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Identification and characterization of corn plants for downy mildew resistance in North Sumatra, Indonesia

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Abstract. *Hanafiah DS, Syamsafitri, Mariati, Hanum C, Muhdi, Rakasiwi G, Abdurrahman MH, Nur MA, Sahtika D. 2025. Identification and characterization of corn plants for downy mildew resistance in North Sumatra, Indonesia. Biodiversitas 26: 2130-2138.* The collection of germplasm determines the success of variety assembly. The genetic material contained in the germplasm has a strategic meaning in the assembly or improvement of varieties. This study aims to identify the kinship between morphological characteristics of individual corn plants. This study was conducted in Karo and Dairi Districts, North Sumatra, Indonesia from July-August 2024. Identification and plant characterization are carried out to preserve germplasm, which is the initial stage in breeding activities, especially in local germplasm. Characterization was carried out on corn genotypes in several villages in two districts in North Sumatra. The survey method used plant descriptors from the International Union for the Protection of New Varieties (UPOV) guide with a purposive method for determining the location and sampling technique. A total of 26 corn plant cultivars were studied. The result showed that based on the cluster method (grouping) of morphological characteristics, 3 groups were formed. The differences include stem color, leaf angle and ear tip shape. The closest cultivars are cultivars 14 and 16 from Kuta Tengah Village, Siempat Nempu Hulu Sub-district. The results of the characterization and identification of corn plants did not find any downy mildew attacks in Karo and Dairi Districts. The implication of this research is information on the diversity of corn germplasm and for the next stage the utilization of germplasm for corn plant breeding programs in North Sumatra.

Keywords: Cultivars, diversity, germplasm, kinship, morphological

INTRODUCTION

Corn, which is one of the most important cereal crops, is used as a source of food, feed, and energy. In Indonesia, corn plays a strategic role in agriculture and economy. Karo and Dairi Districts as the largest corn producing areas and have a diversity of germplasm in North Sumatra, Indonesia (Malasari 2022). This plant has high germplasm diversity and has great potential for development. Germplasm collection determines the success of variety assembly, which is determined by the availability of the gene sources contained therein. The genetic material contained in germplasm is important for the assembly or improvement of varieties. Germplasm must be characterized and evaluated to obtain the required gene source so that it can be optimally utilized (Maulana et al. 2024).

Plant breeding activities begin with the characterization of plant morphology which aims to identify and obtain the diversity of plant characters. Morphological characterization is carried out by grouping germplasm or plant genotypes that have unique properties to produce high genetic diversity (Kumar et al. 2022).

According to data from the Ministry of Agriculture, from January-December 2020, at least five provinces in Indonesia were capable of producing corn with a water content of 15% in large quantities. The five regions include East Java, Central Java, Lampung, North Sumatra, and South Sulawesi. East Java is the largest corn producer with a production of 5.37 million tons. Central Java Province ranks second, with a corn production of 3.18 million tons. Lampung is ranked third, with a corn production of 2.83 million tons. North Sumatra Province ranks fourth with a corn production of 1.83 million. South Sulawesi Province ranks fifth with a corn production of 1.82 million tons (Malasari 2022).

Every plant agroecosystem in Indonesia is restricted by several limitations that result in low and unstable productivity. These changes have been influenced by global climate change. One of the limitations is biotic stress (Hanafiah et al. 2020). Downy mildew is an obligate parasite and a major disease of corn that can damage and reduce corn productivity in tropical and subtropical regions

(Kim et al. 2017). Downy mildew affects corn development in Indonesia because attacks of downy mildew on susceptible varieties can result in plant damage of up to 100% of the cases (Muis et al. 2016).

Downy mildew is caused by the fungus *Peronosclerospora* spp. which is transmitted through morning wind movement from diseased to healthy plants. *Peronosclerospora* species in Indonesia have been identified based on morphological and host characteristics. Several species that cause downy mildew in corn have been reported in the last decade, namely *P. maydis*, *P. phillipinensis*, *P. sacchari*, *P. sorghi*, *P. spontanea*, *P. miscanthi*, *P. dichanthiicola*, *P. eriochloae*, *P. noblei*, *P. heteropogonis*, and *P. eriochloae* (Widiantini et al. 2015; Suharjo et al. 2020). In Indonesia, three species have been identified, namely *P. maydis*, *P. phillipinesis*, and *P. sorghi* (Rustiani et al. 2015; Ginting et al. 2020).

Corn plants have highly variable levels of resistance to downy mildew pathogens. The development of plant breeding activities is very important to increase genetic diversity and conduct appropriate selection programs to obtain the desired plant characteristics (Salazar et al. 2016).

The characterization and evaluation of germplasm is the initial stage of breeding activities, especially in the local germplasm. Corn genotypes were characterized in several villages in the two districts of North Sumatra. Information on the downy mildew that attacks corn plants was obtained by identifying the research location. The results of this study are expected to provide useful information for the development and assembly of corn plants that are resistant to downy mildew, with early maturity and high production.

MATERIALS AND METHODS

Study area

This research was conducted in Karo and Dairi Districts, North Sumatra, Indonesia between July and August 2024.

Materials and tools

The materials used in this study included stationary, plastic labels, questionnaire sheets, and other supporting materials. The tools used in this study included Global Positioning System (GPS), cameras, calipers, analytical balance, meter, rulers, and other supporting tools. The number of corn samples studied was 26 cultivars, namely 9 cultivars from Karo District and 17 cultivars from Dairi District (Table 1).

Table 1. Research location and corn accession numbers in Karo and Dairi Districts, North Sumatra, Indonesia

District	Sub-district	Village	Accession number	Land area (m^2)	Coordinate points
Karo	Tiga Panah	Kuta Bale	A1	5,000	3.0786 N 98.5292 E
Karo	Tiga Panah	Mulawari	A2	10,000	3.0884 N 98.5089 E
Karo	Munthe	Kutambaru	A3	20,000	3.0410 N 98.4045 E
Karo	Munthe	Kutambaru	A4	20,000	3.0524 N 98.3813 E
Karo	Munthe	Pertumbungen	A5	10,000	3.0541 N 98.3774 E
Karo	Munthe	Kineppen	A6	20,000	3.0554 N 98.3856 E
Karo	Kabanjahe	Lau Cimba	A7	2,500	3.0932 N 98.4841 E
Karo	Kabanjahe	Lau Cimba	A8	2,500	3.0931 N 98.4840 E
Karo	Kabanjahe	Sumber Mufakat	A9	2,500	3.1143 N 98.5149 E
Dairi	Siempat Nempu Hulu	Lae Nuaha	A10	4,800	2.7695 N 98.3023 E
Dairi	Siempat Nempu Hulu	Lae Nuaha	A11	4,000	2.7648 N 98.3014 E
Dairi	Siempat Nempu Hulu	Lae Nuaha	A12	4,000	2.7703 N 98.3118 E
Dairi	Siempat Nempu Hulu	Lae Nuaha	A13	5,000	2.7697 N 98.3134 E
Dairi	Siempat Nempu Hulu	Kuta Tengah	A14	4,000	2.7868 N 98.2737 E
Dairi	Siempat Nempu Hulu	Kuta Tengah	A15	4,000	2.7867 N 98.2743 E
Dairi	Siempat Nempu Hulu	Kuta Tengah	A16	3,200	2.7852 N 98.2881 E
Dairi	Barumpu	Karing	A17	2,800	2.7339 N 98.2728 E
Dairi	Barumpu	Karing	A18	1,600	2.7388 N 98.2734 E
Dairi	Barumpu	Karing	A19	5,000	2.7379 N 98.2666 E
Dairi	Barumpu	Barumpu	A20	2,200	2.7552 N 98.2635 E
Dairi	Barumpu	Barumpu	A21	5,000	2.7561 N 98.2643 E
Dairi	Barumpu	Barumpu	A22	3,200	2.7565 N 98.2654 E
Dairi	Sidikalang	Bintang	A23	4,000	2.7701 N 98.3112 E
Dairi	Sidikalang	Kalang	A24	4,000	2.7638 N 98.3046 E
Dairi	Sidikalang	Kalang	A25	3,200	2.7684 N 98.3080 E
Dairi	Sidikalang	Kalang	A26	2,400	2.7687 N 98.3095 E

Procedures

The survey method was used in this study. It was based on interview techniques and direct observation at the corn planting center location, namely, identifying the characteristics of corn in the field. The study locations were determined intentionally (purposive sampling) in several villages and sub-districts in Karo and Dairi Districts, North Sumatra. The research location was determined based on data searches of literature studies to obtain an overview of the location to be surveyed and information from the local community. Karo District has soil pH ranging from 5.5-6.0, average air temperature ranging from 17-25^{0}C and average air humidity ranging from 87-88%. Dairi District has a soil pH ranging from 6.0-6.5, average air temperature ranging from 17-27^{0}C and average air humidity ranging from 88-90%.

Sampling was performed using the purposive sampling method based on information from the local community and certain considerations, especially the age of the plants and their physical condition. Observations were conducted by visiting corn fields owned by farmers in several villages as sample locations. Direct interviews were conducted with farmers using a previously prepared questionnaire. Observations of corn genotype characteristics were carried out by collecting sample data based on the corn descriptor guidebook, namely, the International Union for the Protection of New Varieties of Plants (UPOV 2023), in the form of qualitative and quantitative characters.

Data analysis

Standardized qualitative and quantitative data were processed using IBM SPSS version 21 with cluster analysis to determine the level of kinship between the genotypes of each corn sample used to assess the diversity patterns of the survey data. Phenotypic variability coefficients were calculated using the expected mean square. Furthermore, the Standard Deviation of Phenotypic (Sσ^2p) is calculated based on Syahruddin and Suwardi (2023). σ^2p ≥2 sσ^2p means that the diversity is broad and σ^2p <2 sσ^2p means that the diversity is narrow.

The data collected included descriptions of the symptoms of downy mildew in corn plants at the research location. This study was conducted by surveying corn plants that exhibited symptoms of downy mildew disease. Data were used to describe the symptoms and incidence of downy mildew attacks at the research site. Percent Disease Incidence (PDI) was calculated using the formula 1 described by Thera et al. (2021):

$$\text{Disease incidence} = \frac{\text{Number of infected leaves}}{\text{Total number of population}}\ x\ 100 \qquad [1]$$

The description of the downy mildew symptoms was calculated based on observations using scores, as shown in Table 2 (Sangeetha and Siddaramaiah 2007).

The disease scale was then transformed into the attack percentage formula 2 was based on Gashaw et al. (2014) as follows:

$$\text{DS} = \frac{\Sigma(\text{n x v})}{(\text{Z x N})}\ x\ 100\% \qquad [2]$$

Table 2. Scale/description of downy mildew symptoms

Scale	Description of the symptom
0	Leaves free from infection
1	Small creamy white to light brown spots on leaves covering <5% leaf area
2	Small creamy white to light brown spots with cottony downy growth covering 5.1-10% leaf area
3	Creamy white to light brown spots with cottony growth covering 10.1-25% leaf area
4	Creamy white to light brown spots with cottony growth covering 25.1-50% leaf area
5	Creamy white to light brown spots with cottony growth covering >50% leaf area

Where, DS: Disease Severity; n: Number of affected plants in each category; v: Scale value on each affected plant; Z: Highest scale value; N: Number of plants observed in each attack.

The resistance criteria used for the disease tests was based on Mirsam et al. (2021) as follows: Very Resistant (VR): 0-5%; Resistant (R): >5-20%; Moderately Resistant (MR): >20-40%; Susceptible (S): >40-60%; Very Susceptible (VS): >60%.

RESULTS AND DISCUSSION

Corn identification results

North Sumatra Province is the fourth largest corn producer in Indonesia, and its corn production centers include Karo District, Dairi District, and Simalungun (Malasari 2022). Several districts, such as Dairi and Karo, have made corn one of their leading commodities. However, the competitiveness of local corn production remains low. Another factor in the dependence on corn imports is the low quality of local corn. The water content of corn kernels affects the quality of the corn produced. Local corn typically has a water content of 14-20%. Imported corn has a water content of 12-14% (Directorate General of Food Crops 2011). Feed factories prefer imported corn to local corn because its water content is in accordance with factory needs, and local corn must be re-dried. This indicates that the competitiveness of Indonesian corn remains low.

The identification and characterization of corn plants in the Karo and Dairi Districts yielded 26 corn plant cultivars (obtained from 26 interviewed corn farmers) (Table 1). Leaf color, leaf curvature, stem color, leaf angle, husk color, cob tip shape, ear shape, cob color, and grain color were also observed (Tables 3 and 4). The morphological characteristics of the plants differed for each observed parameter. Indonesian corn has specific morphological characteristics and a better adaptability to its environment. On an average, farmers obtain corn seeds from previous plantations and buy them from seed distributors and other farmers. Morphological characteristics of different plants are carried out by direct observation of the plant phenotype (Islam et al. 2020). Plant phenotypes show the results of interactions between genotypes and environmental factors.

Plant characterization aims to determine the nature of the plant so that it can be used as information material in plant breeding activities (Lutatenekwa et al. 2020). The characterization of plants includes observing the qualitative and quantitative characteristics of plant properties to identify and select appropriate parents for use in the formation or development of varieties. The use of plant morphology characterization not only makes it easier to identify plants but can also facilitate the grouping of plant kinship (Sahid et al. 2022).

Phenotypic appearance shows different morphological characters and appearances in all cultivars. Differences in phenotypic appearance also indicate differences and distinctive characteristics in some cultivars, as shown in Tables 3 and 4. This indicates that there is a high genetic diversity, which can be developed as a source of parents that can be combined with several plant characteristics with the aim of preserving genetic material and increasing plant productivity. The success of plant breeding programs in improving plant characteristics is determined by the availability of genetic resources (Hanafiah et al. 2018). High genetic diversity is used to improve plant characteristics and select appropriate selection techniques for plant breeding (Sravanti et al. 2017). The conservation of plant genetic resources can be achieved by analyzing genetic diversity (Govindaraj et al. 2015). The plant cultivars presented variation in all traits studied, particularly those related to phenology, morphology, and yield. The genetic variability observed between cultivars constitutes an asset for varietal selection programs. It has also been shown that the phenotypic variability of cultivars is more related to their agronomic and morphological traits than to their origins (Ezin et al. 2022).

Breeding programs must analyze genetic diversity to increase crop yield. Morphological and molecular methods can be used to accomplish this (Ky et al. 2022). Characterization of morphological traits is the initial stage in classifying and identifying germplasm from different plants (Balduzzi et al. 2017). Morphological traits such as leaflets, flower color, growth habit, leaflet texture, leaflet shape, canopy pattern, and seed color have all been used in the history of genetic diversity research to distinguish between cultivars with unique traits (Shilpashree et al. 2021). Morphological traits show qualitative and quantitative differences in characters. This indicates that these traits have high diversity among individuals. High genetic diversity facilitates the plant selection process (Pangestu et al. 2023).

Figure 1 showed the differences in the appearance of leaf curvature phenotypes, stem color, husk color, cob tip shape, ear shape, cob color, and grain color among the 26 cultivars. These morphological characteristics differed for each observed parameter. Kusmec et al. (2018) found that the phenotypic variation in corn plants is influenced by the relationship between genetic and environmental factors.

Table 3. Phenotypic appearance of corn cultivars studied in the Karo and Dairi Districts, North Sumatra, Indonesia

Phenotypic appearance cultivars	Traits						
	Leaf color	Leaf curvature	Stem color	Leaf angle	Plant length (cm)	Stem diameter (mm)	Leaf length (cm)
1	Green	Intermediate	Green	Medium	255.5	19	36.7
2	Green	Strong	Green	Medium	227.7	32.3	43.7
3	Green	Strong	Red	Large	312.6	18.4	35.6
4	Green	Strong	Green	Medium	239.5	18.1	29.1
5	Green	Intermediate	Red	Very small	322.7	18.5	33.2
6	Green	Intermediate	Green	Medium	242.7	24.1	41.2
7	Green	Strong	Green	Large	290.1	37.2	57.6
8	Green	Strong	Green	Large	285.6	24.4	34.1
9	Green	Strong	Green	Large	281.4	23.8	50.1
10	Green	Intermediate	Green	Medium	295.5	23.2	48.3
11	Green	Strong	Green	Medium	295	19.6	35.9
12	Green	Strong	Green	Large	274.1	15.2	52.7
13	Green	Strong	Green	Large	285	19.3	48.3
14	Green	Strong	Green	Large	286.7	19.2	59.5
15	Green	Absent or very weak	Green	Large	271.6	18.2	43.9
16	Green	Strong	Green	Large	295.5	23.2	43.7
17	Green	Strong	Green	Medium	254.2	28.1	46.9
18	Green	Strong	Green	Large	270.2	15.3	35.5
19	Green	Strong	Green	Medium	283.1	19.4	45.1
20	Green	Intermediate	Green	Medium	281.6	22.7	50.1
21	Green	Intermediate	Red	Medium	325.8	25.1	52.9
22	Green	Strong	Green	Large	290.1	15.3	61.6
23	Green	Absent or very weak	Green	Large	290	20.2	41.6
24	Green	Strong	Red	Medium	255.3	20.8	62.7
25	Green	Strong	Red	Medium	293.3	19.2	54.8
26	Green	Strong	Green	Medium	306.2	23.1	39.4

Table 4. Phenotypic appearance of corn cultivars studied in the Karo and Dairi Districts, North Sumatra, Indonesia

Phenotypic appearance Cultivars	Traits									
	Tassel: Length of main axis above lowest lateral branch (cm)	Husk color	Ear shape	Ear length (cm)	Weight per ear (g)	Number of ears per plant	Number of colors of grains	Cob tip shape	Color of cob	Color of top of grains
1	36.2	Green	Conico-cylindrical	29.8	165.4	2	1	Taper	White	Orange
2	32.2	Green	Conico-cylindrical	25.5	172.8	3	1	Taper	White	Orange
3	53.5	Red	Cylindrical	33.1	248.6	2	2	Round	Red	Red orange
4	30.1	Green	Conico-cylindrical	27.7	238.5	2	2	Taper	White	Red orange
5	26.1	Green	Cylindrical	29.8	275.2	1	2	Taper	White	Red orange
6	51.2	Green	Conico-cylindrical	26.3	290.3	2	2	Taper	White	Red orange
7	45.1	Red	Cylindrical	35.5	225.9	3	1	Taper	Red	Red
8	39.1	Green	Cylindrical	29.3	239.3	2	1	Taper	White	Orange
9	35.1	Green	Conico-cylindrical	30.8	154.7	2	1	Taper	White	Orange
10	40.4	Green	Conico-cylindrical	31.5	271.5	2	1	Taper	White	Orange
11	39.9	Green	Cylindrical	33.7	275.6	1	2	Round	White	Red orange
12	32.9	Green	Conico-cylindrical	29.1	239.1	2	1	Taper	White	Orange
13	43.6	Green	Conico-cylindrical	30.8	256.7	2	1	Taper	White	Orange
14	38.8	Green	Conico-cylindrical	30.5	274.5	2	2	Taper	White	Red orange
15	46.2	Green	Conico-cylindrical	35.5	261.3	2	2	Taper	White	Red orange
16	42.6	Green	Conico-cylindrical	34.8	243.3	2	2	Taper	White	Red orange
17	33.3	Green	Conico-cylindrical	35.1	286.3	2	1	Taper	White	Orange
18	44.3	Green	Conico-cylindrical	32.7	266.4	1	1	Taper	White	Orange
19	37.7	Green	Conico-cylindrical	38.9	281.6	2	1	Taper	White	Orange
20	41.5	Green	Conico-cylindrical	34.7	268.3	2	1	Taper	White	Orange
21	43.7	Green	Conico-cylindrical	35.9	300.7	3	2	Taper	Red	Red orange
22	44.2	Green	Conico-cylindrical	36.5	287.3	2	2	Taper	Red	Red orange
23	30.1	Green	Cylindrical	32.7	233.3	2	1	Round	White	Orange
24	49.5	Red	Cylindrical	40.6	281.5	1	2	Round	Red	Red orange
25	37.8	Green	Conico-cylindrical	39.9	264.8	2	2	Taper	White	Red orange
26	40.8	Green	Conico-cylindrical	35.7	258.8	2	1	Taper	White	Orange

The phenotypic variations observed in the field were the result of both genetic and environmental variations (Figure 1). The presence of environmental variation makes phenotypic variation less reliable; thus, the decomposition of this variation into its components is a necessary step. Even genotypic variation can be misleading if the interaction effects are high, as is the case with the nonheritable fraction. Therefore, the phenotypic variation was partitioned into heritable and nonheritable fractions. This can be done later with the help of certain genetic parameters, such as the Phenotypic Coefficient of Variation (PCV), Genotypic Coefficient of Variation (GCV), heritability, and genetic advances (Majhi et al. 2020).

The diversity of phenotypic appearances was represented by qualitative and quantitative characteristics. This diversity can be attributed to the number of genes or environmental factors present in each accession (Hanafiah et al. 2018). Genetic diversity is one of the steps in the evolution of all types of plant organisms. Genetic variation affects the evolution of populations under different environmental conditions (Chung et al. 2023). Qualitative characteristics are influenced by many genes and are easily influenced by the environment. Quantitative characters are those whose inheritance is controlled by many genes (polygenic) and influenced by the environment. Quantitative traits are directly observed for individual characteristics (Heino 2014). Quantitative characteristics are also significantly influenced by environmental factors and many genes (Ketthaisong et al. 2014; Govindaraj et al. 2015). Data collected from various villages in the two distircts of Dairi and Karo regarding the phenotypic diversity of several corn cultivars are very useful for preserving corn germplasm and for its use in plant breeding programs. Corn cultivars with wide genetic diversity can be used as genetic materials for crossbreeding.

Cluster analysis and phenotypic relationship

The phenotypic relationships between cultivars were analyzed by cluster analysis of group cultivars using SPSS. Data on the similarity in the phenotypic appearance of each accession were analyzed and are displayed in a dendrogram (Figure 2). The 26 corn plant cultivars consisted of 3 clusters. Cluster 3 consisted of three cultivars (cultivars 3, 7, and 24). These cultivars were grouped based on stem color, leaf angle, and cob tip shape. Cluster 2 consisted of four cultivars (cultivars 5, 15, 23). The cultivars were grouped based on leaf curvature, stem color, leaf angle, cob tip shape, ear shape, and grain color. Cultivars from Clusters 2 and 3 came from the Karo and Dairi Districts. The other cultivars were grouped into cluster 1. Cluster 1 cultivars were obtained from the two observed districts.

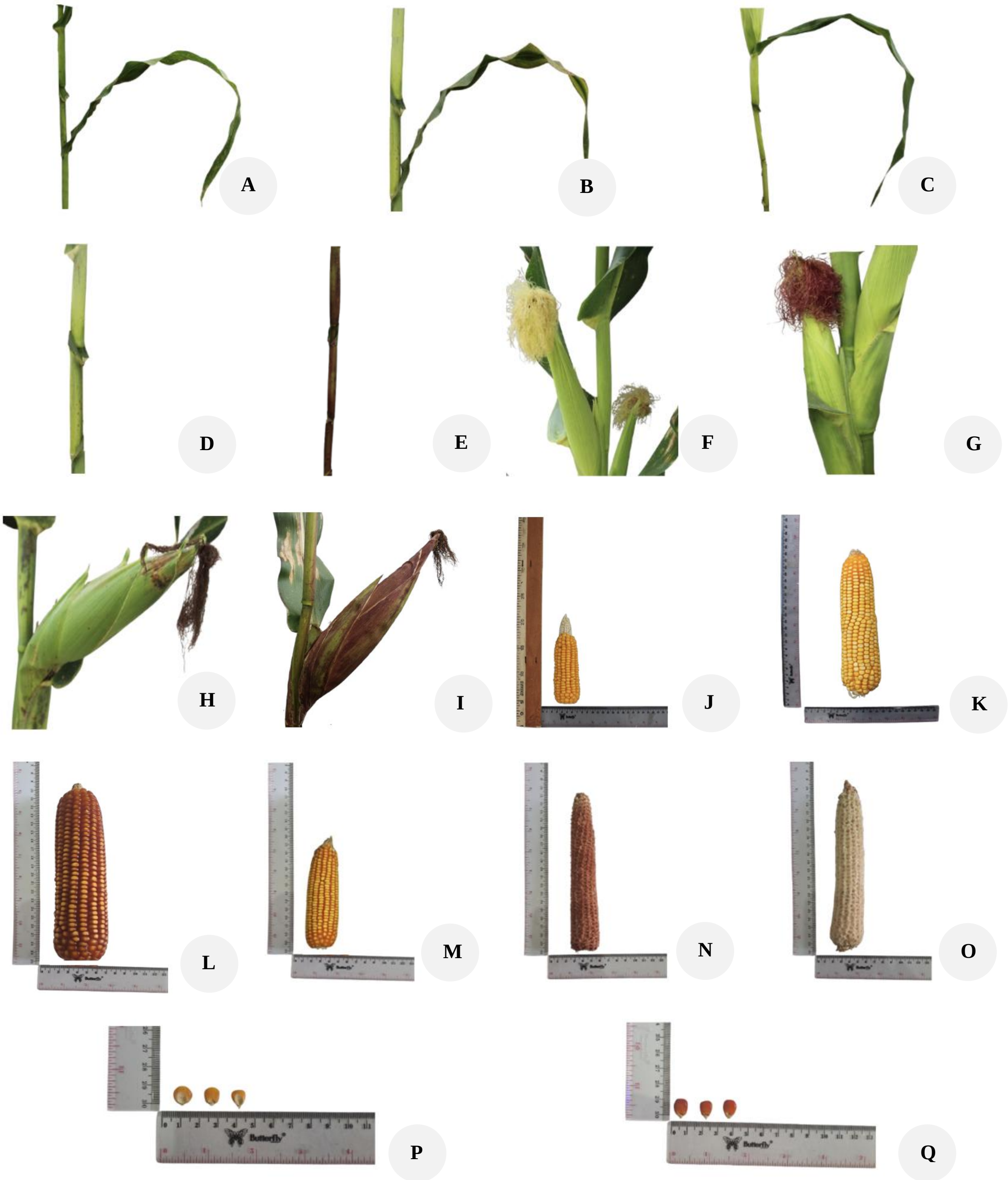

Figure 1. Differences in phenotypic appearance in 26 cultivars of corn plants in Karo and Dairi Districts, North Sumatra, Indonesia. A. Undulation of margin of blade (absent or very weak); B. Undulation of margin of blade (intermediate); C. Undulation of margin of blade (strong); D. Stem color (green); E. Stem color (red); F. Female flower color (yellow); G. Female flower color (red); H. Husk color (green); I. Husk color (red); J. Cob tip shape (pointed); K. Cob tip shape (round); L. Ear shape (cylindrical); M. Ear shape (conico cylindrical); N. Color of cob (red); O. Color of cob (white); P. Grain color (orange); Q. Grain color (red)

The closest cultivars were cultivars 14 and 16, both of which came from the same village and sub-district, namely Kuta Tengah Village and Siempat Nempu Hulu Sub-district. The closest cultivars were 17, 19, and 26, and these three cultivars were from Dairi District. Cultivars can be found in the same cluster because of similar morpho-agronomic characteristics and the same locations, while cultivars can be found clusters far from similar cultivars because of differences in morphological characteristics and locations as shown in Table 1. Tan et al. (2022) stated the smaller genetic distance between individuals in a population indicates that genetic diversity is still low, and individuals are similar.

Genetic variability in maize diversity

Estimated phenotypic variability, standard deviation, and corn cultivars criteria in Karo and Dairi Districts revealed that six characters showed wide diversity, namely plant length, stem diameter, leaf length, tassel length of the main axis above the lowest lateral branch, ear length, and weight per ear, and two narrow characters, namely the number of ears per plant and the number of colors of grains (Table 5). Phenotypic diversity is used as genetic information and a visual differentiator if it is based on broad criteria. However, the preliminary results of the experiment related to morphological traits are very important to characterize the existing cultivars, as they helped estimate the variability existing in the landraces, which was due to individual genotype characteristics (Shrestha et al. 2022).

Downy mildew attacks rate

Survey and investigation of the extent of downy mildew attacks in the Karo and Dairi Districts revealed that no downy mildew attacks occurred, and the category was normal. Downy mildew is a widespread disease affecting agricultural crops worldwide. It causes significant food loss and damages valuable natural ecosystems (Lahlali et al. 2022). In severe cases, disease frequency can reach 100% (Sadravi and Tavakoli 2014; Kemble et al. 2022). Current management techniques include cultural practices, such as planting crops as early as possible to avoid downy mildew. Interviews were conducted with corn farmers in several sub-districts and villages in the Karo and Dairi Districts. Downy mildew attacks were not observed because the corn plants were planted during a planting season that was not suitable for the development of downy mildew.

Table 5. Phenotypic variability estimation values, standard deviations, and criteria for corn cultivars in Karo and Dairi Districts, North Sumatra, Indonesia

Phenotypic appearance	σ^2p	Sσ^2p	2Sσ^2p	Criteria
Plant length (cm)	591,1671	24.31393	48.62786	Broad
Stem diameter (mm)	25.5522	5.054918	10.10984	Broad
Leaf length (cm)	85.93538	9.270134	18.54027	Broad
Tassel: Length of main axis above lowest lateral branch (cm)	45.22174	6.724711	13.44942	Broad
Ear length (cm)	15.54166	3.942291	7.884583	Broad
Weight per ear (g)	1425.798	37.75974	75.51948	Broad
Number of ears per plant	0.278462	0.527695	1.055389	Narrow
Number of colors of grains	0.258462	0.508391	1.016782	Narrow

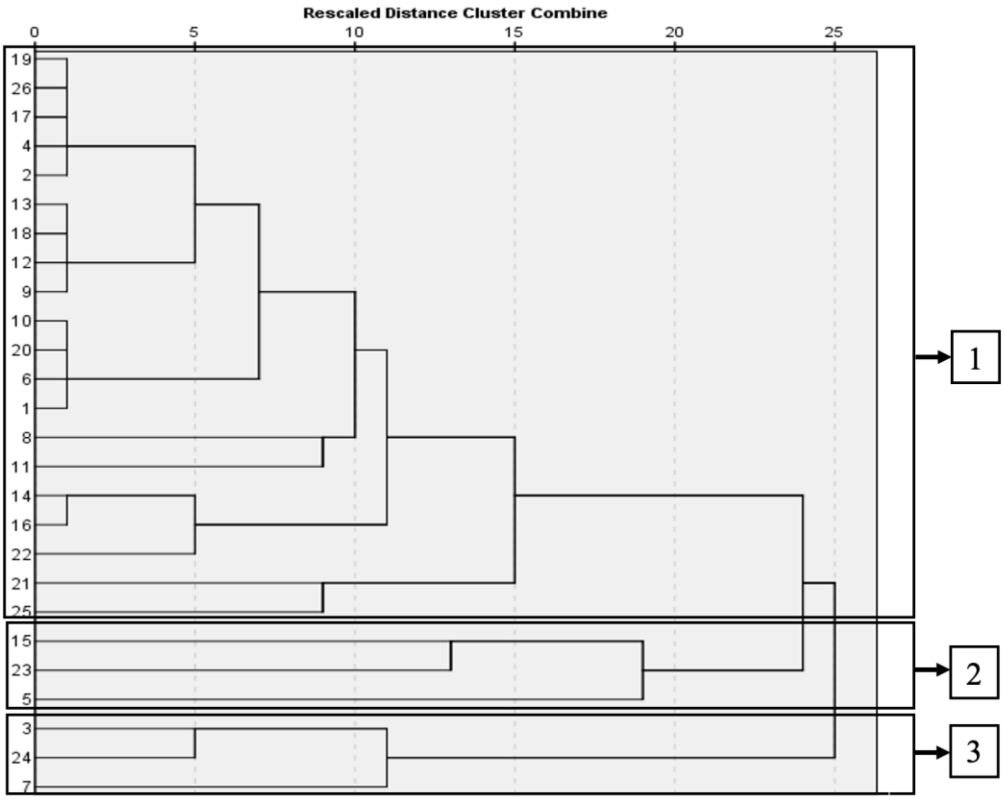

Figure 2. Dendrogram of corn phenotype appearance in Karo and Dairi Districts, North Sumatra, Indonesia

Muis et al. (2016) showed that *Peronosclerospora* spp. are spread across three islands in Indonesia. In one area, more than one species can be found, whereas one species is found in areas endemic for downy mildew. *Peronosclerospora philippinensis* was found only on Sulawesi Island, whereas *P. maydis* and *P. sorghi* were found on all the islands. Common symptoms of downy mildew include chlorotic striping or partial symptoms in the leaves and leaf sheaths, along with dwarfing. The symptoms of downy mildew became clearer with the appearance of downy growth under the leaf surfaces owing to conida formation early in the morning. Based on the data mentioned above, *P. maydis* and *P. philippinensis* are commonly found in the lowlands, while *P. sorghi* is mostly found in the highlands.

Obligate pathogens can also cause downy mildew. Because of the systemic nature of Downy Mildew (DM), susceptible lines usually die when infected during the seedling emergence stage, and when plants are infected during later growth stages, they cannot develop corn ears despite surviving. DM is widespread in tropical regions, although its origin is conjectural, and because of the diversity of DM pathogens and their systemic nature, the development of resistant varieties is needed. Moreover, a renewed emphasis on cost-effectiveness and environmental safety has led to the application of DM management through the development of resistant varieties. In addition, the evaluation of several DM strains using a mapping population could contribute to the accurate assessment of genetic contributions to resistance (Kim et al. 2020). Genetic studies investigating downy mildew resistance also have revealed that resistance is polygenic and has preponderantly additive gene effects but with a threshold, the nature of which depends on the level of infection (Jadhav et al. 2019).

In conclusion, research on the identification and characterization of corn plants in Karo and Dairi Districts was conducted to preserve the source of germplasm and information to support the corn plant breeding program in North Sumatra, and sufficient information was obtained to determine the steps that need to be taken to increase the productivity of corn plants and quality of corn plants. Genetic material of local corn plants with the desired characteristics from the diverse corn germplasm in North Sumatra can be used to produce corn plants that are resistant to downy mildew disease through germplasm screening.

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