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MORPHO-PHENOLOGICAL CHARACTERISTICS OF EXOTIC PIGEON PEA GENOTYPES IN WESTERN BURKINA FASO

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ABSTRACT

Pigeon pea (*Cajanus cajan* L.) is an important legume and multi-use crop, which contributes to food and nutritional security in sub-Saharan Africa (SSA). This crop, however, remains less popular and is thus underutilised in west Africa. The objective of this study was to characterise the morphological and phenological features of exotic pigeon pea genotypes in western Burkina Faso in order to provide an entry point for the breeding programme. The study was conducted at two sites, namely Farakoba and Kouentou, located in western Burkina Faso, involved seven exotic genotypes, namely ICP-15029, ICP-14722, ICP-8863, ICPL-20338, ICPH-2740, ICPH-2438 and ICPL-20092, sourced from ICRISAT, India. Also, two local accessions (FKB Cc1 and FKB Cc2) were included as controls. Results showed that semi-spreading (80% of the genotypes) and indeterminate growth habit (80% of the genotypes) were dominant in the genetic materials, with regards to branching pattern and growth habit, respectively. The genotypes including the two checks, were distinguished by three seed colours, *viz.* brown (three genotypes), dark brown (four genotypes) and grey (two genotypes). There were highly significant differences among the genotypes for phenological (P<0.001) and morphological (P<0.001) traits. The earliest genotype to flower at both sites was ICPL-20338; while the latest was ICPL-20092. A principal component analysis based on the quantitative traits showed that the first two PCs explained 91.78% of the total variation among the genotypes. The most significant contributor traits were stem diameter, leaf size, 50% flowering and plant height. Cluster analysis grouped the genotypes into five clusters.

Key Words: *Cajanus cajan*, diversification, food security, multi-use legume crop

RÉSUMÉ

Le pois d'Angole (*Cajanus cajan* L.) est une légumineuse importante et une culture polyvalente qui contribue à la sécurité alimentaire et nutritionnelle en Afrique subsaharienne (ASS). Cette culture reste cependant moins populaire et est donc sous-utilisée en Afrique de l'Ouest. L'objectif de cette étude était de caractériser les caractéristiques morphologiques et phénologiques des génotypes exotiques du pois d'Angole dans l'Ouest du Burkina Faso afin de fournir un point d'entrée au programme de sélection. L'étude a été menée sur deux sites, à savoir Farakoba et Kouentou, situés à l'Ouest du Burkina Faso, et a porté sur sept génotypes exotiques, à savoir ICP-15029, ICP-14722, ICP-8863, ICPL-20338, ICPH-2740, ICPH-2438 et ICPL-20092, provenant de l'ICRISAT, Inde. De plus, deux accessions locales (FKB Cc1 et FKB Cc2) ont été incluses comme contrôles. Les résultats ont montré que le mode de croissance semi-étalé (80 % des génotypes) et le mode de croissance indéterminé (80 % des génotypes) étaient dominants dans le matériel génétique, en ce qui concerne le modèle de ramification et le mode de croissance, respectivement. Les génotypes, y compris les deux témoins, se distinguaient par trois couleurs de graines, à savoir brun (trois génotypes), brun foncé (quatre génotypes) et gris (deux génotypes). Il y avait des différences très significatives entre les génotypes pour les traits phénologiques (P <0,001) et morphologiques (P<0,001). Le génotype le plus précoce à fleurir sur les deux sites était ICPL-20338 ; tandis que le dernier en date était ICPL-20092. Une analyse en composantes principales basée sur les caractères quantitatifs a montré que les deux premiers PC expliquaient 91,78 % de la variation totale entre les génotypes. Les caractères contributifs les plus significatifs étaient le diamètre de la tige, la taille des feuilles, le taux de floraison à 50 % et la hauteur de la plante. L'analyse groupée a regroupé les génotypes en cinq groupes.

Mots Clés : *Cajanus cajan*, diversification, sécurité alimentaire, culture de légumineuses multi-usages

INTRODUCTION

Pigeon pea (*Cajanus cajan* L.) is a multi-use legume crop in sub-Saharan Africa, that belongs to *Fabaceae* family (Vander, 1990). The crop provides abundant vegetative growth and meets immediate needs of food, fodder income, as well as longer-term needs of soil fertility enhancement through biological N fixation and fencing (Belete, 2022; Orr *et al.*, 2015). In addition to this, pigeon pea can be used for windbreaks or hedges to prevent soil erosion (Bationo *et al.*, 2007). The plucked foliage is rich in protein (21-25%) and fibre (30-35%), and is a good fodder for cattle and other livestock (Saxena *et al.*, 2008). In terms of biological N fixation, it is estimated that pigeon pea has potential to contribute 69 to 100 kg N per hectare per cropping season (Rao *et al.*, 1987).

Despite the considerable agronomic and nutritional significance of the crop, pigeon pea remains an under-exploited crop in west Africa (Ouedraogo *et al.*, 2010) and its cultivation has been trivial in countries like Burkina Faso (FAO, 2023a). Additionally, dismal research activity has been devoted to cultivar development and use in local farming systems (Vall *et al.*, 2019). A few varieties are grown sometimes on small plots or as windbreaks, usually through informal seed introductions. However, these genotypes smuggled into the country are not described for commercial exploitation to date. Accordingly, exotic pigeon pea performance and adaptability to local agro-climatic conditions in Burkina Faso are poorly or not documented (Vall *et al.*, 2019). The lack of such crucial information hinders the crop's attractiveness to farmers for production and subsequent performance of its value chain.

Pigeon pea appears as a crop for forage and feed for the growing peri-urban animal husbandry farms and their increasing needs. As such, pigeon pea could be a cheaper alternative to the use of cereals as feed (Tesfay *et al.*, 2016). For instance, the amount of maize used in the feed industry exceeds 508 000 metric tonnes for poultry per year in Burkina Faso (Knoema, 2022). This quantity could be spared for human consumption and thus lower pressure on food prices in the market (FAO, 2023b). This context offers an opportunity to introduce and develop pigeon pea production in the sub-region, not only as food and feed, but also as an agricultural practice to improve soil fertility cost effectively and possibly integrate this multi-use crop to agropastoral farms (Ido, 2016; Belete, 2022). In this way, this legume crop can contribute to attenuate severe soil degradations due to climatic hazards and anthropogenic actions such as tillage, overgrazing and lack of adequate fertilisation (Hien *et al.*, 2004). Therefore, agronomic and morphological evaluations of new genetic materials are key to the development of a commercial exploitation of pigeon pea in the country.

There is a wide range of morphological and phenological variation among pigeon pea genotypes, with specific adaptability in different environments across the world (Hluyako, 2015; Sameer *et al.*, 2017; Sahu *et al.*, 2018). The objective of this study was to characterise the morphological and phenological features of exotic pigeon pea genotypes in western Burkina Faso in order to provide an entry point for the breeding programme

MATERIALS AND METHODS

Study area. This study was conducted on two sites, namely Farakoba research station (11°60' N latitude, 4° 20' W longitude), and Kouentou (11° 192 N latitude, 4° 072 W longitude), both located in western Burkina Faso. The two locations which were about 40 Km apart, were in the same agro-climatic region (Sudanian zone), and with dominantly Ferruginous soils (Bado, 2002).

The sites are characterised by dry and rainy seasons per year. The rainy season spreads from May to November with an annual average rainfall of 1.200 mm (Ibrahim, 2012). According to meteorological data of the station, mean temperatures varied from 17 to 37 during the dry season and from 10 °C to 32 °C during the rainy season (Ibrahim, 2012).

Plant materials. The study materials included nine pigeon pea genotypes (Table 1). Seven genotypes (here referred to as exotic genotypes) were obtained from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) from India. Two local accessions were obtained from the Institute of Environment and Agricultural Research (INERA) and were used as checks.

Experimental procedure. Treatments consisted of the nine genotypes (seven exotic and two local checks) (Table 1). The experiment was laid out in a randomised complete block design consisting of three replications and nine plots per block. Each plot consisted of 3 lines of 5 m, spaced with 1 m from each other. Seeds were sown at spacings of 40 cm x 100 cm. Two seeds were sown per hole and later thinned to one plant two weeks after sowing.

NPK (14-23-14) fertiliser was applied to each plot at the rate equivalent to 100 kg ha^{-1} in farrows before sowing. Standard agronomic management practices were applied to ensure proper development of plants. Thus, weeding was carried out thrice, and three applications of Emamectine benzoate (50 g kg^{-1}) and Lamda-Cyhalothrin (15 g l^{-1}) were performed to control pests and diseases.

Data collection. Pigeon pea descriptor guidelines (IPGRI and ICRISAT, 1993) were used to select variables relevant to this study. Plant phenology was assessed using days to 50% flowering (50% DF), and days to maturity (DM). Morphological traits assessed included leaf colour and shape, growth habit, flower colour, streak colour, pod colour and shape, and seed coat colour and shape. All observations on leaf were recorded on the 5^{th}

TABLE 1. Pigeon pea genotypes used in the morphological and phenological characterisation of exotic materials in western Burkina Faso

Entry number	Genotype	Key agronomic features	Sourced from
1	ICP 15029	Short duration (E)	ICRISAT
2	ICP 14722	Short duration (E)	ICRISAT
3	ICP 8863	Short duration (E)	ICRISAT
4	ICPL 20338	Short duration (E)	ICRISAT
5	ICPH 2740	Short duration (E)	ICRISAT
6	ICPH 2438	Short duration (E)	ICRISAT
7	ICPL 20092	Short duration (E)	ICRISAT
8	FKB Cc1	Medium duration (L)	INERA
9	FKB Cc2	Short duration (L)	INERA

ICRISAT : International Crops Research Institute for the Semi-Arid Tropics ; INERA : Institute of Environment and Agricultural Research, in Burkina Faso; E = Exotic, L = local

node at the 50% flowering stage. Observations on flowers and stems were made at the 50% flowering stage. Pods were evaluated at dough stage and seeds were assessed after harvest using dry kernels.

Quantitative traits assessed included plant height (PH), stem diameter (SD), and number of primary branches (NPB). Plant height was measured using a measuring tape at the crop's maturity stage, from the ground surface to the apical tip of the plant. Stem diameter was measured at 10 cm above ground surface, using a calliper. The number of primary branches were counted at the maturity stage. All the above measurements were performed on a sample of five plants randomly selected in each entry row, except for characters like days to 50% flowering and days to maturity, which were recorded *in situ* on the plot basis.

Data analysis. Data collected were subjected to analysis of variance (ANOVA) using XLSTAT Software (Version 2022.4.5). Significant means were separated using the Least Significant Differences (LSD) at 5 % level of significance. Correlations between traits were evaluated, and Cluster analysis and principal component analysis (PCA) were also performed using the same software. To establish the distribution of traits that influence genotypes dissemblance, a biplot was constructed with the data.

RESULTS

Qualitative traits. Two pigeon pea genotypes growth habits were observed, namely determinate growth habit (ICPL 20338, ICPL 20092); and indeterminate growth habit (ICP 15029, ICP 14722, ICP 8863, ICPH 2740, ICPH 2438, FKB Cc1 and FKB Cc2) (Table 2). The evaluation of leaflets revealed three colours out of the nine genotypes (Table 2); two had dark green leaflets (ICP 15029 and ICPL 20338), six had green leaflets (ICP 14722, ICP 8863, ICPH 2740, ICPH 2438, FKB Cc1 and FKB Cc2); and one had light green leaflets (ICPL 20092).

There were significant variations among genotypes for flower colour; and for pod and seed colours and shapes (Table 2). Apart from genotype FKB Cc2 which, showed red flowers, all the other genotypes showed yellow flowers. Pod colours included green with purple streaks (seven genotypes), green with brown streaks (one genotype, ICP 15029), and light green (one genotype, FKB Cc2). Seed colours were brown (three genotypes), dark

TABLE 2. Main qualitative traits of pigeon pea genotypes tested at Farakoba and Kouentou in Burkina Faso

Genotypes	Stem			Leaf			Flower			Pod	
	Plant type	Branching pattern	Growth habit	Colour	Shape	Pubescence	Colour	Petal streaks pattern	Colour	Shape	Seed colour
ICP 15029	E	SS	Indeter	Dark green	Obovate	Glabrous	Yellow	Dense	Brown + green streaks	Flat	Dark brown
ICP 14722	E	SS	Indeter	Green	Oblong	Pubescent	Yellow	Medium	Green + purple streaks	Flat	Dark brown
ICP 8863	E	SS	Indeter	Green	Oblong	Pubescent	Yellow	Dense	Green + purple streaks	Flat	Brown
ICPL 20338	E	E	Determ	Dark green	Obovate	Glabrous	Yellow	Dense	Green + purple streaks	Flat	Brown
ICPH 2740	E	SS	Indeter	Green	Oblong	Pubescent	Yellow	Medium	Green + purple streaks	Cylindrical	Dark brown
ICPH 2438	E	SS	Indeter	Green	Oblong	Pubescent	Yellow	Medium	Green + purple streaks	Flat	Brown
ICPL 20092	E	SS	Determ	Light green	Obovate	Pubescent	Yellow	Medium	Green + purple streaks	Flat	Gray
FKB Cc1	E	E	Indeter	Green	Oblong	Pubescent	Yellow	Dense	Green + purple streaks	Flat	Dark brown
FKB Cc2	E	SS	Indeter	Green	Oblong	Pubescent	Red	Medium	Light green	Flat	Gray

E = erect; SS = semi-spreading; Determ = deteminate; Indeter = indeterminate brown (four genotypes) and grey (two genotypes) (Table 2).

Phenological traits. At both study sites (Farakoba and Kouentou), there were highly significant (P = 0.000) variations in days to flowering and days to pod physiological maturity among the pigeon pea genotypes (Table 3). At Farakoba site, genotype ICPL 20338 was the earliest to reach 50% flowering at 45 and maturity at 96 DAS. On the other hand, genotype ICPL 20092 was the latest to reach 50% flowering at 105 DAS and physiological maturity at 166 DAS.

In the case of Kouentou site, genotype ICPL 20338 was the earliest to reach 50% flowering at 56 DAS and physiological maturity at 82 DAS. On the other hand, ICPL 20092 was the latest to reach 50% flowering at 146 DAS and physiological maturity at 184 DAS (Table 3).

Morphological traits. There was significant effect on variability among pigeon pea genotypes for the number of primary branches ($P < 0.05$), plant height at maturity ($P < 0.001$) and stem diameter (P = 0.000) in both locations (Table 4). The tallest genotype at Farakoba research station was the genotype ICPH 2740 (205.5 cm) and the shortest was the genotype ICPL 20338 with 66.66 cm. However, at Kouentou site, FKB Cc2 was the tallest genotype, with a value of 181.9 cm; while ICPL 20338 remained the shortest genotype, with a value of 62.63 cm (Table 4).

Stem diameter was also significantly different across genotypes and study sites (Table 4). At Farakoba research station, genotype ICPL 20338 had the smallest diameter of 8.7 mm; while FKB Cc 1 had the largest diameter (24.3 mm), at this site. At Kouentou location, genotype ICPL 20338 had the smallest stem diameter (9.2 mm), contrasting with FKB Cc 2 which had he largest value (18.2 mm).

Inter-traits correlations. The Pearson's correlation matrix revealed different types of correlations between traits assessed (Table 5). Days to maturity was positively and significantly correlated with days to 50% flowering (r=0.97) and stem diameter

TABLE 3. Days to 50% flowering and days to maturity at two locations in western Burkina Faso

Genotypes	Locations			
	Farakoba		Kouentou	
	50%DF	MD	50%DF	MD
ICPH-2740	83 ^{cd}	141 ^{e}	143 ^{b}	170 ^{c}
FKB Cc1	97 ^{b}	149 ^{b}	144 ^{b}	173 ^{b}
ICP-8863	76 ^{e}	132 ^{f}	106 ^{e}	157 ^{e}
FKB Cc2	79 ^{de}	147 ^{c}	132 ^{d}	160 ^{d}
ICPH-2438	61 ^{f}	119 ^{g}	88 ^{f}	130 ^{f}
ICP-14722	88 ^{c}	145 ^{d}	138 ^{c}	157 ^{e}
ICPL-20092	105 ^{a}	166 ^{a}	146 ^{a}	184 ^{a}
ICP-15029	58 ^{f}	102 ^{h}	75 ^{g}	128 ^{f}
ICPL-20338	45 ^{g}	95 ^{i}	56 ^{h}	82 ^{g}
Pr > F	0.000	0.000	0.000	0.000

TABLE 4. Means for various pigeon pea morphological traits per location, in western Burkina Faso

Genotypes	Locations							
	Farakoba				Kouentou			
	NPB	PH (cm)	SD (cm)	Leaf size (cm)	NPB	PH (cm)	DC(mm)	Leaf size (cm)
ICPH 2740	13.2^{a}	205.2^{a}	20.4^{abc}	6.8^{ab}	14.6^{ab}	159.8^{ab}	14.2^{abc}	6.6^{ab}
ICP 8863	13.4^{a}	176.4^{ab}	19.0^{bc}	5.8^{cd}	9.4^{c}	149.4^{bc}	13.7^{bcd}	6.6^{ab}
FKB Cc 2	13.4^{a}	153.3^{bc}	23.8^{ab}	5.4^{de}	11.8^{bc}	181.9^{a}	18.2^{a}	7.3^{a}
FKB Cc 1	10.3^{ab}	198.2^{a}	24.3^{a}	7.5^{a}	16.7^{a}	178.1^{ab}	17.2^{ab}	6.6^{ab}
ICPH 2438	12.3^{ab}	160.5^{bc}	16.8^{cd}	6.4^{bc}	9.3^{c}	166.4^{ab}	14.2^{abc}	6.5^{ab}
ICP 14722	9.4^{b}	171.8^{ab}	20.2^{abc}	5.9^{cd}	7.8^{c}	114.7^{d}	9.6^{de}	6.05^{bc}
ICPL 20092	9.3^{b}	114.5^{d}	20.8^{abc}	5.9^{cd}	10.5^{bc}	73.0^{e}	13.6^{bcd}	6.06^{bc}
ICP 15029	13.4^{a}	134.3^{cd}	14.0^{d}	4.9^{e}	7.8^{c}	128.7^{cd}	12.8^{cde}	5.41^{c}
ICPL 20338	8.7^{b}	66.6^{e}	8.7^{e}	4.6^{e}	8.4^{c}	62.6^{e}	9.2^{e}	5.75^{bc}
F	2.663	14.153	8.509	9.732	4.612	19.014	4.601	3.034
Pr > F	0.040	0.000	0.000	0.000	0.004	0.000	0.000	0.026

NPB: number of primary branches; PH: plant height; SD: stem diameter (r=0.83). Plant height was also positively and significantly correlated with stem diameter (r=0.74) and leaf size (r=0.8).

Principal component analysis. Principal Component Analysis (PCA) showed that F1 has an eigenvalue of 4.511 (Fig. 1), accounting for 75.18% of the total variation (Fig. 2). The first two axes of the PCA explained up to 91.78% of the total variation among the genotypes (Fig. 2). The most significant contributors to F1 were stem diameter (20.07%) and leaf size (18.56%). The second PC axis F2 accounted for 16.76% of the total variation.

This had a high coefficient of variation observed for the traits related to the cycle of the genotypes, but was negatively affected with plant height and number of primary branches (Fig. 2). The F2 was largely

TABLE 5. Correlation coefficients between traits of pigeon pea in western Burkina Faso

Traits	50%DF (DAS)	NPB	H (cm)	DC (mm)	DM (DAS)
50%DF (DAS)	1				
NPB	0.42	1			
H (cm)	0.46	0.81**	1		
DC (mm)	0.79**	0.74*	0.74*	1	
DM (DAS)	0.97***	0.44	0.49	0.83**	1
Leaf size (cm)	0.69*	0.75*	0.80**	0.81**	0.68*

50%DF = Days to 50% flowering; DM = Days to maturity; NPB = Number of primary branches; H = Plant height; DC = Stem diameter; *: P < 0.05; **: P < 0.01; ***: P < 0.001

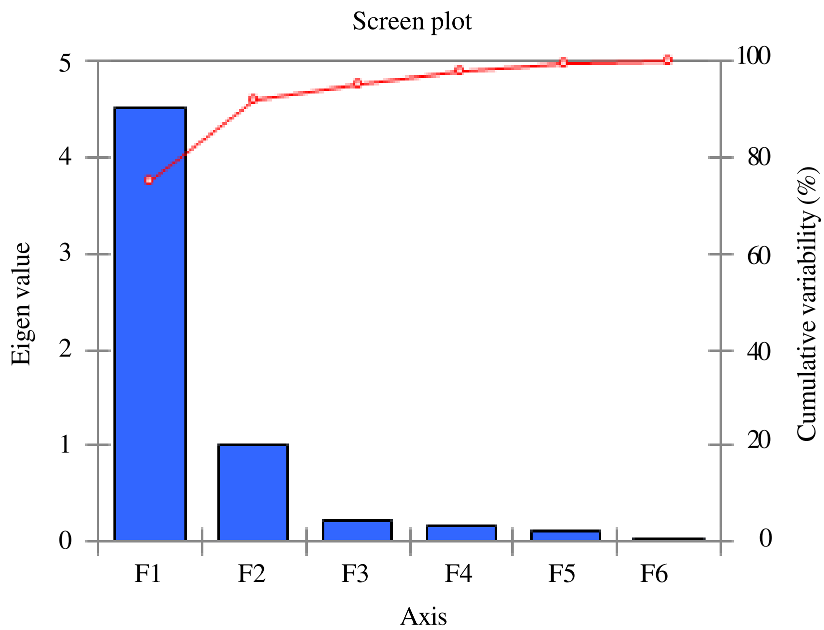

Figure 1. Eigenvalue of principal components of pigeon pea traits evaluated in western Burkina Faso.

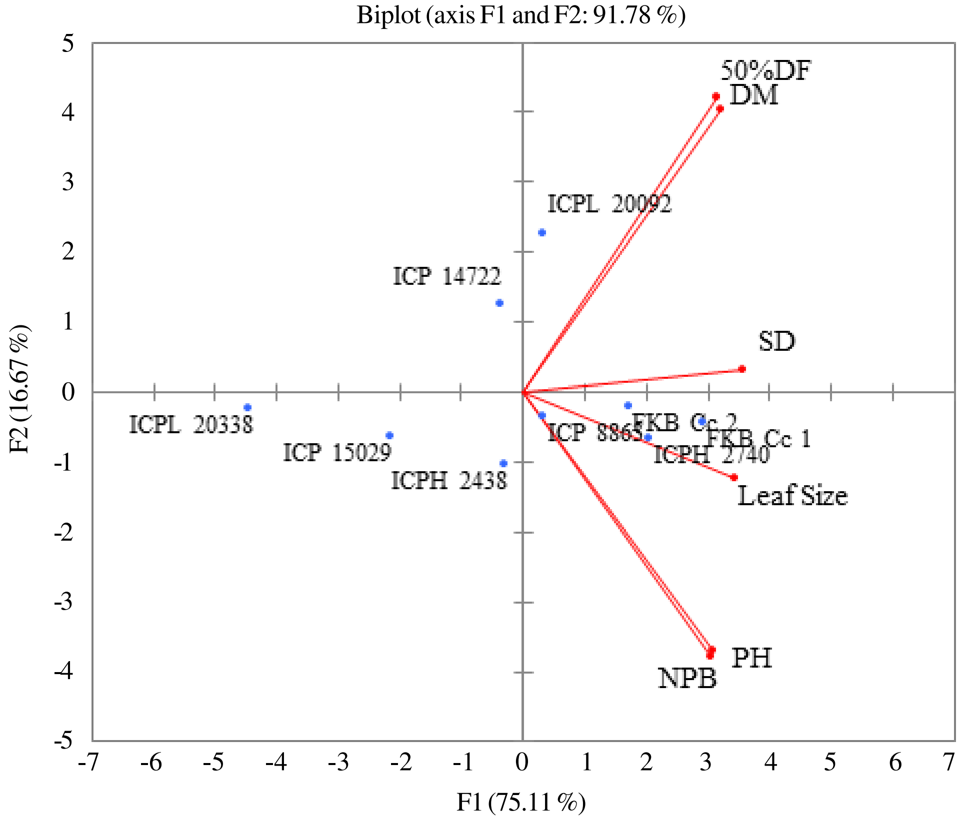

Figure 2. Biplot using the first two components (F1 and F2) of the PCA outcome of the data of pigeon pea genotypes' evaluation. NPB: number of primary branches; PH: plant height; SD: stem diameter, DM: maturity date, 50%DF: days to 50% flowering.

influenced by days to 50% flowering (27.81%), days to maturity (25.5%), number of primary branches (22.5%) and plant height (21.6%).

Genotype ICPL 20092 was found to have associations between days to 50% flowering and days to maturity; whereas FKB Cc2, FKB Cc1 and ICPH 2740 mostly had associations between stem diameter, and leaf size and plant height (Fig. 2). None of the traits measured clearly defined genotypes ICP 14722, ICPL 20338, ICP 15029 and ICPH 2438 (Fig. 2).

Cluster analysis. The matrix of dissimilarity coefficients gave rise to five clusters of genotypes (Fig. 3). Cluster 1 had two genotypes, *viz* FKB Cc 1 and ICPH 2740; whereas cluster 2, the largest cluster, included three genotypes namely FKB Cc 2, ICP 8863, ICP 14722. Cluster 3 and 5 each had only one genotype. Based on mean trait performances of each cluster (Table 6), cluster 1 had the highest value for days to 50% flowering, number of primary branches, plant height, stem diameter and leaf size; whereas cluster 5 had the lowest values for all these traits. Cluster 3 had the highest number of days to maturity.

An assessment of the inter-cluster distances showed that cluster 1 and cluster 5 were the most distant groups (154.61); whereas the lowest inter-cluster distance (31.72) was found between cluster 1 and cluster 2 (Table 7).

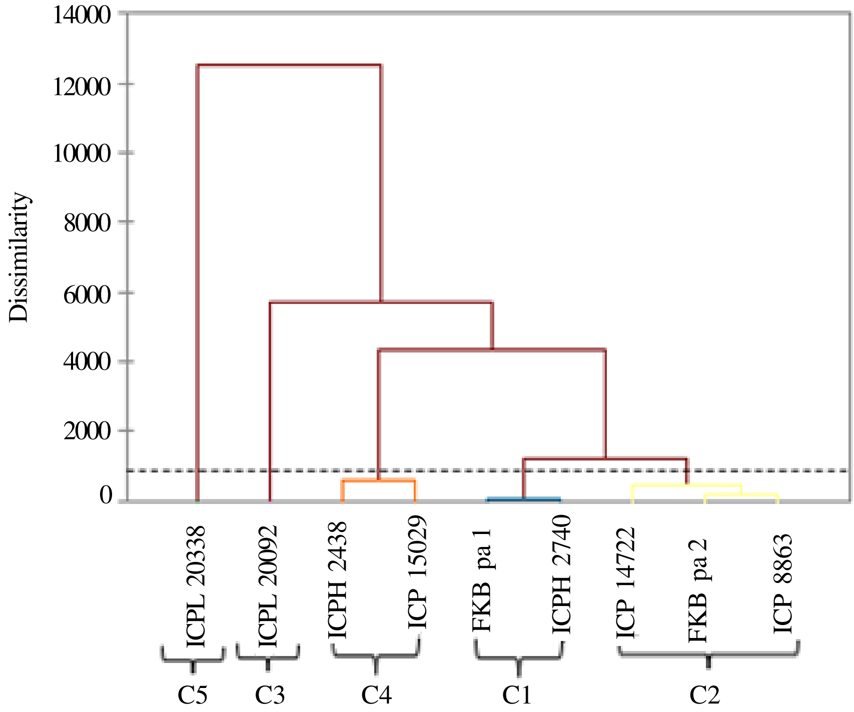

Figure 3. Dendrogram of pigeonpea genotypes based on Euclidean dissimilarity value using data collected in western Burkina Faso.

TABLE 6. Performance of trait in clusters at Farakoba and Kouentou, in western Burkina Faso

Cluster	50%DF (DAS)	NPB	PH (cm)	SD (mm)	DM (DAS)	Leaf size (cm)
1	117.0	13.7	185.3	19.0	158.3	6.9
2	103.6	10.9	157.9	17.4	150.1	6.1
3	125.3	9.7	96.1	17.4	174.9	6.0
4	70.7	10.7	147.5	14.5	119.9	5.8
5	50.5	8.56	64.6	9.0	89.1	5.2

NBP = Number of primary branches; PH = Plant height; SD = Stem diameter, DM: = Maturity date, 50%DF = Days to 50% flowering, DAS = Days after sowing

TABLE 7. Distances between the clusters for pigeon pea, in western Burkina Faso

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
Cluster 1					
Cluster 2	31.72				
Cluster 3	93.64	72.39			
Cluster 4	71.26	45.97	94.73		
Cluster 5	154.61	123.80	118.21	90.85	00

DISCUSSION

Although the evaluation of pigeon pea genotypes only focussed on the description of phenological and morphological traits, it revealed significant variability for most of these traits (Tables 3 and 4), attributable to genotypic diversity (Sameer *et al.*, 2017). Such diversity is valuable for pigeon pea breeding programmes for improvement of desirable traits, including dual purpose objectives (Sanou, 1992; Litrico and Violle, 2015).

All the nine genotypes showed erect growth habit, but about 80% of them presented semi-spreading branching pattern and indeterminate growth habit (Table 2). However, these proportions could be biased due to our choice to evaluate short duration varieties, primarily for dual purpose pigeon pea breeding. Nevertheless, these results corroborate with previous studies that revealed the predominance of erect growth type (Mula and Saxena, 2010; Mallikarjuna *et al.*, 2011), and semi-spreading branching pattern and indeterminate (Sahu *et al.*, 2018; Nyirenda *et al.*, 2020) in pigeon pea collections.

These morphological traits may affect farmers' preferences for pigeon pea adoption. For instance, genotypes with erect or semi-spreading branching appear as suitable for intercropping with cereal species with minimal competition, as reported in India (Rao and Willey, 1983). Besides, genotype with compact canopy branching pattern and indeterminate growth, characterised by a continuous vegetative growth and fruiting (Sameer *et al.*, 2017), are ideal for forage and windbreaks or hedges to minimise soil erosion (Bationo *et al.*, 2007). Other prevailing qualitative traits among the tested genotypes included green leaflets (70%), yellow flowers (90%) and green pod with purple streaks (90%) (Table 2). Not much is known about the agronomic interests of these traits, but flower colours are known to influence pollinators like bees (Coimbra *et al.*, 2020). The fact that most of pigeon pea genotypes worldwide have yellow flowers (Sahu *et al.*, 2018; Nyirenda *et al.*, 2020), makes it a species useful for bee keeping (Lunau and Wester, 2017). One of the most recurrent floral signals for bees is the yellow UV-absorbing area of flowers, the most common colour of anthers and pollen (Hansen *et al.*, 2012; Lunau and Wester, 2017). Such a yellow colour is key stimulus attracting bees, which respond to it innately (Lunau and Wester, 2017). Hence, pigeon pea breeding programs can add the flower colour to their target traits during cultivar development to account for on-farm bee keeping activities.

With three seed colours observed among genotypes (brown; dark brown and grey) (Table 3), this trait is very important for varietal identification and preference (Sameer *et al.*, 2017; Sahu *et al.*, 2018). Thus, seed colours significantly influence the crop adoption for food or feed (Motis, 2021). In Malawi for instance, farmers preferred white cream kernels to other colours, because they consider that white seeds have better cooking quality (Nyirenda *et al.*, 2020). Generally, qualitative traits are highly heritable and thus, remain useful in varietal evaluation and selection (Sameer *et al.*, 2017; Sahu *et al.*, 2018) However, they may be influenced by factors like habitat and spacing of the plants (Sameer *et al.*, 2017), and physiological states and the seed ripening level (Pascual *et al.*, 1993).

Concerning the crop phenology, although the same varieties were the earliest and the latest (ICPL 20338 and ICPL 20092, respectively) at both trial locations, they flowered earlier at Farakoba than at Kouentou (Table 3). This difference was attributable to the fact that pigeon pea is photosensitive and a short-day plant (Botcha *et al.*, 2013). Seeds were sown on 8th September for the trial at Farakoba during short-day period, favourable to the plant growth, whereas at Kouentou, seeds were sown on 15th July; while days were longer, delaying plant flowering (Jeuffroy and Ney, 2007). Overall, genotypes could be classified in three precocity groups, including (i) extra short duration (flowering in less than

60 days); (ii) short-duration (between 60 and 90 days after sowing); and (iii) medium duration (flowering between 90 and 130 days) (Snapp, 2003;; Sahu *et al.*, 2018).

Three of the varieties deemed as short duration in India (Hingane, personal communication), deviated from that original maturity group and presented here extra short duration (ICPL 20338 and ICP 15029) and medium (ICPL 20092). Such modification of the maturity group probably due to effect and/ or interaction with the environment (Yohane *et al.*, 2021). Additionally, positive correlations were found between genotypes duration and their morphological traits including plant height, stem diameter, number of branches and leaf size (Table 5). While morphological traits determine the plant's robustness, they are important for variety identification and adoption (Hluyako, 2015; Reddy *et al.*, 2018). In the present study, the nine genotypes were classified as short (ICPL 20092 and ICPL 20338, below 100 cm tall), medium (ICP 14722 and ICP 15029, between 100 and 150 cm) and tall (FKB Cc 1, ICPH 2740, FKB Cc 2, ICP 8863 and ICPH 2438, above 150 cm). Short and extra-short duration varieties can be easily used in a rotation system (Snapp, 2003); whereas medium and late duration types are suitable to surround farms or fallow, break winds, prevent eolian erosion, restore soil fertility (Sahu *et al.*, 2018), and even serve as fodder.

However, it is worth mentioning that plant morphological and phenological traits can be influenced by etiolation, a condition that is known to alter organs' developmental speed, dimensions, proportions and colours, usually due to low light intensity or shade in the growing environment (Armarego-Marriott *et al.*, 2019). Although such etiolation-inducing factors were unlikely in our trial environments, etiolation could not be ruled out since this was not monitored during the study processes.

The PCA revealed that stem diameter, leaf size and plant height were largely connected to the F1 (Fig. 2). However, traits such as days to 50% flowering (27.81%), days to maturity (25.5%), number of primary branches (22.5%); and plant height (21.6%) were mostly associated to the F2. These results, which are consistent with previous studies (Bautista, 2009; Hluyako, 2015; Nyirenda *et al.*, 2020), show that these traits were important descriptors, accounting for more than 50% of the phenotypic variation expressed among the genotypes (Sahu *et al.*, 2018; Nyirenda *et al.*, 2020). Therefore, the PCA present the most determining factors to the variability among genotypes. Additionally, the five clusters that emerged from this analysis were an indication of noticeable trait variability among the nine genotypes. Despite the usefulness of phenotypic markers in characterising genotypes, the genetic structure would be better described with molecular data.

CONCLUSION

This research contributed to characterisation and evaluation of nine pigeon pea genotypes, based on morphological and phenological traits in western Burkina Faso. ICPL-20338 and ICPL-20092 were the earliest and latest genotypes, respectively, to flower in both locations. The tallest genotype was ICPH-2740 (205.5 cm) and ICPL-20338 (66.66 cm) the shortest. PCA based on the quantitative traits showed that the first two PCs explained 91.78% of the total variation among the genotypes. The most significant contributor traits were stem diameter, leaf size, 50% flowering and plant height. The cluster analysis grouped the genotypes into five classes, showing how diverse the collection is. These results provide a better knowledge of pigeon pea behaviour in western Burkina Faso, and opens possibilities to engage a breeding programme for the crop. Before then, the early maturing genotype ICPL-20338 could be used in intercropping systems to contribute to soil fertility restoration, whilst the late maturing genotype ICPL-20092 and the tallest one ICPH-2740 reveal to be suitable for forage production and windbreaking. Nevertheless, to further support decision making for cultivar selection, this study should be complemented with evaluations of the crop productivity traits, including the response to biotic constraints.

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