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Heritability and Correlation among Sugarcane (*Saccharum* spp.) Yield and Some Agronomic and Sugar Quality Traits in Ethiopia

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Abstract

To assess broad sense heritability and phenotypic and genetic correlations among sugarcane yield components, an experiment was conducted at Wonji and Metehara Sugar Estates of Sugar Corporation of Ethiopia during 2012/2013. High broad sense heritability (h^2) was detected for stalk diameter (0.730), single cane weight (0.672), millable cane number (0.624), stalk height (0.624) and pol % (0.608), indicating that these traits could be selected for easily. Expected genetic gain of the yield components was moderate to high. All traits had low to high genetic correlations (r_g = −0.005 to 0.884) with cane yield and (r_g = 0.027 to 0.999) with sugar yield. On average genetic correlations were higher than phenotypic correlations. High Genotypic Coefficient of Variation (GCV), broad sense heritability and expected genetic advance were recorded for stalk diameter, single cane weight and millable cane number. A selection strategy based on these traits could lead to improvement in cane and sugar yield.

Keywords

Ethiopia, Heritability, Genetic Correlation, Genetic Advance, Sugarcane

1. Introduction

Sugarcane varieties in commercial cultivation are complex polyploid. The heterozygous and polyploid nature of

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this crop has resulted in generation of greater genetic variability. The information on the nature and the magnitude of variability present in the genetic material is of prime importance for a breeder to initiate any effective selection program.

In Ethiopia, as in other tropical counties, sugarcane is the major raw material used for sugar production. Sugarcane has been cultivated in the country mainly for chewing purpose in the backyards of small holder farmers since ancient times. Commercial sugarcane cultivation in Ethiopia started in 1954 at Wonji on 5000 ha. At present sugarcane is cultivated on 37,000 ha and the four sugar mills in different parts of the country produce about 300,000 ton sugar per annum. However, this production does not satisfy the domestic consumption, and thus the deficit is being offset by importing sugar from abroad. To bridge the gap between supply and demand as well as to exploit the international market, besides expanding the existing ones, Ethiopia is in the course of establishing new sugar factories with large tract of sugarcane plantation with the aim of attaining production of 2.25 million tons sugar and 181 million litres of ethanol at the end of the year 2014/15 [1].

Since the start the sugar industry of Ethiopia has been relying on importation of sugarcane varieties from many source countries to satisfy the varietal requirements of the sugarcane plantations. So far more than 300 sugarcane varieties has been imported and preserved in germplasm conservation garden located at Wonji. Importing variety *per se* is not an easy task. Moreover, all the introduced varieties may not become successful commercial cultivars. There is luck of information on these imported varieties *vis a vis* pedigree, identity of the varieties, etc., which is very difficult to trace as many of the clones are of old generation and significant number are of unknown sources. In spite of a long history of the varieties since introduced no systematic effort has been made to understand the morphogenetic behaviour of traits of these cultivars.

To alleviate the problem of varietal requirement of the industry the Ethiopian Sugar Corporation is now determined to establish sugarcane breeding program to develop its own sugarcane varieties. In any breeding program collection of germplasm is always the first step as it provides plant breeders with sources of useful traits. Especially collecting local germplasm and land races would be crucial as they provide locally adapted genes for better crop improvement. Towards this effort, exploration and collection of local sugarcane germplasm in different geographic regions of the country has been conducted and more than 200 materials were collected and preserved [2].

Information about the nature and the magnitude of variability present in these germplasm collections (introduced and locals) is of paramount importance for their efficient management and effective utilization in the future sugarcane breeding program of Ethiopia.

In sugarcane, the cane and sugar yields are considered to be the complex characters. The information on the phenotypic and genotypic interrelationship of cane yield and sugar yield with their component characters would be of immense help to the sugarcane breeder. Understanding the associations between traits is of great importance in breeding and selection studies especially for low heritability or difficulty in measuring traits [3] [4]. Consideration of genetic relationships between important attributes in exploiting genetic populations through breeding and directed selection is essential, primarily to understand how changes made by selecting one character may cause changes in others [5] [6]. This knowledge can be used when devising appropriate selection strategies for particular traits in a sugarcane breeding program [7]. Number of millable stalks, stalk height and stalk diameter were reported to be positively associated with cane yield [8] [9]. Reference [10] studied phenotypic associations between yield and its components in sugarcane and concluded that selecting for stalk number, diameter and length should be emphasized in sugarcane variety development programs where high cane yield was the primary goal.

The breeder also requires information on the nature and magnitude of genetic variability in the material available. Heritability estimates, together with expected genetic gain, are more useful than the heritability values alone in predicting the effects of selecting the best genotypes. Reference [11] reported high heritability and genetic gain for single cane weight followed by number of millable cane indicating substantial scope for cane yield improvement. On the other hand, sucrose content recorded low heritability and genetic gain suggesting little scope for improvement in this character [12]. In their program, [13] found moderate heritability estimates for length of stalk (0.41), diameter of stalk (0.51) and number of millable stalks (0.53) and significant positive genetic correlations between yield and the three traits. However, it should be remembered that the magnitude of heritability and association among traits is peculiar to the type of population and environments in which they are evaluated [14].

Genotypic Coefficient of Variation (GCV) is another measure of relative genetic variation of a trait in a population [15]. Traits exhibiting relatively high GCV estimates may respond favorably to selection. Reference [16] reported high GCV for single stalk weight and millable cane.

Genotype × Environment (G × E) interactions are a serious concern in breeding programs as they affect selection decisions. When the rank of a genotype changes across environments it necessitates evaluation of genotypes across the environments to determine their real value [17]. Studies in various sugarcane breeding programs have reported significant G × E interactions for cane and sugar yield [17]-[19].

Since breeding of sugarcane in Ethiopia is in its inception, information on genetic parameters and the relationships among cane yield and its components is crucial for effective selection strategy. The study was therefore conducted to estimate heritability of sugarcane yield and some of its components, and to determine phenotypic and genetic correlations among sugarcane yield components.

2. Materials and Methods

2.1. Description of the Study Sites and Plant Material

2.1.1. Site description

The experiment was conducted at Wonji and Metehara Sugar Estates during 2012/2013 cropping season.

Wonji

Wonji Sugar Estate is located in Oromia Regional Government State, Eastern Shewa Zone, Adama Woreda, About 110 km from Addis Ababa and about 10 km south of Adama Town with latitude 8˚31'N and longitude 39˚12'E with elevation of 1550 masl. The average annual rainfall is 800 mm with maximum and minimum temperatures 26.9˚C and 15.3˚C respectively.

Metehara

Metehara sugar Estate is located in Oromia Regional Government State, Eastern Shewa Zone about 200 Km from Addis Ababa and about 8 km south of Metahara Town with latitude and longitude 8˚51'N and 39˚52'E respectively and with elevation of 950 masl. Annual rainfall is 554 mm with temperature maximum and minimum of 32.6˚C and 17.5˚C respectively.

2.1.2. Plant Materials

The plant materials for this study consisted of a total of 400 accessions of which 174 were local sugarcane genotypes (**Appendix 1**) collected from different regional states of Ethiopia and 226 were introduced sugarcane variety collections (**Appendix 2**) maintained at conservation garden found at Wonji, Research and Training, Sugar Corporation of Ethiopia. Selection among the local genotypes was made based on geographical regions where the materials were collected and the morphological variations noted during the collection work and when the varieties were quarantined in their collection areas for one year. In exotic/introduced genotypes selection was made taking into consideration the variation in place of origin *i.e.* source countries and different periods of introductions to the country.

2.2. Experimental Design and Field Layout

The experiment was laid out in 20 × 20 partial balanced lattice design with two replications. Canes were cut into three budded sets and planted in single row plots of 5 m × 1.45 m and 20 cm between plants within a row. Uniform crop management practices were applied to all entries in the trial as recommended for the areas.

2.3. Data Collected

Data on quantitative stalk characters and juice quality parameters were recorded *vis* sprout count 1 and 2 months after planting (SPC1MAP and SPC2MAP), tiller counts 4 and 5 month after planting (TC4MAP and TC5MAP), stalk count 10 months after planting (STC10MAP), millable stalk count per hectare (MSCHA), single cane weight (SCW), number of internodes (NOI), internodes length (IL), stalk height (SH), stalk diameter (SD), leaf length (LL), leaf width (LW), leaf area (LA), cane yield quintal per hectare (CYHA), brix percent (brix %), pol percent (pol %), purity percent (purity %), sugar percent (SR %) and sugar yield quintal per hectare (SY). For every accession, ten individuals were used for recording data which were recorded on plot basis. Count data and cane yield were recorded considering all cane stalks from the whole plot.

2.4. Statistical Analysis

Combined analysis of variance over two locations was conducted using the general linear model (GLM) procedure of SAS version 9. Estimates of genetic, genotype by environment and error variance components were computed using the VARCOMP procedure of SAS. These components were used to estimate broad-sense heritability [20] [21].

Heritability on genotype mean basis (2 replicates and 2 locations):

$$h^2 = \frac{\sigma_g^2}{\sigma_p^2} = \frac{\sigma_g^2}{\sigma_g^2 + \frac{\sigma_{gl}^2}{l} + \frac{\sigma_e^2}{rl}}$$

where, σ_g^2 = genotype, σ_{gl}^2 = genotype × location σ_e^2 = error variances, r = number of replications and l = number of locations.

All variance components were converted to their respective coefficients of variation to allow direct comparisons between traits. Genetic coefficients of variation provide a unit less measure of a trait's genetic variance relative to its mean and permit comparisons among traits with different units and scales and give perspective to available variability to be potentially exploited for genetic gain [8]. The phenotypic coefficient of variation (%) was calculated as PCV = 100σ_p/phenotypic mean of a trait, and genotypic coefficient of variation as GCV = 100σ_g/phenotypic mean of a trait.

Expected genetic advance (GA) for each trait was calculated as a proportion of the general mean to allow comparison among traits for potential improvement through selection [8] [22] thus:

$$\text{GA} = \frac{i\sigma_p h^2}{phenotypicmeanoftrait}$$

where i = selection intensity, σ_p = phenotypic standard deviation of trait, h^2 = heritability.

Genetic (r_g) and phenotypic (r_p) correlation coefficients and their standard errors were obtained among all the traits by estimating genetic, genotype by environment and error covariances combined across locations using version 9 of SAS Proc Mixed and the REML analysis method based on the variance and covariance components according to [23] as:

$$r_{ij} = \frac{\sigma_{ij}}{\sigma_i \sigma_j}$$

where r_{ij} = phenotypic or genetic correlation coefficient between trait i and trait j; σ_{ij} = genetic or phenotypic covariances between trait i and trait j; σ_i and σ_j are phenotypic or genetic standard deviations of trait i and trait j respectively. Genetic and phenotypic correlations were considered significant if their absolute value was higher than 1.96 times their standard error [24] [25].

3. Results and Discussion

Significant ($P < 0.01$) differences were observed among the genotypes for cane yield, related traits and sugar quality parameters revealing a high level of genetic diversity among them (**Table 1**). The relatively large genotypic mean squares indicated that clones differed in their potential for the traits. This result indicated that there is significant amount of phenotypic variability and all the genotypes vary each other with regard to the characters that opened a way to proceed for further improvement through simple selection [26] [27]. Genotype × location interactions were significant for all traits except internodes length. The amount of variation accounted for, ranged from moderate ($R^2 = 0.59$) for internodes length to high ($R^2 = 0.81$) for cane yield. Studying on thirteen sugarcane clones [11] on the other hand reported moderate R^2 value for cane yield. This variation might be due to the large number of genotypes considered in this study. Highly significant genotype × location interactions for most of the traits revealed that mean performances of the genotypes were influenced by the locations. This interaction was largely due to changes in the relative ranking of the genotypes across the locations [11]. The relatively higher CV% for some of the traits was due to this higher variability of genotype X location in the performance of the genotypes. This suggests that at this stage evaluating sugarcane genotypes in more locations rather than one may be satisfactory [27] [28].

Table 1. Analysis of variance for twenty stalk characters in 400 sugarcane genotypes grown at Wonji and Metehara during 2012/2013.

Characters†	Location	Replication	Block (Replication)	Genotype	Location * Genotype	Error	Mean	CV (%)	R^2
	(1)	(1)	(19)	(380)	(399)	(780)			
SPC1MAP	10.675**	6.887*	1.102^{ns}	1.978**	1.938**	1.055	14.25	49.24	0.66
SPC2MAP	386.921**	20.108**	1.240^{ns}	1.498**	1.237*	1.044	28.19	35.89	0.65
TC4MAP	567.169**	23.802**	0.983^{ns}	1.875**	1.237**	0.957	76.45	25.27	0.71
TC5MAP	44.092**	0.082^{ns}	0.626^{ns}	0.953**	0.919**	0.559	71.42	18.63	0.65
STC10MAP	46.119**	17.248**	0.372^{ns}	1.066**	0.616**	0.289	59.35	13.88	0.77
MSCHA	40.712**	3.074**	0.409*	1.196**	0.590**	0.252	88,602.95	4.49	0.79
SCW	1.180**	3.156**	0.145^{ns}	0.517**	0.166**	0.123	1.52	23.12	0.74
NOI	779.806**	250.431**	18.531^{ns}	52.037**	26.659**	14.623	28.21	13.57	0.74
IL	20.473^{ns}	1.962^{ns}	7.351^{ns}	15.618**	10.229^{ns}	9.235	8.84	34.35	0.59
SH	88,352.063**	9279.902**	640.917^{ns}	3337.181**	1243.085**	872.007	240.44	12.29	0.74
SD	5.050**	0.001^{ns}	0.042^{ns}	0.337**	0.089**	0.060	2.66	9.18	0.79
LL	8953.181**	5978.962**	212.970^{ns}	526.532**	359.608**	189.594	127.95	10.76	0.72
LW	0.483^{ns}	27.152**	0.483^{ns}	1.844**	0.792**	0.622	4.29	18.39	0.69
LA	132290.602**	545322.802**	6137.660^{ns}	25433.571**	12832.068**	9734.180	413.46	23.89	0.68
CYHA	5,857,126.000**	7,375,569.600**	284,712.100^{ns}	1,667,648.400**	619,916.600**	279,325.000	1360.27	39.12	0.81
Brix%	4.364^{ns}	24.310**	1.271^{ns}	5.225**	2.164*	1.791	19.40	6.90	0.68
Pol%	34.281**	32.627**	1.499^{ns}	6.202**	2.410**	1.861	18.15	7.52	0.71
Purity%	354.399**	19.678^{ns}	7.269^{ns}	13.471**	8.545**	6.697	93.47	2.77	0.64
SR%	61.297**	20.338**	1.036^{ns}	4.052**	1.601**	1.199	12.99	8.44	0.71
SY	38,976.630**	79,538.100**	5466.260^{ns}	30,595.530**	11,103.880**	5298.920	178.89	41.00	0.80

†SPC1MAP and SPC2MAP = Sprout count 1 and 2 months after planting; TC4MAP and TC5MAP = Tiller counts 4 and 5 months after planting; STC10MAP = Stalk count 10 months after planting; MSCHA = Millable stalk count per hectare; SCW = Single cane weight (Kg); NOI = Number of internodes; IL = Internodes length (cm); SH = Stalk height (cm); SD = Stalk diameter (cm); LL = Leaf length (cm); LW = Leaf width (cm); LA = Leaf area (cm^2); CYHA = Cane yield (qt/ha); Brix% = Brix percent; Pol% = Pol percent; Purity% = Purity percent; SR% = Sugar percent; SY = Sugar yield (qt/ha); $^{**}P < 0.01$; $^{*}P = 0.05$; ns = nonsignificant; numbers in parenthesis are degrees of freedom.

3.1. Estimation of Genotypic and Phenotypic Coefficients of Variation

The variance components were used to compute heritability estimates in **Table 2** [29]. Genetic variance is important as it describes the amount of genetic variation present for the trait. The genetic variance component for all traits exceeded the genotype × location (**Table 2**). After partitioning phenotypic variance, it was found that genotypic variance was lower than the environmental one for most of the characters studied except single cane weight and stalk diameter. Genetic and environment variances were similar for single cane weight and stalk diameter. Congruent with the present study [11] studying on fourteen sugarcane clones also reported similar genetic and environment variances for single cane weight and stalk diameter combined over locations and plant and first ratoon crop. These results indicated that a significant role was played by the environmental factors in the inheritance of the characters in sugarcane.

The magnitude of genetic variance was the highest in number of millable canes (δ_g^2 = 838,822,000.00, δ_e^2 = 525,333,966.000) followed by cane yield (δ_g^2 = 261,988.00, δ_e^2 = 163,306.500), sugar yield (δ_g^2 = 4884.90, δ_e^2 = 5604.40) and leaf area (δ_g^2 = 3274.40, δ_e^2 = 9815.80). The high genotypic variance for millable cane number was reported also by other researchers [30] [31]. In contrast to the present study [16] studying on 32 sugarcane

Table 2. Combined components of variances, coefficients of variation, heritability and genetic advance for twenty characters in 400 sugarcane genotypes grown at Wonji and Metehara in 2012/2013.

Characters*	Components†						
	δ_g^2	δ_{gl}^2	δ_e^2	PCV%	GCV%	h^2	GA%
SPC1MAP	0.90	45.354	131.093	52.683	6.641	0.016	1.7
SPC2MAP	41.51	3.517	402.379	42.554	22.859	0.289	25.3
TC4MAP	472.01	0.000	1860.500	40.042	28.418	0.504	41.5
TC5MAP	55.27	373.384	1143.700	32.170	10.409	0.105	6.9
STC10MAP	262.81	197.611	436.485	36.559	27.317	0.558	42.0
MSCHA	838,822,000.00	525,333,966.000	973,984,558.000	41.391	32.688	0.624	53.2
SCW	0.09	0.020	0.126	23.451	19.221	0.672	32.5
NOI	6.14	5.909	14.796	12.677	8.780	0.480	12.5
IL	1.39	0.455	9.317	22.457	13.319	0.352	16.3
SH	513.14	167.716	899.992	11.924	9.421	0.624	15.3
SD	0.06	0.014	0.061	10.759	9.195	0.730	16.2
LL	43.70	83.121	190.334	9.008	5.166	0.329	6.1
LW	0.26	0.079	0.634	15.775	11.879	0.567	18.4
LA	3274.40	1481.400	9815.800	19.453	13.840	0.506	20.3
CYHA	261,988.00	163,306.500	293,369.100	47.472	37.628	0.628	61.4
Brix%	0.76	0.160	1.823	5.859	4.483	0.585	7.1
Pol%	0.93	0.243	1.899	6.797	5.301	0.608	8.5
Purity%	1.14	0.860	6.806	1.936	1.145	0.349	1.4
SR%	0.59	0.181	1.224	7.661	5.931	0.599	9.5
SY	4884.90	2749.800	5604.400	48.927	39.070	0.638	64.3

† δ_g^2 = Genotypic variance; δ_{gl}^2 = Genotype × Location variance; δ_e^2 = Environment variance; PCV = Phenotypic coefficient of variation; GCV = Genotypic coefficient of variation; h^2 = Heritability percentage; GA = Genetic advance in percent of mean *Character abbreviations as given in **Table 1**.

genotypes in Nepal in one environment reported higher genotypic variance over environmental one for cane yield, millable cane number, single cane weight, stalk diameter, stalk length and sucrose percent. The reason for this variation could be the large number of genotypes and more than one environment considered in the present study. Reference [11] also observed in plant cane that the highest magnitude of genetic variance relative to environmental variance was exhibited by number of internodes (151.23%), millable cane (143.84%) and stalk weight (116.31%) indicating that environmental factors influenced their expression less than the other traits.

Genotypic coefficient of variation (GCV) is another measure of relative genetic variation of a trait in a population [15]. Traits exhibiting relatively high GCV estimates may respond favourably to selection. The estimates for phenotypic coefficient of variation (PCV) were higher than for genotypic coefficient of variation (GCV) in all the traits (**Table 2**), suggesting that the apparent variation is not only due to genetics but also due to environmental influences. Reference [32] also found higher PCV over GCV for number of millable cane, stalk height, stalk diameter, single cane weight, brix %, pol % and cane yield.

The highest phenotypic coefficient of variation were observed for sprout count 1 month after planting (PCV = 52.683) followed by sugar yield (PCV = 48.927) and cane yield (PCV = 47.472). On the other hand the highest genotypic coefficient of variation were observed for sugar yield (GCV = 39.070) followed by cane yield (GCV =

37.628) and number of millable cane (GCV = 32.688). High genotypic and phenotypic coefficients of variation for number millable cane were reported earlier [33]. The GCV values for cane yield and its components like single cane weight, number of millable canes, stalk height and diameter were larger than the values for sucrose content (pol %) and juice brix. Large amount of genetic variation for stalk height and diameter, number of millable canes and hand rifractometer brix reading at active growth stage was reported and concluded that progress in breeding for higher sucrose yield can be made by emphasizing selection for high sucrose content at early ripening stage along with higher cane yield [34] [35].

3.2. Heritability

The success of a variety improvement programme depends largely on the amount of genetic variability present in the population. Genotypic coefficient of variation is not a correct measure to know the heritable variation present and should be considered together with heritability estimates. Genetic coefficients of variation along with heritability estimates give a better indication of the amount of genetic variation for a trait than either parameter alone.

In the present study, high heritability estimates were recorded for stalk diameter (0.730), single cane weight (0.672), sugar yield (0.638), cane yield (0.628), millable cane number (0.624), stalk height (0.624) and pol % (0.608) (**Table 2**).

Moderate broad sense heritability estimates ranging from 0.599 - 0.480 were found in sugar %, brix%, leaf width, stalk count 10 months after planting, leaf area, tiller count 4 months after planting and number of internodes. This suggests that a considerable proportion of the total variance is heritable and selection of these traits would be effective. High heritability estimate for millable cane number (0.88), stalk diameter (0.85) and single cane weight (0.84) was reported [16]. Similarly [11] also reported high heritability for stalk diameter (0.928), number of millable canes (0.912), single cane weight (0.907), number of internodes (0.907) and moderate heritability for cane yield (0.515). However, the heritability values were relatively higher than the present study. The probable cause of the disparity could be due to the fact that the heritability of a given trait refers to a particular population under a particular condition or environment. Moreover the study by [16] was conducted in single environment and considered only 32 sugarcane genotypes. Similarly [11] included only 14 genotypes in their study. High heritability estimate was also reported elsewhere for single cane weight [31] [36]. Low heritability estimates were observed in sprout count 1 and 2 months after planting, tiller count 5 month after planting, internodes length, leaf length and purity %. Selections might be considerably difficult or virtually impractical for a character with low heritability (less than 0.4) due to the masking effect of environment on genotypic effects [37] [38]. Generally the heritability values for the important stalk characters studied were high to moderate paving the way for improvement of these characters through simple selection. Knowledge of variability and heritability of characters is essential for identifying those amenable to genetic improvement through selection [39]. Results of the current study indicate that use of the traits with high heritability as selection criteria together with cane yield could lead to genetic improvement in cane and sugar yield. Under the conditions of this study stalk diameter, single cane weight, sugar yield, cane yield, millable cane number, stalk height and pol % were reliable selection parameters.

3.3. Genetic Advance

The effectiveness of selection depends not only on heritability but also on genetic advance [29] [40]. Heritability estimates along with expected genetic gain is more useful than the heritability value alone in predicting the resultant effect for selecting the best genotypes [41]. As presented in **Table 2**, maximum genetic gain (as percent of mean) was observed for sugar yield (64.3%) followed by cane yield (61.4%), millable cane number (53.2%), stalk count 10 months after planting (42.0%), tiller count 4 months after planting (41.5%) and single cane weight (32.5%). Greatest genetic advance is also expected in leaf area (20.3%), leaf width (18.4%), stalk diameter (16.2%) and stalk height (15.3%). The results suggest existence of considerable scope for improvement of these characters by adopting suitable breeding strategy. High genetic advance has also been reported elsewhere for single stalk weight and number of millable cane [42]-[44]. The high genetic gain of these characters was the result of high broad sense heritability and high GCV for these traits [45]. The high broad sense heritability coupled with high genetic advance for these characters indicates these traits are under the control of additive genetic effects and highlights the usefulness of selection based on phenotypic performance [22]. High genetic advance (as percent of mean) for millable cane number was also reported by [16] and for cane yield [11]. Moderate heritability with low genetic advance for sugar quality parameters indicate presence of non-additive gene action and therefore simple selection on phenotypic performance may not be effective [22]. Similarly, low genetic advance with low heritability was recorded for sprout count one month after planting, leaf length, tiller count 5 months after planting, number of internodes and inter node length.

The results suggested that selection should be practiced on the basis of stalk diameter, single cane weight and millable cane number for higher cane and sugar yield. These were followed by stalk height, stalk count 10 months after planting, tiller count 4 months after planting, leaf width and leaf area. The same result for single stalk weight followed by number of millable cane and stalk diameter was reported [11]. Similarly, [16] also reported selection should be practiced on the basis of single cane weight and millable cane number for higher cane yield. Reference [46] showed that plant height, cane diameter, leaf area and intermodal distance had positive and significant correlation with millable cane weight that in turn showed a major contribution towards the final cane yield, however cane diameter, height and internode length can be exploited successfully for further and future cane improvement program. They concluded improvement in these traits would lead to a significant improvement in yield in limited selection cycles. Moderate heritability accompanied by low genetic advance for sugar quality parameters indicated that there is little hope for improvement of these traits by simple selection. Similar results for juice quality characters were obtained [16] [42].

The higher broad sense heritability, expected genetic advance and GCV for cane yield and sugar yield indicated that direct selection for these traits seems plausible. Reference [47] have also reported high estimates of broad sense heritability and expected genetic advance for cane and sugar yield.

3.4. Genotypic and Phenotypic Correlations

Genotypic and phenotypic correlation matrixes are presented in (**Table 3**) and (**Table 4**) respectively. Millable stalk count showed highly significant genetic correlations with tiller count 5 months after planting, stalk count 10 month after planting, single cane weight, stalk diameter, brix percent and significant association with sprout count 2 months after planting. Non significant positive correlation with cane yield, sugar quality parameters and sugar yield was also observed. Similarly, [48] reported significant genetic correlations of number of millable cane with sprout counts, single cane weight and cane yield.

Cane yield had highly significant strong positive genetic correlation with number of internodes, leaf length and width and leaf area and negative significant association with sprout count 1 month after planting and negative non significant correlations with tiller counts and single cane weight. Genetic correlation of cane yield with stalk height, stalk diameter, single cane weight, number of millable stalks and sugar quality traits was positive and non significant. Reference [11] also reported significant positive genetic correlation of cane yield with number of internodes and positive non significant correlation with millable stalk number but in contrast to the present study they found negative and non significant correlation of cane yield with stalk height. Reference [48] also found positive and highly significant genotypic associations of cane yield with single cane weight, number of millable cane per plot, leaf area and germination percent. On the other hand, [13] found in their program significant positive genetic correlations of cane yield with stalk height, stalk diameter and number of millable cane. However, it should be remembered that the magnitude of heritability and association among traits is peculiar to the type of population and environments in which they are evaluated [14]. Moreover the number of genotypes considered in their study and the present work largely varies. More number of genotypes was considered in the current study.

Sugar yield was mainly dependent on number of internodes, stalk diameter, leaf length, pol %, purity % and sugar %. The association with cane yield was positive but nonsignificant. Positive and significant association of sugar yield with cane yield, pol % and sugar % was reported [49].

Single cane weight exhibited highly significant strong positive genetic correlation with sprout count 2 months after planting, tiller count 5 month after planting, stalk count 10 month after planting, stalk diameter, number of internodes and brix percent and non significant positive association with cane yield. Negative non significant genetic correlation with internodes length and non significant positive association with other parameters was observed for this trait. Strong positive genetic correlations of single cane weight with number of internodes, stalk diameter and stalk height and non significant positive association with cane yield was reported [11].

Stalk diameter showed highly significant genetic correlation with tiller count 5 month after planting, stalk count 10 month after planting, number of millable cane, single cane weight, number of internodes and brix percent. It

Table 3. Genetic correlations among 21 phenotypic characters† measured on 400 sugarcane genotypes.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
A	1.000																			
B	−0.471*	1.000																		
C	−0.084	0.663**	1.000																	
D	−0.145	0.738**	0.552*	1.000																
E	−0.094	0.711**	0.363	0.808**	1.000															
F	0.104	0.529*	0.434	0.839**	0.901**	1.000														
G	−0.142	0.628**	0.413	0.812**	0.884**	0.887**	1.000													
H	−0.383	0.357	0.112	0.291	0.370	0.263	0.642**	1.000												
I	−0.490*	0.361	−0.016	0.109	0.021	−0.184	−0.082	0.072	1.000											
J	0.239	0.146	0.402	0.231	0.242	0.342	0.357	0.230	−0.408	1.000										
K	0.014	0.412	0.259	0.633**	0.760**	0.778**	0.887**	0.690**	−0.108	0.376	1.000									
L	−0.515*	0.220	−0.045	0.029	0.064	−0.075	0.327	0.855**	0.186	0.074	0.415	1.000								
M	−0.275	0.188	−0.105	0.152	0.289	0.123	0.293	0.454*	0.127	0.073	0.362	0.353	1.000							
N	−0.470*	0.051	−0.205	−0.220	−0.185	−0.342	0.004	0.617**	0.084	0.068	0.119	0.867**	0.373	1.000						
O	−0.459*	0.135	−0.112	−0.042	−0.005	0.148	0.174	0.650**	0.112	0.134	0.254	0.783**	0.712**	0.884**	1.000					
P	−0.142	0.628**	0.412	0.811**	0.884**	0.887**	1.000**	0.642**	−0.082	0.357	0.887**	0.327	0.293	0.004	0.174	1.000				
Q	0.131	0.154	0.128	0.211	0.238	0.175	0.441	0.646**	0.024	0.117	0.513*	0.538*	0.045	0.262	0.195	0.441	1.000			
R	0.109	0.163	0.122	0.197	0.209	0.143	0.419	0.645**	0.052	0.106	0.490*	0.565**	0.033	0.306	0.225	0.419	0.996**	1.000		
S	0.017	0.161	0.058	0.060	0.025	−0.067	0.232	0.546*	0.128	0.037	0.274	0.618**	−0.017	0.465*	0.331	0.232	0.861**	0.901**	1.000	
T	0.094	0.170	0.118	0.189	0.192	0.123	0.405	0.643**	0.068	0.098	0.474*	0.579**	0.027	0.331	0.242	0.405	0.990**	0.999**	0.921**	1.000

†A = Sprout count 1 month after planting; B = Sprout count 2 months after planting; C = Tiller count 4 months after planting; D = Tiller count 5 months after planting; E = Millable stalk count 10 months after planting; F = Millable stalk count per hectare at harvest; G = Single cane weight (kg); H = Number of internodes; I = Internodes length (cm); J = Stalk height (cm); K = Stalk diameter (cm); L = Leaf length (cm); M = Leaf width (cm); N = Leaf area (cm^2); O = Cane yield (qt/ha); P = Laboratory brix%; Q = Pol%; R = Purity%; S = Sugar %; T = Sugar yield (qt/ha); ** and * = highly significant at $P < 0.01$ and $P = 0.05$ respectively.

had also significant positive genetic correlations with all sugar parameters and sugar yield but showed nonsignificant correlation with sugar percent. In conformity with this finding [11] also reported significant positive genetic correlation of stalk diameter with number of internodes and single cane weight and non significant association with cane yield. In the present investigation, it is interesting that stem diameter had significant positive association with sugar yield and sugar quality characters indicating the significance of this trait in improving sugar quality traits and sugar yield. Similar reports have been made by earlier sugarcane workers [48] [50] for sugar yield.

Number of internodes had highly significant positive genetic correlations with stalk diameter, single cane weight, leaf length, leaf area, cane yield, brix percent, pol percent, purity percent, and sugar yield while it had significant positive correlation with leaf width and sugar percent and positive non significant association with number of millable cane. Similarly, [11] reported significant positive genetic correlation of number of internodes with stalk diameter and single cane weight and non significant positive association with cane yield. Association with other characters was positive and non significant. Significant association of number of internodes with brix percent, sugar percent and sugar yield was also reported by [48].

Leaf area exhibited highly significant strong positive genetic correlation with number of internodes, leaf length and cane yield and significant correlation with sugar percent while association with other characters was nonsignificant. Reference [48] also found highly significant correlation of this trait with cane yield and sugar percent.

Table 4. Phenotypic correlations among 21 phenotypic characters† measured on 400 sugarcane genotypes.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
A	1.000																			
B	−0.288**	1.000																		
C	−0.100*	0.557**	1.000																	
D	−0.120*	0.478**	0.299**	1.000																
E	0.055	0.380**	0.188**	0.571**	1.000															
F	0.131**	0.278**	0.220**	0.615**	0.587**	1.000														
G	−0.063	0.356**	0.231**	0.581**	0.532**	0.833**	1.000													
H	−0.279**	0.177**	0.075	0.120*	0.095	0.045	0.537**	1.000												
I	−0.231**	0.210**	0.029	0.089	0.004	−0.137**	−0.083	0.040	1.000											
J	0.182**	0.036	0.182**	0.112*	0.148**	0.314**	0.344**	0.183**	−0.524**	1.000										
K	0.076	0.175**	0.083	0.289**	0.338**	0.519**	0.646**	0.469**	−0.007	0.458**	1.000									
L	−0.388**	0.131**	0.032	−0.029	−0.085	−0.149**	0.248**	0.721**	0.129*	−0.020	0.144**	1.000								
M	−0.053	0.058	−0.072	0.043	0.089	0.035	0.156**	0.248**	−0.111*	0.107*	0.126*	0.191**	1.000							
N	−0.283**	0.017	−0.054	−0.142**	−0.098	−0.199**	0.042	0.425**	−0.067	0.081	0.055	0.538**	0.232**	1.000						
O	−0.250**	0.041	−0.044	−0.076	−0.043	0.121	0.118*	0.441**	−0.095	0.135**	0.107*	0.502**	0.627**	0.888**	1.000					
P	−0.063	0.356**	0.232**	0.581**	0.532**	0.833**	1.000**	0.537**	−0.083	0.343**	0.646**	0.248**	0.156**	0.042	0.117*	1.000				
Q	0.186**	−0.017	−0.004	0.119*	0.111*	0.146**	0.281**	0.284**	−0.038	0.076	0.222**	0.226**	−0.025	0.016	−0.009	0.281**	1.000			
R	0.187**	0.011	−0.005	0.131**	0.101*	0.129*	0.266**	0.280**	0.004	0.060	0.223**	0.243**	−0.039	0.020	−0.011	0.266**	0.973**	1.000		
S	0.111*	0.104*	−0.008	0.097	0.026	0.004	0.105*	0.163**	0.124*	−0.012	0.128*	0.214**	−0.061	0.050	0.011	0.105*	0.477**	0.664**	1.000	
T	0.183**	0.027	−0.007	0.133**	0.092	0.115*	0.250**	0.271**	0.027	0.049	0.217**	0.247**	−0.046	0.022	0.011*	0.251**	0.936**	0.992**	0.751**	1.000

†A = Sprout count 1 month after planting; B = Sprout count 2 months after planting; C = Tiller count 4 months after planting; D = Tiller count 5 months after planting; E = Millable stalk count 10 months after planting; F = Millable stalk count per hectare at harvest; G = Single cane weight (kg); H = Number of internodes; I = Internodes length (cm); J = Stalk height (cm); K = Stalk diameter (cm); L = Leaf length (cm); M = Leaf width (cm); N = Leaf area (cm^2); O = Cane yield (qt/ha); P = Laboratory brix%; Q = Pol%; R = Purity%; S = Sugar %; T = Sugar yield (qt/ha); ** and * = highly significant at $P < 0.01$ and $P = 0.05$ respectively.

On the other hand [46] reported significant genetic correlation of leaf area with stalk height, stalk diameter and internodes length.

Sugar quality parameters showed highly significant strong positive genetic correlations with each other and with sugar yield revealing that any of these juice quality traits could be considered for selection leading to the simultaneous improvement in the remaining quality traits and sugar yield [48] [51].

Moderate to high highly significant positive phenotypic correlations with most of the traits were observed for number of millable cane and cane yield. The phenotypic correlations of sugar quality parameters and sugar yield with number of millable cane were positive and highly significant. Highly significant negative correlations with number of millable cane were observed for internode length, leaf length and leaf area and non significant positive correlation with cane yield. It was demonstrated by [11] that phenotypic correlations between cane yield and single cane weight, number of internodes, stalk diameter, stalk height and number of millable canes were positive and significant. They further indicated that number of millable canes was negatively correlated with all other yield components.

Phenotypic significant and positive association of cane yield with single cane weight, number of internodes, stalk height and diameter, leaf length and width, leaf area, brix% and sugar yield was recorded. Association with pol% and purity percent was negative and non significant while positive and non significant with millable cane number and sugar%. Negative correlation of pol % with cane yield was also found by [49] in their study. In conformity with the present study significant positive phenotypic correlation of cane yield with number of internodes, stalk height and diameter and millable cane number [11] and with sugar yield [52] was reported.

Sugar yield was observed to have positive significant phenotypic correlation with sprout count 1 month after planting, tiller count 5 months after planting, number of millable cane, single cane weight, number of internodes, stalk diameter, leaf length, cane yield, brix%, pol%, purity% and sugar%. Sugar yield mainly depends on number of tillers, cane weight, pol%, sugar% and purity% [49]. The negative correlation of pol% with cane yield and positive correlation with sugar yield is one of the major constraints in the improvement of sugarcane [49]. Reference [52] reported strong positive phenotypic correlation of sugar yield with number of millable cane, single cane weight, stalk height, cane yield and non significant positive association with stalk diameter.

Single cane weight, number of internodes, stalk diameter and leaf length also showed highly significant positive phenotypic correlations with most of the traits including sugar quality parameters, cane and sugar yield. This is corroborated by the findings of [11] who reported significant positive correlation of single cane weight with number of internodes, stalk diameter, stalk height and cane yield. It is amazing to notice in the current study that single cane weight, number of internodes, stalk diameter and leaf length had significant positive association with both cane and sugar yield indicating the significance of these traits in improving both cane and sugar yields.

Stalk height demonstrated highly significant positive phenotypic correlations with millable cane number, cane yield, brix percent and most of the yield components but the association with sugar yield was non-significant.

Sugar quality parameters showed highly significant moderate to high positive phenotypic correlations with each other and with sugar yield.

In general, genotypic correlation coefficients were higher than their corresponding phenotypic correlation coefficients indicating a fairly strong inherent relationship among the traits [11].

The lower estimates of phenotypic correlation indicated that the relationships were affected by environment at phenotypic level [49]. Such environmental influence in reducing the correlation coefficients in rice was also reported by [53]. Correlations among phenotypic traits may reflect biological processes that are of considerable evolutionary interest and can be the result of genetic, functional and physiological or developmental nature [54] [55].

In this study, most of the important yield components had positive genetic and phenotypic association with cane yield (**Table 3** and **Table 4**). The strong genetic correlation of single cane weight, stalk diameter and number of internodes with other agronomic traits suggests that selection of these traits could simultaneously improve the other traits. On the other hand, though nonsignificant, the negative genetic association of number of millable cane with internodes length, leaf length, leaf area and sugar percent indicates that improvement in the former could result in decrease in the latter traits. These results together with the information obtained on heritability and genetic advance indicated that single cane weight, stalk diameter and millable cane number are the key component characters of cane yield. Sugarcane genotypes with high cane yield have been selected on the basis of stalk number and single cane weight [56].

4. Conclusions

This study revealed that cane yield was associated with its various components, sugar quality traits and sugar yield genetically and phenotypically in various magnitudes. Further, the study has indicated the magnitude of the correlations among cane yield traits, their heritability, expected genetic advance and genotype × environment interactions that could be encountered within the sugarcane breeding programme and demonstrated differential responses of different sugarcane clones to various environmental conditions.

The results suggest that evaluation of sugarcane clones for cane and sugar yield in many locations should identify superior clones. This testing approach coupled with a selection strategy based on single cane weight, stalk diameter and number of millable canes per unit area might result in significant genetic improvement in cane and sugar yield. This study also reveals that higher number of tillers, number of millable cane, single cane weight, number of internodes, stalk diameter, leaf length endowed with better pol%, purity% and sugar% are the important characters which should be considered while selection to be made for higher sugar yield in sugarcane genotypes.

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Appendixes

Appendix 1. Passport data of local sugarcane genotypes collected during 2010/11.

Code No.	Common Name	Date Collected	Collector	Collector's Number	Region/Zone/Wereda/Kebele/ Village	Lat/Long	Altitude (m)
1	Nach Shenkora	10/08/2010	Esayas Tena	3	SNNP/Gurage/Absege/Nachakulit/ Misreta	08˚20.989'/ 37˚33.954'	1521
2	Bicha Shenkora/Weliso	10/08/2010	Esayas Tena	4	SNNP/Gurage/Absege/Nachakulit/ Misreta	08˚20.989'/ 37˚33.954'	1521
3	Kay Shenkora	10/08/2010	Esayas Tena	5	SNNP/Gurage/Absege/Nachakulit/ Misreta	08˚20.989'/ 37˚33.954'	1521
4	Andegna Dereja Canada Shenkora	12/08/2010	Esayas Tena	7	SNNP/Silttie/Silttie/Balokeriso	07˚58.907'/ 038˚22.558'	1824
5	Ye abesha shenkora	21/08/2010	Esayas Tena	19	SNNP/Gamogofa/Bonke/Geresse Zala/	05˚54.307'/ 037˚18.54'	2258
6	Bicha Shenkora	20/08/2010	Esayas Tena	17	SNNP/Gamogofa/Bonke/Geresse Zala/Tsophi	05˚54.476'/ 037˚18.38'	2133
7	Kay Sidancho	27/08/2010	Esayas Tena	31	SNNP/Sidama/Borecha/Yloubancho/ Agoyicho	06˚56.060'/ 038˚22.793'	2042
8	Kay Shenkora	20/08/2010	Esayas Tena	18	SNNP/Gamogofa/Bonke/Geresse Zala/Tsophi	05˚54.476'/ 037˚18.38'	2133
9	Kay Shenkora/Huletegna dereja canada Shenkora	12/08/2010	Esayas Tena	8	SNNP/Silttie/Silttie/Balokeriso	07˚58.907'/ 038˚22.558'	1824
10	Burabure Shenkora	10/08/2010	Esayas Tena	6	SNNP/Gurage/Absege/Nachakulit/ Misreta	08˚20.989'/ 37˚33.954'	1521
11	Yegurage Shenkora/ Kay Shenkora	10/08/2010	Esayas Tena	1	SNNP/Gurage/Absege/Jejeba/Jejeba	08˚16.298'/ 037˚43.384'	1808
12	Yejima Shenkora	10/08/2010	Esayas Tena	2	SNNP/Gurage/Absege/Jejeba/Jejeba	08˚16.298'/ 037˚43.384'	1808
13	Kay Shenkora	12/08/2010	Esayas Tena	9	SNNP/Siltie/Werabe/02 Kebele	07˚49.933'/ 038˚10.793'	2101
14	Ye Abesha shenkora (Nach Shenkora)	17/08/2010	Esayas Tena	13	SNNP/South Omo/Debub Ari/Mester/Jagame	05˚59.202/ 036˚35.037'	1705
15	Wolesh	16/08/2010	Esayas Tena	12	SNNP/South Omo/Debub Ari/Bazet/Ekzek	05˚47. 213'/ 036˚34.900'	1436
16	Wolesh/Tinkish	16/08/2010	Esayas Tena	11	SNNP/South Omo/Debub Ari/Bazet/Ekzek	05˚47. 213'/ 036˚34.900'	1436
18	Nach (Arenguade) Ageda	19/08/2010	Esayas Tena	16	SNNP/Konso Special Wereda/ Gaserge Kebele	05˚96.038'/ 037˚21.194'	1727
19	Burabure Shenkora	18/08/2010	Esayas Tena	15	SNNP/Konso Special Wereda/Busso Kebele	05˚18.495'/ 037˚25.28'	1357
20	Wonji	16/08/2010	Esayas Tena	10	SNNP/South Omo/Debub Ari/ Bazet/Ekzek	05˚47. 213'/ 036˚34.900'	1436
21	Wolshi	17/08/2010	Esayas Tena	14	SNNP/South Omo/Debub Ari/Metser	Collected from market	
22	American	27/08/2010	Esayas Tena	32	SNNP/Sidama/Borecha/Yloubancho/ Agoyicho	06˚55.908'/ 038˚22.793'	2059
23	Jambo	27/08/2010	Esayas Tena	29	SNNP/Sidama/Borecha/Yloubancho/ Agoyicho	06˚56.060'/ 038˚22.793'	2042

Continued

24	Nach Sidancho	27/08/2010	Esayas Tena	30	SNNP/Sidama/Borecha/Yloubancho/ Agoyicho	06˚56.060'/ 038˚22.793'	2042
25	Azaro, Kollo	25/08/2010	Esayas Tena	21	SNNP/Amaro special Wereda/Jijola kebele/Kore village/Cheffa District	05˚40.446'/ 037˚55.669'	1410
26	Wonji	25/08/2010	Esayas Tena	23	SNNP/Amaro special Wereda/Jijola kebele/Kore village/Cheffa District	05˚40.446'/ 037˚55.669'	1410
27	Kembata	26/08/2010	Esayas Tena	25	SNNP/Gedeo/Wenago/Deko	06˚16.889'/ 038˚12.919'	1914
28	Nach Shenkora	25/08/2010	Esayas Tena	24	SNNP/Amaro special Wereda/Jijola kebele/Kore village/Cheffa District	05˚40.446'/ 037˚55.669'	1410
29	Andegna dereja Wonji	01/09/2010	Esayas Tena	44	SNNP/Wolayta/Damotgale/Gacheno	07˚02.280'/ 037˚55.072'	1882
30	Sidama/Yegamo Shenkora	25/08/2010	Esayas Tena	22	SNNP/Amaro special Wereda/Jijola kebele/Kore village/Cheffa District	05˚40.446'/ 037˚55.669'	1410
31	Huletegna dereja Jambo key	26/08/2010	Esayas Tena	27	Oromia/West Arsi/Wondo/Shesha Kebele	07˚05.662'/ 038˚36.203'	1705
32	Andegna dereja Jambo key	26/08/2010	Esayas Tena	26	Oromia/West Arsi/Wondo/Shesha Kebele	07˚05.662'/ 038˚36.203'	1705
33	Sostegna dereja Jambo key/ Metfo Shenkora	26/08/2010	Esayas Tena	28	Oromia/West Arsi/Wondo/Shesha Kebele	07˚05.662'/ 038˚36.203'	1705
34	Moliso	30/08/2010	Esayas Tena	35	SNNP/Konta Special Wereda/Cheka Bocha kebele/Bocha Village	07˚05.953'/ 036˚39.495'	1996
35	Nach Shenkora	30/08/2010	Esayas Tena	37	SNNP/Konta Special Wereda/Cheka Bocha Kebele	07˚06.244'/ 036˚40.164'	2105
36	Tazma/Burabure	30/08/2010	Esayas Tena	34	SNNP/Konta Special Wereda/Cheka Bocha kebele/Bocha Village	07˚05.953'/ 036˚39.495'	1996
37	Wolayta	01/09/2010	Esayas Tena	43	SNNP/Wolayta/Damotgale/Gacheno	07˚02.280'/ 037˚55.072'	1882
38	Kay Shenkora	31/08/2010	Esayas Tena	38	SNNP/Dawro/Mareka/MedaKuli/ Wushay	07˚00.612'/ 037˚12.285'	2163
39	Key Shenkora	30/08/2010	Esayas Tena	33	SNNP/Konta Special Wereda/Cheka Bocha kebele/Bocha Village	07˚05.953'/ 036˚39.495'	1996
40	Atena Moris	02/09/2010	Esayas Tena	45	SSNP/Kembata Tembaro/Kacha Bira/Mesena	07˚10.944'/ 037˚46.746'	1838
41	Dolche	01/09/2010	Esayas Tena	41	SNNP/Wolayta/Damotgale/Gacheno	07˚02.280'/ 037˚55.072'	1882
42	Kay Ageda Shenkora	03/09/2010	Esayas Tena	51	SNNP/Halaba kulito Special Wereda/Alemtena	07˚22.433'/ 038˚06.433'	1797
43	Moris	03/09/2010	Esayas Tena	52	SNNP/Halaba kulito Special Wereda/Alemtena	07˚22.433'/ 038˚06.433'	1797
44	Bolfe	02/09/2010	Esayas Tena	47	SSNP/Kembata Tembaro/Kacha Bira/Mesena	07˚10.944'/ 037˚46.746'	1838
45	Abesha	02/09/2010	Esayas Tena	46	SSNP/Kembata Tembaro/Kacha Bira/Mesena	07˚10.944'/ 037˚46.746'	1838
46	Wotete	02/09/2010	Esayas Tena	48	SSNP/Kembata Tembaro/Kacha Bira/Mesena	07˚10.944'/ 037˚46.746'	1838
47	Tazma/Burabure	31/08/2010	Esayas Tena	39	SNNP/Dawro/Mareka/MedaKuli/ Gendomeda	06˚58.977'/ 037˚11.493'	1803

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48	Betam nach Shenkora	30/08/2010	Esayas Tena	36	SNNP/Konta Special Wereda/Cheka Bocha Kebele	07˚06.244'/ 036˚40.164'	2105
49	Wonji-1	02/09/2010	Esayas Tena	49	SSNP/Kembata Tembaro/Kacha Bira/Wonko	07˚12.316'/ 037˚50.843'	1952
50	Bishoftu	02/09/2010	Esayas Tena	50	SSNP/Kembata Tembaro/Kacha Bira/Wonko	07˚12.316'/ 037˚50.843'	1952
51	Wotet	01/09/2010	Esayas Tena	42	SNNP/Wolayta/Damotgale/Gacheno	07˚02.280'/ 037˚55.072'	1882
53	Yeferenj shenkora	31/08/2010	Esayas Tena	40	SNNP/Dawro/Mareka/MedaKuli/ Gendomeda	06˚58.977'/ 037˚11.493'	1803
54	Yemaytafit Shenkora	29/09/2010	Esayas Tena	56	Oromia/Bale/Agarfa/Wabe	Collected from market	
55	Kay Shenkora	04/10/2010	Esayas Tena	59	Oromia/Arsi/Tena/Kereyuharzuna /Debenshe	07˚42.648'/ 039˚35.844'	1848
56	Wotete	02/10/2010	Esayas Tena	58	Oromia/Arsi/Tio/Bosha		market
57	Shenkora Dima/Kay Shenkora	29/09/2010	Esayas Tena	54	Oromia/Bale/Agarfa/Alochefo/	07˚23.154'/ 039˚46.271'	1497
58	Nach Shenkora/ Shenkora Adi	04/10/2010	Esayas Tena	61	Oromia/Arsi/Tena/Kereyuharzuna/ Debenshe	07˚42.648'/ 039˚35.844'	1848
59	Nach Shenkora	29/09/2010	Esayas Tena	55	Oromia/Bale/Agarfa/Alochefo/ Odachefo	07˚23.154'/ 039˚46.271'	1497
60	Moris	04/10/2010	Esayas Tena	60	Oromia/Arsi/Tena/Kereyuharzuna/ Debenshe	07˚42.648'/ 039˚35.844'	1848
61	Kay Shenkora	30/09/2010	Esayas Tena	57	Oromia/Bale/Goro/Melkabuta/Gadula Gola Dhertu	06˚58.539'/ 040˚35.398'	1611
62	Ye Abesha Shenkora/ Ye Oromo Shenkora	08/10/2010	Esayas Tena	67	Oromia/West Shewa/Ambo/Harutiro	09˚07.613'/ 037˚47.724'	2370
63	Kay Shenkora/Wonji	07/10/2010	Esayas Tena	65	Amhara/North Shewa/Debresina Market	10˚04.978'/ 039˚53.606'	1276
64	Nach Shenkora	07/10/2010	Esayas Tena	66	Amhara/North Shewa/Debresina Market	10˚04.978'/ 039˚53.606'	1276
65	Tikur Ageda	07/10/2010	Esayas Tena	62	Amhara/North Shewa/Kewet/Yelen	10˚04.978'/ 039˚53.606'	1235
66	Nach Ageda	07/10/2010	Esayas Tena	64	Amhara/North Shewa/Kewet/Yelen	10˚04.978'/ 039˚53.606'	1235
67	Nach Kechacha Shenkora/ Getr	07/10/2010	Esayas Tena	63	Amhara/North Shewa/Kewet/Yelen	10˚04.978'/ 039˚53.606'	1235
68	Ye Bako Shenkora	08/10/2010	Esayas Tena	68	Oromia/West Shewa/Ambo/Harutiro	09˚07.613'/ 037˚47.724'	2370
69	Bula Shenkora	06/11/2010	Esayas Tena	77	SNNP/Sheka/Masha/Shibo	07˚44.641'/ 035˚28.511'	2277
70	Kay Shenkora/ Kadiken	04/11/2010	Esayas Tena	69	Gambella/Agnwak/Abobo/Aberimeti	07˚55.825'/ 034˚43.133'	507
71	Bicha Shenkora	06/11/2010	Esayas Tena	76	SNNP/Sheka/Masha/Beto	07˚44.641'/ 035˚28.511'	2277

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72	Shenkora Dima/ Kay Shenkora	05/11/2010	Esayas Tena	73	Oromia/Illubabor/Bure/Wengawobe	08˚09.189'/ 035˚27.382'	1758
73	Kay Shenkora Ageda	05/11/2010	Esayas Tena	72	Oromia/Illubabor/Huka/Abyuadrere	08˚13.781'/ 035˚15.796'	1600
74	Nach Shenkora/ Kadiken	04/11/2010	Esayas Tena	70	Gambella/Agnwak/Abobo/Aberimeti	07˚55.825'/ 034˚43.133'	507
75	Shenkora	05/11/2010	Esayas Tena	71	Gambella/Agnwak/Gog/Badabado	07˚38.955'/ 034˚15.386'	454
76	Tikur Ageda	08/11/2010	Esayas Tena	78	SNNP/Sheka/Yeki/Addisbirhan	07˚11.212'/ 035˚26.095'	1164
77	Ye Kenya Ageda	06/11/2010	Esayas Tena	74	SNNP/Sheka/Masha/Keja	07˚50.149'/ 035˚28.159'	1827
78	Kay Ageda	08/11/2010	Esayas Tena	79	SNNP/Sheka/Yeki/Addisbirhan	07˚11.212'/ 035˚26.095'	1164
79	Kay Shenkora/Dima	02/11/2010	Esayas Tena	69-1	Oromia/Jima Zone/Sekoru Wereda/Habedode Kebele	Collected from market	
80	Ye Kenya Shenkora	06/11/2010	Esayas Tena	75	SNNP/Sheka/Masha/Masha 01	07˚44.641'/ 035˚28.511'	2277
81	Kay Ageda	09/11/2010	Esayas Tena	82	SNNP/Kefa/Gimbo/Bonga 01	07˚15.225'/ 036˚15.303'	1792
82	Tikur Ageda	08/11/2010	Esayas Tena	80	SNNP/Bench Majii /Mizan Teferi/ Hibret Kebele	07˚00.061'/ 035˚35.802'	1356
83	Shembeko Ageda	09/11/2010	Esayas Tena	81	SNNP/Kefa/Gimbo/Bonga 01	07˚15.225'/ 036˚15.303'	1792
84	Tikur Ageda	12/11/2010	Esayas Tena	84	Oromia/Illubabor/Bilonopa/Suli	08˚26.252'/ 035˚36.267'	1417
85	Nach Shenkora	12/11/2010	Esayas Tena	86	Oromia/Illubabor/Bilonopa/Dizy	08˚23.138'/ 035˚36.249'	1559
87	Dalecha Shenkora	12/11/2010	Esayas Tena	83	Oromia/Illubabor/Bilonopa/Suli	08˚26.252'/ 035˚36.267'	1417
89	Kay Shenkora Ageda	12/11/2010	Esayas Tena	85	Oromia/Illubabor/Bilonopa/Suli	08˚26.252'/ 035˚36.267'	1417
90	Kay Shenkora	15/11/2010	Esayas Tena	87	Oromia/Illubabor/Dureni/ Betelegebecha/Hadere	08˚29.860'/ 035˚45.110'	1754
91	Barbados	22/12/2010	Esayas Tena	97	Oromia/Gimbi/Laloasabe/ Harochserdo Kebele		
92	Ye Bako Shenkora	22/12/2010	Esayas Tena	101	Oromia/Gimbi/Laloasabe/ Dengoro 01/Golbe	09˚16.130'/ 035˚40.804'	1730
93	Kay shenkora	22/12/2010	Esayas Tena	99	Oromia/Gimbi/Laloasabe/ Dengoro 01/Golbe	09˚16.130'/ 035˚40.804'	1730
94	Ageda Adi	23/12/2010	Esayas Tena	106	Oromia/Kelem Welega/Sayo/ Gelanometi/Sembo	08˚32.704'/ 034˚43.594'	1730
96	Nech Shenkora	22/12/2010	Esayas Tena	100	Oromia/Gimbi/Laloasabe/ Dengoro 01/Golbe	09˚16.130'/ 035˚40.804'	1730
97	Tabor Shenkora	23/12/2010	Esayas Tena	102	Oromia/Gimbi/Guliso/Wereseyo/ Kobera	09˚10.256'/ 035˚31.592'	1484

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98	Nach Shenkora/Ye Jima Shenkora	21/12/2010	Esayas Tena	95	Benshangulgumuz/Asosa/Bambasi Mender 49 (Sefera Tabia)	09˚49.520'/ 034˚41.766'	1415
99	Shilmu	23/12/2010	Esayas Tena	104	Oromia/Kelem Welega/Dale Wabera/Chanka Burore	08˚49.268'/ 035˚03.747'	1470
100	Nach Shenkora	24/12/2010	Esayas Tena	107	Oromia/Kelem Welega/Hawagelan/Haromechara	08˚43.544'/ 034˚59.141'	1444
101	Kay Shenkora	27/12/2010	Esayas Tena	110	Oromia/West Shewa/Bakotibe/Dembigobu	09˚07.616'/ 037˚04.565'	1620
103	Nach Shenkora	24/12/2010	Esayas Tena	108	Oromia/Kelem Welega/Hawagelan/Haromechara	08˚43.544'/ 034˚59.141'	1444
104	Burabure Shenkora	20/12/2010	Esayas Tena	93	Benshangulgumuz/Asosa/ Megele 32 (Sefera Tabia)	10˚01.179'/ 034˚32.705'	1478
105	Nach Shenkora	20/12/2010	Esayas Tena	92	Benshangulgumuz/Asosa/ Megele 32(Sefera Tabia)	10˚01.179'/ 034˚32.705'	1478
106	Abesha Shenkora/Adi	27/12/2010	Esayas Tena	109	Oromia/West Shewa/Bakotibe/Dembigobu	09˚07.616'/ 037˚04.565'	1620
107	Nach Shenkora	03/02/2011	Esayas Tena	116	Amhara/Debub Gondar/ Derra/Mashenkoro/Misgano	11˚42.976'/ 037˚36.908	1993
110	Yegojam Shenkora	02/02/2011	Esayas Tena	113	Amhara/Debub Gondar/ Fogera/Wagtera	11˚54.574'/ 037˚33.371'	1797
111	Tikur Shenkora	04/02/2011	Esayas Tena	118	Amhara/West Gojam/Bahirdar Zuria/ Tis Abay/Gebere Mahiber	11˚29.128'/ 037˚34.331'	1642
113	Shilmlm Sora	04/02/2011	Esayas Tena	120	Amhara/West Gojam/Bahirdar Zuria/ Tis Abay/Gebere Mahiber	11˚29.128'/ 037˚34.331'	1642
114	Ye Bure Shenkora	04/02/2011	Esayas Tena	121	Amhara/West Gojam/Bahirdar Zuria/ Tis Abay/Gebere Mahiber	11˚29.128'/ 037˚34.331'	1642
115	Nach Ageda	08/02/2011	Esayas Tena	122	Amhara/West Gojam/Jabitehnan/ Mankusa Abdegom/Endalah	10˚41.075'/ 037˚11.357'	1941
116	Tikur Shenkora	08/02/2011	Esayas Tena	123	Amhara/West Gojam/Jabitehnan/ Mankusa Abdegom/Endalah	10˚41.075'/ 037˚11.357'	1941
117	Nach Shenkora/Sendel	09/02/2011	Esayas Tena	124	Amhara/West Gojam/Debub Achefer/Lalibela/Azena	11˚28.590'/ 036˚57.027'	1883
118	Nach Yemailat Shenkora/ CO 1001	09/02/2011	Esayas Tena	125	Amhara/West Gojam/Debub Achefer/Lalibela/Azena	11˚28.590'/ 036˚57.027'	1883
119	Bule/ B52	09/02/2011	Esayas Tena	126	Amhara/West Gojam/Debub Achefer/Lalibela/Azena	11˚28.590'/ 036˚57.027'	1883
121	Nach Shenkora	09/02/2011	Esayas Tena	124-1	Amhara/West Gojam/Debub Achefer/Lalibela/Azena	11˚28.590'/ 036˚57.027'	1883
122	Nach Shenkora	15/02/2011	Esayas Tena	129	BenshangulGumuz/Metekel/Pawe/ Mender 28/29	11˚16.526'/ 036˚27.233'	1097
123	Kay Shenkora	17/02/2011	Esayas Tena	134	Amhara/Awi/Guangua/Mota/ Menta Wuha	10˚50.310'/ 036˚20.642'	1532
124	Kay Shenkora	15/02/2011	Esayas Tena	128	BenshangulGumuz/Metekel/Pawe/ Mender 28/29	11˚16.526'/ 036˚27.233'	1097
126	Nach Shenkora	17/02/2011	Esayas Tena	133	Amhara/Awi/Guangua/Mota/ Menta Wuha	10˚50.310'/ 036˚20.642'	1532
127	Nach Shenkora/ Bishoftu/ China	21/02/2011	Esayas Tena	138	Amhara/East Gojam/ Dejen/Kurar/Dengel	10˚06.578'/ 038˚09.202'	1820

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128	Gojame/Ye Gojam Ageda	21/02/2011	Esayas Tena	141	Amhara/East Gojam/ Dejen/Kurar/Ambayamit	10˚06.490'/ 038˚09.185'	1804
129	Nach Shenkora	21/02/2011	Esayas Tena	139	Amhara/East Gojam/ Dejen/Kurar/Dengel	10˚06.578'/ 038˚09.202'	1820
131	Kay Shenkora/ Bishoftu	21/02/2011	Esayas Tena	137	Amhara/East Gojam/ Dejen/Kurar/Dengel	10˚06.578'/ 038˚09.202'	1820
132	Abadir	21/02/2011	Esayas Tena	142	Amhara/East Gojam/ Dejen/Kurar/Ambayamit	10˚06.490'/ 038˚09.185'	1804
133	Ye Fincha Shenkora	23/02/2011	Esayas Tena	144	Amhara/East Gojam/ Basoliben/Entemen Dejat	10˚03.504'/ 037˚50.264'	2360
134	Kay Ageda	22/02/2011	Esayas Tena	143	Amhara/East Gojam/Dejen/ Dejen Town		
136	Bicha Shenkora	21/02/2011	Esayas Tena	140	Amhara/East Gojam/ Dejen/Kurar/Dengel	10˚06.578'/ 038˚09.202'	1820
138	Kay Ageda	21/04/2011	Esayas Tena	148	Tigray/Semen Mierab Tigray/Tach Koraro/Semena/Maymesreb	14˚11.602'/ 038˚20.897'	1927
139	Kay Shenkora	21/04/2011	Esayas Tena	146	Tigray/Central Tigray/Tahtay Maychew/Mayatsmi	14˚04.680'/ 038˚33.366'	1993
140	Kay Ageda	21/04/2011	Esayas Tena	150	Tigray/Semen Mierab Tigray/Tach Koraro/Semena/Maymesreb	14˚11.602'/ 038˚20.897'	1927
141	Nach Shenkora	21/04/2011	Esayas Tena	147	Tigray/Central Tigray/Tahtay Maychew/Mayatsmi	14˚04.680'/ 038˚33.366'	1993
142	Kay Ageda	21/04/2011	Esayas Tena	149	Tigray/Semen Mierab Tigray/Tach Koraro/Semena/Maymesreb	14˚11.602'/ 038˚20.897'	1927
143	Nach Ageda/ Shenkora	26/04/2011	Esayas Tena	152	Amhara/Semen Welo/Gubalafto/Woynye 011/Medakit	11˚53.630'/ 039˚28.136'	2030
144	Kay Ageda/ Shenkora	26/04/2011	Esayas Tena	151	Amhara/Semen Welo/Gubalafto/ Woynye 011/Medakit	11˚53.630'/ 039˚28.136'	2030
145	Kay Shenkora (Bu-rabure)	04/05/2011	Esayas Tena	159	Amhara/Semen Welo/Habru/09 Kebele/Ante	11˚41.085'/ 039˚38.325'	1695
146	Nach Ye Abesha Shenkora	04/05/2011	Esayas Tena	160	Amhara/Semen Welo/Habru/09 Kebele/Ante	11˚41.085'/ 039˚38.325'	1695
149	Nach Tilik Shenkora	03/05/2011	Esayas Tena	158	Amhara/Debub Welo/Werebabo/ 02 kebele/Bulbulo/Aselel Prim. School	11˚19.354'/ 039˚45.074'	2072
150	Nach Shenkora	29/04/2011	Esayas Tena	154	Amhara/Oromia Special Zone/Kemissie/02 Kebele/Ergi	10˚42.491'/ 039˚51.712'	1422
151	Nach Ageda	02/05/2011	Esayas Tena	155	Amhara/Debub Welo/Borena/04 Kebele/Jimaye	10˚45.172'/ 038˚45.974'	2687
152	Nach Tinish Shenkora	03/05/2011	Esayas Tena	157	Amhara/Debub Welo/Werebabo/ 02 Kebele/Bulbulo/Aselel Prim. School	11˚19.354'/ 039˚45.074'	2072
153	Ye Beskula Shenkora	02/05/2011	Esayas Tena	155-1	Amhara Region/South Welo Zone/Legambo Wereda/Beskula Kebele	Collected from market	
154	Nach Shenkora	29/04/2011	Esayas Tena	153	Amhara/Oromia Special Zone/Kemissie/02 Kebele/Ergi	10˚42.491'/ 039˚51.712'	1422
155	Nach Ye Abesha Shenkora	05/05/2011	Esayas Tena	163	Amhara/Semen Welo/Meket/013 Kebele/Emamoz Fikrte Kirstos Gedam		
156	Nach Ageda/ Shenkora	09/05/2011	Esayas Tena	164	Amhara/Waghmra/Sekota/02 Kebele/Tiya	12˚30.391'/ 039˚05.795'	1978

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157	Kay Ageda/Shenkora	09/05/2011	Esayas Tena	166	Tigray/Debub Tigray/Ofla/Zata	12˚30.924'/ 039˚16.477'	2134
158	Ancha	09/05/2011	Esayas Tena	165	Tigray/Debub Tigray/Ofla/Zata	12˚30.924'/ 039˚16.477'	2134
159	Nach Shenkora	22/06/2011	Esayas Tena	177	Oromia/East Hararghe/Gurawa/01 Kebele/Kera Sefer	09˚08.392'/ 041˚50.424'	2401
160	Shenkora Adi	22/06/2011	Esayas Tena	175	Oromia/East Hararghe/ Kurfachele/Dawe/	09˚17.423'/ 041˚52.611'	1713
161	Nach Shenkora	23/06/2011	Esayas Tena	178	Oromia/East Hararghe/Meta/Chelenko 02 kebele	09˚23.875'/ 041˚33.670'	2179
162	Shenkora Dima	22/06/2011	Esayas Tena	176	Oromia/East Hararghe/ Kurfachele/Dawe/	09˚17.423'/ 041˚52.611'	1713
163	Nach Shenkora/Wonji	23/06/2011	Esayas Tena	180	Oromia/East Hararghe/Meta/ Chelenko 02 kebele	09˚23.875'/ 041˚33.670'	2179
164	Yemilat Nach Shenkora	23/06/2011	Esayas Tena	179	Oromia/East Hararghe/Meta/Chelenko 02 Kebele	09˚ 23.875'/ 041˚33.670'	2179
165	Nach Shenkora	21/06/2011	Esayas Tena	173	Harari/Erer Wereda/Dodota Kebele/ Mudir Village	09˚19.353'/ 042˚13.030'	1376
166	Burabure Shenkora	21/06/2011	Esayas Tena	174	Harari/Erer Wereda/Dodota Kebele/ Mudir Village	09˚19.353'/ 042˚13.030'	1376
167	Kay Shenkora	20/06/2011	Esayas Tena	168	Oromia/East Hararghe/ Babile/Ererguda/ Megida	09˚14.783'/ 042˚15.022'	1315
169	Kay Shenkora/Burabure	20/06/2011	Esayas Tena	168-1	Oromia/East Hararghe/ Babile/Ererguda/Megida	09˚14.783'/ 042˚15.022'	1315
170	Kay Shenkora	20/06/2011	Esayas Tena	171	Oromia/East Hararghe/ Kombolcha/Sibilu/ Gende Wedo Usman	09˚25.248'/ 042˚ 06.965'	2113
171	Kay Shenkora/ Burabure	23/06/2011	Esayas Tena	181	Oromia/East Hararghe/Gorogutu/ Erermedanchine/Ginge	09˚ 24.966'/ 041˚29.590'	1728
172	Guracha Shenkora/ Tikur	20/06/2011	Esayas Tena	169	Oromia/East Harerge/Babile/Ererguda/Megida	09˚14.783'/ 042˚15.022	1315
173	Misrah	29/06/2011	Esayas Tena	187	Oromia/West Hararghe/Gemechis/ Wemecho Dayo/Dekadabu	08˚45.408'/ 040˚53.285'	1496
174	Wonji	29/06/2011	Esayas Tena	186	Oromia/West Hararghe/ Gemechis/Wemecho Dayo/Dekadabu	08˚45.408'/ 040˚53.285'	1496
175	Wonji/Bula/ Shenkora Adi	28/06/2011	Esayas Tena	184	Oromia/West Hararghe/Gubakoricha/ Oda Aneni 05 kebele/Nanofaro	08˚56.717'/ 040˚33.308'	1972
176	Shekole	28/06/2011	Esayas Tena	182	Oromia/West Hararghe/Gubakoricha/ Oda Aneni 05 kebele/Nanofaro	08˚56.717'/ 040˚33.308'	1972
177	Holland	30/06/2011	Esayas Tena	188	Oromia/West Hararghe/Darolebu	08˚36.352'/ 040˚19.278'	1751
178	Bure	28/06/2011	Esayas Tena	185	Oromia/West Hararghe/Gubakoricha/ Oda Aneni 05 kebele/Nanofaro	08˚56.717'/ 040˚33.308'	1972

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179	Shenkora Dima	01/07/2011	Esayas Tena	189	Oromia/West Hararghe/ Mesela/Lubudekeb/Deneba	09˚05.913'/ 041˚08.151'	1647
180	Wonji	01/07/2011	Esayas Tena	190	Oromia/West Hararghe/ Mesela/Lubudekeb/Deneba	09˚05.913'/ 041˚08.151'	1647
181	Gende Lega	28/06/2011	Esayas Tena	183	Oromia/West Hararghe/Gubakoricha/ Oda Aneni 05 kebele/Nanofaro	08˚56.717'/ 040˚33.308'	1972
182	Dikala	06/07/2011	Esayas Tena	196	Oromia/East Hararghe/Deder/Kiyo (Nedi Gelan Sedi)/Tulu	09˚15.638'/ 041˚23.451'	1812
183	Alaa	06/07/2011	Esayas Tena	194	Oromia/East Hararghe/Deder/Kiyo (Nedi Gelan Sedi)/Tulu	09˚15.638'/ 041˚23.451'	1812
184	Bure	06/07/2011	Esayas Tena	191	Somali/Shinele/Erer/Bila	09˚31.774'/ 041˚24.965'	1192
185	Bure	06/07/2011	Esayas Tena	191-1	Somali/Shinele/Erer/Gota	Collected from market	
186	Shenkora Dima	06/07/2011	Esayas Tena	192	Somali/Shinele/Erer/Bila	09˚31.774'/ 041˚24.965'	1192
187	Shenkora Adi	08/07/2011	Esayas Tena	198-1	Oromia/Eastern Haraghe Zone/Meta/Ramis	Collected from market	
188	Aladi	06/07/2011	Esayas Tena	195	Oromia/East Hararghe/Deder/Kiyo (Nedi Gelan Sedi)/Tulu	09˚15.638'/ 041˚23.451'	1812
189	Erero	06/07/2011	Esayas Tena	193	Oromia/East Hararghe/Deder/Kiyo (Nedi Gelan Sedi)/Tulu	09˚15.638'/ 041˚23.451'	1812
190	Engda	07/07/2011	Esayas Tena	197	Oromia/West Hararghe/ Anchar/Chorchora/Megala Deye Market	08˚47.508'/ 040˚17.063	1690
191	Kay Shenkora	07/07/2011	Esayas Tena	198	Oromia/West Hararghe/ Anchar/Chorchora/Megala Deye Market	08˚47.508'/ 040˚17.063	1690

Appendix 2. Introduced sugarcane varieties in Ethiopia used for the study.

Code Number	Cultivar	Country of origin	Year of introduction	Code Number	Cultivar	Country of origin	Year of introduction	Code Number	Cultivar	Country of origin	Year of introduction
192	B3172	Barbados	1983	219	B 51321	Barbados	1974	246	BO 10	Bihar-Orissa (India)	1960
193	B35269	Do	1983	220	B 51410	Do	1983	247	BO 11	Bihar-Orissa	1960
194	B37172	Do	1956	221	B 51415	Do	1974	248	BO 14	Do	1974
195	B39250	Do	1983	222	B 52107	Do	1974	249	BO 29	Do	1974
196	B39254	Do	1983	223	B 52158	Do	1970	250	BO 3	Do	1970
197	B 4098	Do	1960	224	B 52298	Do	1965	251	BO60349	Do	Unknown
198	B41211	Do	1970	225	B 52313	Do	1974	252	CB 36-14	Campos (Brazil)	1974
199	B 4122	Do	Unknown	226	B 53163	Do	1974	253	CB 38-22	Do	1959
200	B 41227	Do	1957	227	B 53164	Do	1974	254	CB 38-39	Do	1959
201	B 42231	Do	1957	228	B 5364	Do	1965	255	CB 40-35	Do	1983
202	B 4362	Do	1957	229	B 54142	Do	1974	257	CB 41-76	Do	1970
203	B 4425	Do	1974	230	B 5490	Do	1974	259	CB 47-15	Do	1959

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204	B 45154	Do	1974	231	B 57133	Do	1974	260	C 105-73	Cuba	2003
205	B 45154	Do	1957	232	B 57141	Do	1974	263	CO 245	Coimbatore	1970
206	B 456	Do	Unknown	233	B 80-250	Do	unknown	264	CO 331	Do	1954
207	B 47386	Do	1974	234	B 5736	Do	1974	265	CO 419	Do	1954
208	B 47419	Do	1957	235	B 5780	Do	1974	266	CO 421	Do	1954
209	B 4744	Do	1963	236	B 58230	Do	1970	267	CO 434	Do	1970
210	B 4906	Do	1974	237	B 59104	Do	1983	268	CO 440	Do	1963
211	B 49119	Do	1962	238	B 59212	Do	1974	269	CO 449	Do	1957
212	B 49224	Do	1974	239	B 59250	Do	Unknown	270	CO 453	Do	1954
213	B 49388	Do	1974	240	B 60125	Do	1974	271	C120-78	Cuba	2003
214	B 50210	Do	1974	241	B 60163	Do	1974	272	CO 467	Coimbatore	1957
215	B 51116	Do	1970	242	B 60267	Do	1974	273	CO 475	Do	1956
216	B 51129	Do	1983	243	B 6109	Do	1983	274	CO 513	Do	1960
217	B 51131	Do	1970	244	B 6113	Do	1983	275	CO 617	Do	1960
218	B 51132	Do	1974	245	B 62347	Do	1974	276	CO 622	Do	1960
278	CO 677	Coimbatore	1970	308	CO 1186	Coimbatore	1974	341	CP69/1059	Canal point	1983
279	CO 678	Do	1960	309	CO 1190	Do	1987				
280	CO 680	Do	1963	310	CO 1198	Do	1987	343	CP 70/321	Do	1983
281	CO 684	Do	1970	311	CO 1202	Do	1987	344	CP 71/396	Do	1983
282	CO 718	Do	1970	312	CO 1208	Do	1987	345	CP 71/421	Do	1983
283	CO 740	Do	1962	313	CO 1230	Do	1974	346	CP 1/441	Do	1983
286	CO 765	Do	1970	314	CO 6023	Do	1974	347	CP 71/443	Do	1984
287	CO 775	Do	1960	315	CO 60191	Do	Unknown	348	CP72/2083	Do	1983
288	CO 785	Do	1987	317	CP 29/291	Canal point	1954	349	CP 73/341	Do	1983
289	CO 798	Do	1963	318	CP 29/320	Do	1953	350	COS 109	Unknown	1965
290	CO 810	Do	1974	319	CP 36/105	Do	1959	351	COS 245	Do	1970
291	CO 842	Do	1974	321	CP44/101	Do	1957	353	COS 510	Do	1962
292	CO 853	Do	1974	323	CP 47/193	Do	Unknown	354	COK 30	Do	1970
293	CO 911	Do	1963	324	CP 48/103	Do	1960	355	D 42/58	Demerara (Guyana)	1974
294	CO 945	Do	1970	325	CP 52/68	Do	1974	356	D 141/46	Do	1974
295	CO 954	Do	1987	326	CP 53/18	Do	1974	357	D 188/56	Do	1974
296	CO 957	Do	1965	327	M202/46	Mauritius	Unknown	359	DB 228/57	Do	Unknown
297	CO 961	Do	1970	328	H48/4605	Hawaii	1965	360	DB 377/60	Do	1974
298	CO 967	Do	1974	330	H49/3533	Do	1974	361	DB 386/60	Do	1974
299	CO 976	Do	1965	331	M442/51	Mauritius	Unknown	362	DB 414/60	Do	1974
300	CO 991	Do	1963	332	CP44/155	Canal point	Unknown	363	DB 414/66	Do	1983

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301	CO 997	Do	1967	333	CP 71-400	Do	Unknown	364	Ebene 1/37	Unknown	1957
302	CO 1001	Do	1970	334	CP 60/23	Do	1974	365	E 88/56	Do	1974
303	CO 1007	Do	1974	335	CP 61/37	Do	1974	366	E 188/53	Do	1974
304	CO 1148	Do	1987	337	M165/38	Mauritius	unknown	367	E 188/56	Do	1974
305	CO 1157	Do	1987	338	CP 65/357	Canal point	1983	368	F 134	Formosa, (Taiwan)	1970
306	CO 1158	Do	1987	339	CP 8/1026	Do	1984	370	H 32/8560	Hawaii (USA)	1960
307	CO 1177	Do	1974	340	CP68/1067	Do	1983	371	H 37/1933	Do	1960
372	CO-602	Coimbatore	unknown	398	N 7	Natal (South A.)	1983	426	NCD 349	Unknown	1970
373	H 38/4443	Hawaii (USA)	1960	399	N 8	Do	1983	427	NCD 376	Do	1956
374	H 39/3633	Do	1960	400	N 11	Do	1987	428	NCO 382	Do	1965
377	H 44/2364	Do	1974	401	N 14	Do	1980	429	PR 905	Puerto Rico	1959
378	H 44/3098	Do	1960	402	N 50/93	Do	1965	430	PR 980	Do	1965
379	HY8RID KS	Unknown	1974	403	SP70-1284	Unknown	Unknown	431	PR 1000	Do	1960
380	L 60-14	Louisiana, USA	1974	404	C86-12	Cuba	2003	432	PR 1007	Do	1970
381	L 60-25	Do	1974	405	Q 70	Natal	1965	433	PR 1013	Do	1970
382	L 60-35	Do	Unknown	406	R 48/3166	Reunion Island, (France)	Unknown	434	PR 1059	Do	1974
383	L 60-40	Do	1974	407	TDRJAN	Australia	1956	435	PPQK 1604	Do	1958
384	M 31/45	Mauritius	1957	408	C90-501	Cuba	2003	436	PDJ 28/78	Proefstation Cost Java (Indonesia)	Unknown
				409	WD II	Local collection	1953	437	Pindar	Unknown	1957
385	M 53/263	D0	Unknown	410	Yellow Cane	Unknown	Unknown	439	Q 50	Queens land (Austaralia)	1957
386	M 112/34	Do	1960	412	C86-165	Cuba	2003	440	SP70-1284	Unknown	Unknown
388	M 147/44	Do	1957	415	S 17	Unknown	Do	441	B80-505	Barbados	Unknown
389	M 377/5	Do	Unknown	417	SP70-1284	Unknown	Unknown				
390	Mex 52/29	Mexico	1970	418	N 51/168	Natal	1974				
391	Mex 53/142	Do	1970	419	N 51/539	Do	1974				
392	Mex 54/245	Do	1970	420	N 52/219	Do	1974				
393	Mex 54/255	Do	1970	421	N 53/216	Do	1974				
394	Mex 57/197	Do	1970	422	N 55/805	Do	1983				

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395	B80-250	Barbados	Unknown	423	NCD 310	Do	1953
396	Mex 59/1828	Mexico	1983	424	NCO 334	Do	1962
397	N 6	Natal (South A.)	1983	425	93-V1	Unknown	Unknown