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Research Article

Assessment of agro-morphological performance of twenty-four corn (*Zea mays l.,)* parent lines resistant to *Striga hermonthica* for determining hybrid parents

N'da Hugues Annicet[1*], Konaté Dofougo[1,2], Kouakou Kouakou Romaric[1], N'cho Achi Laurent[1], Fondio Lassina[1], Abo Kouabenan[2]

[1]Korhogo Regional Directorate, Ferkessédougou Research Station, Corn Millet Sorghum Program Laboratory, 01 BP 1740 Abidjan 01, Côte d'Ivoire
[2]Félix Houphouët-Boigny national polytechnic institute (INP-HB), Doctoral School in Agronomic Sciences and Transformation Processes ; Plant Biology and Health Research Unit. P.O BOX 1093 Yamoussoukro, Côte d'Ivoire

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***Corresponding author:**

E-mail:

ndahuguesannicet@gmail.com

Abstract

The data available on the study of corn parental lines against weeds in Côte d'Ivoire is still limited. The principal objective of the present study was to assess the agro-morphological performance of those resistant to *Striga hermonthica*. Specifically, the objective was to ascertain the hybrid parents of twenty-four individuals from IITA under conditions of artificial *Striga* infestation. The trials were conducted at the CNRA research station in Ferkessédougou, located in northern Côte d'Ivoire. The experimental design was a randomized complete block with three replications. Nine CIMMYT/IBPGR were used. Analysis of variance revealed significant differences between the lines about the different agro-morphological traits. Hierarchical ascending classification (HAC) revealed variability structured into four groups of morphological diversity. Group 2 and Group 4, respectively, contained the earliest (FM = 57.93 +- 1.72 and 58.62 ± 3.15) and most productive (NER = 21.25 +- 4.57 and 13.70 +- 2.77) lines, which also exhibit very good emergence density (DL = 28.25 ± 5.13 and 25.00 +- 7.50). Group 3 contained the intermediate lines (FM = 61.50 +- 1.88; FF = 63.18 +- 2.64; NER = 10.81 +- 5.27; DL = 23.12 +- 8.09). Group 1 contained the late lines (FM = 66.50 +- 2.82; FF = 68 ± 0.00), which demonstrated reduced productivity (NER = 3.75 +- 1.76) and exhibited a low emergence density (DL = 9.25 +- 10.25). Discriminant factor analysis (DFA) identified nine parental lines in groups 2 and 4 that exhibited favorable characteristics about early maturity and productivity. These lines may be used as hybrid parents in a program designed to enhance corn productivity in Côte d'Ivoire.

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1. Introduction

In Côte d'Ivoire, cereal cultivation is dominated by rice, corn, millet, and sorghum (N'da et al., 2014). Corn is typically cultivated for the production of hybrid varieties. These are developed through the controlled cross-pollination of two genetically distinct parental lines. This process allows for the exploitation of the phenomenon of hybrid vigor. This phenomenon is also known as heterosis. The resulting hybrid possesses distinctive characteristics that are more advantageous than those observed in the parental lines. The selection of corn parental lines represents a crucial element of breeding programs aimed at developing improved varieties (Hu et al., 2021). Moreover, this process requires taking into account the biotic constraints associated with cultivation, particularly the presence of *Striga hermonthica*. *Striga hermonthica* causes significant yield losses throughout the world, particularly in West Africa, the region most conducive to its development. Indeed, the incidence of Striga in Africa leads to a 10% to 70% reduction in agricultural yields, depending on the cultivar (Gressel et al., 2004). In sub-Saharan Africa, production losses of sorghum, millet, and maize have been quantified at between 8,110,000 t and 8,520,000 t, or 39-45% of total production (Gressel et al., 2004). In West Africa, production losses due to S*. hermonthica* were estimated at between 24% and 27%, corresponding to 6,555,000 t and 6,926,000 t (Gressel et al., 2004). Heavily infested fields are abandoned in favor of new land, the clearing of which leads to deforestation and desertification. The majority of the selection work conducted thus far on cereal lines has been based primarily on morphological, enzymatic, and molecular markers (Dédé et al., 2020). Several studies have emphasized the significance of genotypic selection based on traits directly associated with grain yield, as well as the impact of genotypic factors on the ultimate stand and yield (Entringer et al., 2017).

Furthermore, the use of selection indices based on traits with a direct impact on grain yield has been proposed as a means of improving the efficiency of genotypic selection in corn populations exhibiting segregation (Silva et al., 2020). Furthermore, the development and selection of ultra-soft corn genotypes using multivariate approaches have been studied to improve the efficiency of selection for superior genotypes (Gonçalves et al., 2018). In Côte d'Ivoire, there has been a paucity of research conducted to assess the agronomical performance of *Striga-resistant* corn lines. Following the selection of *Striga-resistant* parental lines with the potential to develop hybrid varieties, it is essential to assess their agro-morphological performance. The objective of this research is to provide the information required for the selection of corn parental lines for the development of hybrid varieties. This entails the use of agro-morphological descriptors International Board for Plant Genetic Resources (IBPGR), 1991. The specific objectives of this research are twofold: firstly, to determine the morphological and agronomic variability of the various corn parent lines; and secondly, to identify promising parent lines based on their performance, to increase corn productivity in Côte d'Ivoire.

2. Materials and methods

2.1 Study area

The trial was conducted at the research station of the National Center for Agronomic Research (CNRA) in Ferkessédougou, Côte d'Ivoire. The department of Ferkessédougou is located in the northern region of Côte d'Ivoire, within the Sudanian zone. Its coordinates are between longitudes 10°30 and 8°35 West and latitudes 5°55 and 3°30 North (Figure 1). The region is characterized by a relatively low precipitation level, with an annual average of 800. To 1000 mm. The mean annual temperature is approximately 30 °C (Lasm et al., 2012). The predominant vegetation types are wooded and grassy savannahs. Additionally, open forests are present. The soils are derived from shallow granite or gneiss. In the lowlands, the soil is hydromorphic, while in the alluvial terraces of the Bandama River, it is sandy. However, ferralitic soils are the most prevalent, with a shallow topsoil limited by 40–60 cm of cuirass (Bigot et al., 2005).

2.2 Plant material

The study involved 24 parental corn lines (Table 1). The plants exhibited resistance to *Striga hermonthica*. The seeds were provided by the International Institute of Tropical Agriculture (IITA).

2.3 Experimental design

The trials were conducted from July 21 to November 29, 2023, on a plot measuring 850 m^2. The plot was subjected to artificial infestation with *Striga hermonthica*. The infestation consisted in inoculating *Striga* grains into the corn stalks at the corn time of sowing. The impact of striga hermonthica on the different parental lines was assessed by counting the number of striga seedlings germinating at 8 weeks after sowing (SAS) and at 10 SAS, in order to highlight lines with a high level of striga biomass. The effect of the presence of striga was evaluated on the yield of each parental line at harvest. A completely randomized block design with three replications was used. Sowing was carried out on experimental plots, measuring 0.8 m in width and 5 m in length. The distance between plants was 80 cm x 50 cm. There were two seeds planted in each plot. Before *Striga* emerged, the plots were maintained through manual weeding. Following the emergence of the weeds, a control program was initiated, depending on the level of infestation, up to two weeks before the harvest.

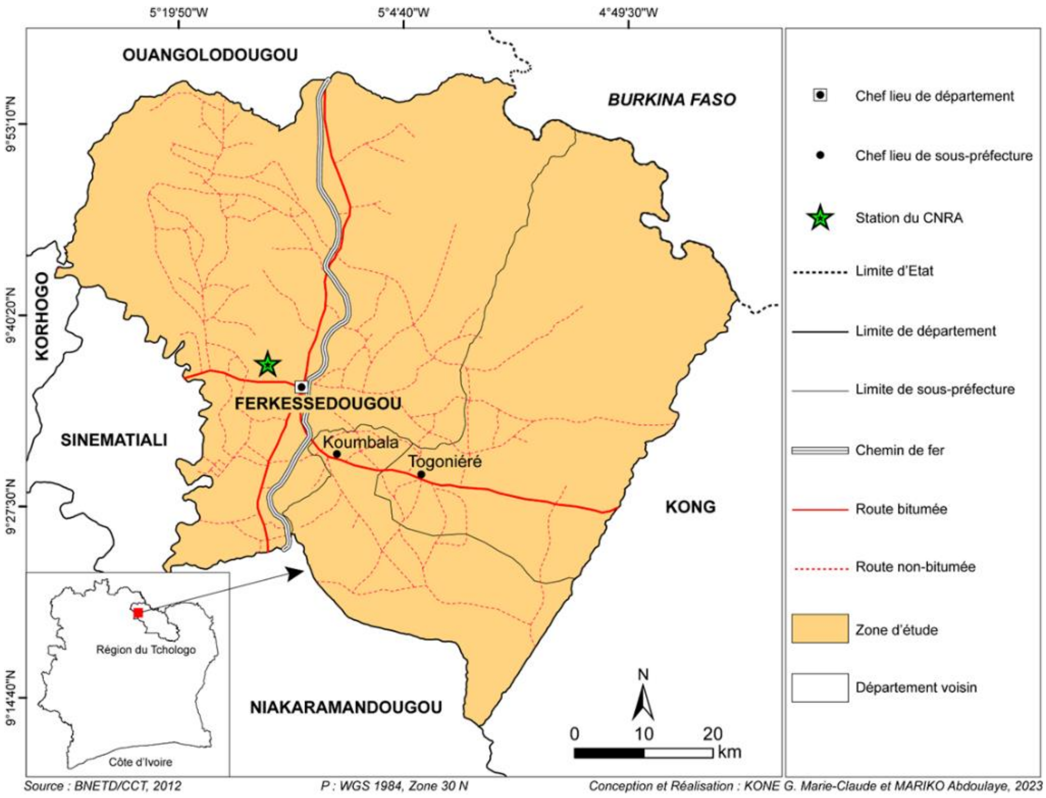

Figure 1. Location of the study area (National Bureau of Technical Studies and Development/Center for Cartography and Remote Sensing, 2012)

Table 1. Different parental lines used

LINES	ORIGIN	COLORS
5057	IITA	WHITE
9540	IITA	YELLOW
TZISTR 1132	IITA	WHITE
TZISTR 1137	IITA	WHITE
TZISTR 1160	IITA	WHITE
TZISTR 1262	IITA	YELLOW
TZISTR 1304	IITA	WHITE
TZISTR 1310	IITA	WHITE
TZISTR 1312	IITA	WHITE
TZISTR 1313	IITA	WHITE
TZISTR 1324	IITA	WHITE
TZISTR 1329	IITA	WHITE
TZISTR 1332	IITA	WHITE
TZISTR 2036	IITA	WHITE
TZISTR 2038	IITA	WHITE
TZISTR 2042	IITA	WHITE
TZISTR 2045	IITA	WHITE
TZISTR 2047	IITA	WHITE
TZISTR 2049	IITA	WHITE
TZISTR 2055	IITA	WHITE
TZISTR 2056	IITA	WHITE
TZISTR 2057	IITA	WHITE
TZISTR 2059	IITA	WHITE

2.4 Data collection

By the Corn Descriptor Manual (IBPGR, 1991), nine quantitative agro-morphological traits were assessed. (Table 2). Within each elementary plot and block, measurements and/or observations were conducted on 10 randomly selected plants. The following traits were assessed: emergence density (ED), male flowering (MF) and female flowering (FF) at 50%, average plant height APH), total number of leaves (TNL), number of ears harvested (NEH), ear length (EL), ear diameter (ED), and ear weight at harvest (EWH).

2.5 Data analysis

A statistical analysis of the traits was conducted to assess the agronomic performance and agro-morphological structuring of the parental lines. It was also used to determine the most discriminating of these traits. The descriptive analysis of quantitative traits entailed the assessment of several statistical parameters, including the arithmetic mean, the standard deviation of the mean, and the coefficient of variation (CV). The data were deemed homogeneous when the coefficient of variation was less than 15%. Conversely, when the coefficient of variation exceeds 15%, the data are deemed heterogeneous. A one-factor analysis of variance was conducted to compare the performance of the lines. An Ascending Hierarchical Classification (AHC) was conducted to categorize the parental lines based on their morphological similarities. The aggregation procedure selected was that of Ward's method. This method is designed to minimize intra-group variance and maximize inter-group variance. The Euclidean distance was used to quantify the dissimilarity between the parental lines. The Mahalanobis distance was used as a means of differentiating the aforementioned groups. Subsequently, a Discriminant Factorial Analysis (DFA) was conducted to ascertain the distinguishing characteristics of the groups delineated by the AHC. The analysis of variance (ANOVA) was conducted using the SPSS Statistics 26 software. Descriptive analyses, hierarchical ascending classification, and discriminant factor analysis were conducted using the Xlstat 2019 statistical software.

Table 2. Description of the agro-morphological parameters studied

Characters	Abbreviations	Descriptions	Units
Quantitative characteristics			
Emergence density	ED	Counting the number of plants that have normally germinated 10 days after sowing	-
50% male flowering	MF	The time is taken from the sowing date to the date when half the plants in the plot generate pollen.	Day
50% female flowering	FF	The time is taken from the date of sowing to the date when half the plants in the plot generate silk.	Day
Average plant height	APH	Measurement in centimeters of the height of the plants, from the ground to the base of the panicle. Measurements were taken on 10 plants in the plot.	Cm
Total number of leaves	TNL	Counting the leaves on the selected plants, taking into account the leaves at the base (which have often fallen off).	-
Number of ears harvested	NEH	Counting the number of mature ears harvested from 10 plants in the useful plot	-
Ear length	EL	Measuring the length of harvested ears on plants in the working plot	Cm
Ear diameter	ED	Measuring the median part of the highest ear harvested on the plants in the useful plot.	mm
Ear weight at harvest	EWH	Measuring in Kg the weight of the ears of the 10 plants in the useful plot	Kg

3. Results

3.1 Variations in the parameters studied

The minimum, maximum, and mean values for the nine (9) quantitative characteristics under investigation, along with the associated coefficient of variation, are presented in Table 3. The variables exhibiting the greatest variability (CV > 15%) were emergence density (2 to 37 plants), mean plant height (93.50 to 182.50 cm), number of spikes harvested (2.50 to 27.50 spikes), and spike weight at harvest (0.19 kg to 3.81 kg). Among the quantitative traits, the duration (in days) of male and female semi-flowering exhibited the least variation (5.27 and 6.19%, respectively). The mean female semi-flowering cycle for the lines under study was found to be 61.21 +- 3.16

days. The earliest line exhibited the onset of female semi-flowering at 54 days, while the latest commenced this process at 68 days. The plant height exhibited a considerable range, spanning from 93.50 cm to 182.50 cm, with an average of 143.97 +- 21.83 cm. The mean number of spikes harvested per plant ranged from 2.50 to 27, with an average of 14.45 +- 7.02 spikes. The range of ear length was 7.10 cm to 14.84 cm, with an average of 11.13 +- 1.53 cm. The analysis of variance in the performance of the different lines revealed a highly significant difference at the 5% threshold for all the quantitative characteristics studied, except the number of ears harvested (Table 4).

Table 3. Descriptive statistics for the nine (9) agro-morphological traits studied

Quantitative variables	Minimum	Maximum	Mean +- Standard deviation	CV (%)
ED	2.00	37.00	24.10 +- 8.43	34.97
MF	54.00	68.50	60.00 +- 3.16	5.27
FF	54.00	68.00	61.21 +- 3.79	6.19
APH	93.50	182.50	143.97 +- 21.83	15.17
TNL	9.50	15.50	13.06 +- 1.24	9.47
NEH	2.50	27.00	14.45 +- 7.02	48.53
EL	7.10	14.84	11.13 +- 1.53	13.75
ED	1.55	3.69	3.18 +- 0.44	13.81
EWH	0.19	3.81	1.89 +- 1.04	55.08

ED: Emergence density, MF: Male flowering, FF: Female flowering, APH: Average plant height, TNL: Total number of leaves, NEH: Number of ears harvested, EL: Ear length, ED: Ear diameter, EWH: Ear weight at harvest, CV: Coefficient of variation.

3.2 Correlations between agro-morphological characteristics

The Pearson correlation matrix revealed significant correlations between the different quantitative traits studied (Table 5). A strong positive significant correlation was observed between emergence density and the total number of leaves (r = 0.64) and the number of ears at harvest (r = 0.68). Female semi-flowering exhibited a strong positive correlation with male semi-flowering (r = 0.91) and a negative correlation with the total number of leaves (r = -0.41), spikes at harvest (r = -0.55), and spike weight at harvest (r = -0.62). The mean plant height exhibited a highly significant positive correlation with the total leaf number (r = 0.73), the number of ears at harvest (r = 0.49), and ear length (r = 0.61). A significant positive correlation was observed between total leaf number and ear number at harvest (r = 0.465). The strongest correlations were observed between morphological traits (HMP, NTF) phenological traits (FM, FF), and yield traits (NER, PER). The strongest positive correlation (r = 0.91) was observed between male and female semi-flowering, while the strongest negative correlation (r = -0.70) was found between the number of days of female semi-flowering and spike weight at harvest.

Table 4. Analyses of variance of the different phenological and morphological parameters

LINES	ED	MF	FF	APH	TNL	NEH	EL	ED	EWH
5057	16.50 +- 3.53 ^{cd}	64.50 +- 0.70 ^{ab}	68.00 +- 1.41 ^{a}	112.00 +- 1.41 ^{fg}	11.50 +- 0.70 ^{b}	2.50 +- 0.70 ^{a}	7.10 +- 0.28 ^{e}	1.55 +- 0.35 ^{c}	0.09 +- 0.13 ^{f}
9540	20.00 +- 1.41 ^{abcd}	58.00 +- 1.41 ^{bcd}	56.00 +- 0.00 ^{de}	170.00 +- 16.97 ^{ab}	12.50 +- 0.70 ^{ab}	13.00 +- 2.82 ^{a}	13.42 +- 0.80 ^{abc}	3.43 +- 0.45 ^{ab}	1.50 +- 0.11 ^{abc}
TZISTR 1132	2.00 +- 0.00 ^{e}	68.50 +- 6.36 ^{a}	68.00 +- 5.65 ^{a}	93.50 +- 23.33 ^{g}	9.50 +- 2.12 ^{c}	5.00 +- 4.24 ^{a}	9.85 +- 0.08	3.20 +- 0.01 ^{ab}	0.59 +- 0.83 ^{abcde}
TZISTR 1137	29.50 +- 3.53 ^{abc}	58.50 +- 0.70 ^{bcd}	59.50 +- 0.70 ^{bcde}	148.00 +- 15.55 ^{bcde}	12.50 +- 0.70 ^{ab}	26.50 +- 4.95 ^{a}	11.67 +- 0.81 ^{cd}	3.43 +- 0.16 ^{ab}	1.24 +- 0.28 ^{abcd}
TZISTR 1160	15.50 +- 0.70 ^{cd}	65.50 +- 3.53 ^{ab}	67.50 +- 6.36 ^{ab}	163.50 +- 12.02 ^{abc}	13.50 +- 0.70 ^{ab}	6.50 +- 2.12 ^{a}	11.35 +- 0.21 ^{cd}	3.00 +- 0.00 ^{ab}	0.26 +- 0.09 ^{ef}
TZISTR 1262	28.00 +- 5.65 ^{abcd}	58.50 +- 0.70 ^{bcd}	58.50 +- 0.70 ^{cde}	140.00 +- 5.65 ^{bcdef}	13.50 +- 0.70 ^{ab}	21.50 +- 12.02 ^{a}	13.87 +- 1.02 ^{ab}	3.33 +- 0.08 ^{ab}	1.63 +- 0.42 ^{ab}
TZISTR 1304	28.00 +- 5.65 ^{abcd}	61.50 +- 0.70 ^{bcd}	63.00 +- 1.41 ^{abcd}	168.00 +- 5.65 ^{abc}	14.50 +- 0.70 ^{ab}	16.50 +- 7.77 ^{a}	10.32 +- 0.45 ^{d}	3.03 +- 0.21 ^{ab}	0.93 +- 0.12 ^{bcdef}
TZISTR 1310	30.00 +- 7.07 ^{abc}	58.00 +- 0.00 ^{bcd}	57.00 +- 0.00 ^{cde}	157.50 +- 7.77 ^{abcde}	14.00 +- 0.00 ^{ab}	27.00 +- 9.89 ^{a}	11.02 +-0.53 ^{cd}	3.53 +- 0.09 ^{a}	1.90 +- 0.01 ^{a}
TZISTR 1312	18.00 +- 2.82 ^{bcd}	58.50 +- 0.70 ^{bcd}	59.50 +- 0.70 ^{bcde}	133.50 +- 4.95 ^{cdef}	13.00 +- 0.00 ^{ab}	14.00 +- 1.41 ^{a}	10.08 +- 0.11 ^{d}	3.30 +- 0.16 ^{ab}	0.89 +- 0.15 ^{bcdef}
TZISTR 1313	24.00 +- 0.00 ^{abcd}	58.00 +- 0.00 ^{bcd}	58.50 +- 2.12 ^{cde}	140.50 +- 3.53 ^{bcdef}	12.50 +- 0.70 ^{ab}	17.00 +- 2.82 ^{a}	10.97 +- 0.81 ^{cd}	3.30 +- 0.12 ^{ab}	1.38 +- 0.45 ^{ab}
TZISTR 1324	21.50 +- 3.53 ^{abcd}	58.00 +- 1.41 ^{bcd}	59.00 +- 0.00 ^{cde}	150.50 +- 0.70 ^{abcde}	13.50 +- 0.70 ^{ab}	22.00 +- 11.31 ^{a}	11.99 +- 0.22 ^{bcd}	3.32 +- 0.10 ^{ab}	1.07 +- 0.11 ^{abcdef}
TZISTR 1329	18.50 +- 2.21 ^{bcd}	58.50 +- 0.70 ^{bcd}	59.50 +- 2.12 ^{bcde}	136.50 +- 13.43 ^{bcdef}	12.50 +- 0.70 ^{ab}	10.00 +- 1.41 ^{a}	11.41 +- 1.00 ^{cd}	3.58 +- 0.23 ^{a}	1.07 +- 0.31 ^{abcdef}
TZISTR 1332	30.00 +- 4.24 ^{abc}	54.00 +- 0.00 ^{d}	54.00 +- 0.00 ^{e}	149.50 +- 2.12 ^{abcde}	14.00 +- 1.41 ^{ab}	20.00 +- 9.89 ^{a}	11.20 +- 0.20 ^{cd}	3.35 +- 0.01 ^{ab}	1.31 +- 0.02 ^{ab}
TZISTR 2036	37.00 +- 5.65 ^{a}	62.50 +- 2.12 ^{bc}	65.50 +- 0.70 ^{abc}	160.00 +- 0.00 ^{abcd}	14.00 +- 0.00 ^{ab}	21.00 +- 2.82 ^{a}	10.68 +- 0.36 ^{d}	3.33 +- 0.31 ^{ab}	0.64 +- 0.21 ^{cdef}
TZISTR 2038	21.50 +- 7.77 ^{abcd}	60.00 +- 0.00 ^{bcd}	61.50 +- 0.70 ^{abcde}	153.00 +- 7.07 ^{abcde}	12.50 +- 0.70 ^{ab}	8.50 +- 2.12 ^{a}	11.34 +- 1.73 ^{cd}	2.53 +- 0.05 ^{b}	0.53 +- 0.28 ^{cdef}

LINES	ED	MF	FF	APH	TNL	NEH	EL	ED	EWH
TZISTR 2042	28.00 +- 11.31 ^{abcd}	60.00 +- 1.41 ^{bcd}	59.50 +- 0.70 ^{bcde}	162.00 +- 4.24 ^{abcd}	15.50 +- 0.70 ^{a}	11.00 +- 7.07 ^{a}	11.05 +- 0.07 ^{cd}	3.30 +- 0.09 ^{ab}	0.74 +- 0.27 ^{bcdef}
TZISTR 2045	35.50 +- 2.12 ^{ab}	58.50 +- 2.12 ^{bcd}	60.50 +- 2.12 ^{abcde}	151.50 +- 9.19 ^{abcde}	14.50 +- 0.70 ^{ab}	22.50 +- 3.53 ^{a}	11.91 +- 0.51 ^{bcd}	3.40 +- 0.21 ^{ab}	1.24 +- 0.10 ^{abcd}
TZISTR 2047	31.50 +- 0.70 ^{abc}	60.00 +- 0.00 ^{bcd}	64.50 +- 0.70 ^{abcd}	182.50 +- 4.95 ^{a}	13.50 +- 0.70 ^{ab}	17.50 +- 7.77 ^{a}	14.84 +- 1.49 ^{a}	2.86 +- 0.61 ^{ab}	1.68 +- 0.25 ^{ab}
TZISTR 2049	20.00 +- 0.00 ^{abcd}	60.50 +- 2.12 ^{bcd}	64.00 +- 0.00 ^{abcd}	149.50 +- 0.70 ^{abcde}	14.00 +- 0.00 ^{ab}	9.50 +- 3.53 ^{a}	10.85 +- 0.50 ^{cd}	3.07 +- 0.29 ^{ab}	0.61 +- 0.63 ^{cdef}
TZISTR 2055	11.00 +- 5.65 ^{de}	60.00 +- 2.82 ^{bcd}	60.50 +- 2.12 ^{abcde}	100.50 +- 3.53	12.00 +- 1.41 ^{b}	6.50 +- 2.12 ^{a}	10.52 +- 0.31 ^{d}	3.68 +- 0.20 ^{a}	0.28 +-0.40 ^{def}
TZISTR 2056	36.00 +- 1.41 ^{ab}	55.50 +- 0.70 ^{cd}	58.50 +- 2.12 ^{cde}	124.5 +- 12.02 ^{ef}	12.50 +- 0.70 ^{b}	12.00 +- 0.00 ^{a}	9.97 +- 0.60 ^{d}	2.88 +- 0.28 ^{ab}	1.19 +- 0.36 ^{abcde}
TZISTR 2057	28.50 +- 2.12 ^{abcd}	61.00 +- 0.00 ^{bcd}	61.50 +- 0.70 ^{abcde}	137.5 +- 3.53 ^{bcdef}	12.00 +- 0.00 ^{b}	15.50 +- 12.02 ^{a}	10.22 +- 0.67 ^{d}	3.31 +- 0.00 ^{ab}	1.05 +- 0.03 ^{abcdef}
TZISTR 2059	24.00 +- 7.07 ^{abcd}	62.00 +- 2.82 ^{bc}	64.00 +- 2.82 ^{abcd}	127.5 +- 3.53^{def}	13.00 +- 0.00 ^{ab}	7.00 +- 7.07 ^{a}	10.27 +- 0.38 ^{d}	3.38 +- 0.23 ^{ab}	0.66 +- 0.14 ^{cdef}
Statistical test	F= 6.56 P = 0.01	F= 5.00 P= 0.01	F= 5.96 P= 0.01	F= 11.37 P= 0.01	F= 4.54 P= 0.01	F= 2.40 P= 0.02	F= 9.18 P= 0.01	F= 6.67 P= 0.01	F= 6.80 P= 0.01

In a column, means followed by the same letter are statistically identical at 5% threshold (Newman-Keuls test); mean +- standard deviation;
ED : Emergence density, MF: Male flowering, FF: Female flowering, APH: Average plant height, TNL: Total number of leaves,
NEH: Number of ears harvested, EL: Ear length, ED: Ear diameter, EWH: Ear weight at harvest.

Table 5. Correlations between the different characteristics studied

Variables	ED	MF	FF	APH	TNL	NEH	EL	ED	EWH
ED	1								
MF	**-0,56**	1							
FF	-0,36	**0,91**	1						
APH	**0,56**	-0,29	-0,21	1					
TNL	**0,64**	**-0,41**	-0,30	**0,73**	1				
NEH	**0,68**	**-0,55**	**-0,54**	**0,49**	**0,46**	1			
EL	0,28	-0,36	-0,36	**0,61**	0,33	**0,47**	1		
ED	0,10	-0,34	**-0,51**	0,09	0,21	**0,44**	**0,43**	1	
EWH	**0,46**	**-0,62**	**-0,65**	0,4	0,23	**0,70**	**0,61**	0,39	1

ED: Emergence density, MF: Male flowering, FF: Female flowering, APH: Average plant height, TNL: Total number of leaves, NEH: Number of ears harvested, EL: Ear length, AD: Ear diameter, EWH: Ear weight at harvest. **In bold, significant values at the alpha = 0.05 threshold (two-tailed test).**

3.3 Lineage classification

The results of the ascending hierarchical classification (AHC) based on Ward's algorithm yielded a dendrogram (Figure 2). Four groups of morphological diversity were identified. It was after splitting into four groups that the test proved significant (P < 0.01). The four-group partition appeared optimal, and was therefore retained. Examination of Figure 2 shows that the first group was made up of 2 lines. This group contains the late and less productive lines. Group 2 and Group 4 contain early, more productive lines with good emergence density. Group 3 was made up of intermediate lines with average productivity. Table 6 shows the total number of lines in the different groups: 2, 8, 8 and 5 for groups 1, 2, 3 and 4, respectively.

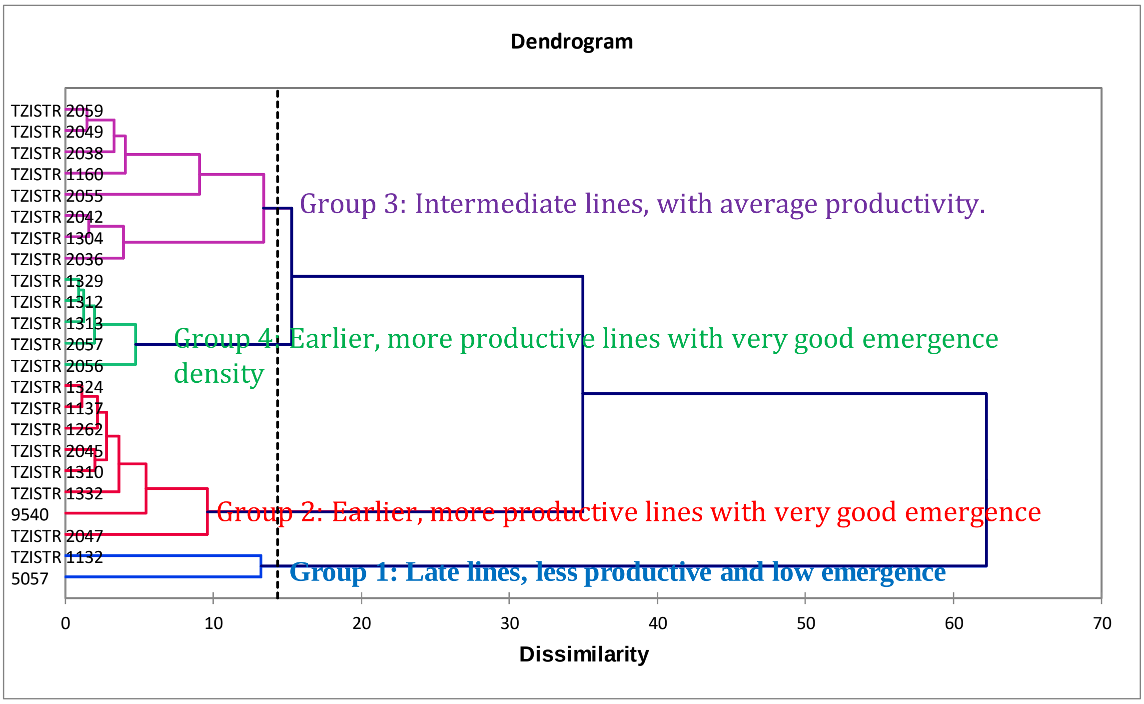

Figure 2. Dendrogram from the AMP of the 24 parental corn lines studied

Table 6. Composition of the different groups of parental lines formed from the ascending hierarchical classification

Group 1	Group 2	Group 3	Group 4
5057	9540	TZISTR 1160	TZISTR 1312
TZISTR 1132	TZISTR 1137	TZISTR 1304	TZISTR 1313
	TZISTR 1262	TZISTR 2036	TZISTR 1329
	TZISTR 1310	TZISTR 2038	TZISTR 2056
	TZISTR 1324	TZISTR 2042	TZISTR 2057
	TZISTR 1332	TZISTR 2049	
	TZISTR 2045	TZISTR 2055	
	TZISTR 2047	TZISTR 2059	

3.4 Characteristics of lineage groups

Table 7 illustrates the Mahalanobis distances between the identified groups. The two groups with the shortest distances between them were Groups 2 and 4, while the two groups with the longest distances between them were Groups 2 and 1. The results of the analysis of variance of the groups resulting from the ascending hierarchical classification also demonstrated a statistically significant difference between the groups (Table 8). Group 1 comprised the late (FM = 66.50 +- 2.82; FF = 68.00 +- 0.00) and small (HMP = 102.75 +- 13.08) lines. These lines demonstrated reduced productivity (NER = 3.75 +- 1.76) and a low emergence density (DL = 9.25 +- 10.25). Groups 2 and 4 contain, respectively, early lines (FM = 57.93 +- 1.72; FF = 58.62 +- 3.15) and (FM = 58.30 +- 1.95; FF = 59.50 +- 1.22), which were more productive (NER = 21.25 +- 4.57; 13.70 +- 2.77) and demonstrate a high emergence density (DL = 28.25 +- 5.13; 25 +- 7.50). Group 3 comprised the intermediate lines, which exhibited the following characteristics: FM = 61.5 +- 1.88; FF = 63.18 +- 2.64; NER = 10.81 +- 5.27; DL = 23.12 +- 8.09**.**

Table 7. Mahalanobis distance between groups of lines studied

	Group 1	Group 2	Group 3
Group 2	175.82		
Group 3	92.65	39.49	
Group 4	108.67	16.81	18.21

Table 8. Characteristics of the groups resulting from ascending hierarchical classification (AHC)

Variables	Group 1	Group 2	Group 3	Group 4	F	Sig.
ED	9.25 +- 10.25 b	28.25 +- 5.13 a	23.125 +- 8.09 a	25.00 +- 7.50 a	3.84	0.01
MF	66.50 +- 2.82 a	57.93 +- 1.72 c	61.50 +- 1.88 b	58.30 +- 1.95 c	13.85	0.01
FF	68.00 +- 0.00 a	58.62 +- 3.15 c	63.18 +- 2.64 b	59.50 +- 1.22 bc	9.71	0.01
APH	102.75 +- 13.08 b	156.18 +- 13.69 a	148.00 +- 22.94 a	134.50 +- 6.12 a	6.15	0.01
TNL	10.50 +- 1.41 b	13.50 +- 0.70 a	13.62 +- 1.12 a	12.50 +- 0.35 a	7.99	0.01
NEH	3.75 +- 1.76 c	21.25 +- 4.57 a	10.81 +- 5.27 b	13.70 +- 2.77 b	11.93	0.01
EL	8.48 +- 1.95 c	12.49 +- 1.38 a	10.80 +- 0.42 b	10.53 +- 0.62 b	9.99	0.01
ED	2.38 +- 1.17 b	3.33 +- 0.20 a	3.17 +- 0.34 a	3.27 +- 0.25 a	3.52	0.01
EWH	0.68 +- 0.70 b	2.90 +- 0.55 a	0.97 +- 0.58 b	2.24 +- 0.35 a	21.01	0.01

ED: Emergence density, MF: Male flowering, FF: Female flowering, APH: Average plant height, TNL: Total number of leaves, NEH: Number of ears harvested, EL: Ear length, AD: Ear diameter, EWH: Ear weight at harvest. In a column, the means followed by the same letter are statistically identical at 5% threshold (Newman-Keuls test); mean +- standard deviation.

3.5 Discriminant factor analysis

A discriminant analysis was conducted to identify the variables that exhibited the greatest degree of discrimination about the groups that had been previously determined. The four groups resulting from the hierarchical classification were used as categorical variables in the subsequent analysis. The test for equality of group means revealed that six (6) variables (out of the nine tested) were able to discriminate between the groups. (Table 9).

Figure 3 illustrates the graphical representation of the four groups in the main plane defined by functions 1-2. As can be observed in this figure, the barycenters of the five groups are clearly delineated. The initial discriminant function facilitated the clear differentiation of groups 2 and 3 from group 1, with no overlap observed between the groups. The second function was used for the purpose of discriminating group 4 from the other groups.

Table 9. Analyses of variance comparing groups of lines for each variable

Variables	Lambda	F	p-value
MF	0.31	13.85	< 0.01
FF	0.39	9.71	< 0.01
TNL	0.44	7.99	< 0.01
NEH	0.34	11.93	< 0.01
EL	0.38	9.99	< 0.01
EWH	0.23	21.01	< 0.01

MF: Male flowering, FF: Female flowering, TNL: Total number of leaves, NEH: Number of ears harvested, EL: Ear length, EWH: Ear weight at harvest.

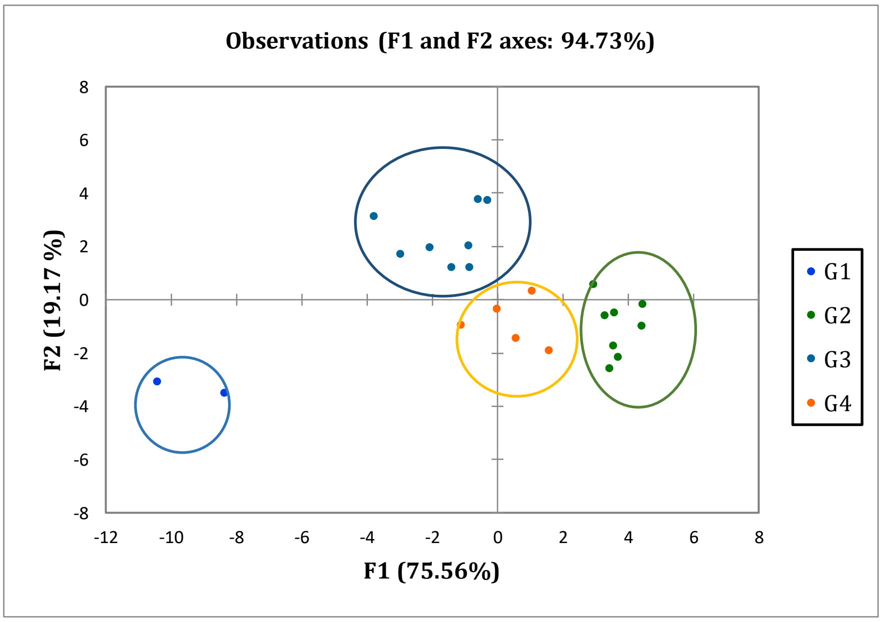

Figure 3: Identification of groups of individuals based on DFA

3.6 Promising lines for a program to improve corn productivity in Côte d'Ivoire

The results of the analyses of the agro-morphological performance of the lines in a context of infestation of the plots by *Striga hermonthica* led to the identification of nine promising parental lines. These lines originate from groups 2 and 4. They included TZISTR 1332 (FM = 54.00 +- 0.00; FF = 54.00 +- 0.00; NER = 20.00 +- 9.89), 9540 (FM = 58.00 +- 1.41; FF = 56.00 +- 0.00; NER = 13.00

+- 2.82), TZISTR 1310 (FM = 58.00 +- 0.00; FF = 57.00 +- 0.00; NER = 27.00 +- 9.89), TZISTR 1262 (FM = 58.50 +- 0.70; FF = 58.50 +- 0.70; NER = 21.50 +- 12.02), TZISTR 1313 (FM = 58.00 +- 0.00 ; FF = 58.50 +- 2.21; NER = 17.00 +- 2.82), TZISTR 2056 (FM = 55.50 +- 0.70; FF = 58.50 +- 2.12; NER = 12.00 +- 0.00), TZISTR 1329 (FM = 58.50 +- 0.70; FF = 58.50 +- 2.12 ; NER = 10.00 +- 1.41), TZISTR 1137 (FM = 58.50 +- 0.70; FF = 58.50 +- 0.70; NER = 26.50 +- 4.95) and TZISTR 1312 (FM = 58.50 +- 0.70; FF = 58.50 +- 0.70; NER = 14.00 +- 1.41). This study provided useful information on parental lines that could be used to create hybrid varieties.

4. Discussion

The study of the agro-morphological performance of the lines revealed considerable variability (CV > 15%) for specific traits, including emergence density, plant height, number of ears harvested, and ear weight at harvest. This phenomenon may be attributed to the interaction of inbreeding and environmental factors observed in these lines. Indeed, lines that have undergone multiple rounds of inbreeding have exhibited a decline in vigor, and in response to the new environment in which they now find themselves, each line has manifested this depression in a distinctive manner. Such circumstances would have had an impact on the vegetative development of the lines. In the majority of cases, these two causes of variation interact significantly (genotype-environment interactions). The observed variability suggests that the germplasm (parental lines) could provide valuable alleles for corn improvement (Nelimor et al., 2019; Aci et al., 2018). However, it is challenging to ascertain their respective contributions to the total phenotypic variation. Nevertheless, conventional methods for estimating the genetic diversity of populations rely on the analysis of morphological and agronomic traits. However, these traits are susceptible to influence from environmental factors (Bautista Salas et al., 2009). Of the 24 lines initially planted in the field, 23 were the subject of our study. Only one line, TZISTR 2002, did not germinate, which may be attributed to the poor condition of the seeds. The analysis of variance revealed a significant difference in performance between the different lines.

The observed differences pertained to emergence density, average plant height, ear diameter and length, ear weight at harvest, male and female semi-flowering, and total number of leaves, as well as ear weight at harvest. These findings are consistent with those reported by Shrestha (2013) and N'da et al., (2024). Indeed, the cycle represents a crucial parameter in the context of corn breeding, as it enables the identification of varieties exhibiting either early or late flowering patterns. The earliest line was TZISTR 1332, with an average cycle length of 54.00 +- 0.00 days, while the latest was TZISTR 1132, with an average cycle length of 68.5 +- 6.36 days. The transition from the male to the female inflorescence occurred within an average time frame of one to three days, with some exceptions where a fourth day was also observed. The data from this study are identical to those obtained by Deffan et al., (2015), who highlighted an interval of 2 to 4 days between male and female flowering in corn. The tallest line was TZISTR 2047 (182.50 +- 4.95), while TZISTR 2055 (100.50 +- 3.53) and TZISTR 1132 (93.50 +- 23.33) were the shortest. Corn height is influenced by a number of genetic factors and environmental conditions, which have a significant impact on corn yield. As posited by Esteban and Baldo (2023) and Olawuyi et al., (2015), corn plant height represents a pivotal agronomic trait, exerting a pronounced influence on corn yield. Environmental factors, such as sowing date and agroecological conditions, also exert a significant influence on plant height and, consequently, on grain yield (Tabaković et al., 2020; Audu and Idris, 2020). The number of leaves in corn is an important trait for predicting photosynthetic activity and therefore has the potential to impact yield. The TZISTR 2042 line exhibited the highest leaf biomass (15.50 +- 0.70), while the TZISTR 1132 line demonstrated the lowest (9.50 +- 2.12). Several studies have demonstrated a correlation between leaf area and crop yield (Sridhara and Prasad, 2002; Beed et al., 2007).

In the improvement of tropical corn varieties, it has been observed that genotypes that improve grain yield tend to maintain or excessively increase vegetative growth (Esteban & Baldo, 2023; Olawuyi et al., 2015). A comprehensive examination of corn lines necessitates an integrated analysis of traits such as ear length and ear diameter. These traits are of central importance in determining corn productivity. The data on corn ear length and ear diameter serve to underscore the significance of these traits in this study. The longest cob length was observed in TZISTR 2047 (14.84 +- 1.49), while the shortest cob length was observed in 5057 (7.10 +- 0.28). Similarly, the largest ear diameter was recorded in line TZISTR 2055 (3.68 +- 0.20), while the smallest was observed in line 5057 (1.55 +- 0.35). These results underscore the significance of these variables in characterizing the corn line and their potential influence on hybrid productivity.

Research has demonstrated that ear volume traits, including ear length and ear diameter, are of paramount importance for assessing corn under diverse nitrogen management conditions, underscoring their significance in agronomic and genetic assessments (Jansen *et al., 2*015). Moreover, studies on genetic variability have indicated that ear diameter and length are important factors influencing corn yield, thus highlighting their role as key yield components (Matin et al., 2017). A notable positive correlation was identified between the duration of male and female semi-flowering. This result serves as an effective indicator of the potential to obtain a greater number of ears at harvest, thereby contributing to an overall increase in yield for the lines in question. The initial prerequisite for fertilization is the accessibility of pollen in conjunction with the receptivity of the silks. As posited by N'da et al., 2024, greater temporal separation between the male and female flowering stages is associated with a reduction in the number of fertilized ovules. This underscores the significance of a positive correlation between the flowering stages. Indeed, several previous studies, notably those by N'da et al. (2014), have also reported a positive correlation between the duration of male and female semi-flowering cycles in corn. It is recommended that traits exhibiting a strong positive and significant correlation with earliness be given particular consideration in the selection of extra-early lines. Indeed, lines with a relatively short cycle and individuals with more developed vegetative traits have been observed to yield the best results (N'da et al., 2017).

The existence of correlations between traits may facilitate genetic improvement. Indeed, when traits are positively correlated, the improvement of one leads to the simultaneous improvement of the others (Bakasso 2010; Abubakar and Bubuche, 2013; Dossou-Aminon et al., 2015). The lines in groups 2 and 4 exhibit comparable agro-morphological and genetic attributes. The distribution of these lines suggests that they are grouped based on their morphological and agronomic similarity. This could be attributed to the diverse heterogeneous groups derived from the ascending hierarchical classification (AHC). This could be attributed to the disparate heterogeneous groups that were generated through the ascending hierarchical classification (AHC). Based on the criteria of earliness, yield parameters, and the most pertinent factors from the DFA, nine promoter lines were identified, comprising the two groups (2 and 4) that were obtained through the AMP grouping. These criteria (earliness and productivity) are mainly used by farmers to select the local varieties grown (Dossou-Aminon et al., 2015). Similar results were obtained by N'da et al., 2024 in their study of maize line selection in Côte d'Ivoire.

5. Conclusion

The objective of this study was to assess the agro-morphological performance of 24 corn parent lines from the International Institute of Tropical Agriculture (IITA). The results demonstrated that there was notable genetic diversity among the diverse corn parent lines. The observed variability for the various agronomic and morphological traits may be utilized in the selection of the most suitable hybrid parents. This variability has been classified into four (4) distinct groups of morphological diversity. Each group represents a heterogeneous pool in which noteworthy traits may be identified. Group 1 comprises the least productive late lines, exhibiting low emergence density. Groups 2 and 4 consist of early lines that are more productive and exhibit an excellent emergence density. Group 3 comprises intermediate lines situated between Groups 2 and 4. On the basis of the most relevant characteristics from the DFA, nine promising parental lines belonging to groups 2 and 4 have been identified. These include TZISTR 1332, 9540, TZISTR 1310, TZISTR 1262, TZISTR 1313, TZISTR 2056, TZISTR 1329, TZISTR 1137, and TZISTR 1312. Moreover, these lines could be used as hybrid parents to enhance corn productivity in Côte d'Ivoire, given their demonstrated agronomic capabilities. To this end, the aforementioned lines could be assessed in a top-cross or diallel study to identify superior combinations. Subsequently, these combinations could be assessed in diverse agroecological zones throughout the country through multilocation trials, to identify the most adapted to the country's environmental conditions.

Conflict of Interests

The authors have not declared any conflict of interests.

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