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Impact of Cultivar and Environmental Factors on Early Maturing Sugarcane Traits

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Abstract

The study investigated the impact of different cultivars and environmental conditions on various traits of early maturing sugarcane, including stalk height, stalk diameter, cane yield, sucrose content, purity, fiber content, and pol percentage. Three different environments (E1, E2, E3) were considered for the analysis. Results indicated significant variations in the performance of different cultivars across the environments. For instance, genotype CoP17437 exhibited the tallest stalk in E1, while CoSe17451 had the highest yield in E2, and CoP17437 performed best in E3. Similarly, variations were observed in other traits such as stalk diameter, cane yield, sucrose content, purity, fiber content, and pol percentage across different environments and cultivars.

Key words : *Sugarcane, cultivars, environmental conditions and genotypic variation.*

Introduction

Sugarcane, scientifically known as *Saccharum sp*. Complex with a chromosome count of 2n=100 to 120, is a significant agro-industrial crop in India, primarily cultivated in tropical and sub-tropical regions. The crop accounts for more than 66% of overall production in the sub-tropical states (1). Indian sugarcane agriculture has recently experienced a rapid increase in cane and sugar production. India is the world's second-largest producer of sugarcane, following Brazil, with approximately 4.79 million hectares of area, 370.5 million metric tons of production, and a productivity of 77.35 tons per hectare (2). Sugar cane cultivation in these regions significantly contributes to the economy by providing a stable source of employment and income. The company offers a range of products and by-products that can be used to operate sugar plants profitably and efficiently utilize sugarcane. Changes in climatic parameters are unpredictable factors that significantly impact the yield and characteristics that contribute to the yield of crops (3). Gene-environment interaction hinders effective plant breeding and development programs by impeding the selection of superior genotypes and reducing heritability (5). Studies on sugarcane have predominantly been empirical, with a primary focus on quantifying interactions between genotype and environment (G × E) and assessing genotype stability. Sugarcane breeding is complex due to its heterozygous nature and greater polyploidy. Genotypes exhibit varying ranks in yield, yield attributing characteristics, and quality across different environments, indicating a significant genotype-environment interaction in multi-environmental yield experiments. G×E interactions have a significant role in sugarcane selection. Understanding the components of genotype-environment (G×E) interaction is crucial for crop development. However, obtaining precise information on how each genotype performs under different environmental conditions can be challenging (2, 6). Two often utilized biplot models are the AMMI biplot (additive main effects and multiplicative interaction) and the GGE biplot (genotype + genotype × environment) as described by Gauch, H.G in 1992. The GGE biplot method is more effective than AMMI analysis for interpreting genotype and genotype-by-environment interactions in a graphical representation. Researchers have using GGE biplot analysis to categorize mega habitats, evaluate genotype ranks, and determine the discriminative and representative settings among those evaluated (7). Sugarcane breeders commonly utilize GGE models to explain genotype by environment interaction and analyze the performance of genotypes and test environments (8). The aim of this experiment was to determine GXE interaction and stability factors for yield and quality traits in ten sugarcane genotypes by identifying appropriate settings.

Materials and Methods

The study was carried out in Pusa and Kalyanpur (Samastipur), RPCAU, Pusa, and Motipur (Muzaffarpur Station Farm) over two crop seasons to assess the performance and consistency of ten sugarcane genotypes in three different environments with two harvesting dates. The genotypes utilized in this investigation were CoSe16454, CoSe17451, CoSe95422(std), CoSe01421(std) from GSSB and RI, Seorahi, and CoP17436, CoP17437, CoP17438, CoP17440, CoP17441 from SRI, Pusa, along with CoLK94184 (std)

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from ISSR, Lucknow. The chosen sugarcane types were assessed across three different settings. The experiment was conducted using a randomized block design with three replications. The suggested cultural practices for sugarcane cultivation were implemented during the research phase. Eleven variables considered in this experiment are Stalk Length (cm) after 10 months at harvest, Stalk diameter (cm) after 10 months at harvest, Brix % at 8 months, Brix % at 10 months, Sucrose % at 8 months, Sucrose % at 10 months, Purity % at 8 months, Purity % at 10 months, Fiber % after 10 months at harvest, Pol % cane after 10 months at harvest, and Cane yield(t/ha) after 10 months at harvest. Data was gathered from ten plants selected at random and then subjected to statistical analysis for this experiment.

Results and Discussion

The data below shows that different cultivars, age at harvest, and their interaction had a substantial impact on stalk height, stalk diameter, and cane production in three different conditions. In the first environment, genotype CoP17437 had the tallest stalk at 299.33 cm, while in the second environment CoP17440 had the tallest stalk at 323.33 cm. In the third environment, the variety CoSe01421 (std) had the longest stalk with a mean length of 316.87 cm. In contrast, CoSe01421(std) had shorter stalks at 268 cm in the first environment, CoP17437 had the shortest stalk at 260 cm in the second environment, and CoP17441 had the shortest stalks at 261.85 cm in the third environment (Table-1).

Table-1 : Mean performance of Stalk length (cm) in three environments.

Genotypes	Stalk length (cm) SL		
	E1	E2	E3
CoSe16454	277.33	296.67	271
CoP17436	282.72	268.33	285
CoP17437	299.33	260	295.3
CoP17438	291.66	275	292.8
CoP17440	288	323.33	291.7
CoP17441	295	291.67	261.85
CoSe17451	273	288.33	281.9
CoLK94184(std)	288	303.33	275.1
CoSe95422(std)	281.67	285	269.73
CoSe01421(std)	268	281.67	316.87
GMean	284.47	287.33	284.12
Fratio	3.38*	2.56*	3.07*
df-Geno	9	9	9
df-Error	18	18	18
Minimum	268	260	261.85
Maximum	299.33	323.33	316.87
S.E.	15.9	12.58	15.43
C.D.(5%)	47.23	37.37	45.83
CV(%)	9.68	7.59	9.41

In the first habitat, the genotype CoP17441 had the highest stalk diameter value of 2.6 cm, whereas in the second environment, CoSe17451 had a diameter of 2.47 cm, and in the third environment, CoP17440 had a diameter of 2.65 cm. In the first habitat, the CoSe01421(std) variety had the smallest stalk diameter of 2.18cm. In environments E2 and E3, the CoLK94184(std) genotype had the smallest values for this feature, measuring 1.87cm and 2.15cm, respectively (Table-2).

Table-2 : Mean performance of Stalk diameter (cm) in three environments.

Genotypes	Stalk diameter (cm)		
	E1	E2	E3
CoSe16454	2.41	2.33	2.38
CoP17436	2.5	2.17	2.46
CoP17437	2.56	2.1	2.45
CoP17438	2.45	2	2.35
CoP17440	2.52	2.17	2.65
CoP17441	2.6	1.97	2.46
CoSe17451	2.35	2.47	2.3
CoLK94184(std)	2.2	1.87	2.15
CoSe95422(std)	2.35	2.03	2.38
CoSe01421(std)	2.18	2.1	2.2
GMean	2.41	2.12	2.38
Fratio	2.78*	2.54*	3.00*
df-Geno	9	9	9
df-Error	18	18	18
Minimum	2.18	1.87	2.15
Maximum	2.6	2.47	2.65
S.E.	0.13	0.14	0.14
C.D.(5%)	0.37	0.42	0.42
CV(%)	9	11.6	10.33

The genotype CoP17441 outperformed other genotypes in cane yield in E1, with a yield of 113.11 t/ha. In E2, the genotype CoSe17451 had the best yield of 110.42 t/ha, while in E3, the genotype CoP17437 had the highest yield of 107.4 t/ha (Table-1). The lowest cane yield values were observed in E1, E2, and E3 for CoSe01421(std) (67.04 t/ha), CoP17441 (71.33 t/ha), and CoSe95422(std) (67.24 t/ha), respectively, as shown in Table-3.

The CoSe01421 (std) genotype reported the highest brix values of 20.4% at 8 months and 19.54% at 10 months in E1. At 8 months, both genotypes CoP17438 and CoSe01421 (std) had the same value of 18.49%, which was the greatest. However, at 10 months, the genotype CoSe01421 (std) had the highest brix value of 20.05% located in E2. At 8 months, the genotype CoSe01421 (std) had the highest brix value of 20.73%. At 10 months in E3, the CoLK94184(std) genotype had the highest brix value of 21.27%. In E1, CoP17441 had brix values of 17.67% at 8 months and 16.67% at 10 months, while the lowest brix values were recorded by CoP17440

Table-3 : Mean performance of Cane yield (CY10M)in three environments.

Genotype	Cane yield (CY10M)		
	E1	E2	E3
CoSe16454	78.44	106.13	76.22
CoP17436	92.98	109.24	91.95
CoP17437	111.88	108.7	107.4
CoP17438	100.12	92.9	96.24
CoP17440	102.23	82.11	96.46
CoP17441	113.11	71.33	98.21
CoSe17451	81.75	110.42	69.38
CoLK94184(std)	74.26	97.51	67.59
CoSe95422(std)	67.96	91.65	67.24
CoSe01421(std)	67.04	109.79	62.37
GMean	88.98	97.98	83.31
Fratio	8.56**	7.51**	5.43**
df-Geno	9	9	9
df-Error	18	18	18
Minimum	67.04	71.33	62.37
Maximum	113.11	110.42	107.4
S.E.	5.95	4.91	7.01
C.D.(5%)	17.66	14.59	20.83
CV(%)	11.58	8.68	14.58

at 8 months (15.89%) and by CoP17436 at 10 months (18.02%) in the second environment. The CoSe95422 (std) recorded the lowest brix values of 16.23% at 8 months and 17.73% at 10 months in E3 (Table-4).

The genotype CoSe16454 recorded the highest sucrose content at 8 months, while the genotype CoSe01421(std) had the highest sucrose content at 10 months in E1, with values of 17.99% and 17.98% respectively. Genotypes CoP17438 and CoSe01421(std) had the highest values of 16.94% and 17.5% at 8 months and 10 months, respectively, for E2. At 8 months, the genotype CoSe01421(std) had the highest sucrose value of 18.21%. The CoLK94184(std) genotype reached the greatest value of 18.68% at 10 months in E3 (Table-2). CoP17438 reported the lowest sucrose value of 15.97% after 8 months, whereas CoP17441 recorded 14.7% at 10 months in the initial environment. CoP17440 had the lowest brix value of 14.07% after 8 months, whereas CoP17441 had a brix value of 16.18% at 10 months in the second environment. The CoSe95422(std) had the lowest sucrose values of 13.65% and 15.45% at 8 and 10 months in E3 (Table-5).

The CoSe16454 genotype achieved the maximum level of purity at 89.07% after 8 months, whereas the CoP17437 genotype reached 89.47% after 10 months in E1. The genotypes CoSe17451 and CoP17436 exhibited the highest values of 93.6% and 90.67% at 8 months and 10 months, respectively, for E2. At 8 months, the genotype CoP17437 achieved the maximum purity rating of 88.4%. At 10 months, the CoP17436 genotype reached the highest value of 89.13% in E3 (Table-6). CoP17441 recorded the lowest purity values of 86.83% at 8 months and 85.7% at 10 months in the first environment. In the second environment, the lowest purity values were 87.41% for CoSe95422(std) at 8 months and 84.59% for CoP17440 at 10 months. The lowest purity values were 87.41% for CoSe95422(std) at 8 months and 86.3% for CoP17440 at 10 months in the E3 environment.

The phenotypic coefficients of variation (PCV) varied from 1.03% for Purity % at 8 months to 21.72% for Cane yield(t/ha) at 10 months (Table-7). The PCV estimation indicated low phenotypic variability (below 10%) for Purity % at 8 months, Stalk Length (cm) after 10 months at harvest, Stalk diameter (cm) after 10 months at harvest, Brix % at 8 months, Brix % at 10 months, Sucrose % at 8 months, Sucrose % at 10 months, Purity % at 8 months, Purity % at 10 months, CCS % at 8 months, Fiber % after 10 months at harvest, Pol % cane after 10 months at harvest (ranging from 1.03% to 8.02%); and high phenotypic variability (above 20%) for Cane yield(t/ha) after 10 months at harvest (21.72%).The genotypic coefficient of variation (GCV) varied from 0.60% for Fiber % to 18.38% for Cane yield(t/ha) after 10 months at harvest. The Genetic Coefficient of Variation (GCV) for Fiber percentage after 10 months at harvest was low at 0.60%, suggesting minimal potential for enhancement.

Estimates of broad-sense heritability (H) varied from 1.65% for Fiber % after 10 months at harvest to 73.04% for Sucrose % after 10 months.All characters exhibited moderate heritability (<80%) in the initial context. The genetic advance (GA) varied from 0.16% for Fiber % to 32.03% for Cane yield(t/ha) after 10 months at harvest. The genetic advance is projected to be considerable, exceeding 20%, in terms of cane output (tons per hectare) after 10 months at harvest. High heritability and genetic advance were observed in the cane yield(t/ha) after 10 months at harvest, suggesting that these traits are influenced by additive gene action. Phenotypic selection for these traits would be effective.

The phenotypic coefficients of variation (PCV) varied from 2.73% for Purity % at 8 months to 15.46% for Cane yield(t/ha) after 10 months at harvest (Table-8). The PCV estimation indicated that the phenotypic variability was minimal, below 10%. 8-month purity, 10-month purity, 10-month sucrose percentage, 10-month Brix percentage, 8-month Brix percentage, Pol percentage of cane after 10 months at harvest, Fiber percentage after 10 months at harvest, 8-month sucrose percentage, Stalk length (cm) after 10 months at harvest, moderate (10-20%) range, Stalk diameter (cm) after 10 months at harvest, Cane yield (t/ha) after 10 months at harvest.

The genotypic coefficient of variation (GCV) varied from 1.42% for Purity % at 10 months to 12.79% for Cane

Table-4 : ANOVA of different characters in three environments.

Genotype	BP8M	BP10M	BP8M	BP10M	BP8M	BP10M
	E1		E2		E3	
CoSe16454	20.2	18.43	16.56	19.11	20.6	20
CoP17436	19	17.72	16.66	18.02	17.87	20
CoP17437	20.23	19.35	18.03	19.38	20.5	20.6
CoP17438	18.2	18.27	18.49	19.21	18.83	18.93
CoP17440	19.07	18.72	15.89	19.2	17.8	17.93
CoP17441	17.67	16.67	16.29	18.05	19.07	19.47
CoSe17451	19.6	18.91	16.43	19.13	16.8	19.67
CoLK94184(std)	20.23	19.51	17.49	19.35	20.4	21.27
CoSe95422(std)	18.87	18.49	17.49	19.38	16.23	17.73
CoSe01421(std)	20.4	19.54	18.49	20.05	20.73	19.4
GMean	19.35	18.56	17.18	19.09	18.88	19.5
Fratio	5.15**	5.36**	2.54*	4.97**	6.50**	7.09**
df-Geno	9	9	9	9	9	9
df-Error	18	18	18	18	18	18
Minimum	17.67	16.67	15.89	18.02	16.23	17.73
Maximum	20.4	19.54	18.49	20.05	20.73	21.27
S.E.	0.42	0.38	0.62	0.28	0.65	0.41
C.D.(5%)	1.24	1.13	1.83	0.82	1.94	1.22
CV(%)	3.73	3.56	6.22	2.51	5.99	3.65

Table-5 : ANOVA of different characters in three environments.

Genotype	SP8M	SP10M	SP8M	SP10M	SP8M	SP10M
	E1		E2		E3	
CoSe16454	17.99	16.95	14.54	17.28	18.14	17.65
CoP17436	16.05	16.05	14.33	16.34	15.4	17.83
CoP17437	17.93	17.9	15.9	17.28	18.12	18.25
CoP17438	15.97	16.83	16.94	16.95	16.56	16.59
CoP17440	16.72	17.23	14.07	16.24	15.32	15.48
CoP17441	15.35	14.7	14.28	16.18	16.61	17.28
CoSe17451	17.44	17.43	15.37	17.02	15.97	17.39
CoLK94184(std)	17.94	17.94	15.82	17.28	18.02	18.68
CoSe95422(std)	16.51	17.12	15.29	17.28	13.65	15.45
CoSe01421(std)	17.98	17.98	16.52	17.5	18.21	17.14
GMean	16.99	17.01	15.31	16.94	16.6	17.17
Fratio	7.27**	9.13**	2.45*	8.74**	19.17**	6.99**
utodf-Geno	9	9	9	9	9	9
df-Error	18	18	18	18	18	18
Minimum	15.35	14.7	14.07	16.18	13.65	15.45
Maximum	17.99	17.98	16.94	17.5	18.21	18.68
S.E.	0.37	0.33	0.64	0.17	0.35	0.41
C.D.(5%)	1.09	0.99	1.89	0.5	1.05	1.2
CV (%)	3.76	3.4	7.19	1.71	3.68	4.09

yield(t/ha) after 10 months at harvest. The Genetic Coefficient of Variation (GCV) for Purity % at 10 months was 1.42%, suggesting less potential for enhancement in the second environment.

Estimates of broad-sense heritability (H) varied from 5.39% for Pol % cane after 10 months at harvest to 72.06% for Sucrose % after 10 months. All the characters displayed moderate heritability (<80%) in the second environment. The genetic advance (GA) for several traits, presented as a percentage of the means, varied from 0.83% for Pol % cane after 10 months at harvest to 21.80% for Cane yield(t/ha) after 10 months at harvest. The genetic improvement for Cane yield(t/ha) after 10 months at harvest was very significant, exceeding 20% strong to moderate heritability and strong genetic progress were not detected for these traits, indicating that they are not influenced by additive gene action and phenotypic selection for them would be futile.

The phenotypic coefficients of variation (PCV) varied from 1.41% for Purity % at 10 months to 22.95% for Cane

Table-6 : ANOVA of different characters in three environments.

Genotype	PP8M	PP10M	PP8M	PP10M	PP8M	PP10M
	E1		E2		E3	
CoSe16454	89.07	88.6	87.62	90.41	88.13	88.27
CoP17436	88.07	87.73	86.02	90.67	86.47	89.13
CoP17437	87.83	89.47	88.2	89.17	88.4	88.63
CoP17438	87.73	88.1	91.62	88.23	87.9	87.63
CoP17440	87.73	88.67	88.51	84.59	86.03	86.3
CoP17441	86.83	85.7	87.68	89.66	87.1	88.77
CoSe17451	88.97	88.1	93.6	89.05	86.47	88.37
CoLK94184(std)	88.67	88.67	90.4	89.32	88.33	87.87
CoSe95422(std)	87.53	88.27	87.41	89.18	84.03	87.17
CoSe01421(std)	88.13	88.13	89.26	87.41	87.8	88.27
GMean	88.06	88.14	89.03	88.77	87.07	88.04
Fratio	2.68*	3.02*	12.66**	2.68*	9.01**	2.65*
in0df-Geno	9	9	9	9	9	9
df-Error	18	18	18	18	18	18
Minimum	86.83	85.7	86.02	84.59	84.03	86.3
Maximum	89.07	89.47	93.6	90.67	88.4	89.13
S.E.	0.42	0.57	0.64	1.21	0.45	0.65
C.D.(5%)	1.25	1.68	1.89	3.59	1.35	1.93
CV (%)	0.83	1.11	1.24	2.36	0.9	1.28

Table-7 : Genetic parameters for twenty traits of early maturing sugarcane across the environment E1.

Traits	PCV (%)	GCV (%)	h^2 (%)	GAM (%)
Stalk Length (cm) after 10 month at harvest	8.63	4.39	25.87	4.60
Stalk diameter (cm) after 10 month at harvest	9.47	2.92	9.52	1.86
Brix % at 8 months	5.76	4.39	58.03	6.88
Brix % at 10 months	5.57	4.29	59.24	6.80
Sucrose % at 8 Months	6.60	5.43	67.64	9.20
Sucrose % at 10Months	6.54	5.59	73.04	9.84
Purity % at 8 months	1.03	0.62	35.92	0.76
Purity % at 10 months	1.44	0.91	40.19	1.19
Fiber % after 10 month at harvest	4.69	0.60	1.65	0.16
Pol % cane after 10 month at harvest	8.08	4.88	36.56	6.08
Cane yield (t/ha) after 10 month at harvest	21.72	18.38	71.59	32.03

Table-8 : Genetic parameters for twenty traits of early maturing sugarcane across the environment E2.

Traits	PCV (%)	GCV (%)	h^2 (%)	GAM (%)
Stalk Length (cm) after 10 month at harvest	8.84	4.54	26.37	4.80
Stalk diameter (cm) after 10 month at harvest	12.60	4.93	15.30	3.97
Brix % at 8 months	7.49	4.16	30.87	4.76
Brix % at 10 months	3.83	2.89	56.97	4.49
Sucrose % at 8 Months	8.75	4.99	32.52	5.86
Sucrose % at 10Months	3.24	2.75	72.06	4.82
Purity % at 8 months	2.73	2.44	79.54	4.48
Purity % at 10 months	2.75	1.42	26.53	1.50
Fiber % after 10 month at harvest	8.21	5.19	39.93	6.75
Pol % cane after 10 month at harvest	7.52	1.75	5.39	0.83
Cane yield (t/ha) after 10 month at harvest	15.46	12.79	68.46	21.80

yield(t/ha) after 10 months at harvest (Table-9). The phenotypic variability estimation for various traits showed low variability (below 10%) for Purity % at 10 months, Purity % at 8 months, Fiber % after 10 months at harvest, Brix % at 10 months, Sucrose % at 10 months, Pol % cane after 10 months at harvest, Stalk Length (cm) after 10 months at harvest, and Sucrose % at 8 months (ranging from 1.41 to 9.79%); moderate variability (10-20%) for Brix % at 8 months, Stalk diameter (cm) after 10 months at harvest (ranging from 10.07 to 10.33%); and high variability (above 20%) for Cane yield(t/ha) after 10 months at harvest (22.95). The genotypic coefficient of variation (GCV) varied from 0.3% for Stalk diameter (cm) to 17.73% for Cane yield(t/ha) after 10 months at harvest.

Table-9 : Genetic parameters for twenty three traits of early maturing sugarcane across the environment E3.

Traits	PCV (%)	GCV (%)	h^2 (%)	GAM (%)
Stalk Length (cm) after 10 month at harvest	9.52	1.43	2.26	0.44
Stalk diameter (cm) after 10 month at harvest	10.33	0.30	0.08	0.02
Brix % at 8 months	10.07	8.10	64.69	13.42
Brix % at 10 months	6.35	5.20	67.00	8.77
Sucrose % at 8 Months	9.79	9.07	85.83	17.30
Sucrose % at 10Months	7.07	5.77	66.62	9.71
Purity % at 8 months	1.73	1.48	72.75	2.60
Purity % at 10 months	1.41	0.60	17.80	0.52
Fiber % after 10 month at harvest	4.94	2.27	21.19	2.15
Pol % cane after 10 month at harvest	7.14	5.77	65.23	9.60
Cane yield (t/ha) after 10 month at harvest	22.95	17.73	59.64	28.20

The genetic coefficient of variation (GCV) for stalk diameter (cm) at 10 months was modest (0.3%), suggesting limited potential for enhancement in the third environment. Estimates of broad-sense heritability (H) varied from 0.08% for Stalk diameter (cm) at 10 months after harvest to 85.83% for Sucrose % at 8 months. With the exception of the character Sucrose at 8 months, the other traits exhibited low heritability (<80%), whereas Sucrose showed high heritability (85.83%) in the third environment. The genetic advance (GA) varied from 0.02% for Stalk diameter (cm) to 28.2% for Cane yield(t/ha) after 10 months at harvest. The genetic advance was moderate (10-20%) for Brix % and Sucrose % at 8 months, and significant (above 20%) for Cane yield(t/ha) after 10 months at harvest. High heritability and genetic progress were detected for Sucrose % at 8 Months, suggesting that these traits are influenced by additive gene action and phenotypic selection for them would be effective.

Conclusion

The study highlights the substantial impact of genotype, age at harvest, and their interaction on the performance of various traits in early maturing sugarcane. Results underscore the importance of selecting appropriate cultivars for specific environmental conditions to maximize yield and quality. Furthermore, traits like cane yield, sucrose content, and stalk height exhibit considerable heritability and genetic advance, indicating the potential for genetic improvement through breeding programs. However, traits such as purity and fiber content show lower heritability and genetic advance, suggesting limited scope for enhancement through breeding efforts alone. Overall, the findings provide valuable insights for sugarcane breeders and growers to optimize cultivar selection and management practices for improved productivity and quality in diverse environmental conditions.

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