects and challenges of sugarcane *gur* production. SWOT is an acronym for Strengths, Weaknesses, Opportunities and Threats. SWOT analysis guides to identify the positives and negatives inside of the organization (S-W) and outside of it in the external environment (O-T) (Uddin *et al.*, 2018).

RESULTS AND DISCUSSION

Socioeconomic status of sugarcane *gur* producers

The socioeconomic condition of the sample farmers is very important in research planning because numerous interrelated and constituent attributes characterize an individual and profoundly influence the development of their behaviour and personality. The age structure of the sample farmers was examined by classifying them into three age groups: (15-29), (30-64) and (above 65). It was found that the highest number of the respondents (79%) belong to the (30-64) age group (higher than the national average of 37.71% according to PHC(2022) (Table 2). Most of the respondents (58%) had a small size family (up to 4 members), which was almost 1.06 times lower compared to the country's average of 4.26 (HIES, 2022). As shown in Table 2, it is seen that the highest portion of the respondents (42%) had no education in the study areas, which was much higher than the national illiteracy rate of 25.34% (HIES, 2022). In order to have efficiency, farmers must have experience in sugarcane *gur* production. Most (58%) of the sample farmers had 21 to 40 years of experience producing *gur*. Extension service provides information and passes to farmers new ideas developed by agricultural research

stations. The majority (61%) of the sample farmers had received extension support in sugarcane *gur* farming. Results, as shown in Table 2, found that the majority (64%) of the sample farmers had received training facilities in producing *gur* in the study areas.

Table 2. Socioeconomic characteristics of the respondents

Particulars	Percentage (%) of respondent	Particulars	Percentage (%) of respondent
Age distribution (years)		Family size (members)	
Below 30	10	Up to 4	58
(30-65)	79	5 to 6	33
Above 65	11	More than 6	9
Educational level		Experience status	
Illiterate	42	Below 21	36
Primary	33	21-40	58
Secondary	18	Above 41	7
Above Secondary	7	Occupational status	
Access to extension support		Agriculture	82
Received	61	Others	18
Non-received	39	Access to training	
		Received	64
		Non-received	36

Source: Field Survey, 2023.

Land tenancy arrangements of sugarcane *gur* producers

The land tenancy is the entire land area operated by a farm operator. Sugarcane *gur* producers were stratified into three groups based on the size of operational holding, viz., small (<1.0 ha), medium (1.01-3.0 ha), and large (>3.0 ha). Most of the farmers (76%) surveyed were small (85% of farm households in Bangladesh operate below one hectare of land (DAE, 2018) and occupied 38.47% of the farm area in sugarcane production. It is seen that the average farm size of small, medium and large farmers was 0.43, 1.82 and 3.03 hectares, respectively. Farmers' own land occupied a major share of land leasing arrangements. The study also found that a small portion of land was rented/leased-out by the medium and large farmers.

Table 3. Land tenancy arrangements of *gur* producers

Farmers' categories	% of farmers	Farm size (ha)	Land leasing arrangements (ha)			Percentage of area in sugarcane cultivation
			Own land	Rented/ leased-in	Rented/ leased-out	
Small farmers (less than 1.0 ha)	76%	0.43	0.35	0.08	0.02	38.47
Medium farmers (1.01 to 3.0 ha)	22%	1.82	1.40	0.52	0.10	23.64
Large farmers (above 3.0)	2%	3.03	3.35	0.00	0.32	13.32

Source: Field Survey, 2023.

Production practices of sugarcane *gur*

Sugarcane is grown in the mill zone and non-mill zone areas. In mill zone areas, sugarcane is mainly used for sugar production; in non-mill zone areas, it is used for *gur* production. It is found that farmers used BSRI-released sugarcane varieties such as BSRI Akh 41, Isd 37, Isd 29 along with a local variety named Holander for producing sugarcane *gur*. Sugarcane has long stems and many roots that penetrate deep into the soil. To intake nutrients from the soil, the land needs to be well prepared for sugarcane cultivation.

Table 4. Production practices of sugarcane *gur*

Particulars	Production practices
Sugarcane variety name	BSRI released variety: BSRI Akh 41, Isd 37 and Isd 29; Local variety: Holander
Land preparation	Mechanized (Power tiller)
Ploughing number	4-5
Ploughing depth	18-20 cm
Sowing methods of seedlings	Line sowing
Line-to-line distance	1 meter
Cultivation with intercrops	Intercrops (Garlic and Onion)
Intercrop transplanting method	Between the gap of two line
Irrigation techniques	Irrigated
Pest management	Insecticides
Weeding frequency	4
Production period	November to December
Juice extracting	Mechanized (Crusher machine)
Juice boiling	Furnace chamber through bagasse
Juice cleaning	Organic way (Sap of wild okra or aloe Vera)
Gur making	Manually (wood handle)

Source: Field Survey, 2023.

It was found that farmers usually plough 4-5 times horizontally at a depth of 18-20 cm through power tiller (Table 4). They sowed sugarcane setts in line sowing method and the line to line distance was 1 meter. Intercropping is a system in which compatible crops of short duration are grown between the two rows of a crop to enable intensive and efficient use of production inputs to maximize profit. As sugarcane is a long-duration crop, farmers cultivated intercrops with the sugarcane in the study areas. It was found that farmers cultivated garlic and onion as the intercrops between the row of two lines of sugarcane. They used different types of insecticides and pesticides in the sugarcane field. Four-time weeding is required from planting to harvesting of sugarcane. Farmers generally transplant sugarcane setts from October to November and harvest from November to December of the following year. After harvesting, farmers threshed sugarcane through a crusher machine to extract sugarcane juice. Different types of crusher machines are used for extracting the juice. *Gur* makers usually use three types of crushers which are animal-powered, diesel-powered and electric-powered crusher.

Most farmers used diesel-drive crusher machines to extract juice in the study areas. After that, they heat the juice in the furnace chamber with the bagasse got from sugarcane after threshing. Farmers used the sap of botanical plants such as wild okra or aloe vera for cleaning the boiled juice. Lastly, the boiling juice of the pan gradually turns into sugarcane *gur* after continuous stirring with the help of the wood handle. This finding collaborates with Venkatesan *et al.* (2022), who reported Jaggery manufacturing is a continuous cycle of heat and mass transfer in which fresh sugarcane juice is used; bagasse is used as raw material as fuel. The progressive heating and stirring of sugarcane juice in an open pan changes the sugarcane juice from liquid to semi-solid, which becomes solid after cooling.

Assessing farmers' perception of sugarcane *gur* production

A set of particulars was used to understand farmers' perception towards sugarcane *gur* production. It is apparent in Table 5 that intercrop practices, soil fertility, sugarcane *gur* price and sharing of work among household members are the main factors influencing farmers' perception of sugarcane *gur* production. It is noted that the respondents in the study areas agreed on these particulars to different extents. Intercrops practices were the highest percentage (75%) responded on agreed to sugarcane *gur* production, followed by soil fertility (70%), sugarcane *gur* price (67%), sharing of work among household members (63%), etc. Still, the lowest percentage was related to credit facilities (20%). On the other hand, the percentage of farmers who disagreed was the highest (80%) related to credit facilities, followed by training facilities (75%) and lowest in intercrops practices (25%).

Table 5. Factors affecting farmers' perception of sugarcane *gur* production

Particulars	Agree (no. of farmers)	Disagree (no. of farmers)	% of farmers agreed	% of farmers disagreed
Credit facilities	18	72	20	80
Soil fertility/ organic matter	63	27	70	30
Extension services	27	63	30	70
Training facilities	23	68	25	75
Sharing of work among household members	57	33	63	37
Minimum tillage	33	57	37	63
Sugarcane/*gur* price	60	30	67	33
Consumers' preferences	48	42	53	47
Intercrop practices	68	23	75	25
Use of fallow land	36	54	40	60

Source: Field Survey, 2023.

Input use and cost of sugarcane *gur* production

Available labor, setts, irrigation, fertilizers and insecticides are the major inputs for sugarcane *gur* production. About 365 man-days of hired labors were required to produce sugarcane per hectare. It was seen that a total of 6.65 tons' sett was required per hectare for producing sugarcane and farmers generally used 440 kg Urea, 598 kg

TSP, 235 kg MoP and 177 kg Gypsum. Among different cost items of sugarcane *gur* production, hired labor cost takes the highest portion (37.62%) of the total cost, followed by irrigation (12.06%), transportation (10.66%), juice boiling (9.68%), fertilizer (7.98%) and threshing cost (7.51%), respectively in the study areas. The result is consistent with the finding of Sarkar *et al.* (2018), where the author found that among the variable inputs, the labor factor incurs a higher cost of 36.85% of the total cost in the North Bengal Sugar Mill area of Bangladesh.

Table 6. Input use and cost of sugarcane *gur* production per hectare

Cost items	Input use (Quantity/ha)	Cost (Tk. ha^{-1})	% of total cost
Variable cost (A)			
Hired Labor	365 man-days	182500	37.62
Sett	6.65 ton	3990	0.82
Power tiller		12928	2.66
Fertilizers			
Urea	440 Kg	11000	2.27
TSP	598 Kg	17940	3.70
MoP	235 Kg	5875	1.21
Gypsum	177 Kg	3894	0.80
Insecticide		7560	1.56
Manure: Cow dung		3500	0.72
Irrigation		58517	12.06
Transportation		51712	10.66
Threshing		36450	7.51
Juice boiling		46940	9.68
A. Total Variable cost		442806	91.28
Fixed cost (B)			
Family labor	45 man-days	13500	2.78
Land use cost		16500	3.40
Interest on operating capital		12320	2.54
B. Total fixed cost		42320	8.72
C. Total Cost (A+B)		485126	100.00

Source: Field Survey, 2023.

Profitability of sugarcane *gur*

To determine the viability of sugarcane *gur*, it is necessary to analyze the profitability. The results in Table 7 show that farmers spent, in total, Tk. 485126 per hectare for producing sugarcane *gur*. The gross return from sugarcane *gur* production is the sum of the returns from the main product sugarcane *gur* and intercrops estimated at Tk. 1050650 per hectare. In addition, farmers earned a net return of Tk. 565524 per hectare for producing sugarcane *gur*. It is apparent that considering the total cost, the overall BCR (undiscounted) was found as 2.17. Thus, the profitability analysis revealed that producing sugarcane *gur* resulted in a profitable enterprise. The

result is similar to the findings of Akter and Bonna (2022), where the authors found that sugarcane production is profitable and the estimated BCR is 1.70 in the Fulbaria upazila of Mymensingh district.

Table 7. Financial profitability of sugarcane *gur* production per hectare

Item	Amount (Tk. ha^{-1})
Total variable cost	442806
Total fixed cost	42320
Total cost (TC= TVC + TFC)	485126
Total sugarcane *gur* production (ton/ha)	11.38
Sugarcane *gur* price (Tk./ton)	80000
Return of sugarcane *gur* (A)	910400
Intercrop production (ton/ha)	2.55
Intercrop price (Tk./ton)	55000
Return of intercrop (B)	140250
Gross return (GR) (A+B)	1050650
Gross margin (GM = GR - TVC)	607844
Net return (GR – TC)	565524
BCR (Undiscounted) (BCR = GR/TC)	2.17

Source: Field Survey, 2023.

Factors affecting adoption of sugarcane *gur* production

Identifying factors that affect agricultural technology adoption is the main tool for policy makers to use as a prerequisite for policy analysis. The logit model used to spot the determinants that influenced the farmers' sugarcane *gur* production in the study areas is represented in Table 8. Out of nine major determinants considered in the model, five had positive and significant influence in adopting sugarcane *gur* production by the farmers. These were respondents' intercrops practices, sharing work among household members, owner of a crusher machine, income generation and access to training. The association between the dependent and explanatory variables is also strong, as described by pseudo R^2 = 0.625, indicating the fitness of model predictors for predicting dichotomous dependent variables. It is evident from Table 8 that farmers' adoption probability of sugarcane gur production would be increased by 1.030, 0.527 and 0.314 times with 1 unit increase in respondents' intercrop practices, sharing work among household members and income generation (significant at 1%, 5% and 10% level of probability, respectively). Also, the probability of adopting sugarcane *gur* production for farmers with crusher machines and access to training was 1.163 and 0.353 times higher than those farmers who did not (significant at 1% and 10% probability level, respectively). Reza *et al.* (2016) proposed that sugarcane production with inter-crop, tilling and pesticides are positively and significantly and human labor is significantly but negatively related to sugarcane production in the Northern area of Bangladesh.

Table 8. Result of logistic regression on adoption of sugarcane *gur* production

Variables	Coefficient	Standard error	P value	Odds ratio
Constant	1.746	1.177	0.638	0.731
Farm size	-0.006	0.024	0.792	0.194
Intercrop practices	1.130***	0.253	0.004	1.030
Sharing work among household members	0.757**	0.367	0.034	0.527
Use of fallow land	-0.044	0.045	0.328	0.145
Risk minimization	0.062	0.592	0.916	0.164
Owner of a crusher machine	1.769***	0.629	0.006	1.163
Income generation	0.714*	0.426	0.062	0.314
Extension support	0.513	0.470	0.219	0.131
Access to training	1.042*	0.606	0.083	0.353
Model summary				
Log likelihood ratio	38.56			
LR chi^2 (10)	256.24			
Prob> chi^2	0.000			
Pseudo R^2	0.625			

Source: Field Survey, 2023.

Note: ***, ** and * indicate significant at 1%, 5% and 10% probability levels, respectively.

SWOT analysis for sugarcane *gur* production

Results in Table 9 represent the SWOT analysis on sugarcane *gur* production which revealed that the major strength was intercropping practices with sugarcane (stated by 100% of respondents). Unavailability of modern crusher machines (100.0%), lack of clean seed (81.7%) and lack of quality control facility (62.2%) were found to be the weakness of sugarcane *gur* production.

Table 9. SWOT analysis for sugarcane *gur* production

	Statements	% of response		Statements	% of response
Strengths	Intercropping practices with sugarcane	100.0	Weakness	Unavailability of modern crusher machine	100.0
	Sugarcane *gur* has social acceptance as a food product	82.6		Lack of clean seed	81.7
	Availability of technical and economic support from research organizations.	72.8		Lack of quality control facility	62.2
Opportunities	High local demand for sugarcane *gur*	90.5	Threats	Lack of high-yielding sugarcane *gur* variety	82.5
	High employment opportunities	75.6		Disease and insect infestation	76.4
	Development of *gur* market could facilitate sugarcane *gur* production	67.6		Inadequate market infrastructure	53.8

Source: Field Survey, 2023.

High local demand for sugarcane *gur* (90.5%), high employment opportunities (75.6%) and the development of *gur* market could facilitate *gur* production (67.6%) were the major opportunities. Lack of high-yielding sugarcane variety (82.5%), disease and insect infestation (76.4%) and inadequate market infrastructure (53.8%) were found as the major threats. The results are supported by (Sachinkumar and Arunkumar, 2012) where the authors identified large employment potential as the major strength, the requirement of high capital as the major weakness, increasing demand for jaggery as the major opportunity and lack of marketing facilities as the major threats of jaggery processing units in Karnataka.

Problems related to input, production and marketing of sugarcane *gur*

As shown in Table 10, most sugarcane *gur* producers commented that unavailability of crusher machine, lack of high-yielding variety and lack of clean seed were the major input-related problems in sugarcane *gur* production. The present findings seem consistent with Sarkar *et al.* (2018); Akter and Bonna (2022), where authors found lack of training, lack of collaboration of mill management with farmers, scarcity of labor, lack of varieties of sugarcane and lack of modern agriculture equipment played a role in discouraging the farmers in sugarcane production.

Table 10. Ranking problems associated with sugarcane *gur* in the study area

Particulars	Extent of problems				PFI	Rank order
	Severe (3)	Moderate (2)	Low (1)	Not at all (0)		
Input-related problems						
Unavailability of crusher machine	55	25	9	1	224	1
Lack of high yielding *gur* variety	45	30	11	4	206	2
Lack of clean seed	40	31	15	4	197	3
High price of seed and fertilizer	38	22	22	8	180	4
Inadequate extension service	32	28	26	4	178	5
Product-related problems						
Low price of output	51	24	13	2	214	1
Lack of fair market	42	34	10	4	204	2
Lack of storage facility	38	35	12	5	196	3
Marketing-related problems						
Lack of knowledge on grading	44	25	19	2	201	1
Lack of facilities to develop value-added product	42	25	23	0	199	2
Lack of transport facility	35	24	28	3	181	3

Source: Field Survey, 2023.

In response to product-related problems, it was found that the lower price of sugarcane *gur* and the lack of a fair market were the main constraint in *gur* production. Furthermore, lack of knowledge on grading and facilities to develop value-added products was the main hindrance in marketing sugarcane *gur* in the study areas. The findings comply with the results of Archana *et al.* (2020) that lack of support from the government for *gur* and lack of remunerative price for jaggery were major problems as perceived by jaggery farmers in jaggery making and its marketing, respectively, in Andhra Pradesh of India.

The study concluded that farmers used high-yielding sugarcane varieties and diesel-drive crusher machines to extract sugarcane juice, which turns into sugarcane *gur*. Intercrop practices, soil fertility, *gur* price and work sharing among the household members were the main factors influencing farmers' adoption of sugarcane *gur* production. Financial profitability of sugarcane *gur* production was also measured and suggests that the production of sugarcane *gur* in the study areas was highly profitable. Cultivating intercrops, sharing work among household members, owner of a crusher machine, income creation and access to training were found to have a significant influence on farmers' decision to adopt sugarcane *gur* production. The study identified that the unavailability of crusher machines, lack of clean seed, low output price and lack of knowledge on grading were the major problems for input, production and marketing of sugarcane *gur* production, respectively. Considering the study's findings, some essential policy recommendations have arisen: high-yielding sugarcane variety should be developed for the farmers considering sugarcane *gur* production, fair price and proper grading of sugarcane *gur* should be ensured. Moreover, government and non-government organizations should motivate farmers by providing modern crusher machines and clean seeds for producing sugarcane *gur* economically profitable.

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REFERENCES

Akter, L. and Bonna, S. 2022. An economic investigation of sugarcane production, processing and marketing: A case study of Fulbaria Upazila at Mymensingh district. *International Journal of Financial Management and Economics*, **5**(1): 75-83.

Archana, K.; Sathyagopal, P.V.; Mukundarao, B.; Radha, Y. and Srinivasarao, V. 2020. Constraints and suggestions perceived by the sugarcane growers for jaggery in sugarcane cultivation, jaggery making and marketing. *International Journal of Agriculture Sciences*, **12**(21): 10350-10353.

BBS. 2022. Statistical Yearbook of Bangladesh, Bangladesh Bureau of Statistics, Statistics and Informatics Division, Ministry of Planning, Government of the People's Republic of Bangladesh.

BSRI. 2022. Proceedings, Research Extension Workshop, Bangladesh Sugarcrop Research Institute, Ishwardi, Pabna.

Chouksey, P.; Kashyap, Y. and Sarawgi, A.K. 2019. Economic analysis of jaggery (Jaggery) production in Narsinghpur District of Madhya Pradesh. *Bull. Env. Pharmacol. Life Sci.* **8**(5): 26-30.

DAE. 2018. Agricultural Extension Manual, Department of Agricultural Extension, Ministry of Agriculture, Government of the People's Republic of Bangladesh.

Dillon, J.L. and Hardekar, J.B. 1993. Farm Management Research for Small Farmers' Development. Food and Agricultural Organization of the United Nations, Rome, Italy.

Dutta, D.N.A. 2015. Review on Recent Advances in Value Addition of Jaggery based Products. *Journal of Food Processing & Technology*, **6**(04).

Gopalan, C., Shastri, B.V.R. and Balasubramanian, S.C. (1991). Nutritive value of Indian foods. National Institute of Nutrition Hyderabad, ICMR.

Gujarati, D.N. 2003. Basic Econometrics. 4th edition, McGraw-Hill, New York. pp. 553-555.

HIES. 2022. Household Income and Expenditure Survey, Bangladesh Bureau of Statistics, Statistics and Informatics Division, Ministry of Planning, Government of the People's Republic of Bangladesh.

Hoque, M.J.; Hossain, M.I.; Sarker, M.A. and Mithun, M.N.A.S. 2021. Problem confrontation of sugarcane farmers in Natore district of Bangladesh. *Int. J. Agril. Res. Innov. Technology adopted*, **11**(1): 101-108.

Khatun, S.; Kamruzzaman, M.; Islam, M.S.; Rahman, M.S. and Rahman, M.H. 2015. Production and Marketing of Sugarcane *Gur* in Selected Areas of Bangladesh. *Bangladesh J. Sugarcane*. **36**: 119-125.

PHC. 2022. Preliminary Report on Population and Housing Census, Bangladesh Bureau of Statistics, Statistics and Informatics Division, Ministry of Planning, Government of the People's Republic of Bangladesh.

Rahman, M.S.; Khatun, S. and Rahman, M.K. 2016. Sugarcane and sugar industry in Bangladesh: An overview. *Sugar Tech*, 18. 10.1007/s12355-016-0489-z.

Reza, M.S.; Riazi, M.H. and Khan, M.M.H. 2016. Productivity and profitability of sugarcane production in Northern Bangladesh. *Indian Journal of Commerce & Management Studies*, **7**(1): 1-9.

Sachinkumar, T.N. and Arunkumar, Y.S. 2012. SWOT analysis of jaggery processing units in Karnataka. *Agric. Update*, **7**(3-4): 175-178.

Sarker, M.S.; Rahaman, M.A. and Rupa, I.J. 2018. Economic analysis of sugarcane production: An empirical study on smallholder farmers in the North Bengal sugar mills area. *Rajshahi University journal of social science and business studies*, **26**: 21-33.

Stephen, A.J.; Ratnam, S. and Singh, B.P. 2021. Inclusive study of jaggery marketing by sugarcane growers of Sitapur District of Uttar Pradesh. *Indian Journal of Applied Economics and Business*, **3**(1): 83-98.

Uddin, M.T.; Goswami, A.; Rahman, M.S.; Dhar, A.R. and Khan, M.A. 2018. Value chain of *Pangas* and *Tilapia* in Bangladesh. *Journal of Bangladesh Agricultural University*, **16** (3):503-512.

Venkatesan, M.S.; Lakshmanan, C. and Raman, N. 2022. Jaggery making process and preservation: A review. *Agricultural Reviews*. DOI:10.18805/ag.r-2367.

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Journal article

Kumar, S.K. and Kumar, D. 2014. Correlation and path coefficient analysis in sugarcane germplasm under subtropics. *Afr. J. Agric. Res.,* **9**(1): 148-153.

Alvi, A.K.; Iqbal, J.; Shah, A.H. and Pan, Y.B. 2008. DNA based genetic variation for red rot resistance in sugarcane. *Pak. J. Bot.,* **40**(4): 1419-1425.

Hossain, M.A.; Shaik, M.M.; Shahnawaz, R.M.S.; Islam, N. and Miah, M.A.S. 2006. Quality DNA isolation using different methods of sugarcane (*Saccharum officinarum* L.). *Bangladesh J. Sugarcane,* **28**: 65-69.

Report

Sanders, W.W. and Elleby, H.A. 1970. Distribution of wheel loads in highway bridges. National Cooperative Highway Research Program Report 83, Transportation Research Board, National Research Council, Washington, D.C.

Book

Williams, R.A. 1987. Communication systems analysis and design. Prentice-Hall, Inc., Englewood Cliffs, N.J.

Sambrook, J., Fritsch, E.F. and Maniatis, T. 1989. Molecular cloning: a laboratory manual, 2nd edn. *Cold Spring Harbor Laboratory Press,* New York.

Book in a series

Scott, W.B. and Crossman, E.J. 1973. Freshwater fishes of Canada. Bull. Fish. Res. Board Can. No. 184.

Part of book

Healey, M.C. 1980. The ecology of juvenile salmon in Georgia Strait, British Columbia. In Salmonid ecosystems of the North Pacific. Edited by W.J. McNeil and D.C. Himsworth. Oregon State University Press, Corvallis, Oreg. pp. 203-229.

Paper in conference proceedings

Kemp, A.L.W. 1969. Organic matter in the sediments of Lakes Ontario and Erie. In Proceedings of the 12th Conference on Great Lakes Research, Ann Arbor, Mich., 5-7 May 1969. International Association for Great Lakes Research, Ann Arbor, Mich. pp. 237-249.

Thesis

Keller, C.P. 1987. The role of polysaccharidases in acid wall loosening of epidermal tissue from young Phaseolus vulgaris L. hypocotyls, M.Sc. thesis, Department of Botany, The University of British Columbia, Vancouver, B.C.

Web site

Quinion, M.B. 1998. Citing online sources: advice on online citation formats [online]. Available from http://worldwidewords.org/articles/citation.htm [accessed 20 October 2005].

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