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Agro-morphological characterization and genetic diversity study on tepary bean (*Phaseolus acutifolius* A. Gray) collection introduced in Burkina Faso

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ABSTRACT

Objective: The present study was conducted to evaluate 36 Tepary bean (*Phaseolus acutifolius* A. Gray) genotypes introduced in Burkina Faso and to determine genetic diversity in this collection using both quantitative and qualitative traits.

Methodology and Results: *A* field experiment was conducted following an augmented bloc design with an extra early maturing cowpea variety as control. Data was recorded on six qualitative and seven quantitative traits. Results show existence of important genetic diversity among Tepary bean accessions. For all quantitative traits assessed, ANOVA were significant and PCV (Phenotypic Coefficient of Variability) was slightly superior to GCV (Genotypic Coefficient of Variability) indicating low effect of the environment on traits expressions. GCV and PCV were also high for number of pods per plant, plant height and hundred seeds weigh. H (Heritability) ranged from 90.61% to 99.91% and GA (Genetic Advance) from 9.56% to 54.88%. Tepary bean genotypes were clustered into three groups separated from the control.

Conclusions and application of findings: The present study revealed that these 36 Tepary bean accessions introduced in Burkina Faso are perfectly adapted to the ecological conditions of the country. The genetic diversity, both qualitative and quantitative, will help enrich local biodiversity in terms of grain legumes whilst constituting an important basis for a future Tepary bean-breeding program. High heritability coupled with high expected genetic advanced calculated for seeds yield related traits namely “number of pods per plant”, “plant height” and “hundred seeds weigh” suggest an important genetic gain for future breeding activities on these traits in tepary bean for Burkina Faso

Keywords: Tepary bean (*Phaseolus acutifolius* A. Gray), genetic diversity, heritability (H), expected genetic advance (GA)

INTRODUCTION

Tepary bean (*Phaseolus acutifolius* A. Gray) is an annual legume belonging to the *Fabaceae* family and to the genus *Phaseolus*. This grain legume is a diploid specie (2n = 2x = 22) (Shinkel and Gept, 1988) and preferentially self-pollinating. It is one of the five (05) domesticated species of the genus *Phaseolus* (Mhlaba et *al*., 2018) the other species being *P. vulgaris* (common bean), *P. coccineus* L. (runner bean), *P. dumosus* Macfady and *P. lunatus* (lima bean) (Freytag and Debouck, 2002). According to Nabham and Felger in 1978, Tepary bean is native to the desert regions of northwestern Mexico, the southwestern United States and is cultivated primarily for its dry, ripe seeds, which boiled, steam, fried or baked. Gujaria-Verma et *al*., (2016) reported that, there are four botanical varieties (var.) of Tepary bean: *acutifolius* varieties (wild and domesticated), *latifolius* variety and the *tenuifolius* variety. Domesticated tepary bean is an underutilized and understudied crop mainly grown using local unimproved varieties or wild accessions (Schinkel and Gepts, 1988; Debouck, 1991). On a nutritional aspect, Bhardwaj & Hamama, (2005) reported that Tepary bean seeds have about 24% protein content, 33% saturated fatty acids, 67% unsaturated fatty acids, 24% monosaturated fatty acids, 42% polyunsaturated fatty acids and essential mineral elements (C, Mg, Cu, Fe, K, Mn, S, Zn, Na). In addition, it is described as one of the healthiest foods for diabetics due to its relatively low glycemic index (Mendosa et *al*., 2006). It is an annual, climbing, sometimes more or less erect and bushy plant with a stem that can reach up to 4m long and a fibrous root. Tepary bean is particularly known for its resistance to heat, drought and several diseases (Salgado et *al*., 1994; Miklas and Stavely, 1998; Rao et *al*., 2013). Indeed, according to Jury and Vaux, (2007), Tepary bean can thrive in intense droughts with low annual rainfall requirements ranging from 500 mm to 1700 mm. All these qualities make it an ideal crop for semi-arid and arid regions of sub-Saharan African countries such as Burkina Faso. For these reasons, proper utilization of Tepary bean in these regions can help overcome food and nutritional insecurity due to the climate change. Therefore, the objective of this study is to evaluate the genetic diversity within a collection of Tepary Bean imported from CIAT (International Center for Tropical Agriculture) for introduction in Burkina Faso.

MATERIALS AND METHODS

Plant material: Plant material used in this study was composed of thirty-six (36) accessions of domesticated Tepary bean (*Phaseolus acutifolius*), from a collection of 47 accessions initially introduced in Burkina Faso in 2017 from CIAT-Colombia (Table 1) GenBank. In this experiment, Sanzi an extra early maturing cowpea variety (*Vigna unguiculata* L.Walp.) originated from Ghana was used as a check crop. Cowpea has been chosen as check crop because to date, it is the major grain legume grown and consumed in Burkina Faso. Like result, when introduced new crop, out of the forty-seven (47) accessions imported, thirty-six (36) germinated (Table 1), reached maturity and allowed collection of morphological data.

Table1: Tepary beans accessions and country of origin

Country of origin	ACCESSIONS
Mexico	G40142; G40142A; G40143; G40144; G40144A; G40144B; G40144C; G4014; G40148; G40159; G40161; G40162; G40163; G40173A; G40173C; G40174; G40279; G40020; G40084; G40112; G40120; G40125; G40272
USA	G40065; G40230; G40176; G40066; G40037; G40023; G40175; G40172
Zimbabwe	G40301; G40302
Zambia	G40122
South Africa	G40041
Morocco	G40008

Experimental Site and design: The experiment was conducted in 2018 and 2019 during the rainy season, from July to September, at INERA (Institut de l'Environnement et de Recherches Agricoles) research station in Kamboinsé, located at 12 ˚ 27 north latitude and 1˚ 32 west longitude, 296 m above sea level. Annual rainfall of 833.9 mm and 932.3mm were recorded respectively in 2018 and 2019 (table 2). The experimental design was an augmented block design as described by Federer in 1956. The trial was composed of three (03) blocks: two (02) blocks of fifteen (15) entries and one (01) block of fourteen (14) entries. Each Tepary bean accession was planted in a 3-meter row with a spacing of 60 cm between plants and 80 cm between rows. Only control crop was repeated in each block. As Tepary bean is an exotic crop in Burkina Faso, the early maturing cowpea variety Sanzi was used as control, in order to evaluate at the same time, the agronomic performance and the adaptability of the Tepary bean accessions with a variety of the major local legume. All agronomic practices necessary for good germination and maintenance of the plants were applied. Using Bioversity international developing crop descriptor lists (2017). Qualitative and quantitative data were recorded on five randomly selected plants from each plot and averaged so that the following traits were assessed for quantitative traits: Number of days to 50% flowering (50%F), number of days to 95% maturity (95%M) plant height (PH), number of pods per plant (NPP), seeds harvested per plant (SHP), pod length (PL), hundred seeds weight (HSW). Six (06) qualitative traits were also recorded and are as follow: hypocotyl colour, flower colour, seed coat colour, growth habit, pod and terminal leaves shape.

Table 2: Rainfall during two years experiments

Rainfall (mm)	Month												Total (mm)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
2018	0	10.1	19	0	16.3	175.9	187.8	216.8	97.9	110.1	0	0	833.9
2019	0	0	5.1	35	19.8	71.3	219.9	385.1	122	74	0	0	932.3

Statistical Analyses: For quantitative traits, analysis of variance (ANOVA) was performed using Statistical Package for Augmented Design Version 1.0, 2003 (SPAD) and XLstat 2016 software was used for cluster analysis. Descriptive statistics and frequency distribution for qualitative and quantitative data were computed using Excel 2016.The mean squares of the genotype and error for each trait who shows significant difference were used to calculate the genotypic variance (δ^2g), phenotypic variance (δ^2ph). Broad sense heritability (H^2), Genotypic Coefficient of Variability (GCV), Phenotypic Coefficient of Variability (PCV) and Genetic Advance (GA) were calculated according to Jalata et *al*., 2011 procedure using formula in table 3.

Table 3: Genetics parameters formula

Genetic parameters	Formula	terms Significance
Genotypic variance (δ^2g)	$\delta^2 g = \frac{(MSG - MSE)}{r}$	- **MSG**: Mean Square of Genotype - **MSE**: Mean Square of error - **r**: Number of blocks
Phenotypic variance (δ^2p)	$\delta^2 p = \delta^2 g + \frac{MSE}{r} = \frac{MSG}{r}$	
Genotypic Coefficient of Variability (GCV)	GCV (%) = $\frac{\delta_g}{X} * 100$	-**X**: Mean of the character -**δg**: Genotypic standard deviations
Phenotypic Coefficient of Variability (PCV)	PCV (%) = $\frac{\delta_P}{X} * 100$	- **δp**: Phenotypic standard deviations
Heritability (Broad sense) (H^2)	H^2 (%) = $\frac{\delta_g^2}{\delta_p^2} * 100$	-**δ^2g**: Genotypic variance -**δ^2p**: Phenotypic variance
Genetic Advance (GA)	GA = H^2 * δp*K	**K** = 2.06 (Selection coefficient)

RESULTS

Genetic diversity for qualitative traits: Results of genetic diversity for qualitative parameters used for characterizing the collection of Tepary bean are shown in table 4 and revealed the presence of a genetic diversity in this collection. This genetic diversity can be seen firstly on hypocotyl pigmentation where 19.44 % of the collection where pigmented(purple) and 80.56 % non pigmented (green). For growth habit, three (03) types were observed: the climbing type observed on 47.22% (17) of the accessions, the indeterminate type observed on 30.56% (11) and the bushy type on 22.22% (17) of the accessions. For terminal leaves shape, 22.22% of the accessions had oval terminal leaves whilst 77.78% had oval-lanceolate terminal leaves.

Table 4: Qualitative traits frequencies

Traits	Type	Frequency%
Hypocotyl	Green	80.56 (29)
	Violet	19.44 (07)
Growth	Indeterminate	30.56 (11)
	Bushy	22.22 (08)
	Climbing	47.22 (17)
Terminal leaves shape	Oval	22.22 (08)
	Oval-lanceolate	77.78 (28)
Color of flower	White	80.56 (29)
	Pink	19.44 (07)
Pod shape	Curved	38.89(14)
	Straight	61.11 (22)

Seed color	black	5.56 (02)
	beige	13.89 (05)
	brown	13.89 (05)
	White-spotted	2.78 (01)
	pink-spotted	2.78 (01)
	White	58.33 (21)
	Yellowish	2.78 (01)

Regarding flowers color (Figure1), two types of coloration were observed: the white color and the pink color. The white color was observed in 29 accessions out of 36 or 80.56% of the collection while the pink color was observed in 7 accessions or 19.44% of the accessions. 38.89 % of accessions showed curved pods and 61.11%straight pods.

Pink Flower

White Flower

Fig. 1: Flower colours

For seeds coat colours (Fig. 2), seven (07) different colorations were observed. Thus, seeds of white colour were observed at 58.33% of the accessions, seeds of beige colour at 13.89% of the accessions, seeds of brown colour at also 13.89% of the accessions, seeds of white-spotted at 02.78% of the accessions, seeds of pink-spotted at 02.78% of the accessions, 02.78% of accession with yellowish seeds and finally black seeds on 5.56% of the accession.

White seeds | Black seeds | Beige seeds | Brown seeds | White-spotted seeds | Yellowish seeds | Pink-spotted seeds

Fig 2: Different seeds colours found in Tepary bean (*Phaseolus acutifolius*) collection

Genetic diversity for quantitative traits: Descriptive statistics and analysis of variance (anova) of this Tepary bean collection revealed for each recorded trait, minimum and maximum values, mean square of genotypes and means square of error and finally the coefficient of variation (table 05). The analysis of variance reveals highly significant differences among the accessions for all the parameters measured, namely: number of days to 50% flowering (50%F) and number of days to 95% maturity(95%M), Pod length (PL), plant height (PH), average number of pods per plant (NPP) and hundred seeds weight (HSW).

Table 5: Analysis of variance and summarized statistics of seven (07) agro-morphological traits recorded on 36 accessions of Tepary beans

Traits	Min - Max	CV%	Means	Means square Genotype	Means square Error
50%Fl	28.5 - 38	2.71	32.89	9.14**	0.86
95%M	69 - 77	1.88	72.89	78.89***	1.67
PH (cm)	16.25 - 42.87	5.07	29.69	63.99***	2.47
PL (cm)	6.3 - 8	9.15	7.14	19.31***	0.73
NPP	10 - 127	2.36	68.58	830.97***	2.17
SHP (gr)	2.24 - 52.92	1.29	33.12	296.97***	0.26
HSW (gr)	9.8 - 16.7	5.6	12.02	4.57**	0.4

Legend: **: highly significant; ***: very highly significant.
Number of days to 50% flowering (50%F). Number of days to 95% maturity (95%Mat). Pod length (PL); Plant height (PH); Number of pods per plant (NPP); Seed harvested per plant (SHP); hundred seeds weigh (HSW).

Number of days to 50% flowering ranged from 29 to 38 days after planting (DAP) with an average number of 34. 22 days while number of days to 95% maturity varied between 55 and 77 DAP with an average of 68.54 DAP. With an average value of 9.32 cm, pods length varied between 6.3 and 15.9 cm and the number of pods per plant varied between 10 and 127 with an average value of 62.31 pods per plant. The average value of plant height was 29.69 cm with a minimum length of 16.25 cm measured on bushy types accessions and a maximum height of 42.87 cm on the indeterminate and climbing types. Finally, hundred seeds weight varied between 9.8 and 16.7 g with an average value of 12.02 g and seeds harvested per plant ranged from 2.24 to 52.92 gr with a mean value of 33.12 gr. The coefficients of variation calculated for each trait indicate however a low heterogeneity (CV<10%) within this collection.

Genetic Variability (PCV and GCV): In this study, phenotypic coefficient of variation (PCV) values was greater than genotypic coefficient of variation (GCV) values for all traits (Table 5). Deshmukh et *al*., 1986 has classify genotypic and phenotypic coefficients of variation into three categories: low (<10%), medium (10-20%) and high (>20%). Base on this scale, magnitude of PCV and GCV was high for pod length (27.2; 26.68), number of pods per plant (26.71; 26.67), and seeds harvested per plant (25.07; 25.06). Medium values of PCV and CVG were calculated for hundred seed weight (11.01; 10.52), and plant height (14.93; 14.64,). Finally, low value PCV and GCV values were observed for traits number of days to 50% flowering (5.12; 4.87) and 95% maturity (7.48; 7.40).

Broad sense Heritability (H) and expected Genetic advance (GA): Heritability and expected genetic advance estimates were classified according to Johnson et *al.*, (1955). In this study, heritability estimates for the seven parameters ranged from 90.61 to 99.91%. The highest amplitude of heritability was observed for trait “seed harvested per plant” (99.91%) followed by “number of pods per plant” (99.74%), “number of days to 95% maturity” (97.89%), “pod length” (96.22%), and “plant height” (96.15%). Relatively lower heritability values were observed for the “hundred seed weight” (91.19%) and “number of days to 50% flowering” (90.61%).

Table 6: Estimates of heritability and genetic advance parameters of 36 Tepary bean lines

Traits	GCV	PCV	H2%	GA/X%
50%Fl	4.87	5.12	90.61	9.56
95%M	7.4	7.48	97.89	15.09
PH	14.64	14.93	96.15	29.58
PL	26.68	27.2	96.22	53.92
NPP	26.67	26.71	99.74	54.88
SHP	25.06	25.07	99.91	51.61
HSW	10.52	11.01	91.19	20.69

Legend*: GCV: Genotypic Coefficient of Variation. PCV: Phenotypic Coefficient Variation. H2: Broad Sens Hereditability. GA: expected Genetic advance. Number of days to 50% flowering (50%F). Number of days to 95% maturity (95%Mat). Pod length (PL); Plant height (PH); Number of pods per plant (NPP); Seed harvested per plant (SHP); hundred seeds weigh (HSW).*

Expected genetic advance values ranged from 9.56% for “days to 50% flowering” to 54.88% for “number of pods per plant”. The highest values were obtained with number of pods per plant, pod length and harvested seed weight per plant. Moderate values of expected genetic gain were observed for the parameters plant height and hundred seed weight. The lowest values of expected genetic advance were recorded for the parameters number of days to 50%flowering and 95%maturity. High heritability associated with high genetic advance as a percentage of mean was observed for traits number of pods per plant (99.74%; 54.88%), seeds harvested per plant (99/91 and 51.61%) and length of pods (96.22% and 53.92%). High heritability associated with moderate genetic advance was observed in plant height (96.15%; 29.58%) and hundred seed weight (91.19%; 20.69%). High heritability with low genetic advance was observed for the parameters number of days to 95% maturity (97.89% and 15.09%) and number of days to 50% flowering (90.61% and 9.56%).

Genetic diversity organization: Hierarchical cluster analysis (HCA) was used to examine the aggregation patterns of the 36 Tepary bean accessions and the cowpea line used in study as control. Four groups where then generated on similarity threshold of 0.74 (Figure 1). The distribution of the Tepary bean accessions as well as the control (Table 4) shows that the thirty-six (36) Tepary bean accessions are essentially divided into three groups: Group I, the largest group, included 20 accessions while Group II included 11 accessions (Table 6). Group III was composed of four (04) accessions. Finally, group IV consisted of a single accession, the check crop.

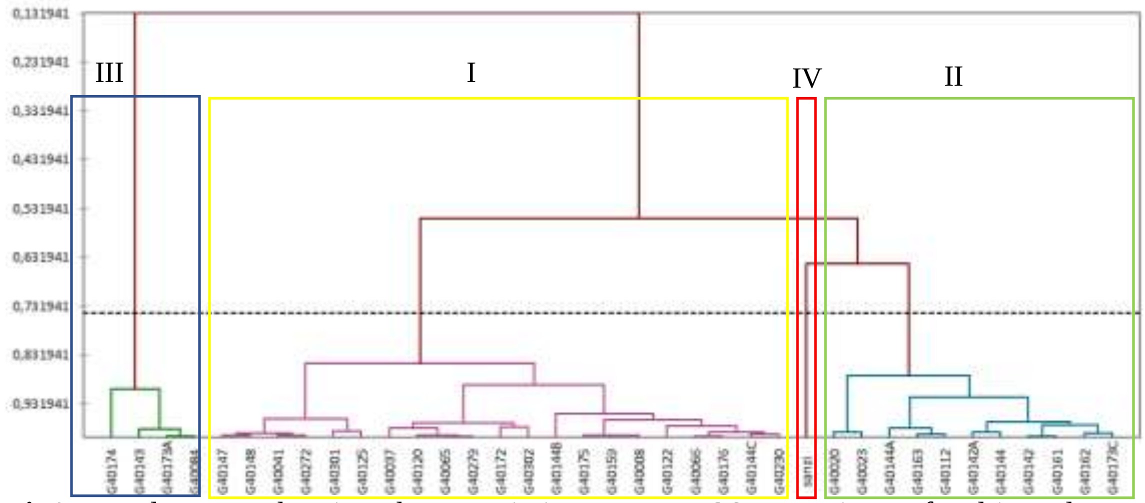

Fig1: Dendrogram showing the associations among 36 accessions of cultivated Tepary bean (*P.acutifolius*) introduced in Burkina Faso and cowpea line sanzi (*V.unguiculata*) as control

The average value of the quantitative parameters measured on the Tepary bean accessions and the check crop are presented in Table 5.

Table 7: Distribution of Tepary bean accessions and cowpea control according to the hierarchical ascending classification

Groups	I	II	III	IV
Accessions	G40065; G40144B; G40144C; G40147; G40148; G40159; G40172; G40175; G40279; G40301; G40302; G40008; G40041; G40066; G40120; G40122; G40125; G40176; G40230; G40272	G40142; G40142A; G40144; G40144A; G40161; G40162; G40163; G40173C; G40020; G40023; G40112	G40143; G40173A; G40174; G40084	sanzi

Thus, the different groups are characterized as follows: Tepary beans accessions, distributed in three groups (I, II and III), are rather similar in terms of vegetative cycle because flowering and reaching maturity almost at the same dates. However, group I accessions are those presenting in average, better yields in terms of number of pods per plant (NGP) and in terms of seeds harvested per plant (SHP). Finally, the accessions of group III are those that show highest hundred seed weight values. Sanzi, the check crop, constituting group IV is completely different from the Tepary accessions by a shorter vegetative cycle, longer pods and a higher grain yield per plant with however a lower number of pods per plant and hundred seed weight than the Tepary bean accessions used in this study.

Table 8: Average values of each trait for each Tepary bean group and the cowpea control

	Means values			
Groups	**I**	**II**	**III**	**IV**
50%F	33.44	38.25	32.33	33.17
95%M	73.44	55.50	72.33	73.17
PH (cm)	29.89	33.63	28.62	30.89
PL (cm)	7.19	15.88	6.97	7.33
NPP	34.44	43.50	92.40	64.42
SHP (gr)	19.91	59.37	43.66	29.85
HSW (gr)	12.23	8.78	12.29	11.53

Legend: *Number of days to 50% flowering (50%F). Number of days to 95% maturity (95%Mat). Pod length (PL); Plant height (PH); Number of pods per plant (NPP); Seed harvested per plant (SHP); hundred seeds weigh (HSW).*

DISCUSSION

Qualitative traits: Genetic diversity evaluation of this collection of Tepary beans (*Phaseolus acutifolius*) using qualitative traits revealed an important diversity. Thus, at germination stage, the purple or green colour of the hypocotyl could constitute an important visual marker for the varietal distinction, as well as, at maturity, the oval or lanceolate shape of the terminal leaves and pods shape. Moreover, regarding the terminal leaves shape, Nabhan (1978) reported that wild forms of P.*acutifolius* could have linear to oval lanceolate leaves while cultivated forms were exclusively oval lanceolate. In addition, the same author reports that the leaves in Tepary beans are smaller in general than in other species of the genus *Phaseolus*, because they have not increased in size with domestication. This could be a major asset in the drought tolerance of *P. acutifolius* compared to a major legume such as common bean (*Phaseolus vulgaris*) less tolerant to water stress. In addition, regarding growth habit, these accessions of Tepary bean are either bushy, indeterminate or climbing. The flowers are either white or purple. This diversity in growth and flower colour could also be related to the wild or cultivated origin of these varieties. Indeed, according to Wolf, (2018), wild forms of Tepary bean have indeterminate or climbing growth while domesticated ones are more often bushy or clumpy. As for flower colour, this would also be related to wild or cultivated forms of *P. acutifolius* (Moghaddam et *al*., 2021). The greatest diversity, even if it remains limited, is observed at the level of seed colour where seven (07) types were observed, the dominant colour being white with 21 accessions out of the 36 evaluated. Indeed, Kaplan (1956) had reported eight (08) different colours in Tepary bean seeds. The range of pod shape, seed colour found in Tepary beans, with a predominance of small white seeds and some accessions with yellow or spotted seeds indicates a bottleneck in domestication (Freytag and Debouck 2002). Finally, seed colour, in addition to being a factor in the acceptance or rejection of a variety, could be related to the content of anti-nutritional compounds such as tannins. However, Tepary bean seeds generally contain less tannins than common bean seeds. In addition, white Tepary bean seeds have low or almost no tannin content compared to seeds of other colours. In contrast, tannin content is moderate in black and brown seeds (Mendosa et *al*., 2006). It should be noted that, according to Bhardhaj et *al*. (2002), there is no correlation between seed colour and yield in Tepary beans. For this reason, Bhardwaj et al. (2002) reported that the lack of differences between genotypes of different seed colours with regards to seed yield, indicates that, depending on consumer preference or other considerations, either genotype could be used for commercial production

Quantitative Traits: The main goal of introducing this collection in Burkina Faso is to enrich genetic diversity in terms of food legumes. Thus, the significant and highly significant differences observed among this Tepary bean collection, for the seven (07) traits assessed in this study following analysis of variance had also been reported by Mhlaba et *al*., 2018b for the same traits in South Africa with accessions of the same origin (CIAT-Colombia). However, Muñoz et *al.* (2004) had reported little genetic differentiation among domesticated Tepary bean genotypes. Furthermore Blair et *al.* in 2012 using SSR markers reported that, in Tepary bean genetic differentiation was relatively higher in wild specie than in domesticated one. The low genetic diversity reported by these authors, had been previously attributed to the natural selection process as well as to artificial selection exerted on Tepary bean during long-term domestication of a limited gene pool (Schinkel and Gepts, 1988). Compared to cowpea, the check crop used in this study, Tepary bean accessions matured relatively later. Earliness has been associated with improved adaptation of certain crops to semi-arid environments, particularly for crops subject to post-flowering drought (Hall et *al.* 1979). However, for different environments and genetic backgrounds, specific times of flowering and maturity would be optimal and extremely early varieties may not be well adapted (Hall 1981). Indeed, some accessions of Tepary, despite their longer cycle, have had agronomic performances close to or better than the cowpea control, notably in terms of seed harvested per plant and number of pods per plant. In general, based on their agronomical performance, these Tepary beans accessions proved to be adapted to the ecological conditions of Burkina Faso. In addition, the number of days to 50% flowering in our study are similar to those measured by Mhlaba et *al*., (2018b) who had observed in field a minimum value of 27 days after sowing (DAS) and a maximum of 41 DAS. However, the number of days to maturity in our study (69 to 77 DAS) is slightly lower than that counted by the same authors (60 to 85 DAS). In consequence, Tepary bean accessions assessed in our study could be considered as early. According to Miklas et *al*., 1994, early maturity combined with cultural practices can help Tepary beans to avoid yield reductions due to BGMV (Beans Golden Mosaic Virus) or to escape epidemics completely. Our results are similar to those reported by Tinsley et *al*., 1985, who described accessions with maturity dates ranging from 60 to 75DAS. These differences could be explained by the influence of environment on quantitative traits that Ullah et *al*., (2012) reported earlier. The average pod length in our study (07cm) is slightly higher than the value observed by Molosiwa et *al*., (2014) in Botswana (6.2cm). The average plant height (29.69cm) is similar to those reported by authors such as Molosiwa et *al*., (2014) (29.9cm) and Mhlaba et *al*., (2018b) in greenhouse (30.32cm). Molosiwa and Ngokong in 2017, has reported that selection of relatively taller plant would lead to significant increase in yield and yield related traits in Tepary bean. Hundred seed weight, number of pods and seed weight per plant in our study are similar to the values observed in greenhouse on some of the best performing varieties reported by Mhlaba et *al*., (2018b) and Nabhan, (1978) and Molosiwa et *al*., (2014) and Kuruvadi and Vadez (1994). Estimates of the phenotypic coefficient of Variation (PCV) and genotypic coefficient of variation (GCV), broad Sens heritability (H2), and genetic advance (GA) revealed that all seven measured quantitative traits are mainly controlled by genotypes. Furthermore, the difference between GCV and PCV was minimal for all traits suggesting less influence of the environment in the expression of these traits and therefore the consideration of phenotypic values for direct selection. However, the relatively high PCV and GCV values for pod length, number of pods per plant and seed harvested per plant indicate a greater contribution of genetic and environmental components. These two components therefore have a greater influence on phenotypic variation in the Tepary bean populations tested. In consequence, Tepary bean breeding for these traits should take into account both genotypic and environmental components. These results corroborate those of Mhlaba et *al*., (2018b) for traits such as number of pods per plant, seed harvested per plant. On the other hand, the low values of PCV and GCV recorded for 50%flowering and 95% maturity are comparable to those calculated by Ghimire and Mandal, (2019) on common bean (*Phaseolus vulgaris*), as well as those of Kouam et *al*., (2018) on cowpea (*Vigna unguiculata*). The moderate PCV and GCV calculated for plant height (PH) and hundred seed weight (HSW) do not corroborate the results of Mhlaba et *al*., (2018) who calculated much lower values.

Broad Sense Heritability (H) and expected Genetic advance (GA): In this study, the high broad-sense heritability values for all measured traits corroborate the results of Mhlaba et *al*., (2018) for plant height, seeds harvested per plan and number of pods per plant. This high heritability reflects a weak influence of environmental factors on the expression and transmission of these traits. In consequence, in this study, the phenotype was the true expression of the genotype. However, since heritability alone cannot predict a favourable response to classical selection, its joint estimation with the expected genetic advance (as percentage of mean of trait) can provide more reliable information (Johnson et *al*., 1955). Thus, the high heritability associated with high-expected genetic advance observed for number of pods per plant, pod length, and seeds harvested per plant predicts that phenotypic selection based on these traits for Tepary bean yield improvement may be possible. Indeed, high heritability values coupled with high-expected genetic advance showed the presence of genes with additive effect. On the other hand, high heritability with low genetic advance observed for number of days to 95% maturity, number of days to 50% flowering, are reflecting the fact that early selection based on these traits may not be very effective due to the presence of genes with a non-additive action.

Cluster analysis: These thirty-six (36) Tepary bean accessions as well as the cowpea control used in this study were grouped into four clusters, with the Tepary bean accessions grouped in three separate clusters is suggesting the existence of genetic diversity within this collection. In addition, the separate classification of the cowpea variety used as control, confirms the specific differences that exist between these two species. Even if some similarities exist between these two species, notably on plant height and number of pods per plant, marked differences appear however on the other traits. Indeed, longer pods, earlier maturity and a higher seed harvested per plant, were recorded on the cowpea variety. Tepary bean accessions from clustered in group I and II have higher hundred seeds weight and number of pods per plant than the sanzi the cowpea variety. These similarities as well as these differences observed could be related to the presence of highly synthetic relationship between these two legumes, or related to the chromosomal rearrangements (translocation, inversion and transversion) occurred during the evolution in this plant family that Moghaddam et *al*., (2021) reported. Within this collection of Tepary bean, the greatest differences were observed for traits such as number of pods per plant, seeds harvested per plant, and hundred seeds weight, all of which are important yield contributing parameters. Indeed, according to Abebe et *al*., (2010), the groups can be separated mainly based on the traits that contribute most to variation, as observed in barley. Molosiwa et *al*., (2014) had also obtained 3 groups of Tepary bean from nine (09) accessions and this resulted in the fact that the structuring of the population is mainly influenced by the traits with the greatest variability. In our study, these traits are as follow: hundred seeds weigh, seeds harvested per plant and number of pods per plant. Base on this, accessions of the group I are those with the highest number of pods per plant, the highest seed harvested per plant. In this group, best genotypes are G40272 and G40125, followed by the accessions of the group II with the genotypes with the longest pods that are: G40163; G40112; G40142 and G40020. Group III is the one gathering accessions with the biggest seeds (highest hundred seed weight) with the best genotypes: G40084; G40175 and G40173A. It should be noted that these genotypes, listed as the best performing ones in this study, are in majority from Mexico (center of origin of the Tepary bean), while only one accession is from the USA. In order to obtain better performing genotypes in terms of seed yield, combining genotypes from these different groups could be a good scenario of breeding for yield in Tepary bean in Burkina Faso.

CONCLUSION AND APPLICATION OF RESULTS

The recognized drought tolerance of Tepary bean in a context of climate change makes it an ideal crop for sub-Saharan Africa. The present study, on Tepary bean in Burkina Faso, revealed the level of genetic diversity of a collection of Tepary bean introduced in Burkina Faso from CIAT. Also, this study shows that these accessions are perfectly adapted to the ecological conditions of the country. Indeed, the agronomic performances observed are similar to the performances in Africa regions where this crop is already cultivated. Tepary bean performance is also at some points similar to the one of the main grown legumes grown in the country namely cowpea. Finally, the high broad sense heritability, combined with the expected genetic advance recorded for yield related traits in addition with identification of best genotypes, could be an important contribution for Tepary bean breeding program in Burkina Faso.

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