RESEARCH ARTICLE

SABRAO Journal of Breeding and Genetics
57 (2) 504-515, 2025
http://doi.org/10.54910/sabrao2025.57.2.10
http://sabraojournal.org/
pISSN 1029-7073; eISSN 2224-8978

GENETIC POTENTIAL OF SUGARCANE GENOTYPES IN ACIDIC SOIL WITH LOW FERTILITY UNDER RAINFED CONDITIONS

D. BUNPHAN[1,2*], R. WANNA[1,2], KAEWDUANGTA[1], T. MONKHAM[3], and G. MALAMBANE[4]

[1]Department of Agricultural Technology, Faculty of Technology, Mahasarakham University, Maha Sarakham, Thailand
[2]Resource Management in Agricultural Technology Unit, Mahasarakham University, Maha Sarakham, Thailand
[3]Department of Agronomy, Faculty of Agriculture, Khon Kaen University, Khon Kaen, Thailand
[4]Department of Crop and Soil Sciences, Botswana University of Agriculture and Natural Resources, Gaborone, Botswana
[*]Corresponding author's email: darika.bu@msu.ac.th
Email addresses of co-authors: ruchuon.w@msu.ac.th, waranyoo.k@msu.ac.th, tidamo@kku.ac.th, gmalambane@buan.ac.bw

SUMMARY

Maha Sarakham, located in Northeast Thailand, has become a traditionally recognized rainfed sugarcane (*Saccharum spp.* L.) cultivation land. The field experiment occurred in 2016–2017. Thirteen promising sugarcane lines, with three check cultivars and arranged in a randomized complete block design (RCBD), had four replications in two sites with low soil fertility and pH. Results indicated sugarcane genotypes considerably influenced all the parameters, with a significant variance between the studied locations. The genotype-by-location interactions were noteworthy for all traits, except stalk diameter, stalk weight, and millable canes. The cultivar Khon Kaen-3 (KK3) (72.77 and 60.71 t ha^{-1}) and genotype 91-2-527 (71.85 and 57.65 t ha^{-1}) produced the higher cane yields at both locations (L1 and L2, respectively). Additionally, the sugarcane genotypes 91-2-527, CSB06-4-12, MPT02-458, and KPS01-12 displayed higher stalk weights, while KK3 and TBy27-1385 yielded more millable canes. Genotype MPT02-458 exhibited superior plant height, cane yield, and commercial cane sugar (CCS) in highly acidic soil conditions. Meanwhile, 91-2-527 demonstrated a greater plant height at both sites (287.3 and 328.7 cm) and also showed higher CCS greater than 10 (11.6 and 11.9). These identified genotypes serve as a benchmark for Thailand's sugarcane commercial system. The presented results suggested some sugarcane genotypes were appropriate for cultivation in acidic soil, with low fertility under rainfed conditions. The study recommends pursuing more investigation in identifying sugarcane genotypes potential for high yield and good ratoon ability.

Communicating Editor: Prof. Naqib Ullah Khan

Manuscript received: October 06, 2024; Accepted: January 27, 2025.

Citation: Bunphan D, Wanna R, Kaewduangta W, Monkham T, Malambane (2025). Genetic potential of sugarcane genotypes in acidic soil with low fertility under rainfed conditions. *SABRAO J. Breed. Genet.* 57(2): 504-515. http://doi.org/10.54910/sabrao2025.57.2.10.

Keywords: Sugarcane (*Saccharum spp.* L.), promising genotypes, yield components, sugar yield, CCS, acidic soil, rainfed conditions

Key findings: Sugarcane (*Saccharum spp.* L.) promising lines incurred evaluation in acidic soil with poor fertility in comparison with control types in plant canes. Genotypes KK3 and 91-2-527 produced the highest cane yield at both locations. Although, genotype 91-2-527 gave a lower CCS, however, it emerged greater than 10% of CCS. These sugarcane promising lines could be beneficial as germplasm to improve the cane production through breeding program.

INTRODUCTION

Sugarcane (*Saccharum spp.* L.) is an economically important crop in tropical and subtropical regions, valued for the highest sucrose content, bioenergy potential, and drought resistance. It serves as the primary raw material for sugar production, contributing over 85% of global sugar output, especially in equatorial regions, i.e., Brazil and other parts of the Asia-Pacific (Krungsri Research, 2021). The byproducts, such as, molasses, filter cake, bagasse, vinasses, and biofertilizers are also outputs during the sugar manufacturing process.

Thailand has dedicated around 1.78 million ha area to sugarcane cultivation, yielding 98.78 m tons, with an average yield of 55.69 t ha^{-1} and a commercial cane sugar (CCS) of 12.35 in 2023. Sugarcane cultivation is prevalent in various regions of Thailand, including the North, Central, East, and Northeast. However, the Northeast stands out as the largest production area. The Northeast region produced cane (45.77 m tons) from an area of 0.79 million ha, with the highest CCS (13.26) (OSCB, 2024). Favorable conditions for sugarcane cultivation include a soil pH range of 5.5–7.0, an electrical conductivity (EC) value of ≤ 4.0 dS m^{-1}, average daytime temperatures between 30 °C–35 °C and nighttime temperatures of 18 °C–20 °C, and an annual total rainfall of approximately 1,000–1,500 mm during the growing season (Department of Agricultural Extension, 2008). However, due to rainfed conditions and low-fertility soils, this region suffers low yields during drought. Sugarcane planting typically begins late in the rainy season (October to December). Sugarcane production has the challenge of cultivation during the rainy season, with low-fertility soils to grow on. Kapech *et al.* (2014) and Fuji *et al*. (2016) reported soil acidity poses significant challenges to sugarcane cultivation by limiting nutrient availability, increasing toxicity, and reducing yields. Developing and evaluating resilient sugarcane genotypes adapted to acidic and low-fertility soils is essential for sustainable production, particularly, in rainfed regions like Northeast Thailand.

Past sugarcane breeding programs mostly focused on enhancing drought tolerance and cane yield. Three commercial cultivars of sugarcane (KK3, LK92-11, and KPS01-12) are widely cultivable in Thailand, with cultivar KK3 covering around 90% of the production area, cultivar LK92-11 covering 5%, and remaining areas covered by other cultivars (Department of Agriculture Thailand, 2022). However, after 10 years of continuous cultivation, varietal depression has emerged. Therefore, improving existing cultivars and evaluating promising lines at farmer fields are the key objectives before releasing new cultivars.

Both government and private agencies, such as, the Office of the Cane and Sugar Board (OSCB), Kasetsart University, Khon Kaen Field Crop Research, and Mitr Phol Group, have become involved in developing new sugarcane lines. Cultivars, such as, KK3, LK92-11, KPS01-12, K84-200, and K88-92 have reached wide adoption; however, varietal depression has necessitated searching for newer and more resilient cultivars. The evaluation of new promising lines functions typically against commercial cultivars in farmers' fields before being released (Hartati and Yuniyati, 2022; Mehareb *et al*., 2022; Sueaken *et al*., 2022). Several studies have documented the performance of different sugarcane genotypes under diverse environmental conditions (Getaneh *et al*., 2016; Set-Tow *et al*., 2019, 2020; Deeyiam and Lersrutaiyotin, 2020; Abu-Ellail *et al*., 2021; Boodseephum and Wongtamee, 2022).

Maha Sarakham Province is in Northeast Thailand, which has the sugarcane production area under rainfed conditions with low soil fertility, with sugarcane mostly cultivated in the late rainy season. Cultivar KK3 is the famous drought-tolerant cultivar grown in low fertility soils, and can produce high cane yield even under extreme environmental conditions. However, given the persistent issues with varietal depression, a pressing need beckons to evaluate new sugarcane lines able to surpass existing cultivars in yield and adaptability. This study hypothesizes specific sugarcane genotypes possess genetic potential that enables them to outperform existing commercial cultivars under rainfed conditions with acidic and low-fertility soils. Thus, the presented study aimed to compare the sugarcane potential lines to well-known cultivars produced under rainfed conditions with acidic and low fertility soils, and to identify high-yielding genotypes as new candidate cultivars.

MATERIALS AND METHODS

Plant material

The latest research selected 13 sugarcane potential lines for evaluation by comparing them with three commercial check cultivars (KK3, LK92-11, and KPS01-12) at the Maha Sarakham**,** Thailand. These sugarcane potential lines, developed by different Thai organizations, comprised the genotypes NSUT08-22-3-13 and RT2004-85, donated by the Department of Agriculture, Thailand, and the lines CSB06-2-15, CSB06-2-21, CSB06-4-162, and CSB06-5-20, obtained from the Ministry of Industry. The other genotype donations include TBy27-1385 and TBy28-0348 (Kasetsart University), MPT02-458 and MPT03-166 (Mitr Phol Group), KK06-501 and KK07-478 (Khon Kaen Field Crop Research Center, Khon Kaen), and genotype 91-2-527 (Suphan Buri Field Crop Research Center, Suphan Buri), all from Thailand.

Experimental design

The field experiment materialized during 2016–2017 under the rainfed conditions in two locations, with differing soil properties and land use at Maha Sarakham Province, Northeastern Thailand. The experiments' layout in a randomized complete block design (RCBD) had four replications. The first location was in the District Kud Rang (16°05'33.6″N 103°03'06.6″E), which was an upland area for sugarcane cultivation, with the planting started on November 09, 2016 (average soil temperature is 28.6 °C) and harvested on December 01, 2017. The second location was in the District Wapi Prathum (15°47'30″N 103°20'18″E), previously used for upland rice, with the sugarcane planted on December 17, 2016 (average soil temperature is 27.9 °C) and harvested on January 03, 2018. Sugarcane potential lines and check cultivars' planting followed local agricultural practices. At the first location (L1), the experimental unit measured 48 m² (6 m × 8 m), with a 1.5-m row spacing. Meanwhile, at the second location (L2), reducing the unit size to 26 m² (5.2 m × 5 m) occurred due to area constraints, with a 1.3-m row spacing.

Soil properties

Soil properties showed extreme acidity (pH = 4.67) at the L2, while L1 was mildly acidic (pH = 6.20) (Table 1). Both locations had very low electrical conductivity (EC) and were favorable for crop growth. Organic matter (OM) was low at both sites, with values of 0.52% in L1 and 0.47% in L2. Phosphorus (P) was much higher in L1 (48 ppm) than the moderate value in L2 (13 ppm). Potassium (K) was low in both sites (42 and 32 ppm, respectively), and the calcium (Ca) levels were 238 and 108 ppm, in L1 and L2, respectively. Magnesium (Mg) was much higher in L1 (42 ppm) than L2 (24 ppm).

Table 1. Soil properties of both locations (L1 and L2) before planting sugarcane.

Locations	pH	EC (dS m^{-1})	OM (%)	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)
L1	6.20 slightly acidic	0.022 very low	0.52 low	48 very high	42 low	238 very low	42 low
L2	4.67 Very strongly acidic	0.019 very low	0.47 very low	13 moderate	32 low	108 very low	24 very low

Agronomic practices

Land preparations followed the farmer's techniques and were consistent across the locations. The nitrogen (N), phosphorus (P), and potassium (K) fertilizer formula (15-15-15) was the applied ratio, and a rate of 312.5 kg ha^{-1} served as a basal fertilizer. After four months of planting the sugarcane, the plants bore top dressing with the same formula and rate, followed by manual weeding. The study locations were environmentally alike, with no pesticide application throughout the growing season.

Meteorological data

Average temperature, relative humidity, and rainfall measurements ensued from planting to harvest (12 months). The meteorological data were similar in both locations, except for the total and monthly rainfall. The aggregate rainfall at the L1 in 2017 was 1885.3 mm, while it was 1426.0 mm in L2, and the rainfall at both locations was adequate for sugarcane cultivation. Although, the rainfall pattern across both locations was similar, the month of July exhibited more rainfall in both locations. Other meteorological data collected came from the Central District Weather Station to represent both locations. In 2017, the lowest and highest temperatures were 18.3 °C and 36.4 °C, respectively, with no considerable effect on sugarcane growth and development. The evaporation ranged from 3.71 to 5.36 mm day^{-1} and 3.52 to 4.96 mm day^{-1} at L1 and L2, respectively.

Data recorded

In each experimental unit, two middle rows of sugarcane were samples for data recording on harvest day (12 months after planting; MAP). The recorded data comprised the yield-related characteristics, i.e., stalk number $plant^{-1}$, plant height, and stalk diameter (8 plants $plot^{-1}$). Yield parameters included cane yield (t ha^{-1}), millable cane (stalks ha^{-1}), and stalk weight (kg). Quality parameters consisted of the total soluble solid (TSS) (eight stalks sampling in each plot) and commercial cane sugar (CCS). The canes bore crushing in the crusher, with their juice examined in the laboratory to estimate the CCS% by the Australian commercial cane sugar (CCS) formula given by Meade and Chen (1977) as follows:

$$\%\text{CCS} = [\frac{3P}{2}(1-\frac{F+5}{100})] - [\frac{B}{2}(1-(\frac{F+3}{100})]$$

Where,
P = the Pol percentage of the first expressed juice, B = the brix percentage of the first expressed juice, and F = the fiber percentage in cane.

Data analysis

All data sets reached pooling over the locations/environments and underwent analysis using the Statistic software version 10.0, with the location considered as a random effect parameter. Before the combined analysis, testing homogeneity of variance across locations/environments used the ratio of the largest mean square error (MSE) to the smallest MSE across different environments, employed as a preliminary method to assess the homogeneity of variance. The study of genotype by environment interactions (GEI) revealed the location-cultivar interactions. As a significant G x E interaction was evident for almost traits, the data analysis ran separately for each environment. The treatment means' comparison and separation employed the least significant difference ($LSD_{0.05}$) test.

RESULTS

The results indicated total soluble solids (TSS) are unable to combine between the environments because of the larger mean square error (MSE) dividing the small MSE, which was bigger than the corresponding tabular *F*, therefore, separating the traits. The findings have primarily selected the six promising sugarcane lines and two check cultivars (LK92-11 and KPS01-12), with TSS over 20.0 °brix, and the highest TSS is in genotypes RT2004-085 and 91-2-527 (22.1 and 22.1 °brix, respectively) at the first location (Figure 1). However, the two check cultivars (LK92-11 and KPS01-12) demonstrated greater TSS (over 20 °brix), while the genotype NSUT08-22-3-13 had also the highest TSS (22.9 °brix) among the nine elite sugarcane lines at the second location (Figure 1).

Combined analysis

After testing the homogeneity of variance, the traits stalk number, plant height, stalk diameter, cane yield, millable canes, and CCS showed highly significant differences for locations, cultivars, and their interactions (L × V). Stalk weight was substantially diverse for the cultivars, however, nonsignificant for locations and L × V interactions. The locations and cultivars considerably affected millable canes. A combined analysis across the locations proceeded for all the traits, recording the stalk diameter, stalk weight, and millable canes with nonsignificant interactions between locations and cultivars (Table 2).

Based on the number of stalks plant^{-1} on harvest day, on average, the L1 had more stalks plant^{-1} (4.4 stalks) than L2 (3.4 stalks) (Table 3). The average plant height at the L1 was markedly lower than L2 (Table 3). Similarly, stalk diameter exhibited higher average values (28.95 and 26.95 mm) for L2 and L1, respectively (Table 3). Overall, significant differences were evident between L1 and L2 for yield attributes, except the stalk weight. The L1 had a 29% higher cane yield (60.5 t ha^{-1}) than L2 (42.86 t ha^{-1}), highlighting that cane yield has a key role in sugar production. Stalk weight was at par at L1 (1.40 kg) and L2 (1.35 kg), and the L1 revealed 36% more millable canes than L2. Notably, the CCS showed substantial

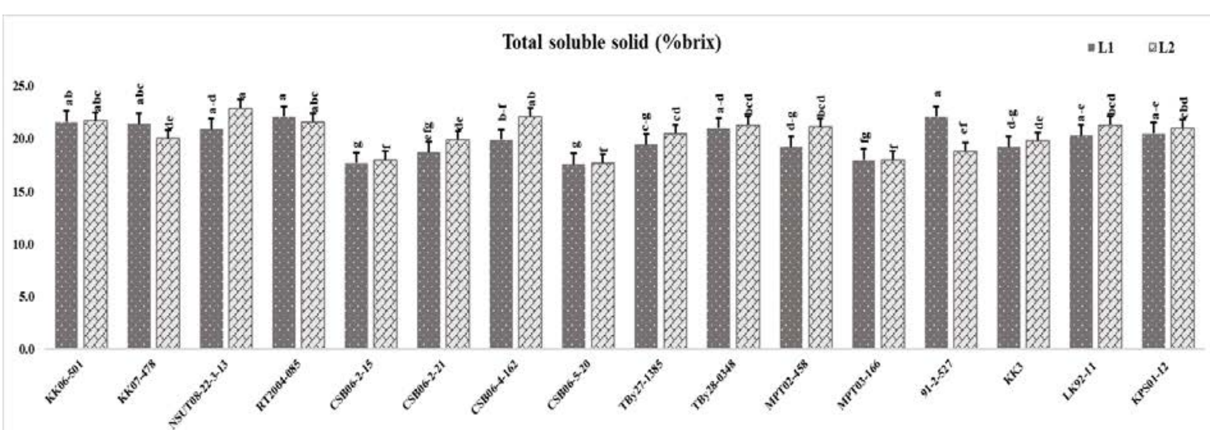

Figure 1. Total soluble solids of 16 sugarcane genotypes at the harvest day across two environments.

Table 2. Combined analysis of some agronomic traits in sugarcane grown under two environments.

Source of variation	Stalk plant^{-1}	Plant height	Stalk diameter	Cane yield	Stalk weight	Number of millable canes	CCS (%)
Locations (L)	*	**	**	**	ns	**	**
Varieties (V)	**	**	**	**	**	*	**
L × V	**	*	ns	**	ns	ns	**
CV (%) (L × Block)	43.56	11.31	11.62	29.94	20.22	40.05	7.77
CV (%) (L × B × V)	17.57	10.89	5.17	19.91	22.82	21.47	6.23

ns, *, and **: non-significant, significant at 95%, and 99%, respectively ($p \leq 0.05$ and 0.01, respectively).

Table 3. Average values of growth, yield, and yield-related traits in sugarcane genotypes across two environments at the harvest day.

Locations	Stalks plant^{-1}	Plant height (cm)	Stalk diameter (mm)	Cane yield (t/ha)	Stalk weight (kg)	Number of millable canes ha^{-1}	CCS (%)
L1	4.4a	233.3b	26.65b	60.50a	1.40	45901a	13.6a
L2	3.4b	275.7a	28.95a	42.86b	1.35	29351b	12.5b
LSD	0.74	12.46	1.40	6.69	-	6517.8	0.44

Means followed by the same letters in the same column are not significantly different in LSD $p > 0.05$.

differences, and the L1 has the topmost average CCS (13.6) compared to L2 (12.5), affecting overall sugar production (Table 3).

No significant interactions emerged between the locations and cultivars for stalk diameter, stalk weight, and number of millable canes. Stalk weight is one of yield components associated with cane yield, ranging from 0.87 to 1.92 kg across both locations. The sugarcane genotype 91-2-527 exhibited the heaviest stalk weight (1.92 kg), although it appeared not significantly different from the two other genotypes, i.e., CSB06-4-162 (1.75 kg) and MPT02-458 (1.75 kg). However, the lightest stalk weight occurred for the lines CSB06-5-20 and TBy27-1385 (Figure 2a). The genotype TBy27-1385 produced more millable canes than other genotypes, except for KK3. Additionally, the sugarcane genotypes CSB06-5-20 and TBy28-0348 had comparable millable canes versus the check cultivar KK3 (Figure 2b).

In the current study, the interaction between locations and cultivars manifested for some agronomic characteristics. As a result, the data for each location had an independent report. The number of stalks per plant is one of the yield components affecting the sugarcane production. The promising sugarcane line RT2004-085 had the most number of stalks plant^{-1} in L1; although, it was non-significantly different from the six other genotypes, i.e., CSB06-2-21, CSB06-5-20, TBy27-1385, TBy28-0348, MPT03-166, and LK9211. For the L2, check cultivar KK3 had the maximum stalks plant^{-1}, however, was found non-significantly varied from three other sugarcane genotypes, KK07-478, CSB06-5-20, and TBy27-1385 (Figure 3).

Although, the plant height is not a direct yield component in sugarcane; however, it has a positive association with cane production and its role in breeding programs. Sugarcane generally grows tall with minimal lodging, with the plant height influenced by both locations and cultivars. The study found promising lines 91-2-527, CSB06-4-162, MPT02-458, and KPS01-12 had greater plant height at both locations. Sugarcane line NSUT08-22-3-13 showed taller plant height at the first location, while the genotypes KK07-478 and RT2004-085 had better plant height at the second location (Table 4).

Cane yield is the most crucial trait in sugarcane crop. The results showed at the L1, two check cultivars KK3 and LK92-11 displayed

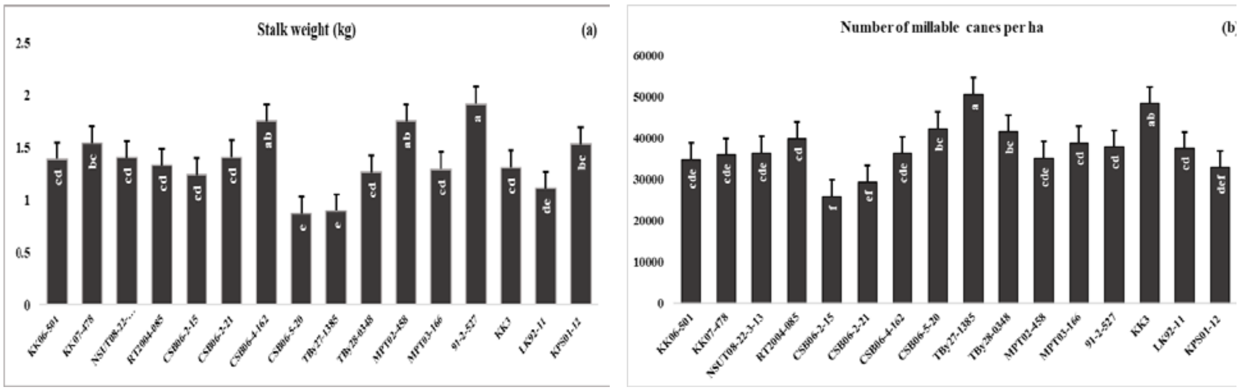

Figure 2. a) Average stalk weight, and b) number of millable canes in sugarcane across two environments at the harvest day.

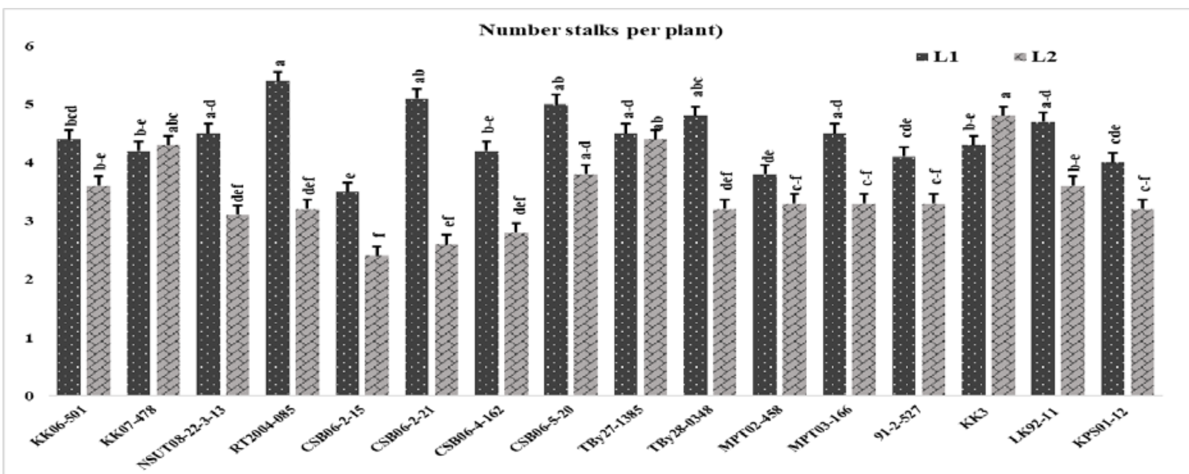

Figure 3. Average number of stalks per plant in sugarcane across two environments at the harvest day.

the highest cane yield (72.77 and 63.28 t ha^{-1}, respectively), while several sugarcane lines (91-2-527, CSB06-2-21, CSB06-4-162, KK07-478, MPT03-166, and KK06-501) also recorded with reasonable cane yields. As for the L2, check cultivar KK3 appeared with the better cane yield (60.71 t ha^{-1}); however, the genotype MPT02-458 (65.69 t ha^{-1}) had the maximum cane yield at this location, along with the genotypes 91-2-527, CSB06-4-162, and KK07-478. The cultivar KK3 and three lines 91-2-527, CSB0-4-162, and KK07-478, recorded with superior cane yields at both locations (Table 4).

CCS is one of the measures of sugar yield in sugarcane. At L1, several elite lines produced superior CCS, including TBy28-0348, KK06-501, NSUT08-22-3-13, and MPT02-458 (14.7, 14.4, 13.9, and 13.8, respectively). However, the single check cultivar KPS01-12 displayed the highest CCS. Contrary to L2, all the check cultivars were predominantly with higher CCS. The results further revealed promising lines CSB06-4-162, NSUT08-22-3-13, RT2004-085, KK06-501, TBy28-0348, and MPT02-458 had the maximum CCS. The findings disclosed some prospective lines demonstrated an increase in CCS at both sites, including KK06-501, NSUT08-22-3-13, TBy28-0348, MPT02-458, and the check cultivar, KPS01-12 (Table 4).

Table 4. Mean performance of sugarcane genotypes for plant height, cane yield, and CCS across two environments at the harvest day.

Sugarcane genotypes	Plant height (cm)		Cane yield (t ha^{-1})		CCS (%)	
	L1	L2	L1	L2	L1	L2
Potential lines						
KK06-501	217.2efg	259.1def	62.23a-d	35.87c-f	14.4a	14.2ab
KK07-478	220.30d-g	307.7abc	67.43a-d	48.48a-d	11.9def	13.7bcd
NSUT08-22-3-13	256.2a-d	241.5ef	54.98c-g	35.54c-f	13.9ab	14.9a
RT2004-085	242.1b-e	333.1a	53.36efg	42.61b-e	12.9bcd	14.7ab
CSB06-2-15	186.2gh	227.5f	48.23fg	21.73f	10.7fg	12.6de
CSB06-2-21	240.25b-f	253.7def	69.72ab	34.13def	10.5g	12.5e
CSB06-4-162	264.5abc	302.6abc	68.00abc	52.73abc	12.4cde	15.0a
CSB06-5-20	203.2fgh	243.5ef	54.21d-g	28.98ef	11.4efg	13.7bcd
TBy27-1385	168.4h	247.1def	45.33fg	46.44b-e	11.2efg	13.0cde
TBy28-0348	226.6c-f	270.8cde	64.46a-e	35.38c-f	14.7a	14.3ab
MPT02-458	268.8ab	327.4a	43.69g	65.69a	13.8ab	14.2ab
MPT03-166	233.9b-f	230.7ef	65.08a-e	28.75ef	11.6efg	10.8f
91-2-527	287.3a	328.7a	71.85a	57.65ab	11.6efg	11.9ef
Check cultivars						
KK3	241.1b-f	283.7bcd	72.77a	60.71ab	12.2cde	14.1abc
LK92-11	213.6efg	239.2ef	63.28a-e	43.25b-e	13.1bc	14.0abc
KPS01-12	263.0abc	315.5ab	57.85b-f	43.31b-e	13.7ab	14.7ab
F-test	**	**	**	**	**	**
CV (%)	11.68	10.22	15.39	30.56	6.58	5.91

**; significant at 99% ($p \leq 0.01$), Means followed by the same letters in the same column are not significantly different in LSD ($p \leq 0.05$).

DISCUSSION

The soils with pH (5.5–7.0), EC (≤4.0 dS m^{-1}), clay, sandy loam, or clay loam texture, with average temperatures (30 °C–35 °C), and rainfall (1000–1500 mm $year^{-1}$) proved appropriate and recommendable for better crop growth and yield of sugarcane (Land Development Department, 2007). In the current study, it was notable in L1, the pH (6.20) falls in the normal range for sugarcane growth; however, in L2, the pH (4.67) showed lesser than ideal for sugarcane planting. At both locations, the organic matter (OM) was low. However, the very low EC occurred more favorable for cultivation of the sugarcane at both locations.

Past reports enunciated rainfall ranging from 1000 and 1500 mm per year was optimum for sugarcane production (Land Development Department, 2007). However, in the current cropping year, the recorded total annual average rainfall was 1885.3 and 1426.0 mm per year in L1 and L2, respectively, which was also higher than previously documented. The temperature at both sites was also ordinary for sugarcane, and evapotranspiration followed a normal pattern in L1 and L2.

Several agronomic and yield-related characteristics were visible in the assessment of sugarcane in past studies, i.e., plant height (Set-Tow *et al*., 2019; Puriya *et al*., 2020; Hartati and Yuniyati, 2022), stalk diameter (Deeyiam and Lersrutaiyotin, 2020; Puriya *et al*., 2020), millable canes (Sueaken *et al*., 2022; Kruangpatee *et al*., 2017; Puriya *et al*., 2020), stalk weight (Kruangpatee *et al*., 2017; Boodseephum and Wongtamee, 2022), cane yield (Arain *et al*., 2011; Mehareb *et al*., 2022), sugar yield (Getaneh *et al*., 2016; Sueaken *et al*., 2022), CCS (Set-Tow *et al*., 2020; Boodseephum and Wongtamee, 2022; Sueaken *et al*., 2022), TSS and Brix values (Ahmed *et al*., 2011, 2014; Mehareb *et al*., 2016; Abu-Ellail *et al*., 2021; Hartati and Yuniyati, 2022).

Some studies reported at harvest, the plant height ranged from 178 to 293 cm (Udon Thani) and 177–267 cm (Kalasin) in Northeastern Thailand, similar to recent research locations (Set-Tow *et al*., 2019). In the latest study, plant height varied from 168.4–287.3 cm at L1 and 227.5–333.1 cm at L2 (Table 4). Sugarcane genotype TBy27-1385 had the minimum plant height at L1, which was included in genotypes with the least plant height at L2. Conversely, check cultivar KK3 and genotype CSB06-4-162 had the tallest plants in Kalasin and Udon Thani, respectively, while the genotypes 91-2-527 and CSB06-4-162 surpassed KK3 in L1 and L2. Puriya *et al*. (2020) found nonsignificant differences among the genotypes for plant height in sandy soils in Phitsanulok, with a range of 217–260 cm. Contrary, Getaneh *et al*. (2016) observed significant differences between sugarcane cultivars for plant height studied in Luvisol and Vertisol soils, but, no interaction effects existed between the soil types and sugarcane cultivars. Lower sugarcane plant height was noteworthy in the dry lands of Indonesia (95.81-199.07 cm), likely due to environmental factors, such as, drought, soil, and rainfall variability (Hartati and Yuniyati, 2022).

The stalk diameter reveals a moderate association with stalk weight and cane yield (0.48^{**} and 0.36^{**}, respectively) (Kruangpatee *et al*., 2017), contrasting with the findings of Soomro *et al*. (2006), who reported a weak relationship. The said trait remains crucial for evaluating the sugarcane cultivars under diverse environmental conditions. Set-Tow *et al*. (2019) reported stalk diameter at Udon Thani was apparently similar to current results recorded at L1; however, the stalk diameter at L2 was slightly lower than the previous report (26.65 mm and 28.95 mm, respectively) (Table 3). However, the stalk diameter (29.50 mm) at Kalasin exceeded in both locations used in the presented studies. Set-Tow *et al*. (2020) observed variability between locations, with average diameter in Udon Thani and Kalasin (28.14 and 20.94 mm, respectively). The current study found higher stalk diameter at L1 and L2 than Kalasin, and the L2 results emerged similar to Udon Thani. Kruangpatee *et al*. (2017) stated the higher diameter at the Khon Kaen and Udon Thani than the locations used in the current study. Sugarcane genotypes KK3 and MPT02-458 had lower diameters, while KPS01-12 showed higher values, contrasting with Puriya *et al*. (2020), who found nonsignificant differences among the sugarcane genotypes for plant height.

Previous studies revealed an association between stalk weight and cane yield existed to be positive (Kruangpatee *et al*., 2017). The presented results were contrary to Boodseephum and Wongtamee (2022), who reported the average single stalk weight of cane plant was 2.12 kg, which was higher than those recorded in L1 and L2. Furthermore, the genotype 91-2-527 had the highest stalk weight; however, it appeared nonsignificantly different from the two other lines, CSB06-4-162 and MPT02-458 (Figure 2a). Kruangpatee *et al*. (2017) evaluated promising sugarcane lines in Khon Kaen and Udon Thani and reported the average single stalk weight was 2.12 and 2.40 kg, respectively, which was higher than results of this study. Meanwhile, they observed different promising lines as compared with the current study. Two check cultivars (KK3 and KPS01-12) and one elite line (MPT02-458), also used in the presented study, revealed genotypes KK3 and KPS01-12 showed lower single stalk weight than other lines. However, the promising line MPT02-458 (1.75 kg) gained classification into the higher stalk weight group in the latest study. The genotype MPT02-458 weighed 2.21 kg in a previous study (Kruangpatee *et al*., 2017), and its stalk weight was higher than the current findings. In contrast, Puriya *et al*. (2020) reported sugarcane genotypes showed nonsignificant differences in stalk weight, as compared to a present result showing significant variations among the genotypes for the said trait.

The average millable canes in Khon Kaen and Udon Thani were nearly twice as high as the recent yield in L2 (29,351 canes ha^{-1}); however, it was marginally higher than the current report at the L1 (Table 3). Sueaken *et al*. (2022) evaluated check cultivars (KK3 and LK92-11) and classified them with higher millable canes than the 16 other sugarcane genotypes, observing the genotypes varied substantially for millable canes. The current results noted cultivar KK3 had higher millable canes, while genotype LK92-11 had lower millable canes (Figure 2a). Puriya *et al*. (2020)

discovered millable canes were remarkably diverse among the genotypes with an average number of millable canes (44,662.5 canes ha^{-1}), which was slightly lower than the presented results in L1 (45,901 canes ha^{-1}) (Table 3); but, it was higher than results at the L2 in the current study. Furthermore, Getaneh *et al*. (2016) declared the higher average millable cane yield in Luvisol and Vertisol and two times higher than the current study outcomes, probably showing the millable cane yield bore influences from the soil type.

The findings of Set-Tow *et al*. (2019) showed cane yield can be as high as 49.37 and 85.62 t ha^{-1} for Kalasin and Udon Thani, respectively, in Thailand. Puriya *et al*. (2020) evaluated sugarcane genotypes under sandy soil and the genotypes provided significant differences for cane yield, with an average of 81.25 t ha^{-1}. This was higher than the presented study results at approximately 25.5% and 47.3% for L1 and L2, respectively (Table 3). Boodseephum and Wongtamee (2022) gathered lower cane yields for the genotypes KK3 and TBy27-1385 by cultivating in clay soil, whereas, the higher cane yield resulted for KK3 in the current study at both locations. Puriya *et al*. (2020) obtained a greater cane yield in the genotype LK92-11, whereas, this genotype only recorded with a better cane yield in L1. Conversely, Deeyiam and Lersrutaiyotin (2020) considered by cultivating in central Thailand, cultivar KPS01-12 produced higher cane yield than the genotype KK3, probably, because the development of cultivar KPS01-12 transpired from Kasetsart University, Central Thailand. Thus, it could be more adaptable to the environmental conditions than cultivar KK3.

The sugar output is the primary product of the sugar industry, and CCS is one of the most important factors for sugarcane production. The CCS appeared nonsignificantly different between locations by cultivating in the Northeastern Thailand. A check cultivar (KPS01-12) recorded with a higher CCS both in L1 and L2. The average CCS in both locations was 13.6 and 12.5 (L1 and L2, respectively) in the presented study (Table 3). Previous reports recorded average CCS ranging at 12.4 and 12.3 in plant cane (Set-Tow *et al*., 2019) and 13.3 and 13.2 in ratoon cane (Set-Tow *et al*., 2020). In clay soil, Boodseephum and Wongtamee (2022) noted CCS of KK3 (15.29) and LK92-11 (14.36) were greater than in the latest study (12.2 and 14.1 in L1 and L2, respectively). Moreover, the genotype TBy28-0348 had a lower CCS (13.55) than this study results (14.7 and 14.3 in L1 and L2, respectively) (Table 4). By planting check cultivars (KK3 and KPS01-12) in central Thailand (Nakhon Pathom), it recorded with lower CCS (9.65 and 11.24, respectively) than past investigations (Set-Tow *et al*., 2019, 2020; Sueaken *et al*., 2022). By applying three amendments to relieve the higher pH in sodic soil with a pH of 8.76, it was evident that CCS had a noteworthy difference (ranging from 9.81 to 12.41), and gypsum application (4.8 t ha^{-1}) emerged with the highest CCS (Manjula *et al*., 2015). These findings suggested the corrective measures for pH adversely affected CSS, and this could be useful in L2, which had a lower soil pH.

Specific varietal responses, despite the acidic soil, cultivar KK3 and genotype MPT02-458 showed relatively higher cane yield and CCS at L2, suggesting a level of tolerance to low pH. NSUT08-22-3-13 had the highest TSS and CCS in L2, indicating potential adaptability to acidic conditions for sugar production. 91-2-527 and CSB06-4-162 performed well across both locations, signifying general adaptability, but potentially requiring further analysis of their physiological mechanisms to confirm tolerance.

At L2, where the soil pH was acidic (4.67), genotypes, such as, MPT02-458 and NSUT08-22-3-13, demonstrated superior adaptability, achieving high CCS and cane yield. In contrast, genotype TBy27-1385 exhibited reduced performance, suggesting lower tolerance to acidic conditions. The higher performance of certain varieties may refer to better nutrient uptake efficiency and stress-mitigating physiological traits. Meanwhile, L2's low EC may have reduced salinity-related stress, the low organic matter likely posed a nutrient challenge. These findings recommend varieties with good performance in L2, such as MPT02-458, can serve as potential candidates for cultivation in acidic soils, though soil amendments, such as liming, could further enhance their performance. Additionally, the promising performance of varieties, like KK3 and LK92-11 across both locations, implies broad adaptability; although, further studies on their response to pH amelioration in acidic soils are necessary. The present study and the past studies highlighted the importance of assessing genotype performance under specific soil conditions to guide varietal recommendations and breeding programs (Singkham *et al.,* 2016; Songsri *et al*., 2019; Palachai *et al*., 2021).

CONCLUSIONS

Promising sugarcane lines underwent evaluation on acidic soils with low fertility under rainfed conditions. The results revealed check cultivar KK3 and line 91-2-527 showed the highest cane yield at both locations. Sugarcane lines 91-2-527, CSB06-4-12, MPT02-458, and KPS01-12 had higher stalk weight, whereas, the genotypes TBy27-1385 and KK3 produced more millable canes. Similarly, genotype MPT02-458 exhibits superior plant height and cane yield in highly acidic soil conditions. Although, 91-2-527 had a lower commercial cane sugar (CCS) than the check cultivars, but, its CCS also exceeded Thailand's sugarcane industry standard (10.0). The results suggested specific genotypes, such as 91-2-527 and KK3, proved appropriate for cultivation on acidic soils with low fertility under rainfed conditions. More research is necessary to confirm the long-term potential of the sugarcane genotypes for ratoon cane yield.

ACKNOWLEDGMENTS

This research project received financial support from Mahasarakham University. Thank you to the Department of Agricultural Technology, Faculty of Technology Mahasarakham University and its students for their valuable assistance.

REFERENCES

Abu-Ellail FFB, El-Taib ABA, Hefny YAM (2021). Stability analysis and performance of promising sugarcane varieties for yield and quality traits. *Electr. J. Plant Breed.* 12(3): 623-636.

Ahmed ZA, Ahmed AM, El-Soghier KS (2014). Evaluation of three sugarcane varieties grown under different number of irrigations. *Egypt. J. Agric. Res.* 92(2): 765-778.

Ahmed ZA, Ahmed AM, Osman MSH (2011). Optimum inter-row spacing and number of ploughings for two promising sugarcane varieties. *Egypt. J. Agric. Res.* 89 (1): 301-315.

Arain MY, Panhwar RN, Gujar N, Chohan M, Rajput MA, Soomro AF, 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(2): 226-230.

Boodseephum P, Wongtamee A (2022). Evaluation of yield components and yields of high yielding sugarcane varieties in plant cane and first ratoon for clay soil area of Phitsanulok province. *Naresuan Phayao J.* 15(1): 109-121.

Deeyiam S, Lersrutaiyotin R (2020). Potential evaluation of Kamphaeng Saen sugarcane varieties to nitrogen fertilizer application in plant cane. *J. Sci. Technol.* 9(1): 1-12.

Department of Agricultural Extension (2008). Sugarcane. Available online: http://www.agriman.doae.go.th/home/t.n/t.n1/2filcrop_Requirement/05_Sugarcane.pdf (Accessed on 1 January 2025).

Department of Agriculture Thailand (2022). Sugarcane breeding manual. Available online: https://www.doa.go.th/fcri/wp-content/uploads/2022/smart-box/sugar-cane2565.pdf (Accessed on 10 May 2023).

Fujii K, Hayakawa C, Panitkasate T, Maskhao I, Funakawa S, Kosaki T (2016). Acidification and buffering mechanisms of tropical sandy soil in northeast Thailand. *Soil Tillage Res.* 156: 102-112.

Getaneh A, Tadesse F, Ayele N, Bikilla M (2016). Agronomic performance evaluation of sugarcane varieties under Finchaa Sugar Estate agro-ecological conditions. *Afr. J. Agric. Res.* 11(44): 4425-4433.

Hartati RrS, Yuniyati N (2022). Field evaluation of the potential of drought-tolerant sugarcane (*Saccharum officinarum* L.) mutants based on morpho-agronomic characters. In: the 2nd International Conference on Sustainable Plantation, Series: Earth and Environmental Science 9. http://doi:10.1088/1755-1315/974/1/012005.

Kapetch P, Sansayawichai T, Pisancharoen K (2014). Effects of environmental variability on sugarcane production in the North and the Northeast of Thailand. *Thai J. Agric. Sci.* 32(1): 2-15.

Kruangpatee J, Songsri P, Jongrungklang N (2017). Evaluation of yield and agronomic traits of sugarcane elite line under rain-fed conditions in the northeastern Thailand. *Prawarun Agric. J.* 14(1): 30-40.

Krungsri Research (2021). Industry outlook 2018-2020: Sugar industry. Available online: https://www.krungsri.com/en/research/industry/industry-outlook/agriculture/sugar/io/io-sugar-20 (Accessed on 20 May 2023).

Land Development Department (2007). Soil management with organic fertilizer for enhancing sugarcane yield. Available online: http://www1.ldd.go.th/menu_Dataonline/G2/G2_05.pdf (Accessed on 20 May 2023).

Manjula S, Vadivel A, Jayalakshmi M (2015). Comparative evaluation of sugarcane varieties on yield and juice characteristics in sodic soil. *Res. J. Agric. Sci.* 6(2): 383-386.

Meade CP, Chen JCP (1977). Cane Sugar Handbook. 10th edition. John Wiley & Sons Inc., New York.

Mehareb EM, Abou-Elwafa SF, Galal MOA (2016). Mean performance and ratooning ability of sugarcane promising genotypes at early clonal selection. *Am. Eurasian. J. Agric. Environ. Sci.* 16(1): 20-27.

Mehareb EM, Osman MAM, Attia AE, Bekheet MA, Abo-Elenen FFM (2022). Stability assessment for selection of elite sugarcane clones across multi-environment based on AMMI and GGE biplot models. *Euphytica* 218(95): https://doi.org/10.1007/s10681-022-03025-9.

OSCB (2024). Report of sugarcane production in 2023/2024. Office of the Cane and Sugar Board (OSCB). Available online: https://www.ocsb.go.th/2024/reports-articles/area-yield/27524/ (Accessed on 20 May 2023).

Palachai C, Gonkhamdee S, Songsri P, Jongrungklang N (2021). Ratooning ability of diverse sugarcane cultivars under natural short- and long-term waterlogged field conditions. *SABRAO J. Breed. Genet.* 53(2): 172-186.

Puriya J, Chamnanpa W, Boodsiphum P, Wongtamee A (2020). Evaluation of potential productivity between plant cane and the first ratoon of 16 sugarcane varieties grown in the sandy soil area in Phitsanulok province. *Naresuan Agric. J.* 17(2): 1-8.

Set-Tow S, Songsri P, Jongrungklang N, Jaisil P (2019). Evaluation of cane yield and agronomic traits of 16 sugarcane advance clones grown under rainfed conditions in northeastern region with different soil texture. *Khon Kaen Agric. J.* 47(4): 641-654.

Set-Tow S, Songsri P, Jongrungklang N, Jaisil P (2020). Evaluation of cane yield and agronomic traits of ratoon crops grown in a drought period of 16 rainfed advanced sugarcane clones. *KMAJ.* 38(1): 42-51.

Singkham N, P. Songsri, P. Jaisil, S. Jogloy, P. Klomsa-Ard, N. Jonglangklang and A. Patanothai (2016). Diversity of characteristics associated with lodging resistance in sugarcane germplasm. *SABRAO J. Breed. Genet*. 48(1): 97-104.

Songsri P, Nata J, Bootprom N, Jongrungklang N (2019). Evaluation of sugarcane elite clones through physiological responses and yield related traits under early rainfed drought stress conditions. *SABRAO J. Breed. Genet*. 51(4): 373-389.

Soomro AF, Junejo S, Ahmed A, Aslam M (2006). Evaluation of different promising sugarcane varieties for some quantitative and qualitative attributes under Thatta (Pakistan) conditions. *Int. J. Agric. Biol.* 8(2): 195-197.

Sueaken S, Chotisan C, Phisayatra W (2022). Evaluation of cane yield and agronomic traits of elite sugarcane clones grown in Kumphawapi district, Udon Thani province. *J. Eng. Technol. Udon Thani Rajabhat Univ.* 1(1): 41-49.