Journal Homepage: - www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)

ISSN (O): 2320-5407
ISSN (P): 3107-4928

Article DOI: 10.21474/IJAR01/22599
DOI URL: http://dx.doi.org/10.21474/IJAR01/22599

RESEARCH ARTICLE

IDENTIFICATION OF ELITE LOCAL ACCESSIONS OF ROSELLE (HIBISCUS SABDARIFFA) BASED ON MORPHO- PHENOLOGICAL TRAITS

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Manuscript Info

Manuscript History
Received: 08 November 2025
Final Accepted: 10 December 2025
Published: January 2026

Key words:-
Identification, local elite accessions, Hibiscus sabdariffa, Roselle, morpho-phenological evaluation.

Abstract

In Cote d'Ivoire, the available data on the diversity and genetic structuring of Guinea sorrel remain limited and not very popularized, thus making research work and varietal improvement efforts particularly difficult. To overcome this problem, a survey conducted in 12 localities has made it possible to have an in-situ collection of 80 accessions. Twenty-nine (29) accessions from this collection were evaluated in this study. The objective was to identify elite accessions, potentially candidates for an improvement program. Nineteen (19) quantitative traits were analyzed on a Fisher block device. Descriptive analysis revealed a high morphological variability between accessions. The coefficient of variation showed a strong heterogeneity between accessions for certain traits. The PCA revealed 70.07% of the total variability. The classification made it possible to distinguish three groups of accessions according to their similarity. The classification by the k-means method made it possible to classify accessions into three groups and to identify the most efficient ones according to the stages of development. Thus, the accessions HSKO 037, HSFE 031, HSBK 004 and Bangolo stood out respectively at the 2-leaf, vegetative, flowering, and fruiting stages by presenting the highest values for the traits evaluated.

Introduction:-

Hibiscus sabdariffa L., commonly known as roselle, is a species belonging to the Malvaceae family (Bakasso et al., 2013).

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It is an annual or biennial plant of tropical and subtropical areas that adapts to all climatic conditions (Kone et al., 2018). According to Grubben and Denton (2004), it was initially domesticated in Africa, probably in Sudan, about 6000 years ago, before spreading to Asia and America. Other authors such as Duke (1993) and (Abu-Tarboush et al., 1997) suggest an origin in eastern India or Saudi Arabia. Sudan is the main producer of sorrel in Africa (Ternoy et al., 2006). The annual area under cultivation varies between 11,000 ha and 57,000 ha, depending on rainfall and prices. In 1995, Sudan exported about 32,000 tonnes of Guinea sorrel calyx (Mc Clintock et al., 2011). According to the Central Bank of Sudan (2012), the quantity of dry calyxes exported was 18,531 tonnes in 2011 and 15,656 tonnes in 2012 for a net gain of US$17.59 million and US$14.09 million, respectively (Ibrahim et al., 2013). Senegal and Mali are the main producers of sorrel in West Africa. However, much of their production is for family consumption or sold in local markets (McClintock et al., 2011). In Senegal, the average annual income from the sale of sorrel leaves ranges from US$41 to US$500 (Diouf et al., 2007).

In addition, in Burkina Faso, Benin, Cote d'Ivoire, Mali, Mauritania and Senegal, a 30 to 50 cl ice pack is sold for between 25 and 50 CFA francs, while a 1-litre bottle for between 1,000 and 1,500 CFA francs (McClintock, 2004). In Cote d'Ivoire, most research on H. sabdariffa is mainly carried out at the biochemical level; little information is available on the morphological, agronomic, and molecular characteristics of H. sabdariffa cultivars. Research activities on regeneration from cuttings (Sie et al., 2008) and agromorphological characterizations (Sie et al., 2009) made it possible to evaluate the diversity of 159 seeds from seeds collected on the markets of Korhogo (Cote d'Ivoire). The research of Anzara et al. (2023) made it possible to have 80 accessions collected in 12 localities in Cote d'Ivoire. The evaluation of accessions collected in 2023 identified 29 elite accessions. Our study proposed to evaluate the morpho-phenological characteristics of these accessions to identify the best ones. The aim was to identify the elite accessions at each stage of development and to identify the elites in a global way by cross-referencing the best at each stage.

Material and Method:-

Study site:-

The study was conducted at the experimental site of the botanical garden of the Peleforo GON COULIBALY UNIVERSITY (UPGC). The experimental plot is located at longitude 5°38 West and Latitude 9°26.

Plant material:-

The plant material consists of 29 Hibiscus sabdariffa accessions from different localities in Cote d'Ivoire (Table I). These accessions are in the form of seeds and are the result of a survey conducted in 2023 (Anzara et al., 2023).

Method:-

Experimental design and data collection:-

The trial was conducted using the randomized Fisher block device with three (3) replicates. The parameters measured concerned 450 plants due to 15 plants per accession. Quantitative variables (Table II) were measured during (4) life stages: the seedling stage, the vegetative stage, the flowering stage, and the fruiting stage (Figure 1).

Table I. List of accessions studied, their origin and number

Area	Collection location	Accession Code
		HSBK 003 HSBK 004
Centre (05)	Bouake (05)	HSBK 005 HSBK 002 HSBK 006
Centre-West (01)	Daloa (01)	HSDA 001
	Boundiali (03)	HSBO 023 HSBO 024
		HSBO 026

	Ferkessedougou (03)	HSFE 028 HSFE 031 HSFE 032
		HSKO 037 HSKO 040
North (17)	Korhogo (09)	HSKO 042 HSKO 043 HSKO 044 HSKO 046 HSKO 047 HSKO 052
		HSKO 053
Northeast (01)	Niakara (02)	HSNI 054
	Agnibilekrou (01)	HSNI 058
	Bangolo	HSAG 080
West (04)	Bangolo (01)	HSAB 015
South (01)	Bangolo campement (01)	
	Bangolo campement Duekoue (01)	
	HSDU 022 Ziagolo (01)	
	Ziagolo Abobo-baoule (01)	
	Abobo-Baoule Koumassi (01)	

Source : Prospecting data (Anzara et al., 2023)

Table II. Quantitative parameters studied during the study

Stage of development	**Descriptors (unit)**	**Code**
	Germination time	TeGe
Seedling (seedling stage)	Sheet length (cm) Sheet Width (cm)	LoFe LaFe
	Diameter from Stem to Collar (cm)	DiTc
	Shaft Diameter (cm)	DiTi
	Number of Separated Lobes	NoLs
	Leaf Petiole Length (cm)	LoPf
Vegetative stage	Leaf Petiole Width (cm)	LaPf
	Blade length	LoLe
	Blade width (cm)	LaLe
	Plant Height (cm)	HaPl
	First flower appearance time (days)	TaF
Flowering stage	Flower diameter (cm)	DiF

	Flower Peduncle Length (cm)	LpF
	Number of Fruits per Plant	NoFr
	Opening date of the first capsules (day)	DoCa
Fruiting stage	Number of fruiting branches	NoBf
	Weight of 100 seeds	Seln
	Number of Seeds per Fruit	NgFr

a: seedling stage

b: Vegetative stage

c: Flowering stage

d: Fruiting stage

Figure 1. Different stages of development

Statistical processing of data:-

Descriptive analysis at a 95% confidence interval showed the variability of the measured traits. After checking for normality, the Kruskal-wallis test was performed to check if there was a difference between the accessions according to the parameters studied. When there was a difference, Dunn's post-hoc test made it possible to group them together and classify the groups obtained. A Pearson correlation test was performed, to see the link between the parameters taken two by two. With K=3, the Classification by the dynamic cloud method (k-means) made it possible to divide the accessions into three different groups, namely the performers, the average performers, and the worst performers. The F-value of the ANOVA coupled with the k-means method made it possible to test the significance of the established groups at a 95% confidence level.

Results and Discussion:-

Results:-

Variability of quantitative traits at each stage:-

Descriptive analysis coupled with the Kruskal-wallis test at each stage of development revealed significant differences ($P<0.05$) between accessions for all variables studied at the 5% threshold except for five variables including leaf length at the seedling stage, stem diameter, leaf petiole width and leaf blade length at the vegetative stage and weight of 100 seeds at the stage of fruiting. At the seedling stage (Table III), the germination time varies between 3 and 6 days with an average of 3.87 ± 0.95 days, for a coefficient of variation (CV) of 25%. The average leaf length is 2.61 ± 0.85 cm (CV = 33%), while the average width is 2.41 ± 0.64 cm with CV = 26%. As for the diameter of the stem at the collar, it shows an average of 0.40 ± 0.13 cm and a coefficient of variation CV of 33%, reflecting a moderate diversity within the accessions. In the vegetative stage (Table IV), the stem diameter increases to an average of 0.807 ± 0.201 cm with a coefficient of variation of 25%, which remains relatively stable. On the other hand, the number of separated lobes varies greatly between accessions (0 to 5), with a mean of 3.393 ± 1.329 and a high coefficient of variation of 39.1%. The average leaf petiole length is 7.473 ± 1.741 (CV = 23.3%), while the leaf petiole width is highly variable and has a high coefficient of variation of 32.7%.

The length and width of the blade show averages of 10.947 ± 1.939 cm (CV = 17.7%) and 9.728 ± 2.072 cm (CV = 21.3), respectively. The height of the plants varies greatly, with an average of 31,560 ± 10,607 cm and a coefficient of variation of 33.5% showing high variability in growth between individuals. At the flowering stage (Table V), the appearance of the first flower varies from 74 to 192 days with an average of 146.705 ± 24.809 days, for a coefficient of variation of 16.9%. While the mean flower diameter is 5.242 ± 1.089 cm (CV = 20.7%), indicating a significant average variability between accessions. The length of the flower peduncle has an average of 1.097 ± 0.509 cm with a coefficient of variation CV = 46.3%, this translates into a high variation. Finally, at the fruiting stage (Table VI), the number of fruits per plant shows a high variability with an average of 28,898 ± 12,080 fruits and a high coefficient of variation of 89.4%. Similarly, the number of fruiting branches shows a significant variation (CV = 71.5%). However, parameters such as the date of opening of the first capsules and the weight of 100 seeds show little variation, with coefficients of variation CV = 12.7% and 18.4% respectively. The number of seeds per fruit shows moderate variability (CV = 21.2%) with a mean of 28.384 ± 6.039.a

Table III. Mean value ± standard deviation, minimum, maximum and coefficient of variation (CV) of the quantitative traits analyzed at the 2-sheet stage

Statistics	Min	Max	Mean ± Standard Deviation	CV (%)	F	Pr > F
TeGe	3	6	3.87 ± 0.95	25	2.681	< 0.05
LoFe	1	5.1	2.61 ± 0.85	33	1.309	=0.147
LaFe	1	5	2.41 ± 0.64	26	1.927	<0.05
DiTc	0.11	0.94	0.40 ± 0.13	33	3.189	< 0.05

TeGe : Germination time, LoFe : Leaf length, LaFe : Leaf width, DiTc : Diameter from stem to collar

Table IV. Mean value ± standard, minimum, maximum deviation and coefficient of variation (CV) of quantitative traits analysed at the vegetative stage

Statistics	Min	Max	Mean ± Standard Deviation	CV (%)	F	Pr > F
DiTi	0.35	1.69	0.807± 0.201	25.00	1.218	= 0.217
NoLs	0.00	5.00	3.393 ± 1.329	39.1	6.134	< 0.05
LoPf	2.40	13.40	7.473 ± 1.741	23.3	1.938	<0.05
LaPf	0.20	9.34	0.443 ± 0.146	32.7	0.862	= 0.667
LoLe	6.10	16.20	10.947 ± 1.939	17.7	1.059	= 0.390
LaLe	4.50	19.50	9.728 ± 2.072	21.3	1.674	< 0.05
HaPl	8.20	71.50	31.560 ± 10.607	33.5	5.011	< 0.05

DiTi : Diameter of the stem, NoLs : Number of separate lobes, LoPf : Length of the leaf petiole, LaPf : Width of the leaf petiole, LoLe : Length of the blade, LaLe : Width of the blade, HaPl : Height of the plant

Table V. Mean value ± standard deviation, minimum, maximum and coefficient of variation (CV) of quantitative traits analyzed at the flowering stage

Statistics	Min	Max	Mean ± SD	CV (%)	F	Pr > F
TaF	74.00	192.00	146.705 ± 24.809	16.9	31.720	< 0.05
DiF	3.168	7.736	5.242 ± 1.089	20.7	11.986	< 0.05
LpF	0.450	2.700	1.097 ± 0.509	46.3	13.152	< 0.05

TaF: First Flower Onset Time, DiF: Flower Diameter, LpF: Flower Peduncle Length

Table IV. Mean value ± standard, minimum, maximum deviation and coefficient of variation (CV) of quantitative traits analysed at the fruiting stage

Statistics	Min	Max	Mean ± SD	CV (%)	F	Pr > F
NoFr	5	155	28.898 ± 12.080	89.4	2.623	< 0.05
DoCa	109	217	187.347 ± 23.780	12.7	29.289	< 0.05
NoBf	1	18	4.625 ± 3.311	71.5	1.820	< 0.05
NgFr	12.6	41.4	28.384 ± 6.039	21.2	7.444	< 0.05
Selen	2	4	2.161 ± 0.396	18.4	1.375	= 0.108

NoFr: Number of Fruit per plant, DoCa: Date of opening of the first capsules, NoBf: Number of fruiting branches, Seln: Weight of 100 seeds, NgFr: Number of Seeds per fruit

Relationship between the parameter traits studied:-

The Pearson correlation matrix between quantitative traits is shown in Figure 2. It revealed significant relationships between the traits studied, with a strong structuring of vegetative, floral and productive traits. Leaf traits are positively correlated with each other, including leaf length and width (r = 0.70), and leaf blade length and width (r = 0.70), reflecting proportional vegetative growth. Plant height is positively associated with flower diameter (r = 0.55) and flower peduncle length (r = 0.54), indicating that vigorous plants develop larger floral organs. On the other hand, the time of appearance of the first flower is negatively correlated with flower diameter (r = –0.68), flower peduncle length (r = –0.63) and number of fruits per plant (r = – 0.56), suggesting that late flowering penalizes the expression of yield traits. The production parameters are strongly related to each other, with a very high positive correlation between flower diameter and the number of fruits per plant (r = 0.93), as well as between the number of fruits per plant and the number of fruiting branches (r = 0.77) and the number of seeds per fruit (r = 0.72).

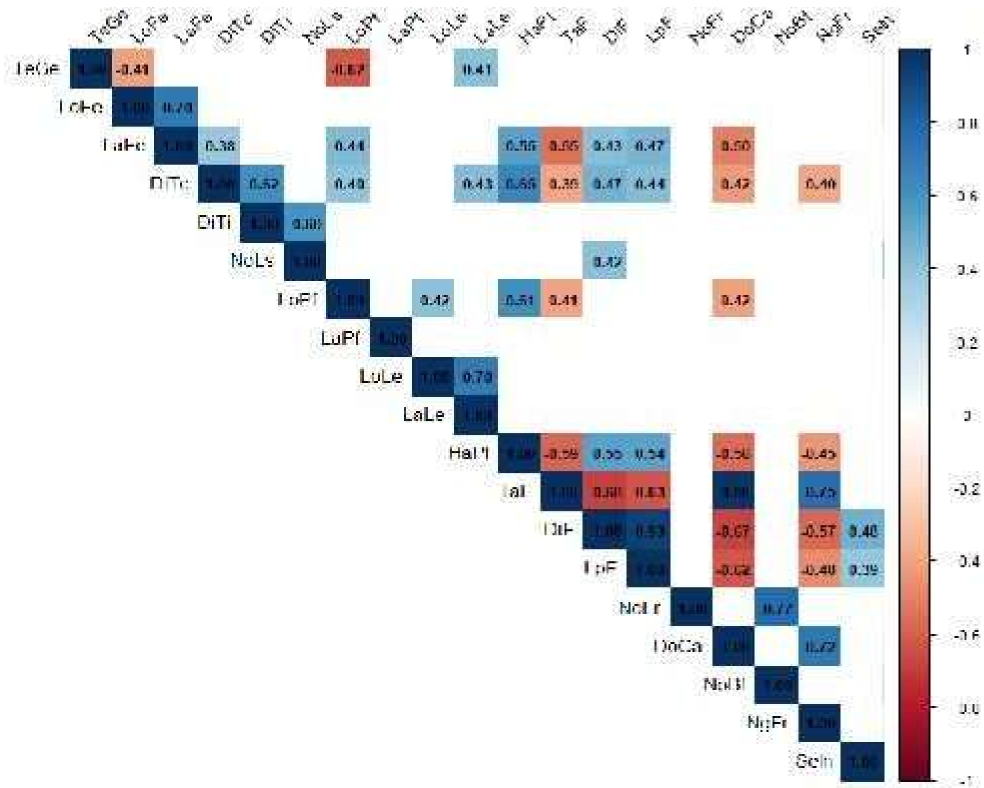

Figure 2. Pearson correlation matrix between quantitative traits

TeGe : Germination time, LoFe : Leaf length, LaFe : Leaf width, DiTc : Diameter of stem at collar, DiTi : Diameter of stem, NoLs : Number of Separate Lobes, LoPf : Length of leaf petiole, LaPf : Width of leaf petiole, LoLe : Blade length, LaLe : Width of leaf blade, HaPl : Height of plant, TaF: First Flower Appearance Time, DiF: Flower Diameter, LpF: Flower Peduncle Length, NoFr: Number of Fruit per Plant, DoCa: Date of Opening of First Capsules, NoBf: Number of Fruiting Branches, Seln: Weight of 100 Seeds, NgFr: Number of Seeds per Fruit

Structure of the morpho-phenological diversity of accessions:-

Table VII presents the results of the Principal Component Analysis performed on quantitative traits. This analysis made it possible to identify five main axes that explain 70.07% of the total variability observed. Axis 1 accounted for 30.39% of the total variability. The variables that contributed most to the formation of this component were the time of appearance of the first flower (TaF), the date of opening of the first capsules (DoCa) and the number of seeds per fruit. All these variables were positively correlated with axis 1. The variables leaf width (LaFe), stem diameter at crown (DiTc), leaf petiole length (LoPf), plant height (HaPl), flower diameter (DiF), and flower peduncle length (LpF) were negatively correlated with this axis, this axis can be referred to as the vegetative vigour axis. Axis 2, which represents 14.75% of the total variance, combining germination time (TeGe), stem diameter (DiTi), blade length (LaLe) and number of fruits per plant. These variables were positively correlated with axis 2. This axis can be considered as an axis of potential yield and robustness. Axis 3, representing 12.20% of the total inertia, positively associates the variable limb length (LoLe). The variable number of separate lobes is negatively correlated with this axis. Axis 4, showing 10.53% of the total variability, positively associates the variable number of fruiting branches (NoBf). Axis 5 (7.21%) was formed, primarily, from leaf length.

Table VII. Eigenvalues, percent variance and correlation between morphophenological traits and the five main PCA factors

	Axis 1	Axis 2	Axis 3	Axis 4	Axis 5
Eigenvalue	5.772	2.802	2.319	2.001	1.370
Variability (%)	30.378	14.745	12.204	10.532	7.210
Cumulative %	30.378	45.123	57.327	67.859	75.070
Variable	Correlation between variables and factors				
TeGe	0.377	0.538	-0.313	-0.439	-0.008
LoFe	-0.279	-0.486	0.216	0.216	0.561
LaFe	-0.688	-0.321	0.278	-0.078	0.333
DiTc	-0.655	0.481	0.173	-0.172	0.060
DiTi	-0.440	0.479	-0.096	-0.129	0.472
NoLs	-0.160	0.599	-0.649	0.155	0.292
LoPf	-0.612	-0.085	0.562	0.142	-0.071
LaPf	0.086	-0.018	0.401	-0.166	0.313
LoLe	-0.109	0.506	0.725	-0.103	0.054
LaLe	-0.131	0.684	0.317	-0.476	0.062
HaPl	-0.770	0.064	0.344	-0.025	-0.274
TaF	0.860	0.149	0.166	0.085	0.269
DiF	-0.843	0.136	-0.319	0.164	0.014
LpF	-0.809	-0.030	-0.281	0.221	0.028
NoFr	0.156	0.650	0.153	0.553	-0.260
DoCa	0.848	0.114	0.181	0.097	0.255
NoBf	-0.076	0.345	0.210	0.804	-0.190
NgFr	0.706	0.047	0.245	0.410	0.196
Selen	-0.270	0.139	-0.217	0.433	0.409

TeGe : Germination time, LoFe : Leaf length, LaFe : Leaf width, DiTc : Diameter of stem at collar, DiTi : Diameter of stem, NoLs : Number of Separate Lobes, LoPf : Length of leaf petiole, LaPf : Width of leaf petiole, LoLe : Blade length, LaLe : Width of leaf blade, HaPl : Height of plant, TaF: First Flower Appearance Time, DiF: Flower Diameter, LpF: Flower Peduncle Length, NoFr: Number of Fruit per Plant, DoCa: Date of Opening of First Capsules, NoBf: Number of Fruiting Branches, Seln: Weight of 100 Seeds, NgFr: Number of Seeds per Fruit

Morphophenological groups of Guinea sorrel accessions:-

At the seedling stage:-

Class 1 includes accessions with longer germination times (TeGe=3.961 days), longer leaves (LoFe=2.871 cm) and widest leaves (LaFe=2.587 cm), reflecting good morphological development from this early stage.

Class 2 is distinguished by intermediate values for most of the measured traits The germination time is the shortest (TeGe=3.441 days), but the leaves are significantly smaller than those of class 1. This class is then composed of the moderately growing accessions, but with faster germination.

Class 3 is characterized by a high value of germination time, showing a longer time for seedling emergence, however it has the lowest values for other traits such as leaf length, leaf width and stem diameter at the collar, suggesting a slower initial development despite late germination. Only the length of the leaves (LoFe) made it possible to clearly differentiate the three groups formed (Table VIII).

Table VIII. Average characteristics of K-Means classes at the seedling stage

Traits	Class 1	Class 2	Class 3	Pr > F(Model)
TeGe	3.961[ab]	3.441[b]	4.286[a]	**<0.05**
LoFe	2.871[a]	2.548[b]	2.163[c]	**<0.05**
LaFe	2.587[a]	2.371[a]	2.100[b]	**<0.05**
DiTc	0.42	0.412	0.362	**=0.132**
	HSKO 044_A	Ziagolo_S	HSDA 001_A	
	HSFE 031_S	HSAB 015_S	HSBK 006_A	
	HSKO 047_S	HSFE 032_A	HSNI 058_S	
	HSAG 080_A	HSBO 024_A	HSBK 003_A	
	Bangolo campement_S	HSBK 002_S	HSKO 040_A	
seedling stage	HSFE 028_A Bangolo_S	HSKO 052_S HSBO 026_S	HSKO 042_S HSNI 054_S	
	HSKO 043_A		Abobo-Baoule_A	
	HSKO 037_A		HSBO 023_A	
	HSBK 004_S		HSKO 046_A	
	HSKO 053_A			

TeGe : Germination time, LoFe : Leaf length, LaFe : Leaf width, DiTc : Diameter from stem to collar

In the vegetative stage:-

Class 1 is characterized by a high plant height (HaPl=37.74 cm), a large blade length (Lole=11.19 cm) and a noticeable blade width (LaLe=9.97 cm). These accessions therefore show good vegetative development and have a high growth potential.

Class 2 is composed of accessions with a higher number of separated lobe (NoLs=4), a length and width of the blade comparable to that of Class 1, but a slightly lower plant height.

Class 3, on the other hand, has the lowest values for many of the traits studied. (Table IX). Only leaf petiole length (LoPf) and plant height (HaPl) significantly differentiated the three classes. However, only the height of the plant made it possible to differentiate them distinctly.

Table IX. Average characteristics of K-Means classes at the vegetative stage

Traits	Class 1	Class 2	Class 3	Pr > F(Model)
DiTi	0.797	0.402	0.772	**0.643**
NoLs	2.682	3.838	3.449	**0.071**
LoPf	7.970[a]	7.540[a]	6.681[b]	**0**
LaPf	0.429	0.41	0.47	**0.701**
LoLe	11.194	11.203	10.573	**0.162**

LaLe	9.977	9.94	9.588	**0.743**
HaPl	37.742[a]	30.624[b]	23.853[c]	**< 0.0001**
	HSBK 006_A	HSAG 080_A	HSDA 001_A	
	Bangolo campement_S	HSBO 024_A	HSKO 047_S	
	HSAB 015_S	HSKO 042_S	HSBO 023_A	
	HSBK 004_S	HSKO 040_A	HSBK 002_S	
	HSFE 032_A	HSBO 026_S	HSKO 053_A	
Vegetative stage	HSKO 043_A	HSKO 044_A	HSKO 046_A	
	Ziagolo_S	HSNI 054_S	HSFE 028_A	
	HSKO 037_A		HSKO 052_S	
	Bangolo_S		HSNI 058_S	
	HSBK 003_A		Abobo-Baoule_A	
	HSFE 031_S			

DiTi : Diameter of the stem, NoLs : Number of separate lobes, LoPf : Length of the leaf petiole, LaPf : Width of the leaf petiole, LoLe : Length of the blade, LaLe : Width of the blade, HaPl : Height of the plant

In the flowering stage:-
Class 1 occupies an intermediate position, with late flowering and medium-sized flowers (DiF=5.8 cm).
Class 2 has an early flowering (TaF=108.26 days), large diameter flowers (DiF=6.14 cm) and relatively longer peduncles. The accessions of this class are the earliest to flower with large fruits with long stalks.
Class 3 is characterized by the highest time of appearance of the first flowers (TaF=161.38 days), associated with the smallest flower diameter (DiF=4.69 cm) and the length of the flower peduncle (LpF=0.837). This shows that the accessions of this class are characterized by a late flowering accompanied by smaller flowers. (Table X)

Table V. Average characteristics of K-Means classes at the flowering stage

Traits	**Class 1**	**Class 2**	**Class 3**	**Pr > F(Model)**
TaF	143.609[b]	108.268[c]	161.703[a]	**< 0.05**
DiF	5.8[a]	6.138[a]	4.66[b]	**< 0.05**
LpF	1.381[a]	1.469[a]	0.811[b]	**< 0.05**
	HSKO 046_A	Ziagolo_S	HSKO 044_A	
	HSAB 015_A	Bangolo campement_S	HSDA 001_A	
	HSBO 026_S	HSBK 004_S	HSKO 047_S	
	HSKO 040_A	HSFE 031_S	HSKO 042_S	
		Bangolo_S	HSFE 028_A	
		HSKO 037_A	HSFE 032_A	
		HSKO 043_A	HSBO 023_A	

			HSBO 024_A	
Flowering stage			HSKO 053_A	
			HSBK 006_A	
			HSAG 080_A	
			HSBK 002_S	
			HSKO 052_S	
			HSNI 054_S	
			HSNI 058_S	
			HSBK 003_A	
			Abobo-Baoule_A	

TaF: First Flower Onset Time, DiF: Flower Diameter, LpF: Flower Peduncle Length

At the fruiting stage:-

Class 1 shows an intermediate position, with an average number of fruits (25.51) and seeds (30.11), but with a longer capsule opening time (DoCa) (201.97 days), which could slow down the availability of seeds at maturity. Class 2 brings together the best performing accessions in terms of productivity with the highest number of fruits per plant (46,046) and a high number of seeds per plant (31,27). It also has the highest number of fruiting branches (6.31).

Class 3 is characterized by the lowest values in number of fruits per plant (20.86) and number of seeds per fruit. (Table XI)

Table XI. Average characteristics of K-Means classes at the fruiting stage

Traits	**Class 1**	**Class 2**	**Class 3**	**Pr > F(Model)**
NoFr	25.514[b]	46.046[a]	20.864[b]	**< 0.05**
DoCa	201.971[a]	191.117[a]	158.476[b]	**< 0.05**
NoBf	4.198[a]	6.308[a]	4.230[b]	**< 0.05**
NgFr	30.269[a]	31.269[a]	22.958[b]	**< 0.05**
Selen	2.115	2.156	2.190	**=0.54**
	HSBO 023_A	HSKO 037_A	Ziagolo_S	
	HSKO 042_S	HSFE 031_S	HSBK 006_A	
	HSAG 080_A	HSBK 004_S	HSBO 026_S	
	HSBK 002_S	HSKO 046_A	Bangolo campement_S	
	HSBO 024_A	Bangolo_S	HSAB 015_S	
	HSKO 040_A		HSKO 044_A	
	Abobo-Baoule_A			
	HSKO 047_S			
Fruiting stage	HSKO 053_A HSNI 058_S			
	HSNI 054_S			
	HSFE 028_A			

	HSFE 032_S			
	HSKO 043_A			
	HSBK 003_A			
	HSDA 001_A			
	HSKO 052_S			

NoFr: Number of Fruit per plant, DoCa: Date of opening of the first capsules, NoBf: Number of fruiting branches, Seln: Weight of 100 seeds, NgFr: Number of Seeds per fruit

Selection of elite accessions by stage of development:-

The k-means classification made it possible to select the best ones at each stage of development. At the seedling stage, Class 1, shows the highest values for leaf length, leaf width and stem diameter at the collar, reflecting good morphological development from this early stage. The elite accessions at this stage are HSKO 044, HSFE 031, HSKO 047, HSAG 080, Bangolo camp, HSFE 028, Bangolo, HSKO 043, HSKO 037, HSBK 004, HSKO 053. At the vegetative stage, the accessions (HSBK 006, Bangolo campement, HSAB 015, HSBK 004, HSFE 032, HSKO 043, Ziagolo, HSKO 037, Bangolo, HSBK 003, HSFE 031) belonging to class 1 appear to be the most promising in terms of vegetative vigour. Class 2 from the flowering stage has the most favourable characteristics early flowering, large flowers, long peduncle, which is often sought after in varietal improvement. The elite accessions belonging to this class are Ziagolo, Bangolo camp, HSBK 004, HSFE 031 Bangolo, HSKO 037, HSKO 043. Class 2 at the fruiting stage, whose elite accessions are HSKO 037, HSFE 031, HSKO 004, HSKO 046, Bangolo, was distinguished by its high yield potential, characterized by a high number of fruits per plant, many seeds per fruit. Some accessions are consistently found in the best performing classes. These accessions (HSKO 037, HSFE 031, HSBK 004, Bangolo), which can be described as elite accessions, have good vigour at the seedling stage, balanced vegetative growth, abundant flowering and a high yield of fruit and calyx at maturity.

Discussion:-

The morpho-phenological evaluation of the different accessions at each stage of development carried out based on quantitative parameters, revealed a heterogeneity between accessions, as indicated by the Kruskal-wallis test. High values of coefficients of variation of traits such as leaf length, stem diameter at collar, number of separated lobes, leaf petiole width, plant height, peduncle length, number of fruits per plant, number of fruiting branches. According to Aljane and Ferchichi (2007), a high value of the coefficient of variation (30%) reflects the heterogeneity of the material studied. The mixing of several morphotypes within the same accession and the spontaneous shattering at maturity of certain accessions, which leads to seed losses, can also explain these results. Regarding morpho-phenological performance, the leaves varied from 4.5 cm to 19.5 cm (width) and from 6.1 cm to 16.20 cm (length) with petioles with an average length of 7.47 cm. According to McClintock et al. (2011), the leaf blade can reach 9 to 15 cm long and 9 to 20 cm wide in Senegalese varieties, and 10 to 16 cm long and 10 to 20 cm wide for Thai varieties (Bakasso, 2010; Hien, 2012). The blade is connected to the stem by a petiole 4 to 12 cm long. The average number of fruits per plant (28.38 capsules) remains low compared to the results of Bakasso (2010), which could be attributed to temperature variation and an early cessation of rains, resulting in flower bud drop. The accessions collected have a flowering date between 74 and 192 days.

Our results differ from those of Bakasso (2010) and Satyanarayana et al. (2017) which found respectively a cycle of 65 to 97 days for 50% flowering for genotypes grown in Niger and 153 to 163 days for 50% flowering for genotypes grown in India. According to Islam et al. (2008), the flowering date of Hibiscus sabdariffa depends not only on environmental conditions and genotypes but also on the sowing date. Hacket and Carolene (1982) reported that Hibiscus sabdariffa was sensitive to day length (i.e., it was a short-day plant that flowered when day length shortened). The correlations observed between the variables, whether positive or negative, could be exploited in a breeding program. And that improving one of these traits would improve the one to which it is positively correlated. For example, positive correlations are observed between leaf blade width and blade length (r = 0.70), petiole length and blade width (r = 0.58), plant height and flower diameter (r = 0.39), and petiole length and leaf blade width (r = 0.58) show that more vigorous plants produce more leaves and fruit. These results are like those obtained by Islam et al. (2008) and Bakasso (2010). Similarly, the positive and significant correlation between the date of opening of the first capsules and the time of appearance of the first flowers (r = 0.88), the length of the peduncle and the diameter of the flower (r = 0.82) and between the number of fruiting branches and the number of fruits per plant (r = 0.81), shows that certain morphological characteristics are directly related to reproductive performance and yield. In addition, negative correlations between certain variables, such as plant height and first flower appearance time (r = -0.47), first flower appearance time and flower diameter (r = -0.60), show that floral earliness is often associated with better vegetative performance. Analysis by the classification of dynamic swarms applied to the different stages of development has made it possible to highlight three homogeneous groups ranked according to the stage of development. At the seedling stage, Class 1, shows the highest values for leaf length, leaf width and stem diameter at the collar, reflecting good morphological development from this early stage. Also at the vegetative stage, accessions belonging to class 1 appear to be the most promising in terms of vegetative vigour. Class 2 from the flowering stage has the most favourable characteristics early flowering, large flowers, long peduncle, which is often sought after in varietal improvement. Class 2 at the fruiting stage was distinguished by a high yield potential, characterized by a high number of fruits per plant, many seeds per fruit. The analysis shows that the most successful accessions are not always consistent from one stage to another. Some early accessions at the seedling stage showed average vegetative vigour thereafter, while others that were slower at the start expressed better agronomic performance at maturity. However, a few accessions stood out for their regularity in the most successful classes at all stages observed. This phenotypic stability suggests good adaptability and high genetic potential. These accessions, considered elite, represent priority candidates for varietal improvement programs.

Conclusion:-

The goal of plant breeding is to create cultivars. It requires both elite accessions for their characteristics and a good understanding of them. The objective of our study was to identify elite accessions of Guinea sorrel through their morpho-phenological evaluation during four (4) stages of development. The results obtained based on the quantitative traits revealed a high variability for several traits related to growth and yield, such as plant height, leaf length, stem diameter and the number of fruits per plant. The structuring of the morpho-phenological diversity of accessions revealed three groups, regardless of the geographical origin of accessions. This study also highlighted important correlations between several variables related to yield and plant cycle. The comparison of accessions over the four stages of development made it possible to identify, at each stage, elite accessions. Some of them, such as HSKO 037, HSFE 031, HSBK 004 and Bangolo, have shown high stability and performance over the entire cycle, and could thus be used as starting material for a Guinea sorrel breeding programme. These accessions could be refined and used as parents for hybridisation trials in order to improve production.

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