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The Cluster of Local Maize Accessions Based on Seed Characteristics from North Sumatra

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THE use of local maize is still in high demand by farmers in Indonesia. The development of local maize needs to be discovered through a morphological approach. This study was to obtain seed characteristics and similarities of local maize from North Sumatra. Local maize accession seeds were taken by four districts/cities (Binjai, Serdang Bedagai, Deli Serdang, and Mandailing Natal) from North Sumatra, Indonesia from July to September 2022. A hybrid variety of maize was selected for comparison. Seed characteristics were measured in each accession with four replications. A descriptive-analytic method was selected in this study and data were analyzed using one-way ANOVA and followed by Tukey at $P<0.05$. Correlation analysis, similarity matrix, hierarchical cluster, and constellation plot were constructed in this study. The results showed that SB-1; DS-3; SB-4; and SB-2 accessions had higher seed characteristics than other accessions. The SB-5 accession had the nearest neighbors (0.743) and two accessions (BI-1; DS-2) were classified into one cluster with a hybrid variety. This finding indicates that several local maize accessions are nearest to the hybrid characteristics. A novelty of this study informed that local maize had an opportunity to be used in the fields.

Keywords: Accessions, Correlation, Hierarchical, Morphological.

Introduction

Maize (*Zea mays* L.) ranks third after wheat and rice in cereal production in the world (Cooper et al., 2014). The Center for Agricultural Data and Information Systems (2020) noted that Indonesia is the 8th country with the highest maize yield in the world from 2014-2018 (24.27 million tons) and North Sumatra Province ranks 6th as the central of the highest maize productivity in Indonesia. This central area of productivity should be maintained and even developed. This productivity central area must be maintained and even developed. If the development of maize productivity is carried out with the alternative of expanding the planting area, it is considered less appropriate to support food self-sufficiency.

The Directorate General of Food Crops (2010) reported that the area of maize planted in Indonesia was around 4.4 million ha with the seed distribution for hybrid, local, and composite varieties by 54%; 41%; and 4%, respectively. It indicated that the farmer's interest in the use of local varieties of seeds. Sukma (2017) found that local maize productivity (Guluk-guluk variety) was classified as low (1.84 ton ha^{-1}), but it had a quickly flowering (anthesis, silking) and harvest time compared to composite and hybrid varieties. In addition, Amzeri (2018) the reason farmers choose local varieties of

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maize because the price of hybrid maize seeds were expensive and limited.

The higher interest of farmers in using local varieties needed an initial effort in the development of local maize varieties by identifying the characteristics and relationships between accessions through the seed morphology approach of several regions. Several researchers have reported the approach of seed morphology characteristics to obtain their relationships (Mobarak et al., 2017; El-Kholy et al., 2023; Alridiwirsah et al., 2023). Likewise, the morphological diversity of local maize plants has been reported in Ivory Coast (N'da et al. 2014), Nigeria (Salami et al., 2007), Benin (Salami et al., 2015), and molecularly in Kupang, Indonesia (Uslan & Jannah, 2020). However, the characteristics and similarities of local maize accessions from North Sumatra have not been scientifically reported. This information is expected to be the basic for efforts to develop the potential of local varieties of maize in Indonesia.

Materials and Methods

Geographical of Local Maize Accessions

Local maize accession seeds were taken by four districts/cities from North Sumatra, Indonesia (Binjai, Serdang Bedagai, Deli Serdang, and Mandailing Natal). Ten cobs were taken from each location marked physiologically mature (brown husk and yellowed seeds in the cob) and assigned an accession code. Geographical and climatic conditions for each local maize accessions were conducted from July to September 2022 (see Table 1 and Figure 1). Local maize seeds were dried to a moisture content until 14%.

Data Collection and Analysis

A descriptive-analytic method was selected in this study. Twelve seeds were taken randomly from each local maize accession and then the characteristics of the seeds were measured including embryo length, crown width, pedicel length, seed length, seed thickness using an electronic digital caliper, and dry weight per seed and 100-seed weight using an analytical balance. Hybrid maize was selected as a comparison, namely the BISI-79 variety from BISI International, Inc. Each accession was replicated four times.

This study used a descriptive-analytic method based on visual observations of seed characteristics and then constructed the dendrogram between accessions. The characteristics of local maize seeds were analyzed using one-way ANOVA then followed by Tukey at $P<0.05$. Correlation of the growing conditions (altitude, temperature, humidity, air pressure) with seed characteristics using the Pearson correlation. The similarity, hierarchical cluster, and constellation plot with the Wards method applying the JMP 17 software (SAS, Cary, NC).

Results

Seed characteristics of local maize accessions from North Sumatra

Results showed that local maize seeds such as embryo length, crown width, seed length, dry weight per seed, and 100-seed weight had significant differences between accessions (Table 2). The embryo length and crown width of local maize accessions ranged from 4.93-8.05mm and 6.72-9.47mm, respectively. The seed length of local maize ranged from 8.33 to 11.95mm. Likewise, the dry weight per seed and 100-seed weight of local maize ranged from 0.14-0.38g and 10.62-34.66g. The difference in the seed size of local maize for each accession with a hybrid variety (comparison) can be seen in Fig. 2.

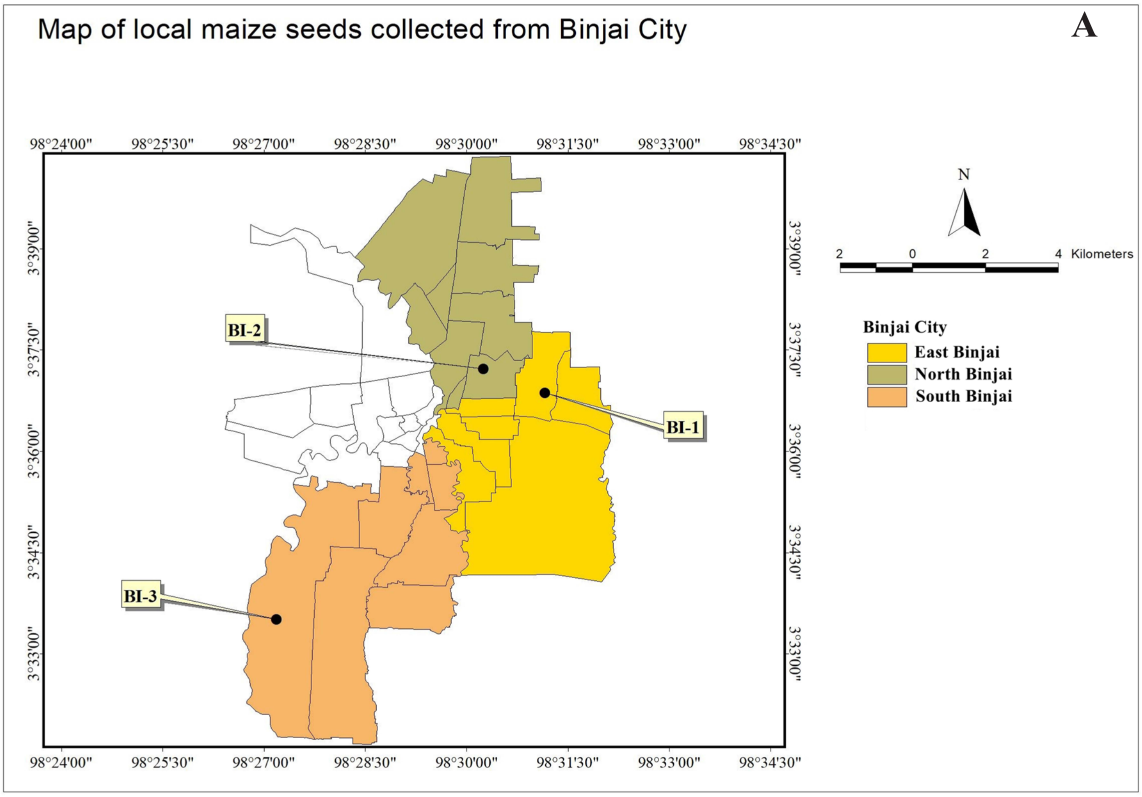
Correlation value

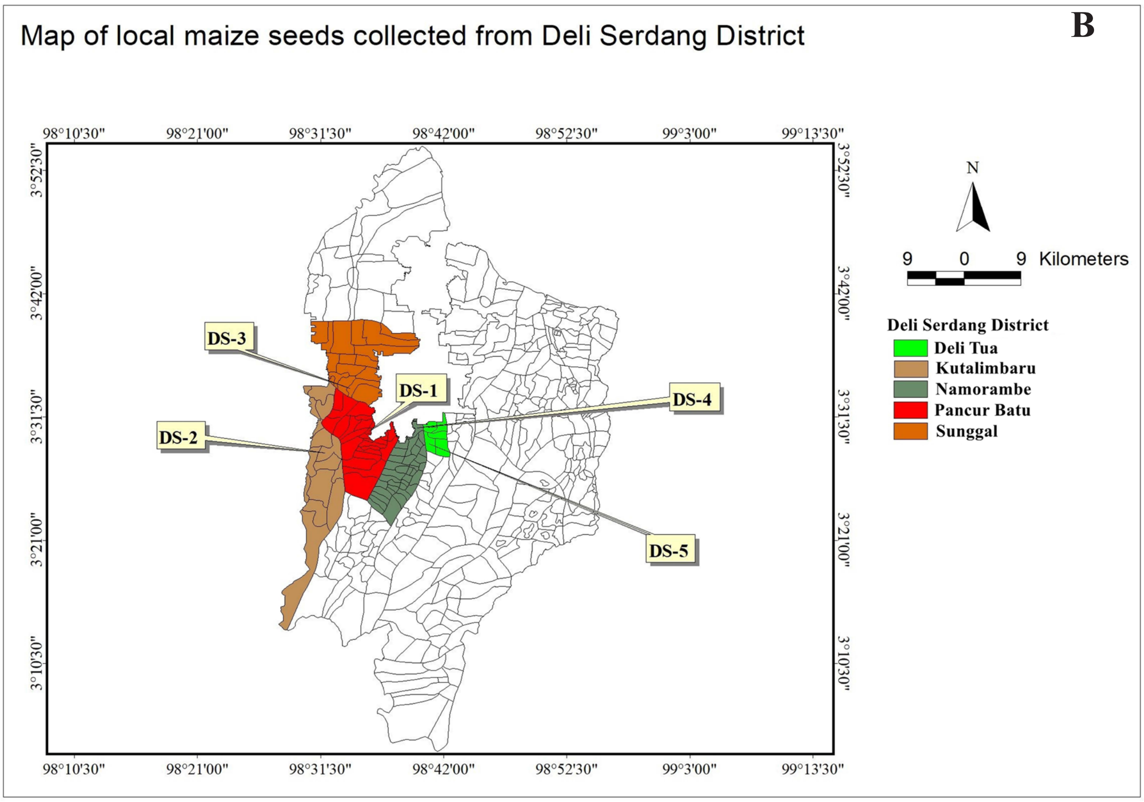
The correlation matrix showed that only humidity had a positive correlation and significant (0.506^*) to seed thickness of local maize accessions from North Sumatra (Table 3). However, altitude was also positively correlated with all seed characteristics of local maize accessions.

Similarity matrix and cluster of local maize accessions

The similarity matrix of the local maize accessions in comparison to the hybrid variety from North Sumatra and a hybrid variety could be seen in Table 4. There was one accession (SB-5) that had the nearest neighbors (0.743) with a hybrid variety. Based on the hierarchical cluster, local maize accessions can be grouped into four groups (Fig. 3).

Group 1 consisted of three accessions (MN-1; DS-4; DS-5) and group 2 also had three accessions (SB-3; SB-5; MN-3). Likewise, group 3 had three accessions (BI-1; DS-2; H) and group 4 consisted of eight accessions (BI-2; BI-3; SB-1; SB-2; SB-4; DS-1; DS-3; MN-2). Group 3 was classified into one group with a hybrid variety.


Map of local maize seeds collected from Binjai City
A
BI-1
BI-2
BI-3
N
2 0 2 4 Kilometers
Binjai City
East Binjai
North Binjai
South Binjai


Map of local maize seeds collected from Deli Serdang District
B
DS-1
DS-2
DS-3
DS-4
DS-5
N
9 0 9 Kilometers
Deli Serdang District
Deli Tua
Kutalimbaru
Namorambe
Pancur Batu
Sunggal

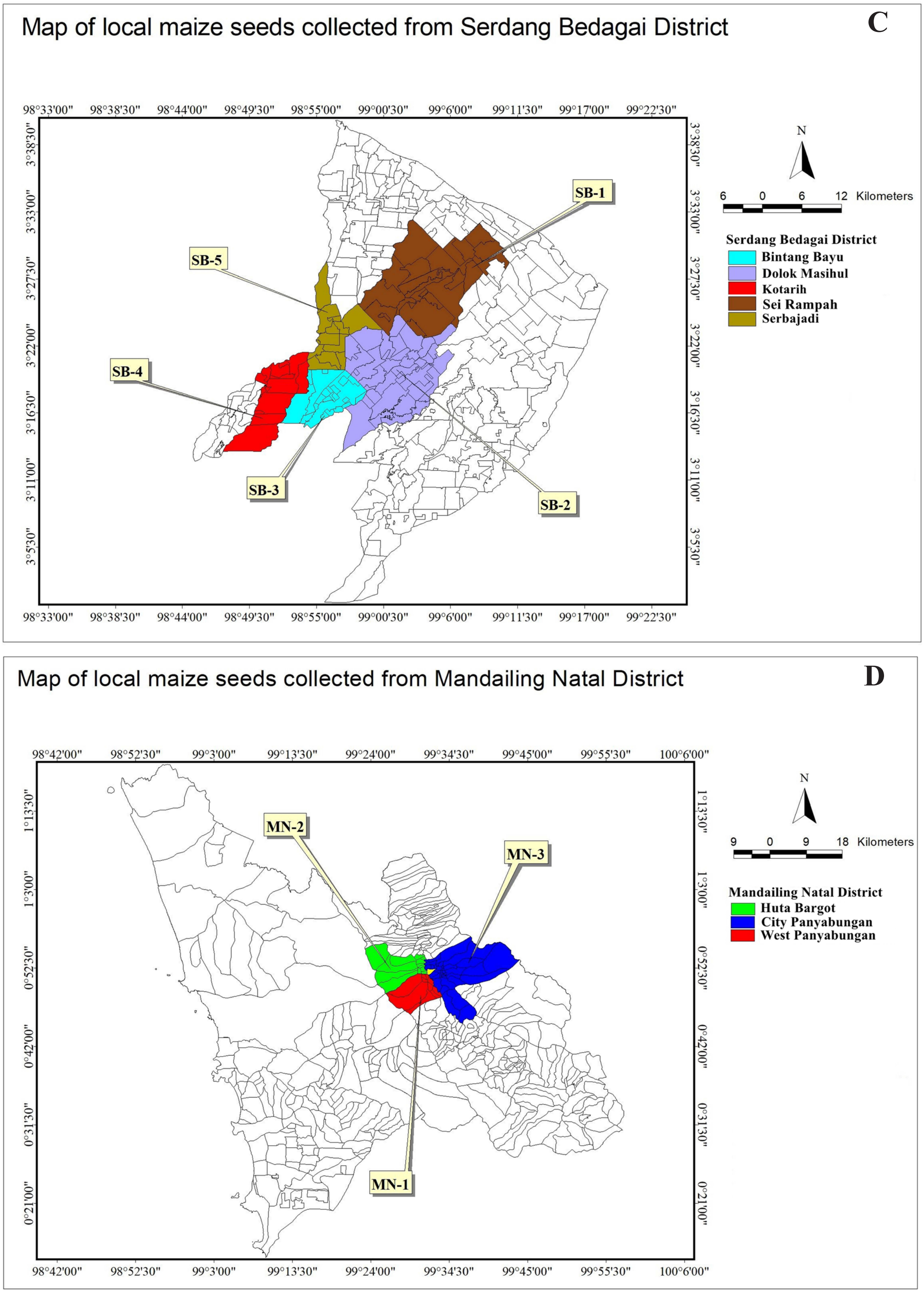


Fig. 1. Map of local maize seeds collected from Binjai (A); Deli Serdang (B); Serdang Bedagai (C); Mandailing Natal (D)

TABLE 1. Collecting locations for local accession of maize seeds from North Sumatra, Indonesia

Districts/ cities	Sub-districts	Villages	Accessions	Longitude	Latitude	Altitude (m asl)	Temperature (°C)	Humidity (%)	Air pressure (hPa)
Binjai	East Binjai	Sumber Mulyorejo	BI-1	98º31.113’	3º37.625’	40	30.0	66	1008
	North Binjai	Nangka	BI-2	98º30.219’	3º36.747’	34	30.0	66	1008
	South Binjai	Tanah Merah	BI-3	98º28.089’	3º34.635’	39	26.2	32	1006
Serdang Bedagai	Sei Rampah	Pematang Ganjang	SB-1	99º08.091’	3º27.761’	12	30.1	63	1007
	Dolok Masihul	Aras Panjang	SB-2	99º05.721’	3º21.020’	42	27.8	83	1007
	Bintang Bayu	Dolok Masango	SB-3	98º52.178’	3º21.046’	99	25.6	53	1010
	Kotarih	Huta Galuh	SB-4	98º50.003’	3º16.276’	151	27.1	75	1008
	Serbajadi	Pulau Tagor	SB-5	98º55.534’	3º24.997’	46	29.9	83	1007
Deli Serdang	Pancur Batu	Lama	DS-1	98º35.720’	3º29.268’	76	25.9	35	1004
	Kutalimbaru	Suka Rende	DS-2	99º33.614’	3º28.779’	69	25.7	32	1009
	Sunggal	Sei Beras Sekata	DS-3	98º35.410’	3º33.106’	46	30.5	62	1007
	Namorambe	Deli Tua	DS-4	99º39.752’	3º29.753’	49	30.8	62	1006
	Deli Tua	Deli Tua Timur	DS-5	98º41.274’	3º28.526’	72	27.6	49	1003
Mandailing Natal	West Panyabungan	Barbaran	MN-1	99º31.032’	0º51.488’	199	32.3	48	1012
	Huta Bargot	Huta Bargot Lombang	MN-2	99º30.808’	0º51.639’	218	32.6	48	1010
	City Panyabungan	Adianjior	MN-3	99º31.520’	0º52.370’	188	32.3	51	1008

TABLE 2. Seed characteristics of local maize accessions in comparison to the hybrid variety from North Sumatra

Accessions	Embryo length (mm)	Crown width (mm)	Pedicel length (mm)	Seed length (mm)	Seed thickness (mm)	Dry weight per seed (g)	100-seed weight (g)
Hybrid (H)	6.81±0.16 bcd	7.79±0.15 d-g	3.10±0.09 ns	10.51±0.14 bcd	4.65±0.20 ns	0.25±0.02 ef	24.72±0.37 ef
BI-1	5.97±0.11 de	6.72±0.14 g	1.98±0.24 ns	10.45±0.25 cd	4.22±0.16 ns	0.22±0.01 f	24.72±0.04 ef
BI-2	4.93±0.15 e	7.10±0.10 fg	2.53±0.10 ns	8.33±0.08 e	4.12±0.07 ns	0.14±0.00 g	10.62±0.21 i
BI-3	6.57±0.13 cd	7.73±0.02 d-g	2.61±0.12 ns	10.82±0.09 a-d	3.82±0.07 ns	0.23±0.01 f	20.92±0.08 h
SB-1	8.05±0.11 a	9.47±0.10 a	2.45±0.06 ns	10.68±0.11 a-d	4.17±0.04 ns	0.36±0.01 ab	30.06±0.19 b
SB-2	7.10±0.07 abc	8.51±0.07 a-d	2.94±0.05 ns	10.81±0.09 a-d	5.01±0.16 ns	0.34±0.01 ab	34.66±0.10 a
SB-3	7.05±0.07 a-d	7.23±0.13 efg	2.66±0.05 ns	11.18±0.11 a-d	4.25±0.07 ns	0.26±0.00 c-f	23.74±0.13 fg
SB-4	7.75±0.04 ab	9.00±0.15 abc	3.52±0.08 ns	11.39±0.20 a-d	4.69±0.06 ns	0.38±0.01 a	34.55±0.18 a
SB-5	7.11±0.04 abc	7.83±0.08 d-g	2.81±0.06 ns	10.23±0.07 d	4.66±0.19 ns	0.26±0.00 c-f	23.88±0.29 fg
DS-1	7.83±0.16 ab	7.88±0.08 c-f	2.70±0.10 ns	11.49±0.13 a-d	4.57±0.17 ns	0.30±0.01 b-e	27.26±0.03 cd
DS-2	7.59±0.05 abc	7.60±0.03 d-g	3.44±0.08 ns	11.32±0.16 a-d	4.11±0.03 ns	0.25±0.01 def	22.91±0.07 g
DS-3	7.22±0.09 abc	8.68±0.10 a-d	3.30±0.17 ns	11.95±0.05 a	4.87±0.11 ns	0.31±0.00 a-d	28.66±0.10 bc
DS-4	7.77±0.04 ab	7.99±0.07 b-f	3.57±0.14 ns	11.72±0.07 abc	4.15±0.09 ns	0.27±0.00 c-f	26.14±0.10 de
DS-5	7.43±0.10 abc	7.93±0.09 b-f	3.48±0.13 ns	11.86±0.16 ab	4.40±0.07 ns	0.27±0.01 c-f	22.28±0.19 gh
MN-1	7.54±0.05 abc	8.96±0.22 abc	2.95±0.02 ns	10.97±0.10 a-d	4.39±0.10 ns	0.27±0.01 c-f	23.41±0.35 fg
MN-2	7.01±0.15 a-d	9.02±0.06 ab	3.27±0.07 ns	11.55±0.08 a-d	4.71±0.06 ns	0.32±0.01 abc	28.55±0.10 bc
MN-3	7.91±0.19 a	8.27±0.16 b-e	2.84±0.03 ns	11.09±0.14 a-d	4.40±0.13 ns	0.26±0.01 c-f	27.53±0.07 cd

Note: the mean followed by a different letter is significant in the Tukey at $P<0.05$ ± standard error. ns= not significant.

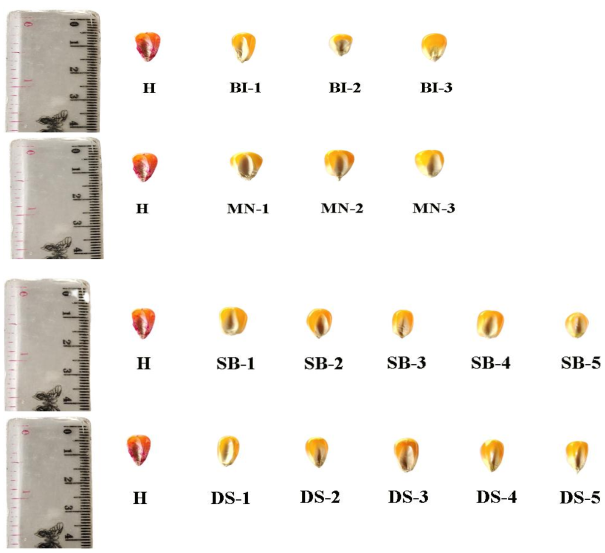


Fig. 2. Differences in seed size of local maize accessions from North Sumatra and hybrid variety (H) visually

TABLE 3. Correlation coefficient between growing conditions with seed characteristics of local maize accessions

Correlation coefficient	Embryo length	Crown width	Pedicel length	Seed length	Seed thickness	Dry weight per seed	100-seed weight
Altitude	0.292	0.395	0.311	0.299	0.255	0.220	0.216
Temperature	-0.034	0.371	-0.021	-0.118	0.180	-0.028	0.013
Humidity	-0.170	0.125	-0.071	-0.322	0.506*	0.225	0.303
Air pressure	-0.125	0.147	-0.095	-0.189	-0.007	-0.057	-0.030

Note: * and **Correlation is significant at the 0.05 and 0.01 levels (2-tailed).

TABLE 4. The value of the similarity matrix between local maize accessions in comparison to the hybrid variety from North Sumatra

Accessions	H	BI-1	BI-2	BI-3	SB-1	SB-2	SB-3	SB-4	SB-5	DS-1	DS-2	DS-3	DS-4	DS-5	MN-1	MN-2	MN-3
H	0																
BI-1	11.694	0															
BI-2	28.052	18.512	0														
BI-3	8.981	6.708	20.723	0													
SB-1	16.660	28.564	61.001	18.269	0												
SB-2	8.382	26.582	60.092	26.297	12.247	0											
SB-3	3.931	5.996	29.144	3.408	15.497	15.200	0										
SB-4	14.442	40.960	77.452	30.493	10.584	4.821	20.400	0									
SB-5	0.743	10.322	27.337	8.842	13.879	8.425	3.708	15.762	0								
DS-1	4.923	15.581	48.028	11.793	8.739	6.757	3.809	9.539	4.091	0							
DS-2	5.601	18.067	37.457	6.685	17.531	18.695	4.094	16.618	7.258	6.589	0						
DS-3	6.891	28.594	59.682	21.530	13.924	4.223	12.095	4.314	8.634	4.861	10.939	0					
DS-4	7.452	24.145	49.356	10.787	14.907	15.738	6.810	10.975	9.624	6.052	1.115	7.688	0				
DS-5	4.901	21.594	43.977	10.586	17.192	14.122	5.499	12.065	6.993	4.947	1.632	5.296	1.384	0			
MN-1	4.542	19.119	39.212	8.774	6.731	10.270	6.368	10.734	4.181	3.977	5.567	5.997	5.311	4.468	0		
MN-2	6.425	27.225	55.010	18.597	10.106	4.055	11.723	3.556	7.886	5.413	10.496	0.792	7.420	5.772	4.134	0	
MN-3	4.110	15.771	42.731	8.909	7.414	8.732	3.980	10.398	3.543	1.391	4.445	6.222	4.165	4.439	1.734	5.661	0

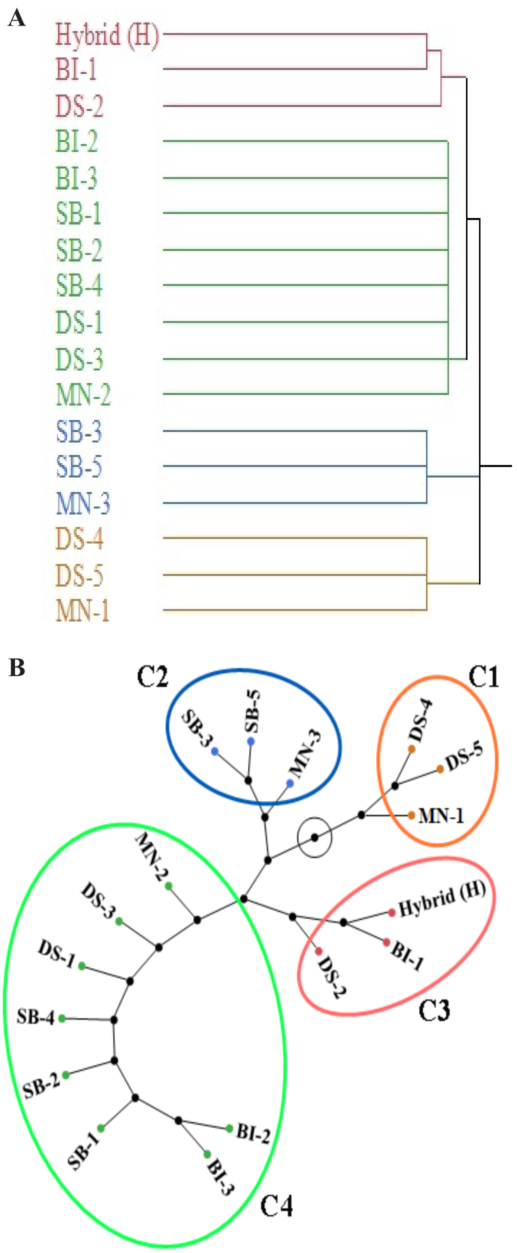


Fig. 3. Hierarchical cluster (A) and constellation plot (B) of local maize accession in comparison to the hybrid variety from North Sumatra [n= 17 samples]

Discussion

Results showed that SB-1; SB-2; SB-4; and DS-3 accessions had the highest seed characteristics among accessions of local maize including hybrid variety. The highest size of embryo length and crown width was found in SB-1 accessions at 18.21% and 21.57%, respectively, compared to a hybrid variety. The highest seed length of local maize was found in DS-3 accession at 13.70%. The highest dry weight per seed and 100-seed weight were found in SB-4 and SB-2 accessions by 52.00% and 40.21%, respectively. In addition to crop cultivation management, growing conditions can also affect the differences in the seed characteristics of local maize from each accession. It could be seen that the characteristics of embryo length, crown width, and seed length of local maize accession were positively correlated with the highest coefficient value (0.292; 0.395; 0.299) with the altitude of the maize planting. The altitude will affect the temperature, humidity, and air pressure. It can be seen that the dry weight per seed and 100-seed weight were correlated with the highest coefficient values (0.225 and 0.303) to the humidity (Table 3). This finding was supported by Oke (2016) that the mean relative humidity has a positive correlation and is highly significant (0.870^{**}) on maize seed production. Omoyo et al. (2015) also added that the increase in relative humidity encourages the evapotranspiration of plants in the field and tends to have an impact on filling maize seeds.

The similarity matrix of the local maize between accessions that were nearest neighbors to the hybrid variety was only SB-5 accession (0.743). The lowest matrix value indicates similar characters. It can be seen that the characteristics of embryo length, crown width, pedicel length, seed length, seed thickness, dry weight per seed, and 100-seed weight between the SB-5 accession was not different from a hybrid variety (Table 2). Based on the hierarchical cluster, there were two accessions (BI-1; DS-2) as clustered to one group with a hybrid variety (Fig. 3). These findings were supported by Uslan & Jannah (2020) who reported the local maize similarity index of eleven populations with the highest genetic distance (0.0004) found in Buraen 2 and Retraen 3. Salami et al. (2015) reported that there were four clusters constructed based on the morphological characteristics from 43 accessions of local maize in the central and 98 accessions in the northern of Benin. Khan et al. (2022) also clustered 35 genotypes of maize based on eleven different characteristics into five groups and the nearest cluster distance (3.441) was found between clusters IV (G1, G2, G6, G7, G15, G16, G19, G23, G24, G25, G30) and V (G4, G5, G11, G13, G14, G18, G21, G27, G29, G31, G34, G35).

This finding indicated that several local maize accessions had similar seed characteristics to the hybrid variety. This information can be used as an initial reference that local accessions from North Sumatra (SB-5) also have a similar potential to the hybrid variety.

Conclusions

The SB-1 accession had the highest embryo length and crown width (18.21 and 21.57%), the DS-3 accession had the highest seed length (13.70%), SB-4 and SB-2 accessions also had the highest dry weight per seed and 100-seed weight (52.00% and 40.21%) compared to the hybrid variety. The nearest neighbors (0.743) was found in SB-5 accession with a hybrid variety. Overall, two accessions (BI-1; DS-2) were classified into one cluster with a hybrid variety.

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Authors' contributions: Conceptualization and methodology (Novilda Elizabeth Mustamu, Koko Tampubolon, Alridiwirsah). Climate collecting and measuring (Mohammad Basyuni, Alridiwirsah). Seed collecting and measuring (Novilda Elizabeth Mustamu, Koko Tampubolon). Validation and data analysis (Koko Tampubolon). Writing, review, editing, and prepare manuscript for publishing (all authors).

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