Relationship and identification of maize germplasm resistant to drought stress

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Abstract. Morphological characterization and identification of drought-stress resistance in maize germplasm are the initial steps toward developing maize varieties with high yield and drought stress resistance. This study used a non-factorial randomized block design with one treatment (genotype) and was repeated three times. The genetic material used in the research consisted of 22 genotypes, comprising 20 pure lines and two comparison varieties (Bisi-X and Jakarin). Twenty maize lines were characterized using 58 morphological characters and tested for drought resistance. The research results showed that the dendogram of morphological characters in the 20 tested lines was classified into two groups, with a similarity coefficient of 0.47-0.95, indicating a diversity of 0.05 - 0.53. The average DSI value indicated that 12 maize lines were drought-stress-resistant, namely G1, G2, G3, G4, G6, G7, G8, G10, G11, G12, G13, and G20. Four maize lines (G14, G15, G16, and G17) had high production character. G1xG16, G1xG17, G2xG16, G2xG17, G3xG16, G2xG17, G8x16, and G8xG17 were cross combinations that can be used to produce hybrid maize varieties with high yield and drought resistance, as they are morphologically distant.

1 Introduction

Breeding maize varieties with high production and drought resistance is one solution to the problem of low maize production in dryland areas [1]. Maize varieties with these character can adapt to environmental conditions with limited water and achieve optimal production [2]. The initial step in producing maize varieties with the desired character is to identify the lines (germplasm) to be used as parents in assembling the varieties [3], [4]. The selected lines must have high yield potential and be drought stress tolerant. Assembling maize varieties using parents w[1]ith the desired characteristics increases the likelihood of success in assembling the desired variety [5]. Parents with superior characteristics (high production and drought resistance) carry genes that control these characters, increasing the likelihood that these genes will be passed on to new varieties created from these parents [6]. Linking maize varieties using parents with desired characteristics will increase the efficiency and effectiveness of variety assembly, as the breeding program will be more focused and faster [7].

Morphological characterization of potential maize lines is very important for determining which lines will be used to assemble maize varieties [8]. Observation of morphological characters (quantitative and qualitative) is used to identify phenotypic diversity, which describes the genetic potential of each line [9]. Morphological character information not only functions as a basis for selection but also as a tool for grouping lines based on similarities or differences in the characters they possess [10]. Analysis of kinship relationships between lines can be conducted based on the similarities and differences in the characteristics of the lines being tested. Lines with distant kinship indicate different genetic backgrounds, making them potential hybrid varieties, as they exhibit maximum heterosis in crosses. Heritability calculations can be performed on quantitative characters to determine the extent to which genetic factors influence the quantitative characteristics of the tested lines [11]. Heritability values can be used as a basis for selecting the breeding program for assembling plant varieties [12][13]. In addition, through quantitative character observations, correlations between characters can be analyzed, which helps determine selection methods in assembling plant varieties [14].

Identification of drought stress resistance in potential maize lines is an important step toward developing superior maize varieties that are drought stress resistant [15]. The value used to determine lines' resistance to drought stress is the drought sensitivity index (DSI). The DSI value provides information on the extent of decline in plant characteristics due to drought stress [16]. Lines resistant to drought stress can be grouped based on DSI values. Lines with DSI value <1 are lines that are resistant

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to drought stress because they show a slight decrease in yield due to drought stress. Furthermore, lines with DSI >1 are sensitive to drought stress, as they exhibit a significant yield decrease under drought [17].

Morphological characterization and identification of line resistance to drought stress are important activities in the assembly of superior maize varieties [18]. Plant breeders can select desired parents based on the morphological diversity of the tested lines. Furthermore, identifying lines' resistance to drought stress can facilitate the selection of parents that are drought stress resistant. These two activities will help develop superior maize varieties with high production potential and drought resistance. This research aims to characterize the morphology and identify drought stress resistance in maize lines.

2 Research methods

2.1 Genetic materials and experimental design

The planting materials used consisted of 22 maize genotypes, including 20 maize lines and 2 comparison varieties (Bisi-X and Jakarin) (Table 1). The research was conducted from May to September 2025. The research was conducted in Bangkalan District, Madura, Indonesia (7°09'14.8"S, 112°44'01.6"E,5 m a.s.l). The average temperature is around 30 °C with an average humidity of 70%. The soil type is grumusol with pH of 7.1.

Table 1. 22 maize genotypes.

Genotype	Code	Origin
G1	TS-S-5-20-1	Madura Island, Indonesia
G2	ES-S-5-21	Madura Island, Indonesia
G3	MS-S-5-12	Madura Island, Indonesia
G4	Ba-S-5-3	Probolinggo, East Java, Indonesia
G5	Ba-S-5-16	Probolinggo, East Java, Indonesia
G6	Kd-S-5-3-1	Kediri, East Java, Indonesia
G7	Kd-S-5-3-12	Kediri, East Java, Indonesia
G8	Klk-S-4-4	Lumajang, East Java, Indonesia
G9	Pn-S-4-12	Ponorogo, East Java, Indonesia
G10	Trg-S-4-18	Trenggalek, East Java, Indonesia
G11	Trg-S-4-22	Trenggalek, East Java, Indonesia
G12	Tul-S-4-2	Tulungagung, East Java, Indonesia
G13	Bli-S-4-24	Blitar, East Java, Indonesia
G14	Su-S-4-2-9	ICERI, Indonesia
G15	Su-S-4-2-22	ICERI, Indonesia
G16	Lm-S-4-3-11	ICERI, Indonesia
G17	Lm-S-4-2-4	ICERI, Indonesia
G18	La-S-4-3-1	ICERI, Indonesia
G19	Sk-S-4-2-21	ICERI, Indonesia
G20	SK-S-4-2-25	ICERI, Indonesia
Bisi-X	-	Hybrid varieties
Jakarin	-	Composite Varieties

The research implementation flow from maize germplasm collection to the determination of maize parents for maize variety assembly is presented in Figure 1. This research used a non-factorial randomized block design with one treatment, namely genotype. The genetic material used in the research consisted of 22 genotypes, comprising 20 pure lines and two comparison varieties (Bisi-X and Jakarin). Each treatment was repeated three times so that there were 66 experimental units. Each treatment was repeated three times, resulting in 66 experimental units. Drought stress using the CYMMYT method [19], namely drought stress is carried out when the plants are 50 days after planting (DAP) until harvest, but irrigation is provided with field capacity from 0 to 40 DAP with an interval of every 10 days. Fertilization is given in three stages, namely when the plants are 7 days after planting (200 kg ha^{-1} SP-36, 100 kg ha^{-1} Urea and 50 kg ha^{-1} KCl), 25 days after planting (100 kg ha^{-1} Urea and 50 kg ha^{-1} KCl, and 40 days after planting (100 kg ha^{-1} Urea and 50 kg ha^{-1} KCl).

2.2 Data collected and data analysis

The observed morphological characters were quantitative and qualitative characters. In total, there were 58 characters based on plant habitus, leaves, stems, panicles, ears, and agronomic traits. At the time of maize harvest in the field, the moisture content of the seeds usually reaches less than 30%. Observations of maize grain yield were carried out on all plant samples for each experimental unit and converted into maize grain yield per hectare at a water content of 15% using the following formula:

$$Y = \frac{10000}{HA} \times \frac{100 - MC}{100 - 15} \times GW \quad (1)$$

Where: Y: Grain yield (kg h^{-1}); HA: Harvested area per plot (m2); MC: Moisture content at harvest time (%); GW: Harvested grain weight per plot (kg).

The Drought Susceptibility Index (s) measurement used the following equation [17]:

$$S = \frac{(1 - (\frac{Yp}{Y})}{(1 - (\frac{Xp}{X})} \quad (2)$$

Where:
Yp : the mean of a genotype subjected to drought stress,
Y : the mean of a genotype not subjected to drought stress,
Xp : the mean of all genotypes subjected to drought stress, and
X : the mean of all genotypes that are drought-tolerant.

A cluster analysis was performed using the Numerical Taxonomy and Multivariate System (NTSYS) program version 2.1. A cluster analysis applied SAHN (Sequentia Agglomerative Hierarchical and Nested) approach was conducted with an Unweighted Pair Group Method Arithmetic (UPGMA) procedure in order to group the genotype based on morphological characters. Quantitative character data was analyzed using the F test. If there is a significant effect, continue with the Honestly Significant Difference (HSD) Test ($p<0.05$) using STAR 2.01 software. Estimation of environmental variance, genetic variance, phenotypic variance, and heritability in abroad sense (h^2_{bs}) was calculated based on the formula [20].

$$h_{bs}^2 = \frac{\sigma_g^2}{\sigma_p^2} \quad (3)$$

Where : h_{bs}^2 = heritability in a broad sense; σ_g^2 = genetic variance; σ_p^2 = phenotypic variance.

Pearson correlation coefficient analysis is calculated based on the formula [21]:

$$r = \frac{n\sum_{i=1}^{n} xiyi - (\sum_{i=1}^{n} xi)(\sum_{i=1}^{n} yi)}{\sqrt{\left[n\sum_{i=1}^{n} xi^2 - (\sum_{i=1}^{n} Xi)^2\right][n\sum_{i=1}^{n} yi^2 - (\sum_{i=1}^{n} yi)^2]}} \quad (4)$$

Where : r = correlation value between variables x and y; n = many observations; xi = the value of variable x in plant-i; yi = the value of the variable y in plant-i.

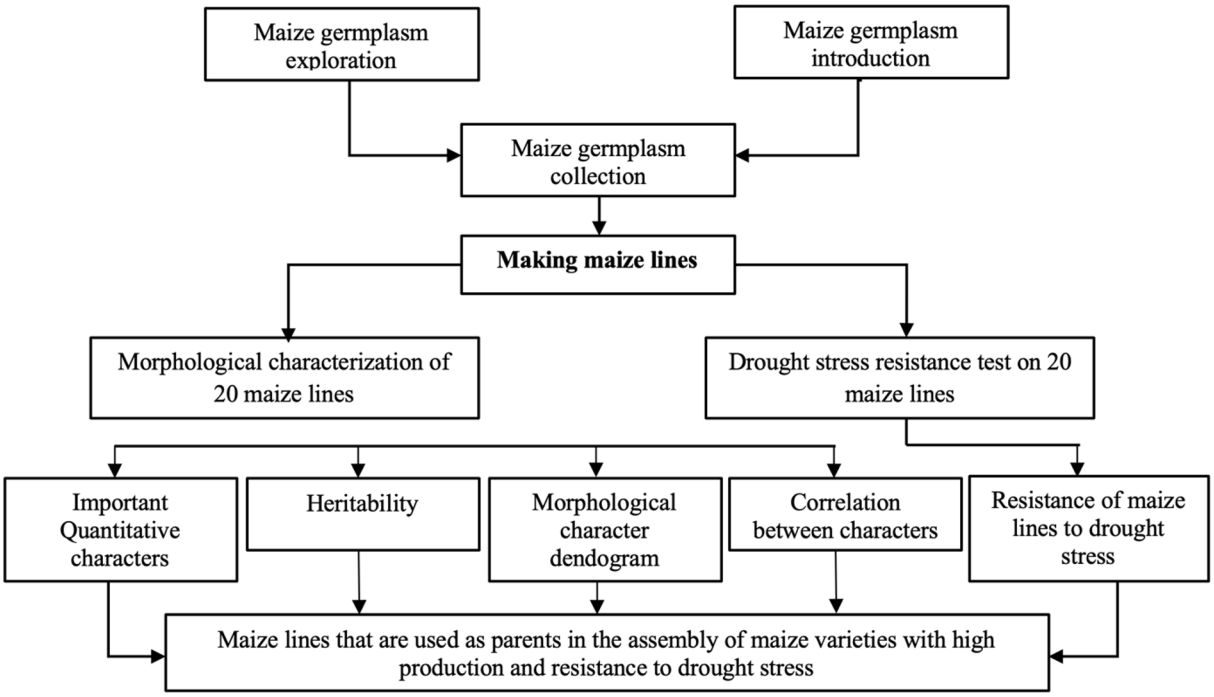

Fig. 1. Research workflow.

3 Result and discussion

3.1 Plant height, days to 50% tasselling, days to 50% silking, harvest age, and ear height

In terms of plant height, all tested lines were shorter than the two comparison varieties (Bisi-X and Jakarin). The genotype with the shortest plant height was G3 (142.00 cm). G14 and G15 had the highest plants among the lines tested at 193.33 cm and 193.00 cm, respectively. All lines tested had plant heights below 200.00 cm. Pure lines are individuals with a homozygous genotype, obtained through selfing, which results in decreased expression of specific characters [22]. In terms of days to 50% tasselling, G2 had the shortest time, namely 33.33 DAP. G14 and G15 had the longest days to 50% tasseling among the lines tested at 52.00 DAP and 51.33 DAP, respectively. In terms of days to 50% silking, G2 had the shortest time at 36.00 DAP. G14 had the longest days to 50% silking among the tested lines, namely 54.33 DAP.

In terms of harvest age, G2 had the shortest, at 66.67 DAP. Five lines had the longest harvest age among the lines tested, namely G14 (98.33 DAP), G15 (96.67 DAP), G16 (98.00 DAP), G17 (97.33 DAP), and G20 (96.77 DAP). In terms of ear height, G3 had the lowest, at 71.33 cm. Six lines had the highest ear height among the lines tested, namely G14 (97.33 cm), G15 (97.00 cm), G16 (95.33 cm), G17 (97.00 cm), G19 (95.67 cm), and G20 (96.67 cm). The comparison variety (Bisi-X) had plant height, days to 50% tasselling, days to 50% silking, harvest age, and ear height higher than the lines tested.

3.2 Ear Length, Ear Diameter, Kernel Weight per Plant, 1000-Kernel Weight, and production per hectare

In terms of ear length, G3 had the shortest, at 7.87 cm. The three lines had the largest ear lengths among the lines tested: G14 (16.27 cm), G15 (16.40 cm), and G17 (16.23 cm). The comparison varieties (Bisi-X and Jakarin) had longer ears than the tested lines. In terms of ear diameter, G2 had the smallest, at 2.77 cm. G15 had the largest ear diameter and exceeded the comparison variety Jakarin, which is 5.23 cm. In terms of kernel weight per plant, G3 had the lowest, at 27.02 g. Four lines had the highest kernel weight per plant among those tested: G14 (72.75 g), G15 (73.42 g), G16 (70.29 g), and G17 (70.26 g). The comparison varieties (Bisi-X and Jakarin) had higher kernel weight per plant than the tested lines.

In terms of 1000-kernel weight, three lines had the smallest 1000-kernel weight, namely G10 (191.33 g), G11 (187.00 g), and G17 (192.67 g). The comparison variety (Bisi-X) had the highest 1000-kernel weight among all

genotypes tested. In terms of production per hectare, G3 had the lowest, namely 1891.40 kg. Four lines had the highest production per hectare among those tested: G14 (5092.73 kg), G15 (5139.17 kg), G16 (4920.53 kg), and G17 (4917.97 kg). The comparison varieties (Bisi-X and Jakarin) had the highest production per hectare characteristics, exceeding the tested lines.

3.3 Heritability

Heritability values play an important role in plant breeding programs because they describe the extent to which genetic factors, relative to environmental factors, influence the expression of a character [23]. Heritability values are used to determine the genetic influence on plant characteristics [24]. Plant characters that have high heritability values indicate that these characters are more influenced by genetic factors than environmental factors [25]. Heritability value is a measure of how much a plant's characteristics can be passed on to its offspring [26]. The heritability in the broad sense for all tested characters in 22 genotypes ranged from 0.47 to 0.99 (Table 4). These results indicated that heritability in the broad sense value falls in the moderate to high range. Nine characters had high heritability values in the broad sense: plant height, days to 50% tasselling, days to 50% silking, harvest age, ear height, ear length, ear diameter, kernel weight per plant, and production per hectare. The character that had a moderate heritability value in the broad sense was 1000-kernel weight.

The results of heritability of the broad sense estimates indicated that genetic factors more influence the observed characters than environmental factors. High heritability values indicated that the tested characters are well inherited from parents to offspring [27]. Selection can be carried out effectively and efficiently on characters with high heritability [28]. A high heritability value for a character is expected to accelerate genetic improvement and increase the likelihood of obtaining new varieties with the desired superior characters [29]. The production per hectare character, an important character in this research, showed high heritability in the broad sense, suggesting that genetic improvement of this character is likely to be successful.

3.4 Morphological characterization

Grouping based on morphological characters produced a dendogram with a similarity coefficient ranging from 0.47 to 0.95, or a diversity of 0.05 to 0.53 (Figure 2). At a similarity of 0.47, two main groups emerged. Group 1 consists of G1, G2, G3, G3, G4, G5, G6, G7, and G8. Group 2 consists of G9, G10, G11, G12, G13, G14, G15, G16, G17, G18, G19, G20, Bisi-X, and Jakarin. Group 1 forms two subgroups, namely group A consisting of G1, G2, G3, G4, G5, G6, and G8, while G7 forms its own group (Group B). Group 2 consists of two subgroups: group C, comprising G9, G10, G11, G12, G13, G14, G15, G16, G17, G18, G19, and G20, and the comparison varieties (Bisi-X and Jakarin), which form subgroup D.

Table 2. Mean plant height, days to 50% tasselling, days to 50% silking, harvest age, and ear height of 20 maize lines and two comparison varieties.

Genotype	PH	DT	DS	HA	EA
G1	157.33 jk	41.67 ijk	43.00 klm	82.00 fg	80.00 hijk
G2	147.67 l	33.33 m	36.00 o	66.67 j	80.33 l
G3	142.00 m	40.33 kl	43.67 mn	81.33 g	71.33 m
G4	157.67 jk	43.33 fgh	46.67 hij	84.67 e	79.33 ijk
G5	154.67 k	43.67 fg	46.33 gh	83.67 ef	77.67 k
G6	162.00 hi	44.00 ef	45.00 hi	83.67 ef	81.67 ghi
G7	159.67 ij	42.33 ghi	44.67 ijk	83.00 efg	80.33 hij
G8	170.33 g	39.33 l	41.67 n	76.67 i	85.67 f
G9	162.33 hi	45.67 d	48.00 ef	89.67 d	81.33 ghi
G10	155.67 k	42.00 hij	44.33 jkl	81.67 g	78.00 jk
G11	163.00 hi	40.67 jkl	43.00 lmn	79.33 h	82.33 gh
G12	165.00 h	40.33 kl	42.67 mn	77.67 hi	83.33 fg
G13	176.00 f	42.00 hij	44.67 ijk	84.00 e	88.67 e
G14	193.33 c	52.00 b	54.33 b	98.33 c	97.33 c
G15	193.00 c	51.33 b	53.67 bc	96.67 c	97.00 c
G16	189.33 d	49.67 c	51.67 cd	98.00 c	95.33 c
G17	192.33 cd	50.67 bc	53.33 bcd	97.33 c	97.00 c
G18	184.00 e	46.33 d	48.33 e	89.33 d	92.33 d
G19	189.33 d	45.33 de	47.67 fg	89.33 d	95.67 c
G20	190.00 cd	49.67 c	52.00 d	96.67 c	96.67 c
Bisi-X	225.00 a	57.33 a	59.67 a	110.33 a	112.67 a
Jakarin	216.67 b	51.33 b	53.67 bc	100.33 b	108.33 b
CV (%)	5.65	6.12	5.99	5.69	5.87
HSD (0.05)	3.59	1.58	1.67	1.90	2.41

Note: PH: Plant Height (cm); DT: Days to 50% Tasselling (days); DS; Days to 50% Silking (days); HA: Harvest Age (days); EH: Ear Height (cm); CV: Coefficient of Variation; HSD: Honestly Significant Difference; The numbers followed by the same letter in the same column are not significantly different according to the 5% HSD test.

Table 3. Mean ear length, ear diameter, kernel weight per plant, 1000-kernel weight, and production per hectare of 20 maize lines and two comparison varieties.

Genotype	EL	ED	KWP	1000KW	PPH
G1	12.70 hi	3.32 hij	46.44 def	196.33 bc	3251.03 def
G2	10.63 k	2.77 k	35.44 g	208.00 bc	2481.03 g
G3	7.87 l	3.17 ij	27.02 h	208.33 bc	1891.40 h
G4	10.57 k	3.13 j	45.26 def	213.33 abc	3168.20 def
G5	10.70 k	3.19 ij	44.27 ef	233.67 ab	3098.67 ef
G6	11.40 jk	3.17 ij	45.73 def	209.67 bc	3201.33 def
G7	11.97 ij	3.36 ghi	46.25 def	218.33 abc	3237.50 def
G8	11.27 jk	3.43 gh	43.27 f	204.33 bc	3028.67 f
G9	14.40 defg	3.37 ghi	46.85 def	193.67 bc	3279.27 def
G10	13.50 gh	3.47 gh	47.51 de	191.33 c	3325.93 de
G11	14.53 def	3.57 fg	47.71 de	187.00 c	3339.93 de
G12	15.10 cd	3.97 de	45.24 def	200.67 bc	3167.03 def
G13	14.77 de	3.87 de	49.26 d	202.67 bc	3447.97 d
G14	16.27 b	5.17 ab	72.75 b	201.67 bc	5092.73 b
G15	16.40 b	5.23 a	73.42 b	204.33 bc	5139.17 b
G16	15.87 bc	4.47 c	70.29 b	197.33 bc	4920.53 b
G17	16.23 b	4.47 c	70.26 b	192.67 c	4917.97 b
G18	14.50 def	3.83 de	59.63 c	201.67 bc	4174.33 c
G19	13.77 fg	3.77 ef	59.79 c	197.67 bc	4185.30 c
G20	14.03 efg	4.00 d	61.12 c	196.67 bc	4278.40 c
Bisi-X	18.27 a	5.23 a	100.99 a	250.67 a	7069.30 a
Jakarin	17.60 a	4.97 b	97.30 a	212.00 abc	6811.00 a
CV (%)	7.18	6.70	7.33	11.29	7.33
HSD (0.05)	0.94	0.21	4.10	40.46	287.04

Note: EL: Ear Length (cm); ED: Ear Diameter (cm); KWP: Kernel Weight per Plant (g); 1000KW: 1000-Kernel Weight (g) ; PPH: production per hectare (kg); CV: Coefficient of Variation; HSD: Honestly Significant Difference; The numbers followed by the same letter in the same column are not significantly different according to the 5% HSD test.

Table 4. Values of genetic variance, environmental variance, phenotypic variance, and heritability.

Character	σ^2g	σ^2e	σ^2p	heritability
Plant height	11.32	471.47	482.79	0.98 (high)
Days to 50% tasselling	1.25	29.65	30.90	0.96 (high)
Days to 50% silking	0.28	30.09	30.37	0.99 (high)
Harvest age	10.37	95.38	105.75	0.90 (high)
Ear height	10.59	114.66	125.25	0.92 (high)
Ear lenght	0.08	6.81	6.89	0.99 (high)
Ear diameter	0.02	0.56	0.58	0.97 (high)
Kernel weight per plant	1.72	338.93	340.65	0.99 (high)
1000-kernel weight	167.04	150.73	317.77	0.47 (moderate)
Produktion per hectare	8408.29	1660747.43	1669155.72	0.99 (high)

Note: σ2g: genetic variance; σ2e: environmental variance; σ2p: phenotypic variance; h2bs: heritability in the broad sense; heritability criteria: high (h2bs ≥ 0,5), moderate (0,2<h2bs<0,5), low (h2bs≤0,2).

3.5 Drought sensitivity index on production per hectare character

The Drought Sensitivity Index (DSI) is an important parameter for assessing a plant's ability to adapt to drought stress. DSI describes the value of the decrease in crop yield under drought stress relative to normal (optimum) conditions [30]. A low DSI value indicates that the plant has high tolerance to drought stress, while a high DSI value suggests that the plant is sensitive to drought stress [31]. Plant sensitivity to drought stress is classified into three categories: tolerant (DSI ≤ 0.5), moderate (0.5 < DSI ≤ 1.0), and sensitive (DSI > 1.0) [17]. The results of the DSI calculation for production per hectare showed that the 20 genotypes tested had different DSI values (Table 5).

The DSI values for the 22 genotypes tested ranged from 0.38 to 1.57. The lines tolerant of drought stress were G2 and G3. The lines that had moderate tolerance to drought stress are G1, G4, G6, G7, G8, G10, G11, G12, G13, and G20. Furthermore, the lines that were sensitive to drought stress are G5, G9, G14, G15, G16, G17, G18, and G19. The comparison variety (Bisi-X) had DSI value of 1.19, so it is categorized as sensitive to drought stress. In contrast, Jakarin had DSI value of 0.60, so it is classified as moderately tolerant to drought stress. Drought-tolerant lines can be used to develop drought-tolerant maize varieties.

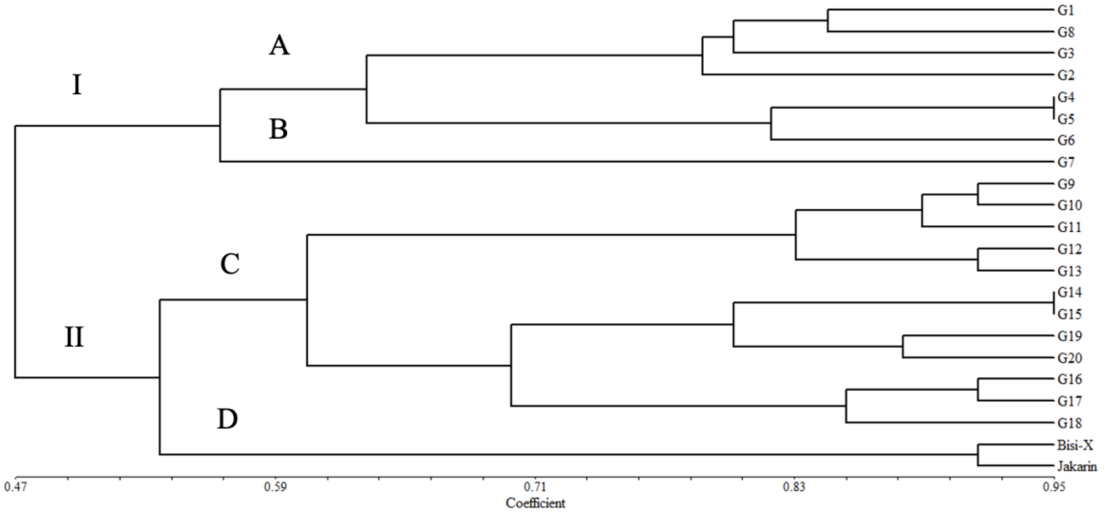

Fig. 2. Maize genotype dendogram based on morphological characters.

Table 5. Drought sensitivity index (DSI) values for production per hectare character.

Genotype	Optimum	Drought Stress	ΔY	S
G1	3251.03	2345.43	905.60	0.61 (MT)
G2	2481.03	1987.43	493.60	0.44 (T)
G3	1891.40	1567.23	324.17	0.38 (T)
G4	3168.20	1897.45	1270.75	0.88 (MT)
G5	3098.67	1457.34	1641.33	1.16 (DS)
G6	3201.33	1987.42	1213.91	0.83 (MT)
G7	3237.50	2087.45	1150.05	0.78 (MT)
G8	3028.67	1843.21	1185.46	0.86 (MT)
G9	3279.27	1711.09	1568.18	1.05 (DS)
G10	3325.93	2081.45	1244.48	0.82 (MT)
G11	3339.93	2117.49	1222.44	0.80 (MT)
G12	3167.03	1897.43	1269.60	0.88 (MT)
G13	3447.97	1966.34	1481.63	0.94 (MT)
G14	5092.73	2115.34	2977.39	1.28 (DS)
G15	5139.17	1943.24	3195.93	1.37 (DS)
G16	4920.53	2142.54	2777.99	1.24 (DS)
G17	4917.97	1973.21	2944.76	1.31 (DS)
G18	4174.33	1193.44	2980.89	1.57 (DS)
G19	4185.30	2094.25	2091.05	1.10 (DS)
G20	4278.40	3214.49	1063.91	0.55 (MT)
Bisi-X	7069.30	3235.16	3834.14	1.19 (DS)
Jakarin	6811.00	4937.44	2573.56	0.60 (MT)
Mean	3932.12	2140.72	1791.40	0.98

Note: ΔY: the difference between production under optimum conditions and dry conditions; S: drought sensitivity index; T: tolerance; MT: moderate tolerance; DS: drought sensitive.

3.6 Correlation between characters

Assessment of character correlations is vital in plant breeding programs. The correlation between characters shows the magnitude of change in one character followed by changes in other characters, either positive or negative. Two characters that show a real positive correlation, then an increase in one character will be followed by an increase in the other character [32]. On the other hand, if two characters have a real negative correlation, an increase in one character will be followed by a decrease in the other character. Correlation values are very useful in simultaneous selection because breeders can combine genetic progress from several characters at once by selecting one main character that represents [33]. Simultaneous selection can make the selection process more efficient in terms of time, energy, and costs.

Assessing characters with high economic value is very important for implementing simultaneous selection. In this research, the character that had high economic value is production per hectare. Correlation assessment of production characters per hectare with other characters is

beneficial for selecting production characters per hectare indirectly. Figure 3 showed that production per hectare had a significant positive correlation with all tested characters, except 1000-kernel weight. Characters that had a significant positive correlation with production per hectare were plant height (0.96**), days to 50% tasselling (0.89**), days to 50% silking (0.89**), harvest age (0.89**), ear height (0.95**), ear length (0.86**), ear diameter (0.89**), and kernel weight per plant (0.99**). Indirect selection to select high production characters per hectare by selecting maize with high plant characters in vegetative growth. Indirect selection for production per hectare, using selection for plant height traits, can save time, energy, and costs because selection is carried out only during the vegetative phase.

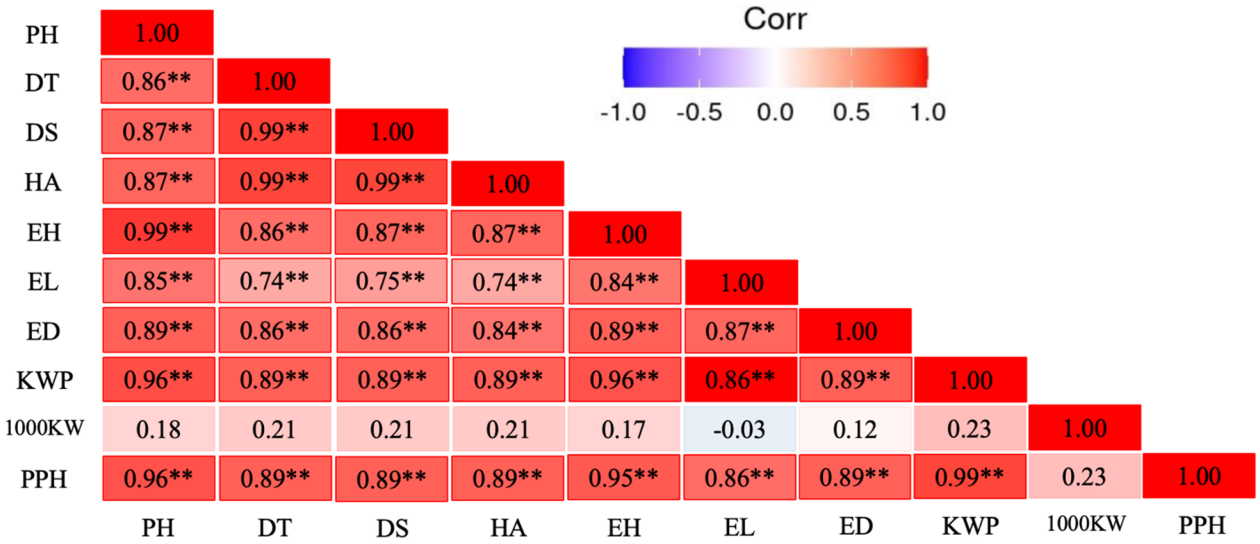

Fig. 3. Phenotypic correlation among characters in genotype maize. Note: PH : Plant Height (cm); DT : Days to 50% Tasselling (days); DS ; Days to 50% Silking (days); HA : Harvest Age (days); EH : Ear Height (cm); EL : Ear Length (cm); ED: Ear Diameter (cm); KWP : Kernel Weight per Plant (g); 1000KW : 1000-Kernel Weight (g) ; PPH : Production per Hectare (kg); **: p<0.01.

3.7 Determination of lines used as parents in assembling superior varieties

Determining the line as a parent is the most important factor in variety assembly, as the success of variety assembly depends on the genetic quality of the parent line [34]. Selecting the right parents can make it easier for plant breeders to combine the superior characteristics of the two lines, producing a new genetic combination that is superior to both parents [35]. In this research, parental selection was used to assemble superior maize varieties with high yield and drought resistance. For this reason, the selected strains must exhibit high production characteristics and be drought-stress resistant.

The study found that the four lines with the highest production per hectare were G14, G15, G16, and G17. The lines that were resistant to drought stress were G1, G2, G3, G4, G6, G7, G8, G10, G11, G12, G13 and G20. Variety assembly can be performed using three methods: hybridization, selection, or hybridization followed by selection [36]. Four lines (G14, G15, G16, and G17) exhibit high production per hectare but were not drought-stress tolerant. The development of corn varieties with high yield and drought resistance using the selection method across four lines cannot be carried out because they lack drought resistance. One method used to develop high production, drought stress resistance maize varieties is hybridization. The Hybridization method can combine two expected characters from both parents. Assembling varieties using the crossing method requires attention to the kinship relationships among several lines that will serve as parents [37]. The level of kinship will determine the success in producing the desired genetic combination [38]. Lines with distant kinship relationships will produce higher genetic diversity, potentially leading to crosses with heterosis effects [39]. In addition, crossing between lines with distant kinship will avoid inbreeding depression [40]. Based on the results of the morphological character dendogram, Groups G1, G2, G3, and G8 are lines that have resistance to drought stress. At the same time, Groups G16 and G17 exhibit high production per hectare characteristics. The two groups have a distant kinship relationship, so that crossbreeding between the two groups has the potential to produce hybrid maize varieties with high production characteristics and resistance to drought stress. The cross combinations used to produce hybrid varieties with high production characteristics and drought stress resistance were G1xG16, G1xG17, G2xG16, G2xG17, G3xG16, G2xG17, G8x16, and G8xG17.

4 Conclusion

Twenty lines tested had quantitative character differences in the 10 quantitative characters tested. The heritability, in the broad sense, for all tested characters across 22 genotypes ranged from 0.47 to 0.99. Grouping based on morphological characters produces a dendogram with a similarity coefficient ranging from 0.47 to 0.95 or a diversity of 0.05 to 0.53. The DSI values for 22 genotypes tested ranged from 0.38 to 1.57. The production character per hectare had a significant positive correlation with the

character of plant height (0.96**), days to 50% tasselling (0.89**), days to 50% silking (0.89**), harvest age (0.89**), ear height (0.95**), ear length (0.86**), ear diameter (0.89**), and kernel weight per plant (0.99**). The cross combinations used to produce hybrid varieties with high production characteristics and drought stress resistance were G1xG16, G1xG17, G2xG16, G2xG17, G3xG16, G2xG17, G8x16, and G8xG17.

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