World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(RESEARCH ARTICLE)

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Agro morphological characterization of fifteen (15) new lines of yellow maize obtained after gamma irradiation of seeds of the EV8728 variety in Daloa, Côte d'Ivoire

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World Journal of Advanced Research and Reviews, 2022, 13(03), 316–328

Publication history: Received on 28 January 2022; revised on 10 March 2022; accepted on 12 March 2022

Article DOI: https://doi.org/10.30574/wjarr.2022.13.3.0176

Abstract

Maize (*Zea mays* L.) is one of the cereals with many economic and nutritional interests. However, maize cultivation faces the challenges of climate change. This phenomenon leads to the soils unproductivity and many crops including maize. Thus, to address this problem, fifteen new yellow maize lines were evaluated in the field on the basis of their agromorphological characteristics (pre-flowering and flowering). Descriptive analysis of the collected data revealed significant diversity among the studied lines. Thus, based on growth parameters, lines L^{95A}, L^{95B}, L^{30}, L^{72A} and L^{91} showed large growth with larger photosynthetic area compared to control line (L^{1}). In contrast, lines L^{48} and L^{54} showed small size and shape. Regarding flowering parameters, lines L^{48} and L^{54} showed a very late inflorescence (62 days on average for both organs) compared to 50 days for the early lines (L^{99}, L^{89}, L^{1}, L^{95B} and L^{95A}). The inflorescence of the other lines is intermediate. The time of appearance of 50% pollen and silk varied (1 to 3 days) from one lineage to another and on the same plant (monoecious plant). The silk and panicle of lines were dominated by purple and green color, respectively. The majority of lines had spikes well covered by the spathes except for lines L^{46}, L^{99} and L^{72A} where the spike tip remained open revealing the spike grains. The roots are mostly stilt type (adventive) with two insertion nodes (underground and above ground).

Keywords: Maize lines; Variety EV8728; Inflorescence; Agro-morphology; Gamma irradiation

1. Introduction

In Côte d'Ivoire, cereal cultivation is dominated by rice, maize, millet and sorghum [31]. Maize is the most cultivated cereal after rice with an estimated national production of 1,176,000 tons, for a total area of 558406 ha. The national average yield is estimated at 2.11 t/ha [17]. Maize occupies a prominent place in the diet of the Ivorian population as well as in animal nutrition (poultry, pigs, cattle [15; 46]. Nutritionally, maize is very rich in sugar, starch, water-soluble polysaccharides, water, protein, vitamin A and potassium [44], antioxidants such as polyphenols, flavonoids and carotenoids [7]. It is also used as a raw material in some industries (brewery, soap factory and oil factory). Also, it is used to make biodegradable plastics, biofuels and even alcohol [5; 23]. Long considered a simple subsistence product, maize is now the subject of undeniable agricultural speculation, leading to the intensification of its cultivation in Côte d'Ivoire with an increasingly important economic stake. Thus, nearly 50 % of its production is located in the savannah region located in the north of the country [18]. However, despite its multiple interests, its cultivation remains confronted with constraints such as the decline in soil fertility as well as its high sensitivity to drought [32] which are

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responsible for the considerable decline in productivity [9], acting on all stages of development of the plant [38; 42]. Also, large-scale adoption of traditional varieties with very low production potential decreases maize yield [32]. To contribute to yield improvement, it is therefore necessary to overcome these different constraints by developing improved varieties with high yield potential through conventional methods [2; 29;38] or through induced mutation [4;13]. The latter method necessarily involves obtaining lines for which knowledge of their agronomic characteristics is very necessary for the creation of future improved varieties. It is in this context that this study was initiated to characterize fifteen new maize lines induced by gamma irradiation of the seeds of the variety EV8728.

2. Material and methods

2.1 Study site and plant material

2.1.1 Study site

The study was conducted on the experimental plot of the University Jean Lorougnon Guédé of Daloa, from March 27 to July 30, 2020. Daloa, located in the Center-West of Côte d'Ivoire between 6°30 and 8° North latitude and between 5° and 8° West longitude, is the capital of the Haut-Sassandra Region. The relative humidity ranges from 63 to 95%. The maximum temperature in the city of Daloa is between 29 °C and 35 °C, and a minimum temperature of 21 °C to 23 °C. The climate of this region is humid tropical with an annual rainfall ranging between 1200 and 2000 mm of water. The soil substrate of the city of Daloa belongs to the old Precambrian basement composed of granites, migmatites and granito-gneiss. The soils of the Daloa region are mostly ferralitic of granitic origin and slightly denatured, not very sensitive to erosion, generally very deep with a high level of organic matter. These soils have a sandy-silty texture and a pH of 5.0 with good agricultural aptitude and are suitable for all types of crops [6; 39]

2.1.2 Plant material

The plant material consists of fifteen (15) yellow maize (*Zea mays*) lines, fourteen (14) of which are derived from seeds of the variety EV8728 irradiated with gamma radiation at different doses (200 and 300 Grays) and one non-irradiated control line EV8728. The seeds, originating from the CNRA of Korhogo in Côte d'Ivoire, were irradiated at the IAEA Genetic and Plant Breeding Laboratory in Seibersdorf, Austria. This variety is adapted to the pedoclimatic conditions of the majority of regions of Côte d'Ivoire. It has a good taste and is one of the most cultivated improved varieties in Côte d'Ivoire. These lines studied are: L^{1D0}; $L^{30}D^{300}$; $L^{46}D^{300}$; $L^{46}AD^{300}$; $L^{48}D^{300}$; $L^{54}D^{300}$; $L^{54}AD^{300}$; $L^{60}D^{300}$; $L^{67}D^{300}$; $L^{72}AD^{300}$; $L^{89}D^{200}$; $L^{91}D^{200}$; $L^{95}AD^{200}$; $L^{95}BD^{200}$; $L^{99}D^{200}$.

2.2 Methods

2.2.1 Experimental Device

The device used is composed of a completely randomized block, designed using Crop Stat version 7.2 software. The block is subdivided into three sub-blocks 2 m apart. Each sub-block is a replicate containing 15 lines (14 irradiated lines and one control line). The position of each line changes from one sub-block to another. The lines are separated by 0.8 m and contain twelve (12) pits 0.4 m apart. In each poquet two grains are sown, that is twenty-four (24) grains per line. A total of 1080 maize plants, 360 per block (24 x 15 x 3) were studied. Each sub-block has an area of 49.28 m2 (11.2 m x 4.4 m) with a margin of 2 m of border, for a total area of 188.48 m^2.

2.2.2 Crop Setting up

Seeding and maintenance of plot

At the time of seeding, twelve (12) pits of approximately 2 to 3 cm were dug on each of lines and then treated with a mixture of two insecticides Pyrical 5G and Vital 3G. A tablespoon of mixture was put in each poquet to protect the grains (two grains per poquet) against the pests. Manual weeding was regularly done to control weeds. Then, an insecticide (viper) was sprayed on the plants to neutralize the insects devouring the young leaves.

Fertilization

In this experiment, N P K fertilizer (15 15 15) was applied at the plants foot at amount of 7.5 g per plant on 15th day after sowing to facilitate the young plants growth and development. Urea was applied during flowering to allow good formation and filling of ears.

Data collection

Measurements were made on a population of 45 randomly selected plants in each line, 15 plants per replication. Fifteen (15) characters (11 quantitative and 4 qualitative) selected among the maize descriptors were retained for the characterization of fifteen maize lines:

- Pre-Flowering Characteristics: Quantitative: plant height (PH), plant crown diameter (CD), leaves number/plant (L.Nb), leaf area (LA), ear insertion height (EIH), ear insertion index (EII). Qualitative: roots aspect (RA).
- Flowering characteristics: Quantitative: time to panicle appearance (TPA), time to spike appearance (TSA), time to 50 % male inflorescence emission (50 % pollen), time to silk appearance (TSiA), number spikelets (Nb.S).
- Qualitative: spikelets color (SpiC), silk color (SC), root aspect (RA) and spike cover (SpC). The spike coverage is defined as the distance between the stalk tip and the spathes top of spike. It is determined by a scale from 1 to 6 (longest to shortest).

2.3 Statistical analysis

The obtained data were subjected to descriptive analysis using R software version 3.6.2 where a one-factor analysis of variance (ANOVA) was performed. All tests performed were significant when the probability $p < 0.05$. In case of significance, Tukey's HSD test at 5% threshold was used for lineage classification. Then, a correlation matrix was constructed using the Pearson test of R software. Also, a principal component analysis (PCA) was performed using the R software package ade4.

3. Results

3.1 Pre-flowering parameters

The analysis results recorded in Table I showed that the relative pre-flowering traits of growth and development of studied lines showed a very highly significant difference ($p < 0.001$). Significant differences are observed between the mean values of quantitative variables of lines for growth and development traits such as plant height (PH), ear insertion height (EIH), ear insertion index (EII), crown diameter (CD), number of leaves (Nb.L) and leaf area (LA).

3.1.1 Plant Height

Table 1 shows the average variation in height between the lines studied with very high significance. Thus, the height plant varies from 98.09 cm (L^{54}) for small line to 173.07 cm (L^{95A} and L^{95B}) for large lines. Thus, Lines L^{54}, L^{48}, L^{46A}, L^{89}, L^{54A}, L^{46}, L^{91}, and L^{72A} achieved the smallest heights against lines L^{95A}, L^{95B}, L^{99}, L^{60}, and L30 which were found to be larger compared to the L^{1} control (150.12 cm). Tukey's HSD test at 5% threshold classified the lines into ten overlapping groups in the following ascending order: L^{48}, L^{54}, and L^{46A} (1st group (a)); L^{89} (2nd group (b)); L^{46}, L^{91}, L^{54A} (3rd group (bc)); L^{67} (cd), L^{72A} (de), L^{1}(e), L^{30}(ef), L^{60}(fg), and L^{99} (gh) 4th, 5th, 6th, 7th, 8th, and 9th groups, respectively, and finally L^{95B} 10th group (h).

3.1.2 Height and insertion index of ear

The ear insertion height shown in Table 1 ranges from 35.76 cm (L^{48}) to 88.29 cm (L^{95B}). The lowest insertion heights are held in order of growth by lines L^{48}, L^{54}, L^{46A}, L^{46} and L^{54A} relative to L^{1} control (68.69 cm). On the other hand, the highest insertions are recorded by lines L^{95B}, L^{30}, L^{99}, L^{60}, L^{95A}, L^{72A} and L^{67}. Lines L^{89} and L^{91} are identical to the control line. Tukey's HSD test at 5 % threshold grouped the lines into eight (8) groups: L^{48}, L^{54} (a) < L^{46A} (b) < L^{46}(c) ≤ L^{54A} (cd) ≤ L^{1}, L^{89}, L^{91} (de) ≤ L^{60}, L^{99}, L^{72A}, L^{95A} (e) ≤ L^{67} (ef) < L^{30}, L^{95B} (g).

Regarding the insertion index in Table I, the values vary from 0.35 (L48) to 0.69 (L30). Small index are recorded in lines L^{48}, L^{54}, L^{46A} and L^{95A} opposite to lines L^{30}, L^{89}, L^{67}, L^{91}, L^{95B}, L^{72A}, L^{54A}, L^{60} and L^{99} in which this insertion index is large compared to control L1 (0.46 cm). Tukey's HSD test 5% threshold grouped the lines into six groups ranging from lowest to highest ear insertion: L^{48} (a) ≤ L^{54} (ab) ≤ L^{67}(bc) ≤ L^{1}, L^{46A}, L^{95A}, L^{91}, L^{95B}, L^{72A}, L^{54A}, L^{60}, L^{99} and L^{46}(c) ≤ L^{89} (cd) ≤ L^{30} (d).

3.1.3 Crown diameter

Table 1 shows the values ranging from 10.29 mm (L^{54}) to 20.77 mm (L^{72A}). Low values crown diameter compared to control L^{1} (18.79 cm) are respectively lines L^{54}, L^{48}, L^{99}, L^{46A}, L^{30}, L^{89}, L^{54A}, L^{91}, L^{67}, L^{46} and L^{95A} versus diameters robust occupied by lines L^{72A}, L^{60} and L^{95B}. Tukey's HSD test 5 % threshold grouped the lines in increasing order of diameter into nine groups: L54 and L48 (1st group (a)); L^{99} (2nd group(b)); L^{46A} (3rd group(bc)); L^{30}, L^{89}, and L^{54A} (4th

group(cd));L^{91} and L67 (5th group(de)); (L^{46} and L^{95A})6th group (ef); 7th group(fg) L^{95B}; 8th group (gh) L^{60}; and finally 9th group (h)(L^{72A}).

3.1.4 Number maize leaves

Table 1 shows the small value which is 17 leaves (L^{48}) and the large value is 23 leaves (L^{91}). The lines with fewer leaves than L^{1} control (19.61) are: L^{48}, L^{54}, L^{67}, L^{46}, L^{99}, L^{89} and L^{72A}. Those with many leaves consist of lines: L^{91}, L^{95B}, L^{60}, L^{54A}, L^{30}, L^{46A} and L^{95A}. Comparison of means using Tukey's HSD test at 5% threshold distinguished nine groups: L^{48} and L^{54} 1st group (a); L^{67} and L^{46} 2nd group (b); L^{99}, L^{89}, and L^{72A} are 3rd group (bc); L^{95A} is the 4th group (cd); L^{46A} and L^{30} 5th group (de); L^{54A} 6th group (ef); L^{60} 7th group (fg); L^{95B} 8th group (g) and L^{91} 9th group (h).

3.1.5 Leaf area

Table 1 Mean values of quantitative variables for growth and development traits of maize lines studied

Quantitative characters						
Lines	**PH (cm)**	**EIH (cm)**	**EII**	**CD (mm)**	**Nb. L**	**LA (cm^2)**
$L1_{D0}$	150.12 ±19.28^{e}	68.69 ± 13.00^{de}	0.46 ± 0.08^{ac}	18.79 ± 2.92^{fg}	19.61 ± 1.31^{bc}	518.74 ± 91.80^{g}
$L30_{D300}$	152.53 ± 30.58^{ef}	87.40 ± 15.74^{g}	0.69 ± 0.93^{d}	15.72 ± 2.04^{cd}	20.18 ± 1.03^{de}	416.16 ± 81.34^{de}
$L46_{D300}$	129.47 ± 15.24^{bc}	59.80 ± 11.56^{c}	0.46 ± 0.07^{ac}	18.01 ± 3.01^{ef}	18.96 ± 1^{b}	524.80 ± 87.56^{g}
$L48_{D300}$	102.02 ± 7.41^{a}	35.76 ± 7.69^{a}	0.35 ± 0.06^{a}	10.86 ± 2.81^{a}	17.80 ± 1.20^{a}	219.95 ± 67.32^{a}
$L54_{D300}$	98.09 ± 16.44^{a}	37.07 ± 8.41^{a}	0.38 ± 0.08^{ab}	10.29 ± 1.46^{a}	17.84 ± 1.58^{a}	238.43 ± 71.21^{a}
$L60_{D300}$	156.82 ± 15.08^{fg}	76.22 ± 7.93^{e}	0.49 ± 0.05^{ac}	20.02 ± 2.76^{gh}	20.67 ± 1.41^{fg}	401. 79 ± 80.60^{de}
$L67_{D300}$	138.16 ± 15.03^{cd}	72.80 ± 10.02^{ef}	0.53 ± 0.06^{bc}	17.43 ± 1.35^{de}	18.89 ± 1.68^{b}	442.59 ± 63.75^{ef}
$L89_{D200}$	124.04 ± 14.84^{b}	68.60 ± 10.53^{de}	0.55 ± 0.06^{cd}	15.99 ± 2.06^{cd}	19.04 ± 1.19^{bc}	348.77 ± 59.04^{bc}
$L91_{D200}$	134.93 ± 14.06^{bc}	68.56 ± 9.23^{de}	0.51 ± 0.05^{ac}	16.92 ± 2.34^{de}	23.58 ± 1.06^{h}	491.74 ± 63.27^{fg}
$L99_{D200}$	160.78 ± 11.73^{gh}	76.69 ± 10.68^{e}	0.48 ± 0.06^{ac}	13.91 ± 1.97^{b}	19.00 ± 1.13^{bc}	384.89 ± 54.53^{cd}
$L46A_{D300}$	103.69 ± 14.43^{a}	46.58 ± 11.09^{b}	0.45 ± 0.08^{ac}	15.14 ± 2.72^{bc}	20.07 ± 0.99^{de}	325.82 ± 84.48^{b}
$L54A_{D300}$	127.38 ± 16.92^{bc}	62.44 ± 10.87^{cd}	0.49 ± 0.05^{ac}	16.12 ± 2.44^{cd}	20.33 ± 1.26^{ef}	406.89 ± 92.42^{de}
$L72A_{D300}$	149.31 ± 12.38^{de}	75.18 ± 8.80^{e}	0.50 ± 0.05^{ac}	20.77 ± 2.59^{h}	19.33 ± 1.37^{bc}	429.84 ± 73.7^{ef}
$L95A_{D200}$	173.07 ± 15.18^{h}	75.27 ± 14.07^{e}	0.45 ± 0.05^{ac}	18.16 ± 2.00^{ef}	19.82 ± 1.13^{cd}	529.72 ± 89.51^{g}
$L95B_{D200}$	173.07 ± 11.73^{h}	88.29 ± 12.13^{g}	0.51 ± 0.05^{ac}	19.01 ± 2.48^{fg}	20.91 ± 1.53^{g}	491.77 ± 79.31^{fg}
F	88.05	89.38	5.47	73.84	53.98	80.57
P	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

P = Approximate Probability of Tests F = File Constancy; Means followed by the same letter are significantly identical at the 5% threshold. PH: Plant height; EIH: ear insertion height; EII: ear insertion index; CD: plant crown diameter; Nb.L: leaves number/plant; LA: leaf area

Table 1 on the variation in photosynthetic area shows values ranging from 219.95 cm^2 (L^{48}) to 529.72 cm^2 (L^{95A}). The leaf area values lower than that of L^{1} control (518.74 cm^2) are lines L^{48}, L^{54}, L^{46A}, L^{89}, L^{99}, L^{60}, L^{54A}, L^{30}, L^{72A}, L^{67}, L^{91} and L^{95B}, respectively. The largest leaf areas were recorded in lines L^{46} and L^{95A}. Tukey's HSD test at 5 % level classified the lines into eight overlapping groups: 1st group (a): L^{48} and L^{54} < 2nd group (b): L^{46A} ≤ 3rd group (bc): L^{89} ≤ 4th group (cd): L^{99} ≤ 5th group (de): L^{60}, L^{54A} and L^{30} ≤ 6th group (ef): L^{72A} and L^{67} ≤ 7th group (fg): L^{91} and L^{95B} ≤ 8th group: L^{46} and L^{95A} (g).

3.2 Inflorescence parameters

Analysis results recorded in Table II show that the inflorescence characters of studied lines show a very highly significant difference ($p < 0.001$). Significant differences are observed between the mean values of quantitative variables of lines for following flowering characters: Time to panicle appearance (TPA), Time to spike appearance (TSA), Time to 50 % pollen appearance (50 % Po), Time to silk appearance (TSiA), and Number of spikelet in panicle (NbSpi).

3.2.1 Time to panicle appearance

Table 2 shows the variation in mean time to panicle appearance between the lines studied with very high significance. Thus, the time of panicle appearance is between 49 (L^{99}) and 62 (L^{48}) days. This leads to determine the following sowing-flowering cycles: L^{99}, L^{89}, L^{1} and L^{95A} are early lines and have a panicle cycle of 49 to 50 days. The second early seeding cycle contains lines L^{95B}, L^{67}, L^{30}, L^{46}, L^{72A} and L^{91}, and has a cycle of 51 to 53 days. Third late-seeded cycle, containing lines L^{60} and L^{54A}, has a cycle length of 54 to 55 days. Late lines L^{54} and L^{46A} have a cycle of 59 to 60 days. Finally, very late line L48 has a cycle 62 days. The comparison of the means with Tukey's HSD test at 5% threshold yielded twelve (12) groups: Group 1 (a) L^{99}; Group 2 (ab) L^{89}; Group 3 (b) L1; Group 4 (bc) L^{95B} and L^{95A}; Group 5 (c) L^{30} and L^{67}; Group 6 (d) L^{46}; Group 7 (de) L^{91} and L^{72A}; Group 8 (e) L^{60}; Group 9 (f) L^{54A}; Group 10 (g) L^{54}; Group 11 (gh) L^{46A} and Group 12 (h) L^{48}.

3.2.2 Time of appearance of ear

Table 2 records time to ear emergence with values fluctuating between 49 (L^{95A}) and 62 (L^{54}) days. The variation in ear emergence time leads to classify lines in different sowing-flowering cycle compared to control. Thus, lines L^{95A}, L^{99}, L^{89}, L^{46} and L^{95B} are early with a cycle 49 to 50 days. The early seeded lines are L^{67}, L^{1}, L^{30}, L^{60} and L^{72A}, with a cycle 51 to 52 days. The late-seeded lines, L^{91} and L^{54A}, have a cycle 53 to 55 days. The late line L46A has a cycle 59 days. The very late lines L^{48} and L^{54} have a cycle of 61 to 62 days. Classification of lines based on means with Tukey's HSD test at 5% threshold defined seven (7) groups: L^{95A} and L^{99} group 1 (a) ≤ L^{89}, L^{46}, L^{95B} and L^{67} group 2 (ab) ≤ L^{60}, L^{72A} and L^{30} group 3 (bc) ≤ L^{91} group 4 (c) < L^{54A} group 5 (d) < L46A group 6 (e) < L^{54} and L^{48} group 7 (f).

3.2.3 Time to 50% pollen count

Time to pollen emergence recorded in Table 2 ranges from 56 (L^{95A}) to 68 (L^{48} and L^{54}) days. Thus, the sowing-flowering cycle is as follows: the early lines compared to L^{1} control (58 days) are L^{95A} and L^{95B} and L^{67} with a cycle 56 to 57 days. The early-seeded lines, including L^{46}, L^{89}, L^{1}, L^{99} and L^{30}, have a cycle 58 to 59 days. The late seeded lines are characterized by L^{91}, L^{72A}, L^{60} and L^{54A} with a cycle of 60 to 62 days. Late line L^{46A} has a cycle of 65 days. Finally, the 50 % very late pollen delay is seen in lines L^{48} and L^{54} with a cycle 68 days. Tukey's HSD test at 5 % threshold classified the lines into ten (10) groups: 1st group (a) L^{95A}; 2nd group (ab) L^{95B}; 3rd group (b) L67; 4th group (c): L^{89}, L46 and L1; 5th group (d) L30 and L99; 6th group (e) L^{91}; 7th group (f) L^{72A}; 8th group (g) L^{54A} and L^{60}; 9th group (h) L^{46A}; 10th group (i) L^{54} and L^{48}.

3.2.4 Time to silk appearance

Variation in the time to silk appearance lines resulted in seeding-flowering cycles that ranged from 56 (L^{95}B) to 67 (L^{48} and L^{54}) days. Early onset relative to control L^{1} (58.89) is identified in lines L^{95B}, L^{30}, and L^{95A}, with a 56-day cycle. Early seeding is observed in lines L^{67}, L^{89}, L^{99}, L^{46} and L^{72A} with a cycle of 57 to 58 days. Late-seeded lines including L^{1}, L^{60}, L^{91} and L^{54A} cycle in 59 to 60 days. The late line L46A has a cycle of 64 days. The very late lines consist of L^{48} and L^{54} with a cycle of 67 days. Classification of lines into seven (7) groups was done with the Tukey HSD test at 5 % threshold. L^{95B} and L30 (1st group (a)); L^{95A}, L^{67} and L^{89} (2nd group (ab)); the L^{99} and L^{46} (3rd group (b)); L^{72A} (4th group (bc)); L^{1}, L^{60}, L^{91} and L^{54A} (5th group (c)); L^{46A} (6th group (d)); L^{54} and L^{48} (7th group (e)).

3.2.5 Spikelets Number

The number of spikelets panicles obtained by the lines gave in table II average values that varied from 5 (L54) to 21(L^{91}) spikelets. To this effect, lines L^{54}, L^{48}, L^{54A}, L^{99}, L^{46A}, L^{89}, L^{46}, L^{30}, L^{60} and L^{95B} recorded the lowest number of spikelets compared to L^{1} controls respectively (15,20). The highest number of spikelets was carried by lines L^{91}, L^{72A}, L^{95A} and L^{67}. Tukey's HSD test at 5% level classified the lines into eight groups: group 1(a) L54 and L^{48} < group 2(b) L^{54}A < group 3(c) L^{99} and L^{46A} ≤ group 4(cd) L^{89} ≤ group 5(d) L^{46} ≤ group 6 (de) L^{30}, L^{60}, and L^{95B} ≤ group 7(e) L^{95A}, L^{67}, and L^{1} ≤ group 8(f) L^{91} and L^{72A}.

Table 2 Mean values of inflorescence traits of maize lines

Quantitative characters					
LIG	**TPA**	**TSA**	**50 % Po**	**TSiA**	**NbS**
$L1_{D0}$	49.87 ± 2.51^{b}	51.11 ± 2.86^{b}	57.83 ± 2.14^{c}	58.89 ± 3.49^{c}	15.20 ± 5.86^{e}
$L30_{D300}$	51.07 ± 1.60^{c}	51.49 ± 1.32^{bc}	58.80 ± 3.14^{d}	56.22 ± 2.24^{a}	14.64 ± 2.38^{de}
$L46_{D300}$	51.53 ± 2.19^{d}	50.40 ± 1.74^{ab}	57.76 ± 1.33^{c}	57.22 ± 1.99^{b}	14.00 ± 4.08^{d}
$L48_{D300}$	62.29 ± 1.75^{h}	60.60 ± 1.95^{f}	67.53 ± 1.69^{i}	66.64 ± 3.05^{e}	6.44 ± 2.30^{a}
$L54_{D300}$	58.53 ± 4.56^{g}	62.00 ± 3.05^{f}	68.03 ± 1.07^{i}	67.10 ± 0.55^{e}	5.38 ± 1.56^{a}
$L60_{D300}$	53.89 ± 1.35^{e}	51.89 ± 0.98^{bc}	61.87 ± 1.74^{g}	59.38 ± 2.18^{c}	14.91 ± 2.71^{de}
$L67_{D300}$	50.96 ± 1.82^{c}	50.51 ± 2.13^{ab}	57.24 ± 2.35^{b}	56.69 ± 2.48^{ab}	15.60 ± 3.47^{e}
$L89_{D200}$	49.53 ± 1.70^{ab}	50.00 ± 1.80^{ab}	57.76 ± 1.09^{c}	56.73 ± 1.52^{ab}	12.80 ± 3.63^{cd}
$L91_{D200}$	52.67 ± 1.37^{de}	52.67 ± 1.58^{c}	59.71 ± 2.64^{e}	59.50 ± 2.12^{c}	21.60 ± 3.01^{f}
$L99_{D200}$	49.16 ± 1.52^{a}	49.47 ± 1.79^{a}	58.43 ± 1.52^{d}	57.20 ± 1.52^{b}	11.27 ± 2.17^{c}
$L46A_{D300}$	59.67 ± 3.44^{gh}	58.56 ± 5.23^{e}	65.49 ± 2.57^{h}	63.51 ± 3.31^{d}	11.53 ± 3.40^{c}
$L54A_{D300}$	55.04 ± 1.82^{f}	54.60 ± 2.20^{d}	62.31 ± 1.35^{g}	59.76 ± 1.51^{c}	10.91 ± 2.77^{b}
$L72A_{D300}$	52.60 ± 1.95^{de}	51.89 ± 1.64^{bc}	60.42 ±1.44^{f}	58.02 ± 1.08^{bc}	19.47 ± 5.40^{f}
$L95A_{D200}$	50.40 ± 1.90^{bc}	48.87 ± 5.35^{a}	55.71 ± 0.69^{a}	56.42 ± 0.96^{ab}	15.87 ± 2.83^{e}
$L95B_{D200}$	50.51 ± 2.34^{bc}	50.47 ± 1.50^{ab}	56.33 ± 1.30^{ab}	56.07 ± 0.81^{a}	15.04 ± 4.63^{de}
F	152.6	96.87	182.9	88.55	50.9
P	0.0001	0.0001	0.0001	0.0001	0.0001

P = Probability associated with the ANOVA statistic F = Constancy of the Ficher test variable; Means followed by the same letter are identical at the 5% threshold; Means followed by different letters are significantly different at the 5 % threshold. Time to panicle appearance (TPA), Time to spike appearance (TSA), Time to 50 % pollen appearance (50 % Po), Time to silk appearance (TSiA), and Number of spikelets in panicle (NbSpi).

3.3 Quality characteristics of pre-flowering and flowering

Table 3 presents the qualitative characters of preflowering and flowering that expressed their abundance within the lines. These include: silk color (S.C), root appearance (RA), spikelet color (SpiC) and spike cover (SpC).

3.3.1 Silks Color

Table 3 shows the different colors of silks lines which are of three types: purple, pink and white. Color is dominated by purple and includes lines L^{1}, L^{30}, L^{60}, L^{67}, L^{99}, L^{54A}, L^{72A}, L^{95A} and L^{95B}. Then, the pink color which contains the lines L46, L54, L89, L46A and L48. Finally, the white color which is composed of lineage L^{91}.

3.3.2 Roots Aspect

Table 3 shows three patterns root appearance of lines. These are stilt roots with two nodes of insertion with one underground and the other above ground, and which dominate all the lines (L^{1}, L^{30}, L^{46}, L^{54}, L^{60}, L^{67}, L^{89}, L^{46A}, L^{48}, L^{54A} and L^{95A}). The stilt roots have three nodes of insertion with one underground and two (2) above ground. These are lines L^{91}, L^{99} and L^{95B}. Line L^{72A} has the appearance of a fasciculate root with one underground insertion node.

3.3.3 Spikelets Color

Table 3 is dominated by green and purple. Color character set is dominated by green color and includes lines L^{1}, L^{30}, L^{54}, L^{60}, L^{89}, L^{91}, L^{54A}, L^{72A}, L^{95A}, and L^{95B}. Purple color is noticed in lines L^{46}, L^{67}, L^{99}, L^{46A} and L^{48}.

3.3.4 Maize ear cover

Table 3 presents six forms according to formation of spikes of lines. These are: long cover which includes line L^{99}; medium long comprising lines L^{1}, L^{54}, L^{67}, L^{46A} and L^{95A}; short (L^{30}, L^{60}, L^{89}, L^{48}, L^{54A} and L^{95B}); very short closed held by lines L^{46} and L^{91} and very short open carried by line L^{72A}.

Table 3 Abundance of qualitative pre-flowering and flowering traits of lines

characters qualitative				
LIG	**SC**	**RA**	**Spi. C**	**Sp. C**
$L1_{D0}$	purple	R.Ec à 2 nœuds I.S.A	green	3 (Medium. Long)
$L30_{D300}$	purple	R.Ec à 2 nœuds I.S.A	green	4 (Short)
$L46_{D300}$	pink	R.Ec à 2 nœuds I.S.A	violet	5 (Very Short closed)
$L54_{D300}$	pink	R.Ec à 2 nœuds I.S.A	green	3 (Medium. Long)
$L60_{D300}$	purple	R.Ec à 2 nœuds I.S.A	green	4 (Short)
$L67_{D300}$	purple	R.Ec à 2 nœuds I.S.A	violet	3 (Medium. Long)
$L89_{D200}$	pink	R.Ec à 2 nœuds I.S.A	green	4 (Short)
$L99_{D200}$	white	R.Ec à 3 nœuds I.S.A	green	5 (Very Short closed)
$L99_{D200}$	purple	R.Ec à 3 nœuds I.S.A	purple	2 (Long cover)
$L46A_{D300}$	pink	R.Ec à 2 nœuds I.S.A	purple	3 (Medium. Long)
$L48_{D300}$	pink	R.Ec à 2 nœuds I.S.A	purple	4 (Short)
$L54A_{D300}$	purple	R.Ec à 2 nœuds I.S.A	green	4 (Short)
$L72A_{D300}$	purple	R.Fa à 1 nœud I.S	green	6 (Very Short open)
$L95A_{D200}$	purple	R.Ec à 2 nœuds I.S.A	green	3 (Medium. Long)
$L95B_{D200}$	purple	R.Ec à 3 nœuds I.S.A	green	4 (Short)

Silk color (S.C); root appearance (RA); Spikelet color (SpiC) and Spike cover (SpC); **R.Fa at 1 node I.S**: Fasciculate Root at 1 node of subsurface insertion; **R. Ec at 2 nodes I.S.A:** Stilt root at 2 nodes of Insertion (Underground and Aerial); **R.Ec at 3 nodes I.S.A:** Stilt root at 3 nodes of Insertion (Underground and Aerial); **2:** Long cover ear; **3:** Medium. Long cover ear; **4:** Short cover ear; **5:** Very Short closed cover ear; **6:** Very Short open cover ear

3.4 Correlation analysis of different agro-morphological parameters

The correlation matrix shows significant correlations between several pairs of variables of growth and development traits, at level of flowering traits and a correlation between growth and flowering variables (Table 4). Thus, analysis reveals within a single trait and between different traits significant correlations, strong significant correlation and very strong significant correlation.

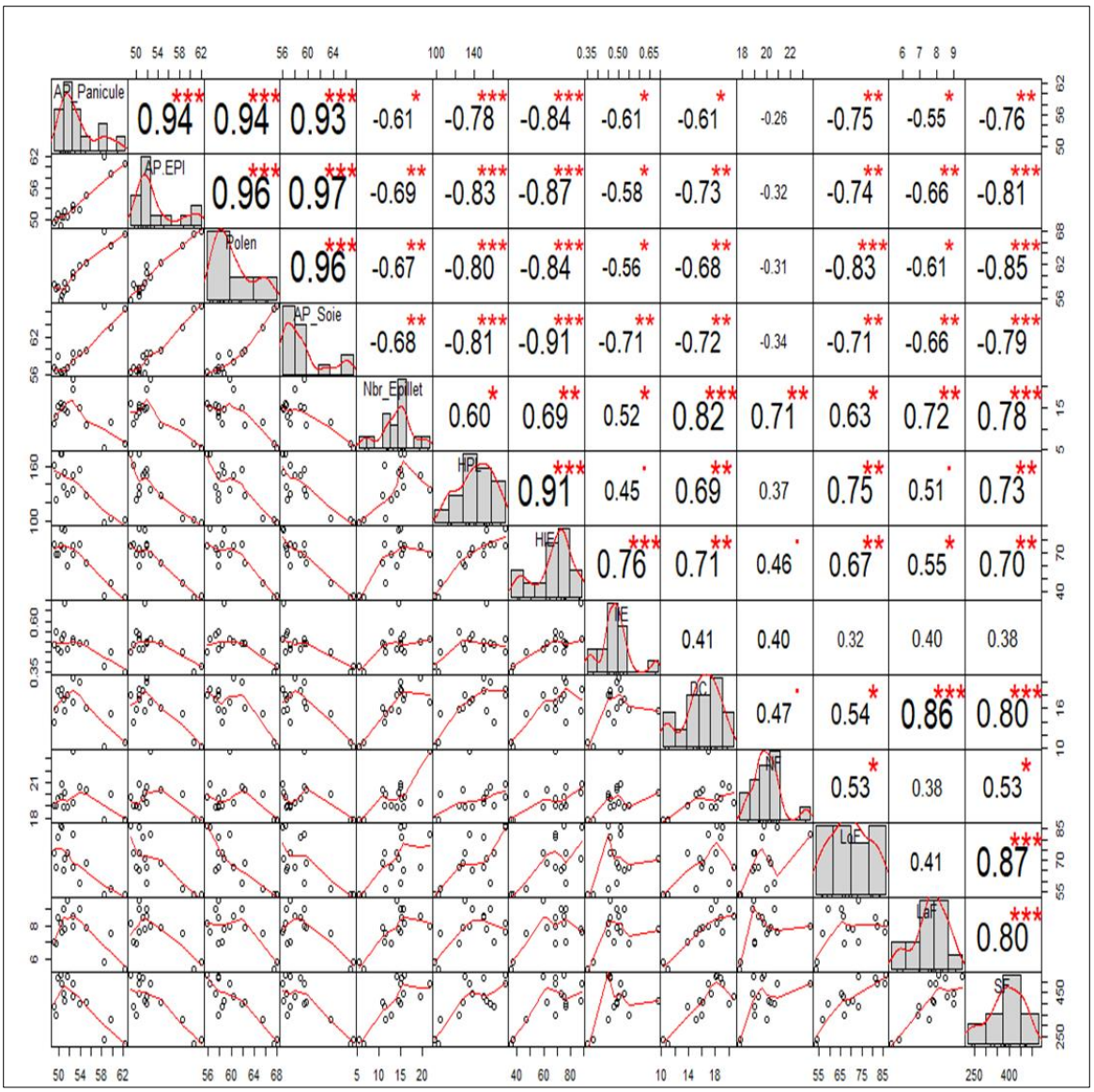
3.5 Principal Component Analysis (PCA) and agro-morphological performance

The heterogeneity of the values obtained for each parameter determined contributed to classification of lines. The projection of variables in factorial plane showed that all variables participated in the discrimination of studied traits. Thus, agro-morphological performance allowed the classification of lines: figure 1 and figure 2.

Figure 1 shows the projection of growth and development traits of lines on factorial plane formed by axes 1 and 2, which together explain 76.25% of variability. Examination of correlations of variables with first component (Dim1), which accounts for 64.77 % of the variability, shows that following agro-morphological variables: LA; CD; PH and EIH presenting a strong contribution, are positively correlated with this component. The second component (Dim2), which explains only 11.48% of total variability, is strongly correlated with the EII variable. The projection of mean points maize lines in the factorial plane allows to distinguish four main groups lines. Thus, lines L^{54} and L^{48} in group 1 have small size with few leaves, small leaf area, small crown diameter, small ear insertion height and low ear insertion index. Group 2 consisting lines L^{46A}, L^{54A}, L^{99}, L^{89} and L^{30} were not influenced by any factor. Lines L^{67}, L^{60}, L^{72A} and L^{46} constitute

group 3. They are characterized by a very large leaf width and collar diameter. Group 4 contains lines L^{1}, L^{91}, L^{95A} and L^{95B} which have many very long leaves with a large leaf area.

Table 4 Correlation matrix between variables of agro-morphological parameters of maize lines



*: significant correlation; **: strong significant correlation; ***: very strong significant correlation; positive value (+): indicates a positive correlation; negative value (-): negative correlation

Figure 2 shows that the line flowering variables projection on to factorial plane formed axes 1 and 2 showed an overall variability of 97.17 %. Examination of correlations of variables with axis 1 accounts for 87.39 % of total variability. This shows that the flowering variables: time to panicle emergence, time to spike emergence, time to 50 % pollen count and spikelet number have a strong contribution and are positively correlated with this component (Dim1). The second component (Dim2) accounted for 9.78% of total variability. The projection of mean points of maize lines in factorial plane allows us to distinguish three main groups of lines. Thus, group 1 includes lines L^{95A}, L^{95B}, L^{89}, L^{99}, L^{46}, L^{30}, L^{67} and L^{1} with a negative correlation, has short ear appearance time, silk appearance time, panicle appearance time and 50 % pollen appearance time. These are short and early cycle lines.

Group 2 is not influenced by any factor. It includes lines L^{91}, L^{72A}, L^{60} and L^{54A}. The lines L^{46A}, L^{48} and L^{54} constitute group 3. This group is dependent on parameters such as time to ear appearance, time to silk appearance, time to panicle appearance and time to 50% pollen appearance and have a positive correlation. The lines belonging to this group are characterized by a long and late cycle. However, the lines have a small number of spikelets.

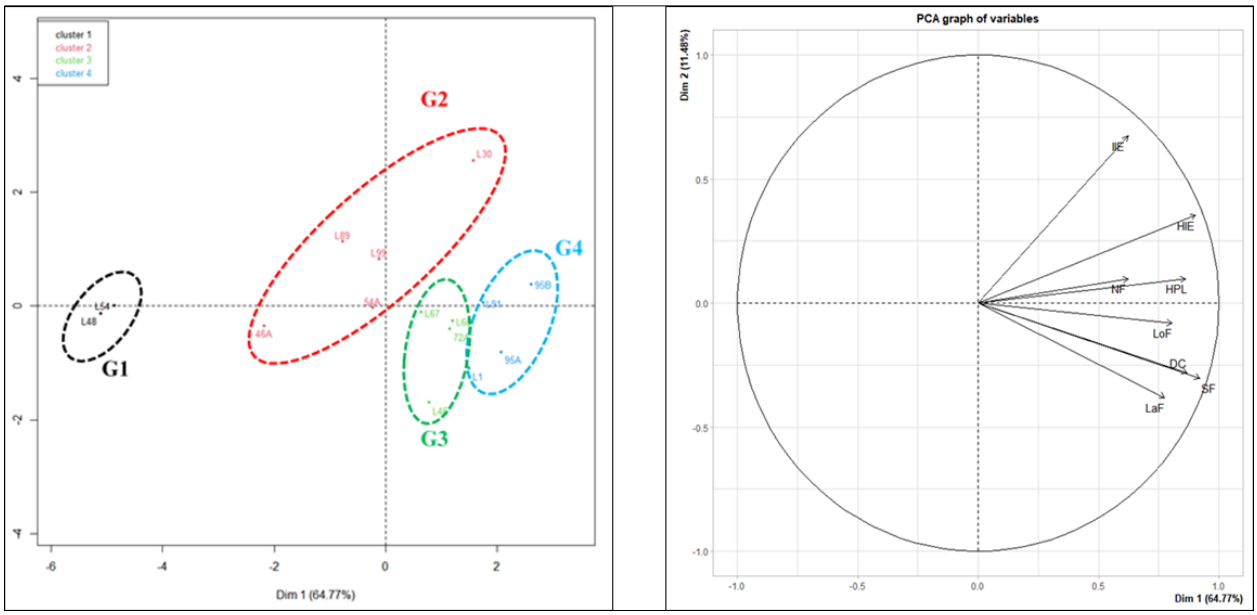


Figure 1 Projection of growth and development variables of lines in plane formed by axes 1 and 2

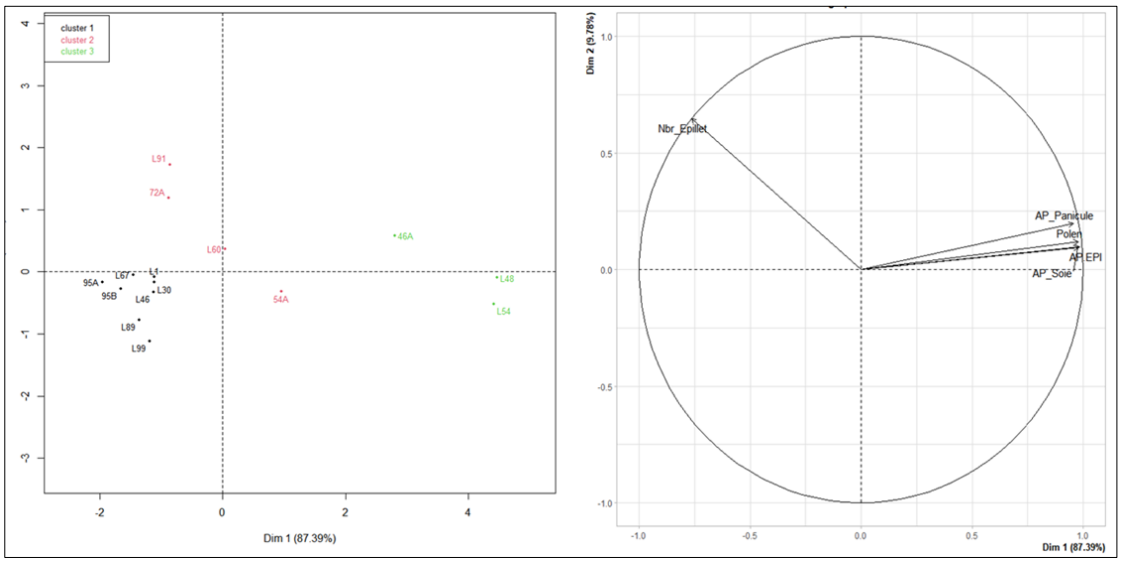


Figure 2 Projection of line flowering variables in plane formed by axes 1 and 2

4. Discussion

Agro-morphological characterization is important steps in the description and classification of crop plants. Indeed, any improvement program necessarily relies on morpho-phrenological variability [31]. It provides improvers with crucial information needed for research work [12; 41]. It is in context that an agro-morphological study of 15 new yellow maize lines derived from gamma irradiated seeds of the variety EV8728 was necessary. This diversity concerned the pre-flowering and flowering parameters of new lines. Descriptive analyses showed very significant differences between the mean values for all agro-morphological traits analyzed. This indicates a significant inter-line variability.

4.1 Interlines variability in quantitative pre-flowering traits

The results of the statistical analysis of growth and development variables showed that the lines differed from each other in plant height, ear insertion height, ear insertion index, crown diameter, number of leaves and leaf area. Thus, these variables differed from each other by small size and shape versus large size and robustness compared to control.

These different variations allowed to highlight a hetero-diversity of studied lines. This morphological diversity would be linked to variability of genetic resources of each line. The same variability was reported by [12; 30; 40;42]. Similar results related to high morpho-phenotypic diversity were obtained by [31] by characterizing one hundred and seventy-one (171) maize accessions collected in the Savannah regions (Denguélé, Vallée du Bandaman, Moyen-Cavally and Bas Sassandra) of Côte d'Ivoire. According to [8; 31; 33], the morphological diversity of cultivated maize is related, not only, to agronomic traits of seeds but also to peasant management practices of exchanging seeds of varieties among farmers. [42; 43] confirmed this peasant practice as responsible for this diversity among crop populations. The observed variability among the growth traits of studied lines would also result from the ability of these lines to adapt to growing environment. Work by [11; 19] on tomato varieties linked varietal growth difference to genotype and environment in which they were tested. Indeed, the different behavior of lines would be attributed to their genome expression. In addition, the different doses of irradiation from which the lines emanate would be responsible for controlling different behavior of these lines. For [16], mutations induced at plant level are responsible for the variation in plant growth. Our results are similar to those of [14] in tomato. According to them, tomato plants that received high doses of gamma irradiation recorded low growth, showing growth diversity at tomato plant level. The results related to the synthesis of leaves and expression of their surface also revealed a diversity. This diversity could also be explained by the application of ionizing radiation responsible for screening of lines. Thus, these lines will have different morphological and physiological behaviors. For [45], doses of gamma radiation have a depressive effect on plant development. This results in changes in the shape of photosynthetic surface and the number of leaves. This agro-morphological character variation was observed in peanut accessions [1; 2].

4.2 Interlines variability in quantitative flowering traits

The lines studied showed very different behaviors in flowering time. This again shows the diversity of lines studied. This difference was observed between the lines and also within the same line where a gap ranging from 1 to 4 days was observed between the time of appearance of panicle and that of ear. Thus, in some lines the panicle appeared before ears, in others it is the opposite behavior. In other lines, both reproductive organs appear at same time. The time of panicle and ear appearance showed an early sowing-flowering cycle of 50 days and a very late cycle of 62 days with a delay of 12 days. This behavior would therefore be linked to the genetic traits of each line. The work of [21] on tomato flowers also showed the differences in flowering expressed under genotypic expression and are responsible for diversity of plants. According to this author, this genome expression can be influenced by external factors in plant's environment. The time to 50% pollen and silk appearances varied (1-3 days) across lines and on same plant (monoecious plant). According to [12], the variability in inflorescence initiation originates from the change in seeding-flowering cycles of cultivated varieties. The appearance of pollen and silk in lineages occurs either in order pollen-silk or silk-pollen or both at same time. These diverse behaviors of lines could be attributed to genetic, agro-ecological (temperature) and agro-pedological (soil structure and mineral composition) factors. These results are consistent with those of [27] on the agro-morphological performance of local and improved maize varieties. For them, the required interval between male and female flowering is 3 to 9 days and is highly dependent on soil temperature and relative humidity. Number of spikelets varied greatly between lines with a difference of 16 spikelets between smallest value and largest. These different variations in number of spikelets may be related to interaction between genotypes and environment. According to [38] from flowering initiation to floral maturity, several genetic, biochemical and physiological phenomena are involved in the mobilization of mineral elements. Therefore, the capacity of each line to draw mineral elements and water is under effect of environmental factors (light, temperature). [29]

4.3 Interlines variability of qualitative agro-morphological traits

Variability in colors of silk, spikelets, proportion of cob cover by spathes and root appearance was observed in the studied maize lines. The color of the silk or beard was dominated by purple while the spikelets of the panicle showed mostly green color. The majority of lines had ears well covered by spathes except for lines L^{46}, L^{99} and L^{72A} where tip of ear remained open revealing the kernels of ear. The root structure is mostly dominated by the stilt type (adventive) with two insertion nodes, one underground and the other above ground. These expressions may be the effect of modification of genetic information to gamma irradiation from which lines result. This modification would also be related to action of environmental factors. This is in agreement with work of [13] who state that effect of gamma irradiation acts on genes by altering certain pigments resulting in organ color diversity. For [3;10], some external factors, such as water availability and temperature have a direct impact on metabolism and genome characteristics hence the observed color diversity. In contrast, degree of spike coverage is typically under the control of genome. The same genome also controls root structure [22]. On the other hand, the different aspects of the root observed at lineage level can be caused either by type of inking, the mode of nutrition or by environmental factors. Indeed, thanks to their root system, plants have ability to adapt to their environment in order to better exploit the water and mineral resources available to plant [8; 20; 23; 24].

5. Conclusion

The study of agro-morphological characterization (pre-flowering and flowering) of fifteen maize lines grown at Jean Lorougnon Guédé University in Daloa, Côte d'Ivoire, reveals a significant agro-morphological diversity. Each variable constitutes a potential source of interesting traits for improvement of maize production in Côte d'Ivoire. The lines studied are L^{1}, L^{30}, L^{46}, L^{46A}, L^{48}, L^{54}, L^{54A}, L^{60}, L^{67}, L^{72A}, L^{89}, L^{91}, L^{95A}, L^{95B} and L^{99}. The control line L^{1} EV8728 is not irradiated. The lines were compared to each other and to control through the agro-morphological variables. After observing the differences between lines through the comparison of averages, it appears from this study that lines L^{48} and L^{54} presented variables of small size, small diameter, few leaves, small leaf area and are very late. Lines L^{95A}, L^{95B}, L^{89} and L^{99} have better vegetative characteristics compared to the control and are early. The other lines are intermediate. These improved lines could provide a solution to constraints that undermine maize cultivation in Côte d'Ivoire. In order to optimize the exploitation of these lines, it would be very important to characterize the production of these lines and to make a biochemical analysis of grains of these lines.

Compliance with ethical standards

Acknowledgments

The authors thank the Professor KOUADIO Yatty Justin managed the literature searches.

Disclosure of conflict of interest

The authors declare that they have no conflict of interests regarding the publication of this paper.

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