Agromorphologic Characterisation of local and introduced Common Bean (*Phaseolus vulgaris*, L.) varieties performances in Côte d'Ivoire central region

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1 ABSTRACT

The aim objective of this study was to evaluate the agro-morphological performances of 35 common bean accessions from local collections or introduction under the agro-ecological conditions of Côte d'Ivoire. For this purpose, the trial was established according to a randomized complete blocks design (RCBD), and screening was made vegetative growth parameters, phenological stages, and yields and yield components. The results obtained in the present study showed significant difference for vegetative development, between accessions for the number of nodes, pod length, seed length and diameter. Regarding the flowering stage and maturity time, early and late maturing accessions were identified. Yield and its components, less productive accessions and ones that are more productive were observed regardless of their provenance. Among the accessions studied, HARI04/BKE18, HARI12/GHA18, HARI13/GHA19, HARI16/GHA19, HARI18/GHA18, HARI28/GHA19 and HARI35/GHA19 were identified as the most promising.

2 INTRODUCTION

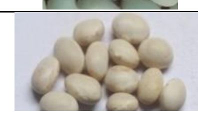
Agriculture is a major economic sector on which counts the big part of African population for its livelihood, particularly that of Cote d'Ivoire. The sector employs more than 60% of the active population and contributes to more than 35% of the country's gross domestic product (GDP) (OECD/FAO, 2016). Agriculture remains the foundation of the Ivorian economy with a large share offered by export crops. Through implementation of the country policy on food security, agriculture products were diversified with the promotion of food crops, among them grain legumes, including the common bean (OECD/FAO, 2016). Common beans contain more than 20% proteins and are a key source of minerals in human diet, especially iron and zinc and other essential micronutrients that are found in low amounts in the cereals and root crops (Wang *et al.,* 2003). Common bean cultivars show variability for seed mineral accumulation with iron concentration ranging from 30 to 120 ppm (Guzman-Maldonado *et al.,* 2003, 2004; Islam *et al.,* 2002) and zinc concentration ranging from 20 to 60 ppm (Welch *et al.,* 2000;

Hacisalihoglu *et al.,* 2004). Common beans are therefore one of the best sources of iron and zinc; two of the most common nutritional deficiencies affecting more than 2 billion people in the world (Mirindi *et al.,* 2018). Common beans are widely distributed and very diverse all around the world (Blair *et al.,* 2010). The world production of faba beans reaches 4.3 Million tons from total cultivated area of 2.55 Million hectares (FAO STAT, 2010). The common bean occupies an important place in tropical Africa in terms of consumption volume after groundnut and cowpea. In 2008, Côte d'Ivoire produced 4,761 tons of green beans and 25,950 tons of cowpeas (PNIA, 2017). Regarding national production of dry beans, statistics could not provide any data because this crop is in danger of disappearing (PNIA, 2017). In fact, surveys have shown that dry bean cultivation has become marginal in the producing areas. A few producers, particularly women in rural areas, now practice it. Moreover, it is mainly used for family consumption. Its cultivation being relegated to the background, favours its disappearance. The varieties used by producers are traditional with low yields (MINADER, 2009). Faced with this situation, the National Centre for Agronomic Research (CNRA) through the Vegetable and Protein Research Program (VPRP) has initiated research on this crop and will provide to farmers well adapted high yielding dry bean varieties. The aim of this study is to promote dry beans varieties with well-established agro-morphological characteristics. The study will focus especially on (1) determining the morphological characteristics and phenological stages of the accessions or bean lines; (2) estimating the yield parameters of the accessions or bean lines; (3) and identifying promising accessions or bean lines based on yield.

3 MATERIALS AND METHODS

3.1 Plant material: The plant material consists of the seeds of 35 accessions from local collection and common bean varieties introduced from Ghana and Kenya. Among the bean accessions collected across Ivory Coast regions, one (01) was from the northern, another one (01) from the centre region and two (02) accessions from western region. Two (02) accessions and twenty-nine (29) lines were introduced respectively from Kenya and Ghana. All the accessions were named with a specific code, HARI standing for bean and followed by a serial number of the collection and the locality in the country or country of origin; and a number 18, 19 or 20 representing respectively the years of collection or introduction 2018, 2019 and 2020. The three Ivory Coast localities and the two countries of origin are represented as following Bouaké (BKE); Bonon (BON); Ferkessédougou (FER); Ghana (GHA); and Kenya (KEN) (Table 1).

Table 1: List of accessions collected in three localities of Ivory Coast and lines introduced from Ghana and Kenya

Groups	Accessions or lines	Seed type and colour
1	HARI16/GHA19 ; HARI20/GHA19 ; HARI21/GHA19 ; HARI23/GHA19 ; HARI24/GHA19	
2	HARI03/FER18 ; HARI14/GHA19 ; HARI15/GHA19 ; HARI17/GHA19 ; HARI18/GHA18 ; HARI25/GHA19 ; HARI26/GHA19 ; HARI28/GHA19 ; HARI29/GHA19 ; HARI30/GHA19 ; HARI31/GHA19 ; HARI34/GHA19	
3	HARI05/BON18 ; HARI06/BON18 ; HARI19/GHA19 ; HARI27/GHA19	
4	HARI07/GHA18 ; HARI08/GHA18 ; HARI09/GHA18 ; HARI10/GHA18 ; HARI11/GHA18 ; HARI12/GHA18 ; HARI13/GHA18 ; HARI33/GHA19	
5	HARI01/KEN16 ; HARI02/KEN18 ; HARI04/BKE18 ; HARI32/GHA19 ; HARI35/GHA19	
6	HARI22/GHA19	

BKE: Bouaké; **BON**: Bonon; **FER**: Ferkessédougou; **GHA**: Ghana; **KEN**: Kenya. **From 01 to 35**: Are serial numbers of accessions or lines. **18, 19 and 20** represent respectively 2018, 2019 and 2020 which are years of accessions or lines introduction.

3.2 Methods

3.2.1 Experimental design: The trial was conducted in a randomized complete block design (RCBD) with 3 replicates. The block factor was the accessions or lines. Each replication consisted of 35 elementary plots of 1 meter apart from each other. Each elementary plot consisted of 4 lines of 3 m long. On each line, 15 plants were counted; equal to 60 plants per elementary plot. The area of the experiment, including the alleys, was estimated at 3,000 m² with a total of 2,100 seedlings.

3.2.2 Cultural practices: Seeding was carried out at a density of 50 cm × 20 cm in the open field under rainfed conditions. One seed was sown per seed hole at a depth of about 3 cm. This sowing density corresponds to 300 000 seedlings/ha. Two hand weeding were carried out, the first one 21 days after sowing (DAS) and the second one 40 DAS. Seedlings staking was carried out 45 DAS. No fertilizer was applied during the cropping cycle. While conducting this experiment, climate data were collected. The average rainfall, temperatures and relative moistures (hygrometry) for each month of the crop cycle and the entire cropping season and year averages were calculated (Table 2).

Table 2: Monthly recorded Rainfall, temperatures and relative humidity (hygrometry) and for the entire cropping cycle and the year 2019.

	March	April	May	June	July	Cropping cycle	Year
Mean rainfall (mm)	150.50	106.00	133.90	42.90	114.60	547.90	1139.50
Mean temperatures (°C)	34.30	32.50	32.40	29.50	28.10	31.40	31.20
Mean relative Humidity (%)	78.00	81.10	82.60	83.60	92.30	83.50	84.50

3.2.3 Variety screening and data collection: Variety screening and evaluation were made on growth and vegetative development parameters including number of stem nodes, root collar diameter, leaf length and width, leaf area, pod and seed length, seed diameter and germination rate. The root collar was measured using a hardener stainless steel 0-150 Mm Digital Calliper. The leaf length and wide, the pod length and the seed diameter were measured with a ruler. The germination rate was calculated as follows, number of germinated seeds by number of sown seeds. The leaf area (LA) of the real leaves areas (Sf) is calculated using the equation:

$\mathrm{LA} = 0{,}86 \times \left[0{,}91 \times 3\left(0{,}95 \times \mathrm{L} \times \mathrm{l} \times {}^{\pi}/_{4}\right)\right]\mathrm{cm}^2$ (Cornelissen et al. (2002)).; where L = length of the leaf and l = width of the leaf.

Phenological stages (50% flowering, 50% pod filling, dehydration during fruit ripening and first harvest times) were established. The flowering time was determined when 50% of the plants had flowered, and it was the same for the fructification, which was, determined when 50% of the plants had its fructification. For dry common beans, flowering is considered early when it occurs before 35 days after sowing, and late when it is happened beyond that date. Yield parameters were also determined, to include number of seeds/pod, number of seeds/plant, pod weight /plant, seed weight/plant, pod weight/ha, seed weight/ha and the ratio (seeds weight/pods weight).

3.2.4 Statistical analysis: All data collected were analysed using STATISTICA 7.1 software, and one-criteria analysis of variance (ANOVA) was performed for all parameters studied. When a significant difference was observed between different parameters ($p < 0.05$), the comparison of means was done using Duncan's multiple range test (DMRT) at 5% significance level. A multivariate analysis with a hierarchical ascending classification (HAC) was performed, and it allowed to visualize the degree of similarity between common bean accessions or bean lines. The Ward's hierarchical clustering method (1963) was used as a criterion of agglomerative clustering, Euclidean distance, and the similarity index as a classification method.

4 RESULTS AND DISCUSSION

4.1 Growth and vegetative development Parameters:

Parameters: Table 3 illustrates the germination rate, leaf length, leaf width and leaf area in common beans. The analysis of variance (ANOVA) did not indicate any variability between accessions and lines with respect to the agro-morphological parameters studied; except for the germination rate which varied among accessions and lines. The lowest germination rates (from 1.3 to 3.33%) were observed in lines HARI01/KEN18, HARI09/GHA18 and HARI23/GHA19. While the highest rates were (from 46.66 to 49.77%) noted in HARI33/GHA19, HARI31/GHA19, HARI32/GHA19, HARI11/GHA18 and HARI26/GHA19.

Table 3: Germination rate, leaf length, leaf width and leaf area in common beans

Accessions and lines	Germination rate (%)	Leaf length (cm)	Leaf width (cm)	Leaf area (cm^2)
HARI01/KEN18	1.33±0.00[a]	10.50±0.70[a]	7.00±1.41[a]	518.26±138.66[a]
HARI02/GHA18	37.78±8.65[c]	8.30±0.99[a]	5.00±0.28[a]	289.66±18.23[a]
HARI03/FER18	12.66±4.66[b]	8.90±2.12[a]	6.80±1.41[a]	434.36±189.17[a]
HARI04/BKE18	42.21±5.97[c]	10.8±0.59[a]	5.25±0.35[a]	371.36±46.79[a]
HARI06/BON18	14.22±2.35[dde]	10.10±0.42[a]	5.70±0.14[a]	402.98±6.93[a]
HARI07/GHA18	40.88±10.01[c]	8.26±0.30[a]	5.33±1.44[a]	310.67±96.10[a]
HARI08/GHA18	25.33±12.02[bc]	7.73±0.58[a]	4.86±0.80[a]	26183±27.23[a]
HARI09/GHA18	3.33±0.67[a]	9.26±1.14[a]	5.26±0.57[a]	344.75±76.28[a]
HARI10/GHA18	14.22±2.91[b]	7.55±1.04[a]	4.33±1.52[a]	236.62±115.44[a]
HARI11/GHA18	48.44±9.41[cd]	9.66±1.47[a]	4.46±0.64[a]	406.78±204.44[a]
HARI12/GHA18	21.33±4.00[bc]	8.73±1.41[a]	5.70±0.14[a]	310.67±96.10[a]
HARI13/GHA19	13.77±8.58[b]	7.73±0.58[a]	3.93±0.50[a]	214.12±41.74[a]
HARI14/GHA19	23.33±10.60[bc]	9.25±1.76[a]	5.80±0.00[a]	372.06±149.80[a]
HARI15/BON18	30.66±6.01[c]	876±1.53[a]	5.40±1.04[a]	333.92±100.80[a]
HARI15/GHA19	28.00±18.00[bc]	8.46±0.64[a]	4.80±0.91[a]	266.36±59.73[a]
HARI16/GHA19	6.67±2.67[ab]	8.53±0.70[a]	5.10±0.14[a]	291.25±91.11[a]
HARI17/GHA19	7.33±6.00[ab]	10.30±0.70[a]	5.80±0.85[a]	418.37±26.72[a]
HARI18/GHA18	34.21±20.44[c]	8.13±0.70[a]	5.20±1.38[a]	326.64±127.47[a]
HARI19/GHA19	7.33±3.33[ab]	7.96±0.891[a]	5.40±0.70[a]	346.45±32.51[a]
HARI20/GHA19	34.22±10.45[c]	7.40±0.20[a]	4.40±0.80[a]	228.41±45.46[a]
HARI21/GHA19	7.11±2.35[ab]	9.50±0.95[a]	5.60±0.40[a]	373.61±58.60[a]
HARI22/GHA19	26.66±20.69[bc]	10.50±0.70[a]	5.043±0.39[a]	292.95±58.37[a]
HARI23/GHA19	3.33±2.00[a]	8.66±1.14[a]	5.62±1.24[a]	338.97±78.34[a]
HARI24/GHA19	27.55±13.25[bc]	7.80±1.05[a]	4.93±1.10[a]	273.42±93.87[a]
HARI25/GHA19	25.33±12.02[bc]	9.13±0.50[a]	5.73±1.33[a]	369.69±105.21[a]
HARI26/GHA19	47.55±622[cd]	7.53±0.40[a]	4.26±0.70[a]	223.65±27.78[a]
HARI27/GHA19	20.66±0.66[bc]	8.40±1.841[a]	4.90±0.70[a]	291.76±90.13[a]
HARI28/GHA19	22.22±13.86[bc]	9.26±0.72[a]	5.93±1.85[a]	389.86±1145.11[a]
HARI29/GHA19	23.33±20.67[bc]	11.20±5.38[a]	4.66±0.47[a]	470.91±284.85[a]
HARI30/GHA19	19.33±7.33[bc]	9.700±0.42[a]	5.40±1.13[a]	345.83±88.15[a]
HARI31/GHA19	46.22±0.58[cd]	8.60±0.70[a]	4.86±1.22[a]	296.85±96.64[a]
HARI32/GHA19	46.66±17.35[cd]	8.24±1.06[a]	5.80±2.22[a]	406.30±189.17[a]
HARI33/GHA19	49.77±2.35[cd]	8.26±1.22[a]	4.73±1.85[a]	284.62±153.95[a]
HARI34/GHA19	6.67±0.58[ab]	9.10±0.14[a]	5.53±0.64[a]	325.10±14.06[a]
HARI35/GHA19	34.66±6.66[c]	9.15±0.45[a]	4.66±1.20[a]	268.37±81.96[a]
Means	26.25	8.75	5.18	324.63
Significances	0.0242	0.1024	0.5627	0.2247
Cv (%)	8.20	14.83	20 .86	33.16

Means ± se in column of agro-morphological parameters followed by the same letter do not differ significantly at the 5% level of significance (Duncan's test).

Root collar diameter, number of nodes, pod length, seed length and diameter of the common bean accessions are presented in Table 4. The results in this study showed that variability was observed between accessions for number of nodes, pod length, length and diameter of seeds. However, there was no significant difference between accessions for root collar diameter. For the number of nodes, the smallest value (from 4 to 10) was found by the accessions HARI01/KEN18, HARI11/GHA18, HARI22/GHA19 and HARI23/GHA19. In addition, the accessions HARI07/GHA18, HARI08/GHA18, HARI09/GHA18, HARI10/GHA18, HARI13/GHA19, HARI18/GHA18 and HARI26/GHA19 yielded the highest values ranging from 27.66 to 30. As for the length of the pod, the accessions HARI15/GHA19 and HARI16/GHA19 were characterised with the highest values ranging from 11.54 to 11.59. For seed length, only HARI01/KEN18, HARI04/BKE, HARI09/GHA18, HARI17/GHA19 and HARI19/GHA19 showed the highest values from 1.10 to 1.30 cm compared to HARI02/GHA18, HARI03/FER1, HARI04/BKE18, HARI07/GHA18, HARI12/GHA18, HARI13/GHA19, HARI15/GHA19, HARI18/GHA18 and HARI20/GHA19, HARI23/GHA19, HARI26/GHA19, HARI27/GHA19, HARI28/GHA19 and HARI33/GHA19 which gave smaller values (0.70-0.93 cm). For seed diameter, the highest values (0.45 cm) were found on seeds of HARI01/KEN18, HARI04/BKE18, HARI17/GHA19, HARI27/GHA19 and HARI31/GHA19; while twelve (12) accessions from Ghana and one from Ivory Coast have the smallest values of the diameter (0.30-0.33 cm).

Table 4: Collar diameter, number of knots, pod length, seed length and diameter in common beans

Accessions and lines	Collar diameter (cm)	Nodes number	Pod length (cm)	Seed length (cm)	Seed diameter (cm)
HARI01/KEN18	3.00±0.00[a]	4.0 1±2412[a]	6.85±0.35[a]	1.20±0.14[c]	0.45±0.07 [c]
HARI02/GHA18	2.80±0.72[a]	21.00±4.24[bc]	8.45±011[a]	0.90±0.14[a]	0.35±0.07 [ab]
HARI03/FER18	3.60±0.00[a]	19.00±4.24[b]	9.26±1.30[a]	0.93±0.06[a]	0.35±0.07[ab]
HARI04/BKE18	3.00±0.00[a]	12.50±4.94[ab]	7.74±0.34[a]	1.30±0.42[c]	0.45±0.07[c]
HARI06/BON18	3.13±2.23[a]	23.50±9.20[c]	9.40±0.25[a]	1.05±0.07 [bc]	0.35±0.21[ab]
HARI07/GHA18	3.13±0.23[a]	29.66±3.05[cd]	8.93±1.16[a]	0.85±0.07[a]	0.30±0.00[a]
HARI08/GHA18	3.00±0.00[a]	28.33±9.07[cd]	8.30±0.50[a]	1.03±0.06[b]	0.33±0.06 [a]
HARI09/GHA18	3.26±0.30[a]	27.66±10.26[cd]	9.66±0.99[ab]	1.30±0.44[c]	0.40±0.00[b]
HARI10/GHA18	3.83±0.76[a]	27.66±10.78[cd]	8.52±0.42[a]	1.00±0.20 [b]	0.40±0.00[b]
HARI11/GHA18	3.07±0.11[a]	6.00±1.00[a]	8.50±1.36[a]	0.97±0.12[ab]	0.33±0.06[a]
HARI12/GHA18	3.00±0.00[a]	22.00±14.93[bc]	8.85±30.75[a]	0.90±0.26[a]	0.35±0.07 [ab]
HARI13/GHA19	3.13±2.23[a]	30.660±5.77[cd]	10.47±0.45[ab]	0.77±0.06 [a]	0.43±0.06[b]
HARI14/GHA19	3.40±0.56[a]	30.00±0.00[cd]	9.85±21.31 [a]	1.05±0.21[bc]	0.35±0.07[ab]
HARI15/BON18	3.00±0.00[a]	19.60±9.81[b]	8.20±0.52 [a]	1.03±0.06[b]	0.30±0.00[a]
HARI15/GHA19	3.40±0.35[a]	15.33±11.37[b]	11.59±1.07 [b]	0.90±0.10[a]	0.33±0.06[a]
HARI16/GHA19	3.40±0.28[a]	14.00±15.55[b]	11.54±0.90[b]	1.00±0.10[b]	0.30±0.00[a]
HARI17/GHA19	3.00±0.00[a]	12.00±11.31[ab]	8.40±0.42 [a]	1.10±0.14[c]	0.45±0.07[c]
HARI18/GHA18	3.00±0.00[a]	28.66±6.02[cd]	8.233±0.35 [a]	0.87±0.12[a]	0.37±0.06[b]
HARI19/GHA19	2.87±0.23[a]	12.00±5.65[ab]	8.30±0.09[a]	1.25±0.07[c]	0.40±0.14[b]
HARI20/GHA19	2.93±0.11[a]	11.33±8.74[ab]	8.50±0.35[a]	0.83±0.06[a]	0.43±0.06[b]
HARI21/GHA19	3.07±0.12[a]	10.33±7.02[ab]	7.30±0.89 [a]	1.00±0.00[b]	0.43±0.06[b]
HARI22/GHA19	3.20±0.35[a]	8.66±3.78[a]	9.67±0.99 [a]	1.07±0.06[bc]	0.30±0.10[a]
HARI23/GHA19	2.90±0.14[a]	9.50±9.19[a]	7.90±1.07 [a]	0.93±0.06[a]	0.30±0.14[a]
HARI24/GHA19	3.08±0.14[a]	10.33±7.76[ab]	10.14±2.17 [ab]	0.95±0.21[ab]	0.37±0.06[b]
HARI25/GHA19	2.73±0.80[a]	23.00±3.60[c]	9.50±0.54 [a]	0.93±0.06[abc]	0.33±0.06 [a]
HARI26/GHA19	3.06±0.11[a]	30.00±5.29[cd]	7.93±2.34 [a]	0.83±0.06[a]	0.30±0.00[a]

HARI27/GHA19	3.40±0.28[a]	10.00±8.48[a]	8.16±1.33[a]	0.70±2.47[a]	0.50±0.00[c]
HARI28/GHA19	3.06±0.30[a]	17.00±1.00[b]	8.32±0.02[a]	0.90±0.14[a]	0.37±0.12[b]
HARI29/GHA19	3.00±0.00[a]	12.00±5.66[ab]	8.39±1.86 [a]	1.00±0.14[b]	0.45±0.07[c]
HARI30/GHA19	3.20±0.56[a]	16.33±2.82[b]	8.50±1.14[a]	1.07±0.12[bc]	0.35±0.07[ab]
HARI31/GHA19	3.47±0.12[a]	11.00±3.00[ab]	10.39±0.54[ab]	1.20±0.17[cd]	0.47±0.06[c]
HARI32/GHA19	3.40±0.00[a]	20.67±4.04[bc]	10.34±0.86[ab]	1.00±0.00[b]	0.37±0.06[b]
HARI33/GHA19	3.06±0.11[a]	13.33±5.03[ab]	9.90±0.38[ab]	0.93±0.06[a]	0.33±0.06[a]
HARI34/GHA19	3.60±0.00[a]	12.66±7.57[ab]	9.85±0.70 [ab]	1.00±0.00[abc]	0.33±0.06[a]
HARI35/GHA19	3.06±0.11[a]	15.00±6.92[b]	8.23±1.78 [ab]	0.85±0.21[ab]	0.30±0.10 [a]
Means	3.11	17.94	9.16	0.99±0.18	0.37±0.08
Significances	0.2440	0.0240	0.0000	0.0198	0.0466
Cv (%)	10.70	54.97	14.51	18 .18	21.62

Means ± se in column of agro-morphological parameters followed by the same letter do not differ significantly at the 5% level of significance (Duncan's test).

Of the nine (9) agro-morphological parameters that were studied, only those related to leaf morphology (leaf length and width) and collar diameter showed no significant difference between the bean accessions used. The accessions and lines evolved independently of their origin. The growing site did not also influence leaf morphology and collar diameter in the dry bean accessions. According to Peyman (2015), the environmental factors had a small effect on the inheritance of traits with high heritability. The work of Foto *et al.* (2012) on the evaluation of growth parameters of different types of dry bean cultivars revealed variability between lines. According to Foto *et al.* (2012), the traits studied are influenced by both genetic and environmental factors. In addition, parameters such as germination rate, number of knots, pod length, seed length and diameter were found to be a source of variability between bean accessions. The bean accessions behaved differently from each other, and accessions from the same source were not the exception to this. The genes that control these traits may be different in these accessions. Each of these accessions belonging to the vulgaris species could be a given variety. Arjun and Anjan (2017) also obtained variability between a dozen of common bean genotypes with respect to pod and seed lengths.

4.2 Common bean phenological stages: The flowering, pod filling, pod drying and first harvest times were recorded in Table 5, and estimated in number of days after sowing (DAS). The analysis in this table showed a variability between accessions or lines for the phenological parameters studied. The flowering date allowed to determine accessions or lines whose values varied from 29 to 34 DAS, were qualified as early maturing accessions or lines. However, HARI01/KEN16 and HARI29/GHA19, which flowered 43 DAS after, were qualified as late maturing accessions or lines.

For pod filling times, accessions or lines such us HARI03/FER18, HARI04/BKE18, HARI07/GHA18, HARI09/GHA18, HARI10/GHA18, HARI11/GHA18, HARI14/GHA19, HARI15/GHA19, HARI16/GHA19, HARI17/GHA19, HARI18/GHA18, HARI22/GHA19, HARI23/GHA19, HARI25/GHA19, HARI26/GHA19, HARI28/GHA19, HARI30/GHA19, HARI31/GHA19, HARI33/GHA19 and HARI34/GHA19 in which values ranged from 40 to 44 DAS were considered early maturing; while HARI01/KEN16 was maturing late accessions with values that reach 53 DAS. With respect to dehydration during fruit ripening, early plants were observed in accessions or lines that produced values between 57 and 60 DAS. Only HARI29/GHA19 showed late dehydration during fruit ripening. As for the delay of first harvest, it was observed early maturing accessions or lines between 69 and 74 DAS. Late harvest accessions were at 82 DAS for HARI01/KEN16, HARI02/KEN18, HARI11/GHA18, HARI19/GHA19, HARI21/GHA19, HARI29/GHA19, HARI29/GHA19 and HARI35/GHA19.

Table 5: Flowering, fruiting, drying and first harvest times for common beans

Accessions and lines	Flowering time (DAS)	Pod filling time(JAS)	Pod drying time (DAS)	First harvest time (DAS)
HARI01/KEN16	43.00±3.32[bc]	53.00±6.14[bc]	68.00±9.02[b]	82.00±9.55[bc]
HARI02/KEN18	39.67±2.65[b]	51.33±2.65[b]	64.00±3.25[b]	82.00±4.78[bc]
HARI03/FER18	33.00±2.45[a]	43.00±2.36[a]	57.00±4.23[a]	69.00±2.98[a]
HARI04/BKE18	33.00±1.75[a]	43.00±4.55[a]	57.00±4.55[a]	69.00±0.95[a]
HARI05/BON18	38.67±0.00[b]	50.33±3.46[b]	65.00±6.23[b]	77.67±7.58[b]
HARI06/BON18	39.67±4.65[b]	49.67±3.21[b]	66.33±7.09[b]	77.67±5.04[b]
HARI07/GHA18	32.00±2.98[a]	42.67±5.67[a]	59.00±8.14[a]	77.67±6.33[b]
HARI08/GHA18	36.33±4.36[ab]	46.33±6.32[ab]	63.67±2.98[ab]	77.67±1.79[b]
HARI09/GHA18	31.00±2.45[a]	41.67±5.02[a]	58.33±3.25[a]	77.67±2.46[b]
HARI10/GHA18	32.00±0.00[a]	42.00±3.25[a]	58.67±4.36[a]	77.67±5.44[b]
HARI11/GHA18	30.00±0.01[a]	41.33±1.89[a]	59.33±3.26[a]	82.00±5.32[bc]
HARI12/GHA18	35.00±3.92[ab]	45.00±2.35[ab]	63.00±8.16[ab]	77.67±4.62[b]
HARI13/GHA18	34.00±2.63[a]	45.33±4.29[ab]	59.33±7.74[a]	73.33±7.02[a]
HARI14/GHA19	33.00±4.01[a]	43.00±2.53[a]	57.00±5.22[a]	69.00±3.65[a]
HARI15/GHA19	32.00±1.22[a]	42.33±3.45[a]	57.67±3.59[a]	69.00±5.10[a]
HARI16/GHA19	33.00±0.69[a]	43.00±3.82[a]	57.00±4.61[a]	69.00±4.33[a]
HARI17/GHA19	32.00±.000[a]	42.33±1.46[a]	57.67±2.89[a]	69.00±1.64[a]
HARI18/GHA18	32.33±2.56[a]	42.00±3.48[a]	57.67±2.46[a]	69.00±8.52[a]
HARI19/GHA19	39.00±4.12[b]	48.00±4.39[b]	64.00±7.13[b]	82.00±6.74[bc]
HARI20/GHA19	34.00±3.65[a]	45.33±1.53[ab]	59.33±3.48[a]	73.33±4.97[a]
HARI21/GHA19	35.33±2.56[ab]	46.33±3.64[ab]	60.33±0.75[a]	82.00±3.66
HARI22/GHA19	32.00±4.31[a]	42.33±4.23[a]	57.67±0.47[a]	73.33±4.68[a]
HARI23/GHA19	32.00±3.35[a]	42.33±3.64[a]	57.67±3.25[a]	73.33±4.65[a]
HARI24/GHA19	40.67±4.13[b]	51.33±7.00[b]	68.00±7.45[b]	77.67±7.35[b]
HARI25/GHA19	32.00±3.14[a]	42.33±5.23[a]	57.67±0.28[a]	69.00±5.43[a]
HARI26/GHA19	31.00±0.97[a]	41.67±1.89[a]	59.33±4.23[a]	77.67±5.61[b]
HARI27/GHA19	34.33±0.05[a]	45.00±4.62[ab]	59.67±6.18[a]	77.67±6.42[b]
HARI28/GHA19	33.67±2.63[a]	44.00±4.38[a]	58.33±2.12[a]	73.33±3.48[a]
HARI29/GHA19	43.00±3.17[bc]	53.00±2.65[bc]	71.00±9.10[bc]	82.00±1.94[bc]
HARI30/GHA19	29.67±1.65[a]	40.33±3.44[a]	58.67±3.56[a]	69.00±4.30[a]
HARI31/GHA19	31.00±0.98[a]	41.67±3.29[a]	59.00±2.48[a]	69.00±5.41[a]
HARI32/GHA19	34.00±4.00[a]	46.33±2.99[ab]	60.67±9.17[a]	77.67±3.13[b]
HARI33/GHA19	33.00±2.81[a]	44.33±2.58[a]	60.00±3.59[a]	73.33±5.06[a]
HARI34/GHA19	30.33±1.69[a]	40.33±.344[a]	58.33±1.99[a]	69.00±1.65[a]
HARI35/GHA19	37.33±3.25[b]	49.67±5.61[b]	64.00±2.79[ab]	82.00±3.51[bc]

Means	34.34±4.33	44.90±4.47	60.55±4.68	75.07±5.89
Significances	0.0001	0.0002	0.0001	0.0003
CV (%)	13.05	12.00	07.53	08.33

Means ± se in column of agro-morphological parameters followed by the same letter do not differ significantly at the 5% level of significance (Duncan's test).

The phenological stages in this study (flowering, pod filling, pod drying and first harvest delays) varied according to the accessions. Early and late maturing accessions were identified both for the plant material of the same or different origins. Early and late maturing accessions have been identified for plant material of the same or different origin. This would mean that the phenological stages were little influenced by their origin or by the environment of the experiment. The early or late phenological stages seem to be an endogenous character at each accession. Results from our study were similar to those obtained by Amanuel *et al* (2018). According to their conclusions; flowering, pod filling and pod ripening delays showed a significant difference between three (3) cultivars from Southwest Ethiopia.

4.3 Yield Components: The number of seeds per pod and seeds per plant, and pod and seed weights per plant in common beans were calculated and presented under Table 6. Of the four (4) parameters studied, only the number of seeds per pod and seeds per plant showed variability between accessions. The number of seeds per pod of HARI04/BKE18, HARI06/BON18 and HARI15/BON18 were identified as the best performers. Moreover, for the number of seeds per plant of HARI22/GHA, HARI11/GHA18, HARI12/GHA18 and HARI26/GHA19 were characterised as the best lines; as opposed to HARI27/GHA19, HARI19/GHA19 and HARI09/GHA18, which had the lowest values for this yield components.

Table 6: Number of seeds per pod, number of seeds per plant, weight of pods and seeds per plant in common beans

Accessions and lines	NbSd/Pod	NbSd/plt	WPod /plt (g)	WSd /plt (g)
HARI01/KEN18	8.50±0.71[ab]	98.50±26.16[c]	12.00±5.89[a]	10.00±4.24[a]
HARI02/GHA18	6.50±0.71[a]	98.00±5.66[c]	16.10±0.98[a]	14.50±2.64[a]
HARI03/FER18	6.50±0.71[a]	70.50±17.68[ab]	13.80±1.92[a]	17.80±0.28[a]
HARI04/BKE18	9.50±0.71[b]	160.50±81.32[e]	13.86±1.80[a]	10.50±4.04[a]
HARI06/BON18	10.50±0.71[b]	108.00±0.00[cd]	13.90±5.80[a]	17.00±11.78[a]
HARI07/GHA18	7.33±0.58[a]	92.33±4.93[c]	16.70±1.46[a]	11.00±4.63[a]
HARI08/GHA18	7.33±0.58[a]	91.67±29.70[c]	22.13±4.30[a]	18.66±6.36[a]
HARI09/GHA18	7.67±0.58[ab]	60.67±46.44[a]	16.40±1.51[a]	11.00±1.70[a]
HARI10/GHA18	8.00±1.00[ab]	99.33±24.01[c]	14.06±1.44[a]	13.53±2.64[a]
HARI11/GHA18	7.67±0.58[ab]	128.33±16.80[de]	24.33±4.04[a]	11.80±3.30[a]
HARI12/GHA18	8.00±0.00[ab]	138.50±4.95[de]	18.20±3.46[a]	13.50±0.70[a]
HARI13/GHA19	8.33±0.58[ab]	184.00±65.48[f]	19.2313.50[a]	11.50±1.28[a]
HARI14/GHA19	7.50±0.71[ab]	104.00±5.66[cd]	24.25±0.35[a]	17.00±1.41[a]
HARI15/BON18	11.00±1.00[b]	120.67±31.77[d]	11.20±1.96[a]	8.66±1.4[a]
HARI15/GHA19	8.00±1.00[ab]	119.33±12.10[d]	14.60±2.88[a]	15.20±3.86[a]
HARI16/GHA19	7.50±0.71[ab]	117.50±37.48[d]	17.53±3.9[a]	13.66± 5.66[a]
HARI17/GHA19	6.50±0.71[a]	91.00±12.73[c]	20.30±2.68[a]	13.50±5.94[a]
HARI18/GHA18	7.00±1.00[a]	118.00±63.21[d]	14.60±5.12[a]	15.73±0.70[a]
HARI19/GHA19	6.00±0.00[a]	63.50±9.19[a]	16.75±7.42[a]	16.10±4.84[a]

HARI20/GHA19	7.00±1.00^{a}	104.67±19.66^{cd}	13.66±4.17^{a}	11.20±1.44^{a}
HARI21/GHA19	8.67±1.15^{ab}	118.33±41.02^{d}	12.00±4.24^{a}	11.00±4.35^{a}
HARI22/GHA19	7.33±0.58^{a}	133.00±51.10^{de}	21.73±5.99^{a}	13.66±11.60^{a}
HARI23/GHA19	7.50±0.71^{ab}	84.50±13.44^{b}	13.08±4.96^{a}	21.10±1.55^{a}
HARI24/GHA19	7.67±0.58^{ab}	107.00±7.81^{cd}	17.20±3.53^{a}	14.00±3.00^{a}
HARI25/GHA19	7.33±0.58 ^{a}	114.67±27.01^{cd}	14.20±2.25^{a}	11.66±2.08^{a}
HARI26/GHA19	7.33±0.58^{a}	125.67±24.79^{de}	13.92±4.38^{a}	9.96±1.17^{a}
HARI27/GHA19	6.50±0.71^{a}	60.00±21.21^{a}	8.83±5.59^{a}	7.00±5.66^{a}
HARI28/GHA19	7.00±0.00^{a}	84.33±14.57^{b}	21.30±0.70^{a}	14.40 ±11.13^{a}
HARI29/GHA19	7.50±0.71^{ab}	113.50±30.41^{cd}	14 .60±1.97^{a}	13.20±1.27^{a}
HARI30/GHA19	8.00±1.41^{ab}	110.00±7.07^{cd}	14.90±2.10^{a}	12.00±2.82^{a}
HARI31/GHA19	6.67±0.58^{a}	84.33±6.81^{b}	17.80±13.03^{a}	18.20±5.20^{a}
HARI32/GHA19	7.00±0.00^{a}	80.00±28.48^{b}	16.24±12.96^{a}	21.20±5.03^{a}
HARI33/GHA19	7.33±0.58^{a}	112.67±18.56^{cd}	14.80±0.30^{a}	10.33±1.52^{a}
HARI34/GHA19	6.67±0.58^{a}	103.67±24.70^{cd}	15.40±5.09 ^{a}	10.66±5.50^{a}
HARI35/GHA19	7.00±0.00^{a}	115.67±13.65^{d}	19.50±2.68^{a}	11.80±2.84^{a}
Means	7.59±1.16	106.93±35.40	16.21	13.44
Significances	0.000	0.0170	0.3322	0.3119
Cv (%)	15 .28	5.05	34.48	38.61

Means ± se in column of agro-morphological parameters followed by the same letter do not differ significantly at the 5% level of significance (Duncan's test). **NbSd/Pod**: Number of seeds per pod; NbSd**/plt**: number of seeds per plant; **WPod /plt**: weight of pods per plant; **WSd /plt**: weight of seeds per plant

From the Table 7 where pods and seeds yields and ratios of the thirty-five (35) accessions of common beans are presented, the ratio estimation revealed no significant difference between the accessions, while pods and seeds yields varied among accessions. In terms of pods yield, HARI13/GHA19 gave the highest yield; HARI12/GHA19 had the lowest yields. For seeds yield, HARI04/BKE18, HARI16/GHA19, HARI28/GHA19 and HARI35/GHA19 had the best performance.

Table 7: Pods and Seeds Yields and Ratio (Pod Fill Index) for Common Beans

Accessions and lines	Pods yield (t/ha)	Seeds yield (t/ha)	Ratio
HARI01/KEN18	1.66±0.54^{b}	0.96±0.45^{a}	0.84±0.09^{a}
HARI02/GHA18	1.86±0.09^{c}	1.02±0.18^{ab}	0.84±0.06 ^{a}
HARI03/FER18	2.11±0.45^{cd}	1.21±0.45^{ab}	0.83±0.01^{a}
HARI04/BKE18	2.24±0.81^{cd}	1.47±0.81^{b}	0.78±0.03 ^{a}
HARI06/BON18	1.41±0.18^{ab}	0.63±0.01^{a}	0.79±0.13 ^{a}
HARI07/GHA18	1.96±0.07^{c}	1.24±0.08^{ab}	0.80±0.10 ^{a}
HARI08/GHA18	1.45±0.14^{ab}	0.71±0.14^{a}	0.84±0.06 ^{a}
HARI09/GHA18	1.83±0.19^{bc}	1.11±0.20^{ab}	0.81±0.09 ^{a}
HARI10/GHA18	1.66±0.34^{b}	0.89±0.13^{a}	0.82±0.02 ^{a}
HARI11/GHA18	1.96±0.20^{c}	1.18±0.28^{ab}	0.83±0.12^{a}
HARI12/GHA18	0.72±0.36^{a}	1.90±0.20^{c}	0.84±0.01^{a}
HARI13/GHA19	2.80±1.38^{d}	1.85±1.21^{c}	0.88±0.02 ^{a}
HARI14/GHA19	1.98±0.08^{a}	1.27±0.38^{a}	0.88±0.03^{a}
HARI15/BON18	1.74±0.27^{b}	1.02±0.44^{a}	0.77±0.02^{a}
HARI15/GHA19	1.92±0.34^{bc}	1.23±0.37^{ab}	0.85±0.02^{a}
HARI16/GHA19	2.05±0.54^{c}	1.46±1.46^{b}	0.83±0.00^{a}
HARI17/GHA19	1.98±0.27^{c}	1.27±0.33^{ab}	0.89±0.02^{a}

HARI18/GHA18	2.08±0.72[c]	1.47±0.63[b]	0.89±0.05[a]
HARI19/GHA19	1.92±0.73[bc]	1.28±0.73[ab]	0.83±0.05[a]
HARI20/GHA19	1.79±0.00[bc]	0.89±0.00[a]	0.82±0.11[a]
HARI21/GHA19	1.74±0.39[b]	1.22±0.40[ab]	0.81±0.06[a]
HARI22/GHA19	1.91±0.44[bc]	1.26±0.29[ab]	0.78±0.07[a]
HARI23/GHA19	1.92±0.54[bc]	1.34±0.66[ab]	0.91±0.02[a]
HARI24/GHA19	1.82±0.09[bc]	1.09±0.35b[a]	0.86±0.02[a]
HARI25/GHA19	1.70±0.52[b]	1.03±0.37[ab]	0.82±0.03 [a]
HARI26/GHA19	2.09± 0.52[c]	1.28±0.57[ab]	0.74±0.04 [a]
HARI27/GHA19	1.21±0.27[ab]	0.70±0.27[a]	0.47±0.13[a]
HARI28/GHA19	2.34±0.96[cd]	1.53±0.90[b]	0.79±0.02[a]
HARI29/GHA19	1.66±0.18[b]	1.00±0.03[ab]	0.79±0.01[a]
HARI30/GHA19	1.66±0.18[b]	1.02±0.00[ab]	0.80±0.00[a]
HARI31/GHA19	1.92±1.00[bc]	1.23±0.82[ab]	0.83±0.03[a]
HARI32/GHA19	1.66±0.64[b]	1.02±0.59[ab]	0.86±0.08[a]
HARI33/GHA19	2.04±0.22[c]	1.28±0.35[ab]	0.73±0.05[a]
HARI34/GHA19	1.53±0.26[ab]	0.96±0.06[a]	0.78±0.10[a]
HARI35/GHA19	2.35±0.38[cd]	1.56±0.37[b]	0.81±0.08[a]
Means	1.90±0.52	1.19±0.47	0.82±0.07
Significances	0.0423	0.0171	0.3255
Cv (%)	27.37	39.5	8.54

Means ± se in column of agro-morphological parameters followed by the same letter do not differ significantly at the 5% level of significance (Duncan's test).

The estimation of yield components across all common bean accessions showed that pods and seeds weights per plant and then pod filling index (ratio) were statistically identical. The parameters studied appear to be little influenced by external factors and the nature of each accession. The lack of variability of these agro-morphological parameters in accessions could be an intrinsic characteristic into the vulgaris species. In addition to the determination of pods and seeds numbers per plant and subsequent pods and seeds yields, less productive and more productive accessions were identified. Contrary to the results of this study, which presented yield components with variability between accessions and others without any significant difference, Ammar *et al.* (2015) in their study indicated significant differences among Faba bean genotypes for all the yield components. Among the thirty-five (35) accessions under screening in this study, seven accessions including HARI04/BKE18, HARI12/GHA18, HARI13/GHA19 ,HARI16/GHA19, HARI18/GHA18, HARI28/GHA19 and HARI35/GHA19 produced 1.5 t/ha or more for seeds yields. The best performing in-group were HARI12/GHA18 and HARI13/GHA19 with a yield closer to 2 t/ha.

4.4 Highlighting the degree of similarity and classification of accessions and common bean lines: To analyse the structuration of variability within the common bean collection, a hierarchical bottom-up classification was carried out using Ward's (1963) method. A dendrogram based on means of fifteen (15) parameters studied has identified three groups of agro-morphological diversity (Figure 1). The first cluster (group I) includes HARI05/BON18, HARI08/GHA18, HARI11/GHA18, HARI13/GHA, HARI18/GHA18, HARI20/GHA19, HARI26/GHA19, HARI27/GHA19, HARI29/GHA19 and HARI33/GHA19. The accessions and lines were characterized by a high germination rate and a high number of seeds per plant. The second cluster (Group II) groups together HARI01/KEN18, HARI06/BON18, HARI12/GHA18, HARI14/GHA19,

HARI15/BON18, HARI17/GHA, HARI22/GHA19, HARI23/GHA19, HARI24/GHA19, HARI28/GHA19, HARI32/GHA19 and HARI34/GHA19, which have generated the highest seed yield. And the third cluster (Group III) includes HARI02/GHA18, HARI03/FER18, HARI04/BKE18, HARI07/GHA18, HARI09/GHA18, HARI16/GHA19, HARI19/GHA19, HARI21/GHA19, HARI25/GHA19, HARI30/GHA19, HARI31/GHA19 and HARI35/GHA19 with more leaves development. Based on the high values of the Fisher's coefficient (F > 3), it was found that leaf area, number of seed/plant, and seed yield variables were the most discriminating (Table 8).

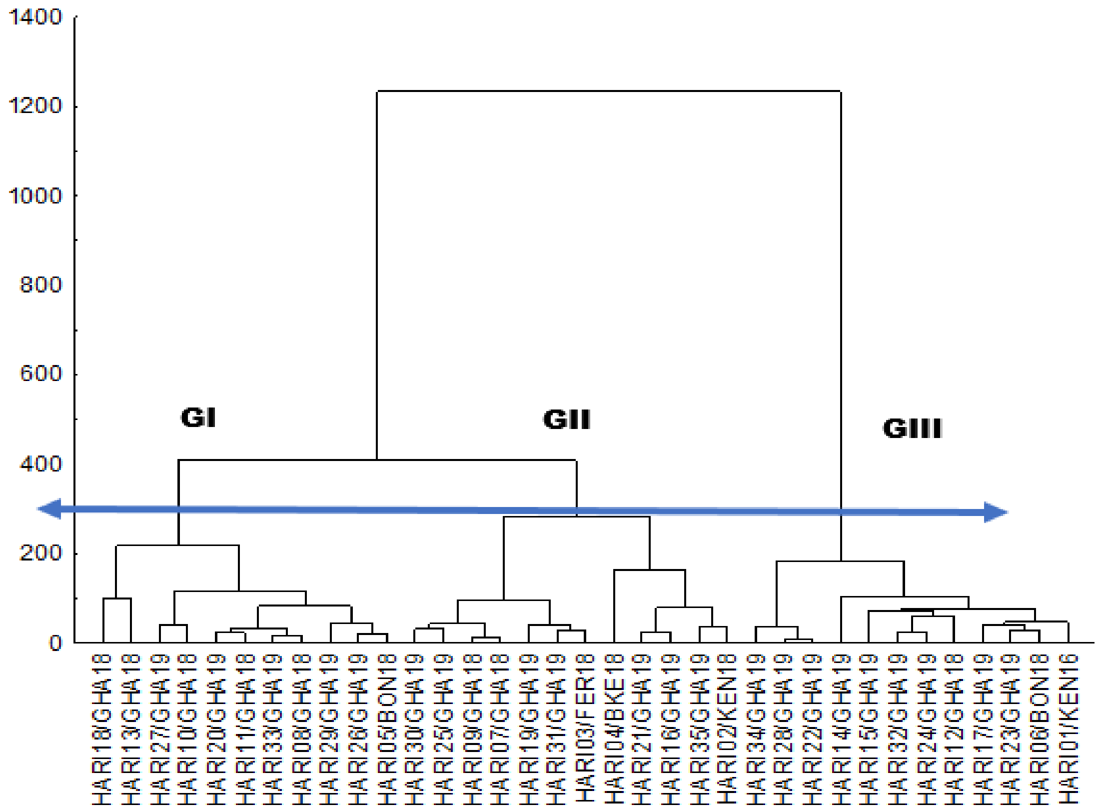


Figure 1: Ward's Hierarchical Ascending Classification (HAC) of 35 common bean accessions and lines

Table 8: Means, standard deviations and tests for comparison of group agro-morphological parameters resulting from the hierarchical classification of 35 common bean accessions and lines.

Agromorphological descriptors	Groups			Statistics	
	G1	G2	G3	F	p
Germination rate	33.06±5.39	23.05±3.99	14.44±5.24	**3.52**	**0.0421**
Leaf area	244.39±47.65	295.47±45.79	392.07±49.79	**27.53**	**0.0000**
Pod/plant weight	14.94±4.91	15.83±3.87	15.64±5.84	0.10	0.9086
Grain/plant weight	12.40±4.40	13.16±3.89	13.40±5.59	0.13	0.8773
Ratio	0.82±0.05	0.82±0.07	0.84±0.05	0.36	0.7011
Number of seeds/pod	7.90±1.29	7.42±1.24	7.83±1.11	0.54	0.5899
Number of seeds/plant	121.70±54.52	108.17±43.67	95.75±20.74	**4.59**	**0.0300**

Seed length	0.98±0.24	0.99±0.22	1.02±0.16	0.09	0.9133
Seed diameter	0.39±0.07	0.38±0.06	0.39±0.09	0.17	0.8445
Pods yield	1.71±0.41	2.16±0.46	1.96±0.46	2.88	0.0711
seeds Yield	0.97±0.38	1.55±0.45	1.18±0.48	**4.01**	**0.0383**
Flowering time	33.63±2.45	33.72±3.23	34.53±4.21	0.24	0.7891
Fruiting time	44.30±2.70	44.33±3.49	44.78±4.17	0.07	0.9370
Pod drying time	59.93±2.47	59.58±2.79	60.72±4.35	0.36	0.6996
First harvest time	75.07±4.19	74.06±5.79	73.33±4.53	0.34	0.7156

The results of the hierarchical classification carried out on the adjusted averages of the 15 agro-morphological parameters have allowed to generate three (3) classes of accessions separated from each other. The analysis of the grouping of these accessions into classes revealed that the individuals in group 2 had the best seeds yields. Those of group 1 had the highest germination rate and the highest number of seeds per plant. Group 3 accessions had the best leaves development. This structuring revealed that accessions from different geographical locations were grouped together in the same group, and similarly accessions from the same location were placed in different groups. Therefore, the structuring of accessions into groups in relation to the agro-morphological variables is independent of the geographical origin of the accessions. This result corroborates those of Kaushik *et al.* (2007) and Sunil et al (2010) who indicate that geographical diversity does not necessarily represent the genetic diversity between collected accessions. Furthermore, these accessions from different localities in Africa expressed significant performance. Results of their study indicates that the common bean has a certain plasticity (Prasad *et al.,* 2000) which is reflected in its high ecological adaptability as reported by several others authors (Achten *et al.,* 2008). This plasticity could favour the introduction of new common bean varieties in all agro-ecological zones in Ivory Coast. Similar results have been reported from Benin (Assogbadjo *et al.,* 2009). The presence of accessions from different origins in the same group could also be explained by their genotypic and phenotypic characteristics.

5 CONCLUSION

The results in this study showed that all bean accessions present the same performances for growth and vegetative development. On the other side, variability was noted between the different accessions on phenological stages and yield parameters. Highly and poor productive accessions were found in the group, seven (7) among these accessions were identified as promising lines as yields varied from 1.47 to 1.90 t/ha. HARI04/BKE18, HARI12/GHA18, HARI13/GHA19, HARI16/GHA19, HARI18/GHA18, HARI28/GHA19 and HARI35/GHA19 are the potential lines identified for further adaptability tests before release in the country.

6 Conflict of interest: The authors do not declare any conflict of interest.

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