

Evaluation 16 elite sugarcane lines for ethanol yield and yield related traits under rainfed conditions

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Abstract

The world demand for clean renewable energy has seen a rise in use of sugarcane in production of bioenergy products like bio-ethanol which is produced from molasses and extracted juice of stalk. This then brings a competition between production for food and for bioenergy in the sugarcane industry. Therefore, this calls for breeders and producers to develop and produce high yielding sugarcane varieties to meet the demand. We undertook a study with the aim to screen the recently released elite lines for the ethanol yield and related traits. The study was conducted in two locations under rainfed conditions in Maha Sarakham, Thailand. The results showed that all the locations had no effect on the studied genotypes thus suggesting that they are stable over different locations. The mean values show that SG, KK07-478 and RT2004-085 showed better performance recording higher juice yield, juice weight, TSS, percent of ethanol and estimated ethanol yield in both locations. We found interaction between location and variety except in TSS and percent of ethanol, RT2004-085 showed the highest TSS, juice weight, SG, PE and EEY in combine both locations. A high correlation of EEY to juice yield (0.967***) and juice weight (0.978***) also percent ethanol was highly correlated with TSS (0.953**) this then suggest that to improve ethanol yield breeders should focus on improved the performance of juice yield, juice weight and the TSS. Because of the higher performance, KK07-478 and RT2004-085 should further be evaluated in several other locations before they are adopted by farmers.

Keywords: Polarization, CCS, brix value, sugar content, association traits.

Abbreviations: TSS_Total soluble solid; Pol_Polarization; CCS_ commercial cane sugar; SG_specific gravity; OM_organic matter; EC_electrical conductivity; RCBD_ randomized complete block design; PE_percent of ethanol; EEY_estimated ethanol yield.

Introduction

The effects of climate change caused by continued use of fossil fuels and the ever-fluctuating petroleum prices has driven researchers into finding alternative renewable energy sources. Several crops have been identified as suitable for bioenergy production and among these crops' sugarcane has shown to be the most promising in production of bioethanol, as most of the ethanol currently produced is derived from sugarcane juice (Waclawovsky et al., 2010; Santchurn et al., 2014). The global production of sugarcane has seen an upward trend over the years mostly driven by the demand of sugar and sugar byproducts (Rumánková and Smutka, 2012) and the increasing production of bioethanol and biofuel (Svatoš et al., 2013). These increases in demand for sugar and other industrial byproducts calls for increase in production of sugarcane but there are several factors that hamper the increase in sugarcane production. Climate change and environmental stress has been the major challenge to agriculture more especially the crop production (Zhao and Li, 2015) and just like any other agricultural enterprise, sugarcane is also vulnerable to these challenges more especially the changes in temperatures (Knox et al., 2010; Carvalho et al., 2015) and precipitation (Li and Wei, 2006; Li

and Yang, 2014). In view of this demand in sugarcane as both food crop and bioenergy crop and the challenges the production faces, the breeders continuously strive to breed and release varieties that will be high yield in order to meet demand from the two important sectors in today life.

Sugarcane (*Saccharum officinarum* L.) is thought to have originated from the South Pacific in the New Guinea by crosses and back-crossing with the original type, *S. spontaneum*, occurring wild from Africa, India and through the Pacific to New Guinea (Purseglove, 1974). It is one important industrial crop that has been exploited globally in sugar production and bioenergy feedstock as one alternative energy crop (McMillan, 1997). It is thus considered the most essential crop as its byproducts are used in almost every household the world over (Zulu et al., 2019) and has been suggested as the most important cash crop in some Asian countries (Sapkota et al., 2019; Karim et al., 2016). Sugarcane, on average, accounts for nearly 80% of global sugar production and with the top ten producing countries (India, Brazil, Thailand, China, the US, Mexico, Russia, Pakistan, France, Australia) accounting for nearly 70% of global output (International Sugar Organization, 2020).

Thailand is on the top ten sugarcane producing countries in the world, thus making the crop to have high economic importance in the country. Sugarcane production in Thailand for the year 2018/2019 was recorded at 131.9 m t from the production area of 1.96 m ha. Even though Thailand is one of the top producing countries, some of the production areas still have challenges in obtaining good productivity per unit area. The Northeast of Thailand accounts for higher production area (0.85 m ha) but has lower production yield (45.88 m t) as compared to other part of Thailand which shows bad productivity. One of the major reasons for low productivity in this part of the country is mainly because most farmers produce under rainfed conditions. In addition, the low soil fertility in the area adds on to the factors that leads to low productivity. Therefore, specific varieties for sugarcane production for the Northeast Thailand are required. To counter these problems, it is important to invest in specific varieties that will do well in the poor soils and with minimal water. Recently, new sugarcane varieties have been developed by breeders specifically to address the problem of low productivity in the North eastern part of the country were rainfed production is highly practiced.

Bio-ethanol production from molasses were reported several previously studies (Lavarack 2003; Arshad et al., 2017; Alamri et al., 2015), but so far there has been a few studies (Giri et al. 2013; Bunphan et al., 2015) that focusses on evaluating ethanol yield and yield related traits from juice cane. It is every farmer wish to plant cultivars that will give them better returns for their money. With the plant breeders continuously releasing varieties, it is thus upon us researchers to evaluate this varieties in different environments to select the appropriate ones to recommend to farmers. Therefore, our current study aims at evaluating the estimated ethanol yield and related yield traits of sixteen (thirteen elite and three check) sugarcane varieties grown under rain-fed condition in Maha Sarakham province, Thailand.

Results and discussion

Soil properties

The result of soil analysis results (Table 1), shows that we could characterize planting locations as low fertility soil with slightly acidity (L1; sugarcane field); and very low fertility soil with low acidity (L2; upland paddy rice field). The soil pH recorded at L1 field show slightly acidity (low soil pH) at 6.20 as compared to L2 field which recorded very low acidity with pH of 4.67. Organic matter (OM) recorded from both locations were very low (0.52 and 0.47 %); similar to electrical conductivity (EC) of both locations were very low. Other soil analysis results show that Phosphorus (P) at L1 location was recorded at 48 ppm which was about was more than 3 times higher when compared to L2 location which recorded 13 ppm. Results of other minerals like potassium (K), calcium (Ca) and magnesium (Mg) of both locations were very low; however, K, Ca and Mg content in L1 location was higher than in L2 location (Table 1). These results show that both areas were suitable for planting sugarcane as they were within the recommended rates.

The results of the soil analysis came with a recommendation of lime application at a rate of 100 kg ha⁻¹ was proposed, but in this study the application of lime was not done. Even though previous studies have shown the optimum pH for sugarcane production to be around pH 7 (McEnroe and Coulter, 1964), it has also been shown that the acidic soils do not affect yield that much and it tolerates pH ranging from 5-

8.5 (Srivastava and Rai, 2012). Although, the low soil pH did not have any effect on the juice quality parameters such as the TSS and PE, it did affect the growth and yield of the crops (data not shown), as yield from both experimental fields were lower as compared to potential sugarcane yield. This low cane yield was then thought to have affected the ethanol yield as it was previously found that cane yield has positive correlated to ethanol yield in sweet sorghum (Bunphan et al., 2014).

Meteorological data

An aggregate rainfall recorded during the planting period of this study was 1694.8 mm. The water requirement for sugarcane production has been estimated to range from 1500-2500 evenly distributed over the growing season (Bella et al., 2009; Choudhary et al., 2013; Rijajaya, 2020). The recorded aggregate rainfall for this current study thus falls around the minimum rainfall needed for minimal sugarcane growth and development. The daily temperature ranged between 24.1-30.6 °C with average temperature calculated at 27.8 °C and relative humidity (RH) recorded at 73.1 % (data not shown). The temperatures ranges experienced during the research period were with the recommended ranges of growth and development of sugarcane as it was between 20°C and 35°C (Mohsen et al., 1998; Bonnet et al., 2006)

Genotype by environment interaction

The results obtained from the ethanol yield related traits during growth and development of the sugarcane in both fields were subjected to Analysis of variance (ANOVA) and is presented in Table 2. The location (L) effect on performances of the 16 sugarcane varieties showed that the location had no significant effect on the growth and development of the sugarcane cultivars in the two locations, our results were in contrast to various other studies which has shown that location had an effect on performance of genotypes (Rea and Vieira, 2002; Khan et al., 2015) and Mattos et al., (2013) had contrasting results showing location having a large percent influence on yield traits. A different result was observed by Ftwi et al., (2018) who observed both locations were not significance for some traits and significance for other traits of sugarcane when grown in various locations. This could suggest that the genotypes used in this study had a stable performance over the two locations. The genotype (G) effect showed to have had influence as the means of all agronomic traits among the sixteen varieties showed high significance differences, similarly Momotarz et al. (2020) and Guilly et al. (2017) found out that the differences attributed to genotypes was higher than the one attributed to the locations. A high G x L interaction in all traits except TSS and PE was observed in this study, a higher interaction was also observed by (Jamooza et al., 2019;) when evaluating several cultivars of sugarcane under different environments and in contrast Rodríguez et al. (2010) and Kumar et al. (2018) found out that the interaction accounted for a lesser percentage in difference in yield traits.

Combined analysis of two locations for the ethanol yield and yield related traits

Cane yield in our study showed no significant difference between the 16 varieties over the two locations of study (data not shown). A Similarly study by Khumla et al. (2012) on cane yield also showed no significant difference between the varieties studied. In that study the cane yield, TSS and pol were slightly higher than in our study probably on the check varieties, something that might be attributed to the

difference in environmental conditions. However, fiber and purity in our present study recorded higher values as compared to the previous study in those cultivars.

Further, an analysis on the ethanol yield traits that were studied in our research (juice yield, juice weight, fiber, pol, purity, PE, total soluble solid and EEY) were subjected to statistical analysis (Table 3). The EEY in our research was calculated as per Somani and Taylor (2003) using the other yield traits like TSS, SG and juice yield for calculation as it has proved to be more efficient and reliable for calculating ethanol yield (Bunphan et al., 2015).

The results showed that Kku07-478 recorded the highest average of both juice yield and juice weight (42710.0 l/ha and 45.05 t/ha, respectively) and it also had higher fiber (16.24%), however, this cultivar recorded a lower pol and PE (15.42 and 11.57% respectively). Whereas,

RT2004-085 recorded the highest values on several traits, like, juice yield (39230.0 l/ha), juice weight (44.86 t/ha), moreover this cultivar recorded the highest fiber, pol and PE (17.04%, 16.67 and 12.60% respectively), but it recorded a lower purity (86.24%).

Something to be noted, is that some cultivar had outstanding performances in few traits i.e. cv. Kku06-501 and NSUT08-22-3-13 had higher fiber (16.15 and 16.60% respectively), pol (16.52 and 16.62% respectively) and purity (87.76 and 89.45% respectively), while cv. TBy28-0348 showed higher pol (16.62%) and purity (88.54%), whereas cv. 91-2-527 showed higher juice weight but having a lower juice yield (Table 3). The check varieties KPS01-12 and LK92-11 had also recorded higher purity on cane juice at (88.69 and 87.79% respectively).

The total soluble solids analysis recorded an average ranging between 18.23 and 22.15° brix, where cv. RT2004-085 had the highest TSS at 22.15° brix. Several other cultivars (KK07-478, KK06-501, NSUT08-22-3-13 and KPS01-12) recorded TSS of more than 20° brix (Fig.1). Quantification of the estimated ethanol yield (EEY) gave values that ranged from 1846.06 to 5062.19 l/ha on the studied cultivars. Similar to TSS, cv. RT2004-085 had the highest EEY of 5062.19 l/ha, the two other cultivars that had higher EEY were KK07-478 and 91-2-527 that recorded EEY of 4998.44 and 4648.19 l/ha respectively (Fig. 2).

Analysis per location

Sugarcane field (L1) for the ethanol yield and yield related traits

Analysis of results showed that all studied traits had significant different except for the specific gravity (SG) in this study location. The SG is a very important trait for determining the EEY. The SG of the cane juice was also determined and the results shows that it had no significant difference among the cultivars studied. The mean values recorded for the SG ranged from 1.048 to 1.079 for all the 16 cultivars.

In this location the cv. KK07-478 recorded the highest values on several ethanol yield related traits i.e. juice yield and juice weight was recorded at 55496.9 l/ha and 58.9 t/ha respectively, it also had the highest PE at 12.08%. However, this cultivar recorded lower values for some traits i.e. pol and fiber recorded at 17.23 and 14.27% respectively. One other cultivar that recorded high juice yield is the cv. 91-2527 which had 45676.3 l/ha. In this location, higher values of Pol were

recorded under cv. TBy28-0348 at 19.51 while PE was recorded at 11.95% for the same cultivar. Two more cultivars (KK06-501 and RT2004-085) had promising values of pol and PE, whereas cv. NSUT08-22-3-13 also recorded promising values of Pol for this location (Table 4).

The TSS in this location ranged between 18.22 to 22.44° brix, and cv. KK07-478 had the highest TSS at 22.44% followed by cv. RT2004-085, TBy28-0348, KK06-501 and KPS01-12 at 22.15, 22.03, 21.70 and 21.18° brix respectively (Fig.3). The results recorded for EEY showed that KK07-478 had the highest EEY at 6684.38 l/ha, this was not surprising as this cultivar had recorded high values on traits related to EEY, the other two cultivars which recorded good values for EEY were cv. 91-2-527, CSB06-4-162 and KK3 with values of 4251.88 l/ha, 3703.75 and 3635.28 l/ha respectively (Fig.4).

Upland paddy rice field (L2) for the ethanol yield and yield related traits

Similar to the first location, all ethanol yield related traits were analyzed and found to be significantly different except SG. The SG ranged between 1.024 to 1.173 and RT2004-085 had the highest SG. Among the other cultivars, cv. RT2004-085 recorded outstanding results for most of the traits, as it had the highest juice yield (57647.5 l/ha), juice weight (67.6 t/ha), fiber (19.61%), pol (14.72) and PE (13.26%). Results for other cultivars consistent as they recorded high values for other traits and lower values for other traits like the cv. 91-2-527 which had higher juice yield (45433.8 l/ha) and juice weight (48.8 t/ha) but also recorded the lower fiber, pol and PE when compared among other cultivars. Also, the cv. NSUT08-22-3-13, CSB06-4-162 and KPS01-12 recorded the highest fiber and pol however while other traits i.e. juice yield, juice weight and percent of ethanol were lower (Table 5).

The TSS of sixteen varieties ranged between 18.32 to 22.15 ° brix, cv. RT2004-085 also had the highest TSS (22.15 ° brix), whereas several cultivars recorded moderately higher TSS such as CSB06-4-162, NSUT08-22-3-13, KK06-501, KK3 and KK07-478 (Fig. 5). Cultivar RT2004-085 also recorded the highest value for EEY at 7633.13 l/ha, followed by cv. 91-2-527 and cv. MPT02-458 at 5044.38 and 4083.75 l/ha, respectively (Fig. 6).

The correlation analysis among the traits related to ethanol a yield in sugarcane

Correlation analysis of recorded traits was performed it showed that EEY had highly positive correlation to juice yield ($r=0.967^{***}$) and juice weight ($r=0.978^{***}$) (Fig. 7A and B). The other high positive correlation was observed between juice weight and juice yield at $r=0.986^{***}$ (Fig. 7J). Moreover, we found PE to have high to moderate positive relationship with several traits, like; PE to TSS ($r=0.975^{***}$), PE to pol ($r=0.883^{***}$), PE to fiber ($r=0.712^{***}$) and PE to SG ($r=0.664^{***}$) (Fig. 7C to 7F respectively). Fiber was moderately associated to TSS (Fig 7G) and to Pol (Fig 7I) and moreover TSS has highly correlated to pol was also found in recent study ($r=0.904^{***}$) (Fig. 7H). Moreover, in the current study we found a moderate positive correlation between purity and fiber at 0.523* and purity had moderate association to pol at 0.731** (data not shown). Several other studies (Péné and Béhou, 2020) have shown that the most relevant traits were related to the juice yield. Previous studies have also studied correlations between yield and yield

Table 1. Soil properties at Sugar cane field (L1) and upland paddy rice field (L2).

Location	pH	OM (%)	EC (dS/m)	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)
Sugarcane field (L1)	6.20	0.52 (low)	0.022	48	42	238	42
Upland paddy rice field (L2)	4.67	0.47 (very low)	0.019	13	32	108	24

Table 2. Analysis of variance results for Juice and juice yield related traits of sixteen sugarcane varieties at two study locations.

Factors	df	Juice yield	Juice weight	Total soluble solid (brix)	Fiber	Pol	Purity	Percent of ethanol	Estimated ethanol yield
Location (L)	1	ns	ns	ns	ns	ns	ns	ns	ns
Variety (V)	15	**	**	**	**	**	**	**	**
LxV	15	**	**	ns	**	*	*	ns	**

ns= non-significant; * and ** = significant at $\alpha = 0.05$ and 0.01

Table 3. combined means of Juice yield and related traits of 16 sugarcane varieties of the two study locations.

Variety	Juice yield (l/ha)	Juice weight (ton/ha)	Fiber (%)	Pol (%)	Purity (%)	Percent of ethanol
KK06-501	20884.4fg	22.37gf	16.15abc	16.52a	87.76abc	11.73b
KK07-478	42710.0a	45.05a	16.24abc	15.42c	84.95def	11.57bc
NSUT08-22-3-13	16305.0g	17.30h	16.60ab	16.62a	89.45a	11.43bc
RT2004-085	39230.0ab	44.86a	17.04a	16.67a	86.24cde	12.60a
CSB06-2-15	18723.1fg	19.80gh	14.86def	13.88de	84.07efg	10.04ef
CSB06-2-21	34626.9bc	36.73bc	16.09abc	13.45de	84.51d-g	10.06ef
CSB06-4-162	29391.9d	31.75cd	15.82bcd	15.93abc	87.34abc	11.28bc
CSB06-5-20	26430.0de	27.77def	15.26c-f	13.49de	87.90abc	9.51f
TBy27-1385	18386.3fg	19.63gh	14.30ef	13.30e	83.49fg	10.21def
TBy28-0348	21173.1fg	22.57fgh	15.49bcd	16.72a	88.54ab	11.55bc
MPT02-458	27480.6d	29.26de	15.77bcd	16.23abc	88.56ab	11.26bc
MPT03-166	30683.1cd	31.34cd	14.13f	14.13de	82.39g	9.92f
91-2-527	42198.1cd	40.10ab	15.44cde	14.35d	83.38fg	11.00bcd
KK3 (check)	34551.3bc	36.03bc	16.36abc	15.46bc	86.34bcd	10.78cde
LK92-11 (check)	27477.5d	29.82d	15.58bcd	15.80abc	87.79abc	11.23bc
KPS01-12 (check)	22313.1ef	23.62efg	15.74bcd	16.49ab	88.69a	11.33bc
F-test	**	**	**	**	**	**
CV (L*R)	29.37	26.4	62.16	56.67	1.90	4.34
CV (L*R*T)	15.42	16.5	6.37	5.89	2.23	6.56

** = significant at $\alpha = 0.01$

Table 4. Juice yield and related traits of sugarcane grown under rain-fed condition in location 1 (L1)

Variety	Juice yield (l/ha)	Juice weight (t/ha)	SG	Fiber (%)	Pol	Purity (%)	Percent of ethanol
KK06-501	23281.9fgh	24.5def	1.058	13.50b-h	18.92ab	87.20abc	11.68ab
KK07-478	55496.9a	58.9a	1.055	14.27bcd	17.23c-f	83.12e-h	12.08a
NSUT08-22-3-13	24438.8e-h	25.9def	1.062	13.63b-g	18.50abc	88.78a	11.17a-d
RT2004-085	20991.9fgh	22.1ef	1.057	14.47bc	18.62abc	84.08efg	11.94a
CSB06-2-15	28516.9c-f	30.2b-e	1.057	12.20gh	14.97h	82.15fgh	9.49e
CSB06-2-21	32820.6cde	34.7bc	1.058	16.33a	15.85fgh	83.06e-h	10.03cde
CSB06-4-162	34548.1c	37.3b	1.079	12.13gh	16.79efg	84.83c-f	10.70b-e
CSB06-5-20	21666.3fgh	22.7ef	1.051	14.87ab	15.66gh	85.48b-e	9.50e
TBy27-1385	17783.1h	18.8f	1.059	13.07c-h	15.54gh	80.87h	10.13cde
TBy28-0348	25048.1d-h	26.7def	1.065	12.63e-h	19.51a	88.60a	11.95a
MPT02-458	18570.6gh	20.0f	1.075	12.87d-h	18.31a-d	87.96ab	11.30abc
MPT03-166	26907.5c-g	28.2cde	1.048	12.00h	16.26fgh	83.86efg	10.13cde
91-2-527	45676.3b	31.4bcd	1.060	14.10b-e	16.79efg	82.04gh	10.92a-d
KK3 (check)	33336.9cd	35.4bc	1.063	14.03b-f	16.92d-g	84.44d-g	10.68b-e
LK92-11 (check)	27656.3c-f	29.3b-e	1.063	12.87d-h	17.77b-e	87.02a-d	10.91a-d
KPS01-12 (check)	25333.1d-h	26.6def	1.053	12.47fgh	18.35a-d	88.03ab	11.30abc
F-test	**	**	ns	**	**	*	**
CV (%)	17.77	16.32	1.02	7.01	5.11	1.92	6.67

Ns, * and ** =non-significant, significant at α and 0.05 and 0.01 respectively

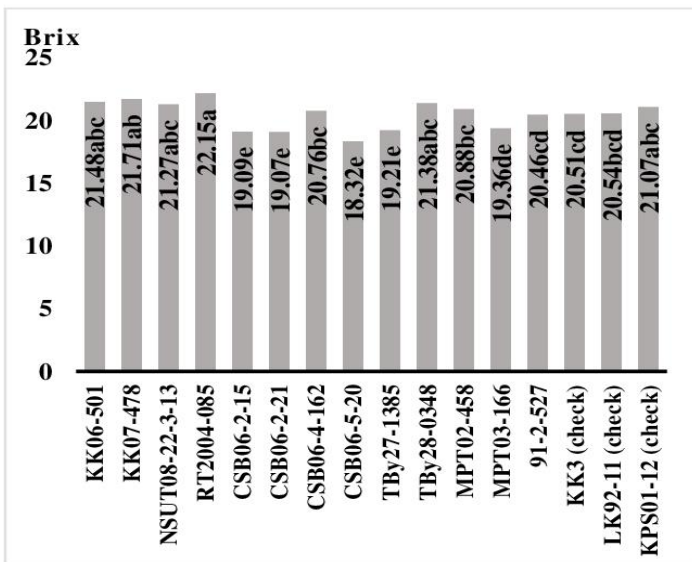


Fig.1 Means of TSS of 16 sugarcane varieties at two study locations

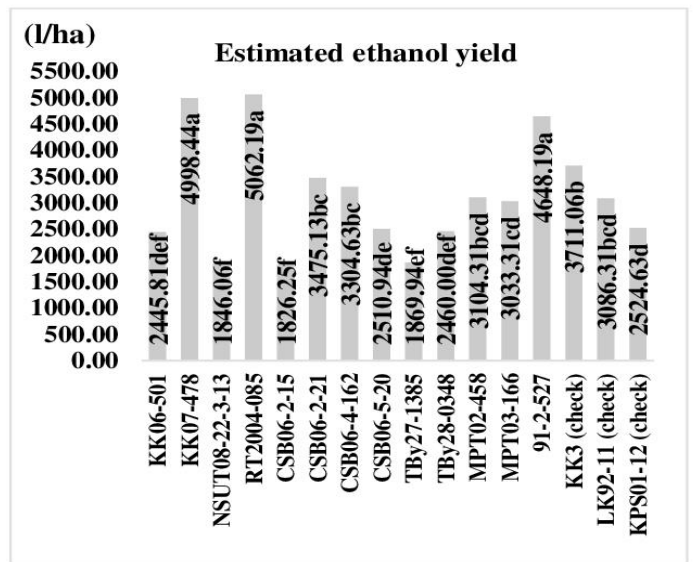


Fig.2 Means of estimated ethanol yield of 16 sugarcane varieties at two study location

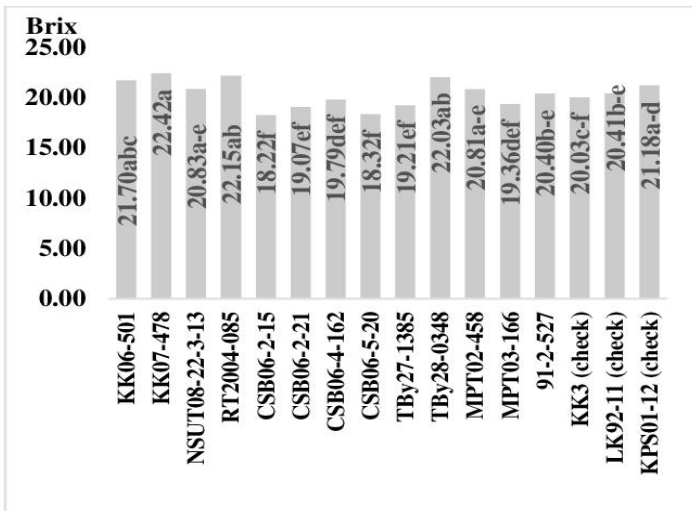


Fig.3 Means of TSS value of 16 sugarcane varieties grown at location 1 (L1)

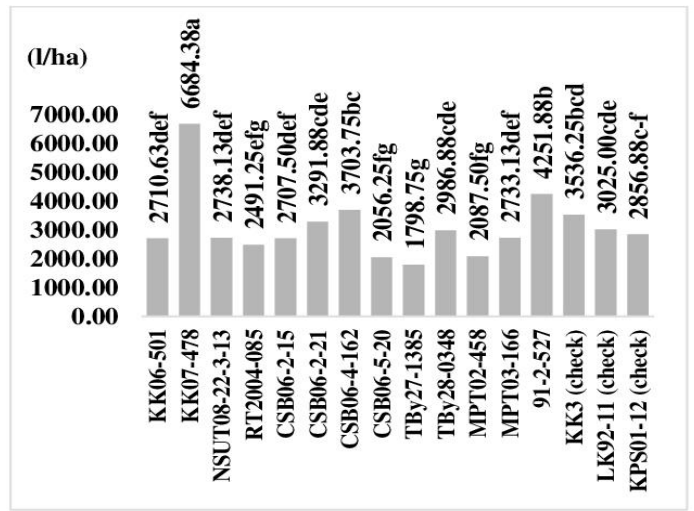


Fig.4 Means of estimated ethanol yield of 16 sugarcane varieties grown at location 1 (L1)

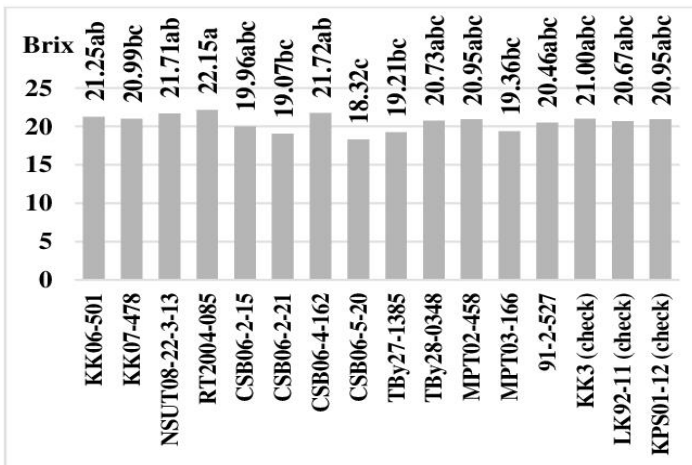


Fig. 5 Means of TSS value of 16 sugarcane varieties grown at location 2 (L2)

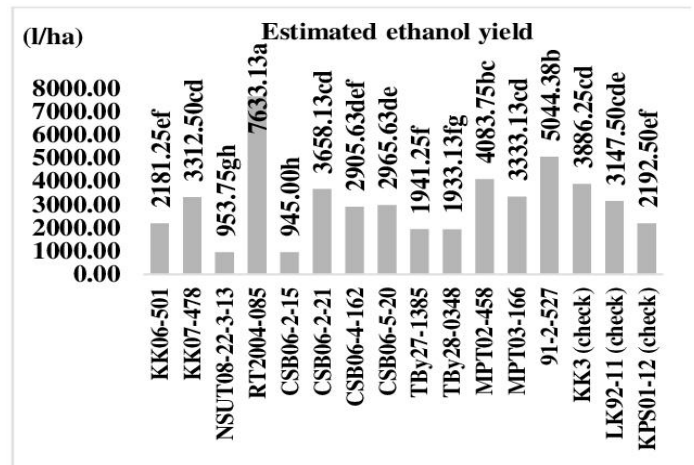


Fig. 6 Means of estimated ethanol yield of 16 sugarcane varieties grown at location 2 (L2)

Ns= not significant, ** = significant at $\alpha = 0.01$.

Table 5. Juice yield and related traits of sugarcane grown under rain-fed condition in location 2 (L2).

Variety	Juice yield (l/ha)	Juice weight (t/ha)	SG	Fiber (%)	Pol	Purity (%)	Percent of ethanol
KK06-501	18486.9def	20.2def	1.093	18.79ab	14.12ab	88.31abc	11.79b
KK07-478	29923.2cde	31.2cde	1.042	18.22abc	13.59ab	86.78bcd	11.06b-e
NSUT08-22-3-13	8171.3f	8.7f	1.059	19.57a	14.74a	90.11ab	11.69bc
RT2004-085	57467.5a	67.6a	1.173	19.61a	14.72a	88.39abc	13.26a
CSB06-2-15	8929.4f	9.5f	1.058	17.17bcd	12.80bc	85.99cd	10.60c-g
CSB06-2-21	36433.2bc	38.7bc	1.064	15.85d	11.06d	85.96cd	10.09efg
CSB06-4-162	24235.6cde	26.2cde	1.075	19.52a	15.07a	89.85ab	11.84b
CSB06-5-20	31194.4cd	32.8cde	1.053	15.66d	11.33cd	90.33a	9.51g
TBy27-1385	18988.8def	20.5def	1.077	15.43d	11.05d	86.10cd	10.30d-g
TBy28-0348	17298.1ef	18.5ef	1.066	18.34abc	13.92ab	88.48abc	11.15b-e
MPT02-458	36390.6bc	38.5bc	1.059	18.68ab	14.16ab	89.15abc	11.22b-e
MPT03-166	34458.8bc	34.5cbd	1.002	16.26d	12.00cd	80.91e	9.71fg
91-2-527	45433.8ab	48.8b	1.074	16.79cd	11.92cd	84.73d	11.07b-e
KK3 (check)	35765.6bc	36.6bc	1.024	18.68ab	14.00ab	88.23a-d	10.88b-f
LK92-11 (check)	27298.8cde	30.3cde	1.107	18.30abc	13.82ab	88.57abc	11.54bc
KPS01-12 (check)	19293.1def	20.7def	1.071	19.02a	14.63a	90.76a	11.35bcd
F-test	**	**	ns	**	**	**	**
CV (%)	15.27	16.66	4.33	5.87	2.30	2.40	6.46

related parameters on sugarcane (Khan et al., 2012) and on other ethanol producing crops like sweet sorghum (Bunphan et al., 2014). These studies did not go further into studying specifically the relationship between ethanol yield and its related traits as compared to our study where we focused most importantly on ethanol yield. In our report, the TSS had moderate correlation with Pol, this was also observed by Krishna and Kamat (2017) and Khan et al. (2012) who reported that these traits had highly positive correlation. A study by Khumla et al. (2012) found out that TSS had positive correlation to pol and purity, a small contrast to our study as we did not find any relationship between TSS and purity.

Materials and methods

The experiments were conducted at two locations under rain-fed and paddy field conditions in Maha Sarakham province; the first location (location 1 or L1) is located at Huai Peung sub-district, Kut Rang district (sugarcane field) where is the upland and sugarcane production area, another field was located at Hua Rue sub-district, Wapi Prathum district (location 2 or L2; previously used as upland paddy rice field). Both experiments were conducted under rain-fed condition, that is no additional water was used for irrigation on both the fields as the whole growth was maintained by natural rainfall only.

The experiments were set up in a randomized complete block design (RCBD) with sixteen varieties made up of thirteen (13) elite lined developed by breeders around Thailand and three check varieties that have been used in sugarcane production for more than 10years in Thailand. The study was conducted in two locations as stated above. The sixteen (16) sugarcane lines were used as the treatments in this study and each treatment was replicated 3 times. The sixteen (16) varieties used in this research are varieties KK06-501, KK07-478, NSUT08-22-3-13, RT2004-085, CSB06-2-15, CSB06-2-21, CSB06-4-162, CSB06-5-20, TBy27-1385 TBy28-0348, MPT02-458, MPT03-166, 91-2-527, KK3, LK92-11 and KPS01-12; with the last three varieties in the list being check varieties. The plots were made such that the consists of 4*6m rows making

a total plot size of 31.2 m² (sugarcane field; L1) and 26 m² (paddy rice field; L2) because the length was reduced to 5m. The spacing was set at 1.30 m between rows and 0.50 m between the plants. The sixteen varieties were planted on the 9th November 2016 and 17th December 2016 in the rain-fed and paddy rice fields, respectively. A NPK (15-15-15) fertilizer was applied at a rate of 50 kg/rai (312.5 kg/ha) at 2 and 6 months after planting, weeding was done by hand at 2 and 6 months after planting. Prior to planting, soil samples were collected from the 0-30cm plough layer and taken to the lab to for soil analysis and the results are shown on Table 1.

Data collection

Because the primary focus of this research was on yield and juice attributes of sugarcane, therefore, data was recorded at 12-13 months after planting when the plants were mature. The sixteen sugarcane varieties were harvested on December 1st 2017 and January 3rd 2018 at sugarcane field and upland paddy rice field, respectively. Harvesting was strategically done so that samples for data collection were harvested in the middle two rows and the guard rows excluded to avoid any errors. The eight parameters recorded included; juice yield (L ha⁻¹) was determined after squeezing juice from the stalk, juice weight (ton ha⁻¹) was determined by digital scale, total soluble solid (TSS) was recorded by using hand refractometer (ATAGO N-1E, city, Japan, specific gravity (SG) was calculated by using formula $D=M/V$ when M is juice weight and V is juice volume or juice yield; percent of ethanol, pol, fiber, purity and ethanol yield was calculated as per Somani and Taylor (2003):

$$\frac{\text{L ethanol}}{\text{ha}} = \frac{(\text{Brix} - 3)\text{kg suc}}{100 \text{ kg juice}} \times \frac{\text{SG kg juice}}{\text{L juice}} \times \frac{\text{L juice}}{\text{ha}} \times \frac{0.59 \text{ L ethanol}}{\text{kg suc}}$$

Data analysis

Data collected was subjected to the Analysis of variance (ANOVA) using STATISTICS 9 computer software package and treatment means were separated using least significant difference (LSD) at 5 % probability level. A G x E analysis was

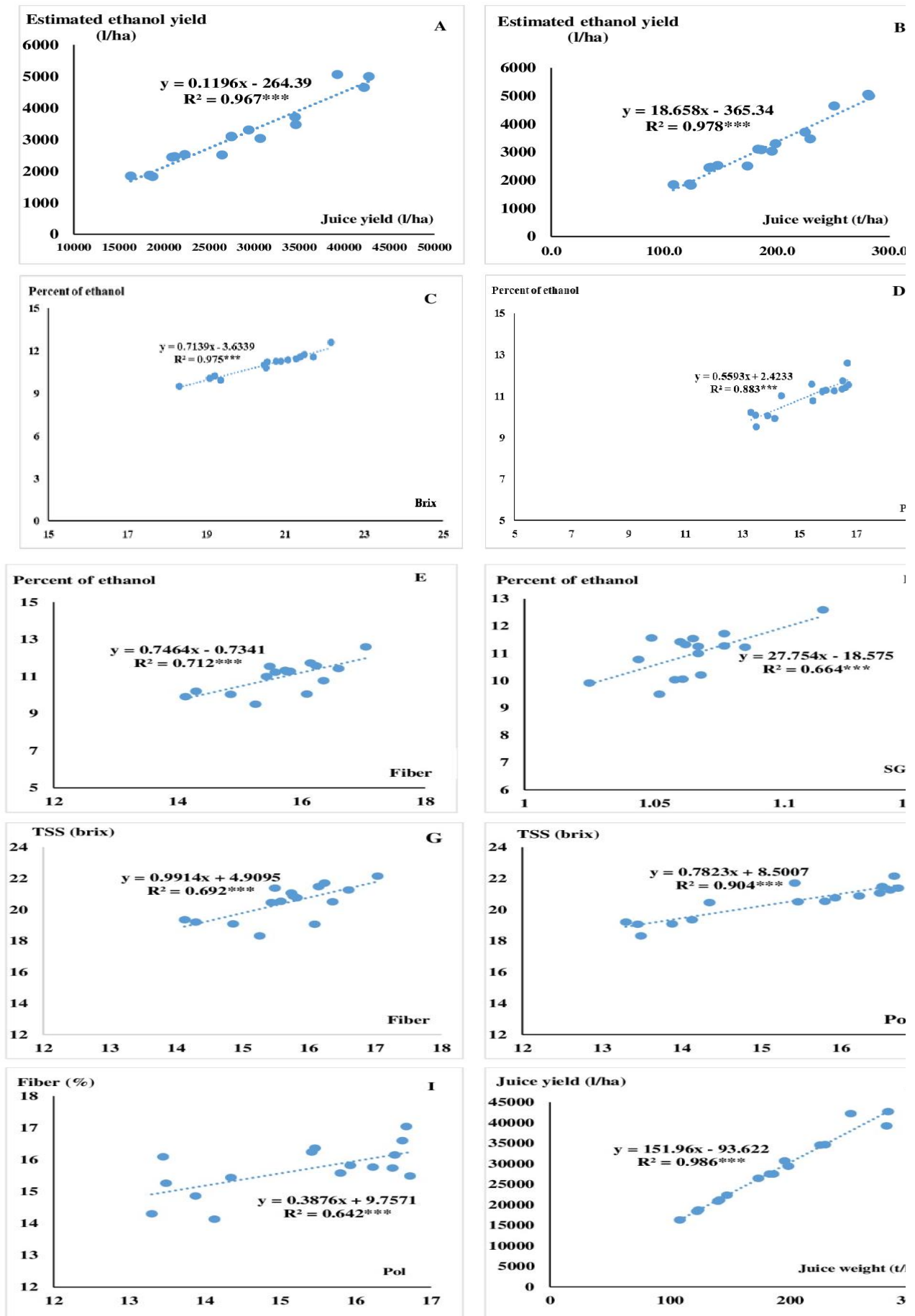


Fig 7. Regression analysis between the ethanol yield related traits of 16 sugarcane varieties at two study locations grown under rain-fed condition.

also performed on the results to determine the interaction between location and the varieties. A correlation analysis was done to determine the relationship between the cane and ethanol yield with the other agronomic traits.

Conclusions

Our study showed that the varieties under evaluation were not affected by location and thus can be thought to be stable across location but a further study on more locations will be ideal. Correlation analysis in our study showed that to improve the ethanol yield of sugarcane it is important to first improve the yield related traits like cane yield, juice yield and TSS. Two varieties KK07-478 and RT2004-085 showed to perform better than others in respect to the ethanol yield related parameters like high cane and juice yield therefore can be studied further before being released to farmers.

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