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

(Research Article)

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Phenotypic analysis of the diversity of nine (9) tepary bean (*Phaseolus acutifolius*) lines by agronomic performance evaluation in Burkina Faso

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World Journal of Advanced Research and Reviews, 2024, 23(02), 2345–2353

Publication history: Received on 05 March 2024; revised on 24 August 2024; accepted on 27 August 2024

Article DOI: https://doi.org/10.30574/wjarr.2024.23.2.0788

Abstract

Tepary bean is a neglected and underutilized grain legume. Tepary bean has a greater potential to cope with the effects of climate change and contribute to food and nutritional security in Burkina Faso. Although it is a versatile legume, its use in human food and as fodder remains poorly understood. It is in this context that this study was initiated at the Gampèla experimental station with a view to improving knowledge of tepary beans by evaluating the agronomic performance of nine (9) lines introduced from Mexico. They were evaluated on seven (7) qualitative variables and fourteen (14) quantitative variables in a randomized complete block design with three (3) replications. The study showed the existence of agronomic variability within the lines studied with regard to qualitative parameters (type of plant, colour of flowering, colour of mature pods, dehiscence of pods, creeping stem, leaflet shape, seed colour) and quantitative parameters (emergence, flowering). Line 13IS-7500 scored highest in pod length (7.9 centimeters); pod weight (0.9 gram); seed length (9.36 centimeters); seed width (9.34 centimeters) and 100-seed weight (15.028 grams). The line 13IS-7500 deserves to be popularised for its seed size and was the best line on yield components.

Keywords: Tepary bean; Agronomic performance; Yield; Burkina Faso

1. Introduction

Sahelian countries, climatic hazards are becoming more and more frequent. These phenomena have particularly contributed to weakening the food situation of peasant populations, thus compromising numerous development initiatives [1]. To overcome these events, plant genetic resources for food and agriculture constitute the biological basis of world food security [2].

The introduction of new food crops with good nutritional value and resistance to adverse biophysical conditions offers hope for countries where famine is a direct result of these climatic conditions. Among these new plants is the tepary bean, which has a high potential to contribute to food security and poverty reduction [3].

The cultivated tepary bean (*Phaseolus acutifolius* A. Gray) is a short-cycle legume native to the deserts and semi-arid environments of north western Mexico and southwestern USA [4]. It is grown pure or in association with cereals (sorghum, millet, maize), vegetables (*Allium, Brassica, Capsicum, Cucurbita spp.*), or other pulses. Tepary bean seeds are very rich in protein, and the seeds contain natural antioxidants that contribute to the reduction of many cardiovascular diseases and coronary heart disease [5]. It is known for its resistance to heat, drought and many diseases [6]. These characteristics make it an ideal crop in tropical America, the Caribbean and Africa [7].

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Despite its nutritional importance and resistance or tolerance to biotic and abiotic stresses, tepary bean is neglected and underutilized with limited research support [8]. This is demonstrated by the lack of breeding activities aimed at genetic improvement of the crop [9]. As a result, very few genotypes improved in yield performance and other key yield-influencing traits have been developed and released into cultivation [7].

This state of affairs should prompt researchers to place particular emphasis on improving the tepary bean, which has a relatively short cycle and is therefore an important foodstuff during the lean season [10]. This requires knowledge of the phenotypic diversity of tepary bean lines introduced into Burkina Faso.

The overall objective of this study is to analyse the phenotypic diversity of nine (9) lines of tepary bean lines by evaluating their agronomic performance in Burkina Faso. The specific objectives are (i) to evaluate the seed yield of the lines and (ii) to identify the best lines for extension in rural areas.

2. Materials and Methods

2.1. Experimental Site

The experimental plot of the team of genetic and plant breeding located in Gampéla was used for the experiment. Gampéla is about twenty (20) kilometers east of Ouagadougou on the Ouagadougou-Zorgho axis. The geographical coordinates are 12°25' north latitude and 1°12' west longitude [11].

The climate is of the Sudano-Sahelian type, characterised by an alternating rainy season and a longer dry season [12]. The soils belong to the group of more or less leached tropical ferruginous soils representative of the central plateau. These soils have developed on materials rich in kaolin clay with a surface horizon poor in organic matter. This first horizon is followed by a second and third horizon which is the parent rock.

The sandy-clay soil type is composed of total nitrogen (0.028%), total phosphorus (192.2.10-6 mg/kg), and total potassium (2.22.10-3 mg/kg) with a water pH of 5.20 [13].

The vegetation is composed of a swampy savannah located in the lowlands along the Massili River, which passes over the station, and a dense or sparse shrub savannah with numerous tree species that are testimony to the existence of a tree savannah that eventually disappeared under demographic pressure [12].

For this wet season 2017-2018, July was very rainy with a water height of 246 mm. The cumulative rainfall for the year 2018 from July to the end of September was 657 mm in 63 days [14].

2.2. Plant Material

Plant material consists of nine (9) tepary bean lines of Mexican origin from the INERA/Saria germplasm. These lines are tolerant to drought, heat and salinity and their pods are dehiscent at maturity (table 1).

Table 1 List of lines

N°	Lineage	Origin	N°	Lineage	Origin	N°	Lineage	Origin
1	13IS-7500	Mexico	4	13IS-7525	Mexico	7	13IS-7594	Mexico
2	13IS-7506	Mexico	5	13IS-7527	Mexico	8	13IS-7599	Mexico
3	13IS-7520	Mexico	6	13IS-7528	Mexico	9	Local	Mexico

2.3. Methods

2.3.1. Experimental device

Experimental design of the study was a Fisher block with three (03) replicates. Each replication consisted of nine (9) elementary plots, each corresponding to a line. Each line was sown in three (03) lines of three (03) metres, with a spacing of 0.4 metres between lines and 0.2 metres between patches. The individual plots were separated from each other by one metre and the replicates by two metres.

2.3.2. Conduct of the trial

A ploughing was carried out with a tractor to a maximum depth of 25 cm. This was followed by harrowing to loosen the soil to provide a good seedbed. Sowing was done on 21 July 2018 by hand at a rate of 2 seeds. We carried out a de-sprouting at 1 foot per pack after emergence. Maintenance operations consisted of manual weeding, fertiliser application and phytosanitary treatments. The first weeding was done 15 days after sowing and the second 30 days after sowing. NPK fertiliser (14-23-14) was applied at the first weeding at a rate of 100 kg per hectare applied to the feet of the seedlings. Two insecticide treatments were made; one at flower bud formation to prevent their destruction by insects and their fall and the other at pod formation to control pests. The other treatments were made as needed. The insecticide used was Titan EC which is an emulsifiable concentrate composed of Acetamiprid at 25g/l. It is a systemic insecticide effective against biting and sucking insects and was used at a rate of 2 ml per litre of water. The harvesting of by-products (tops) per tepary bean line followed that of the pods. The different batches of harvested haulms were air-dried for fourteen (14) days.

2.3.3. Data Collection

Various parameters were collected, measured and counted. The variables were :

- Emergence: corresponds to the number of days between sowing and the emergence of the seedling from the soil;
- 50% flowering date: period between sowing and the date when 50% of the plants have flowered on an elementary plot. It is expressed in days after sowing (DAS);
- SPAD: Chlorophyll content (TC) in plants at flowering stage, pod formation;
- 95% maturity date: the period between sowing and the date when 95% of the pods have dried on an elementary plot;
- One hundred (100) seed weight in grams: measured on each elementary plot consisted of a random count of 100 seeds of each line per replication, followed by weight measurement using an electronic scale (Model PL601-L/00);
- Seed weight per line determined with an electronic scale (Model PL601-L/00), was expressed in kilograms, and allowed the calculation of seed yield by the formula: Yield = [(seed weight x 10000) / unit area];
- Fodder yield in kilograms per line was determined using an electronic scale (Model PL601-L/00). Its yield is also calculated by the following formula: [(fodder weight x 10000) / unit area];
- Number of pods per plant: counting the number of pods on the plant;
- Number of seeds per pod: calculated as the ratio of the number of seeds to the number of pods;
- Leaflet width: measure the width of the central leaflet with a ruler graduated in cm;
- Length of the pod: measure the pod with a ruler graduated in centimeter;
- Pod weight: obtained by weighing the pods of a line on an electronic scale in gram;
- Seed length: this is the measurement of the length of a seed using a calliper in millimeter;
- Seed width: this is the measurement of the width of a seed using a calliper in millimeter.

Qualitative parameters were also taken into account:

- Type of plant, it is a question of identifying whether they are plants with erect stems, semi-erect stems or creeping stems;
- Leaflet shape: lanceolate, oval-lanceolate, or oval;
- Colour of the flower in full bloom: determination of the colour of the flower;
- Mature pod colour: identify the colour of the mature pod ready for harvesting;
- Pod dehiscence; this involves leaving some pods on the plant to assess their dehiscence;
- Presence of creeping stems: identify lines with creeping stems;
- Seed colour: this is an assessment of the colour of the seed after harvest.

2.3.4. Analysis of statistical data

The agronomic data collected in the field were entered into an Excel 2016 spreadsheet. For the qualitative data, numerical codes were assigned to the different variants of each qualitative characteristic observed in the field. A synthesis of the data was made by line and by observed characteristic. A frequency calculation of each variant for the different qualitative characteristics was then carried out using the XLSTAT 2016 software. The quantitative data were then subjected to analyses of variance (ANOVA) at the 5% threshold to assess the variability between the 9 tepary bean lines. The relationships between the quantitative variables were estimated by the Pearson correlation coefficient. All these analyses were performed using XLSTAT 2016 software.

3. Results

3.1. Variation in Quality Characteristics of The Tepary bean

The results of the qualitative characteristics are recorded in Table 2. These observations showed that all the tepary bean lines have semi-erect growth habit, white blooming flowers, yellow pods with mottling at maturity, mature indehiscent pods and the presence of creeping stems in all lines. Variability was observed in the shape of the leaflet and the colour of the seed. Thus, the shape of the leaflet was lanceolate for 88.89% (8 lines) of the lines and oval-lanceolate for 11.11% (1 line) (figure 1). The seeds showed two colours (Figure 2); namely white seeds (88.89%) and brown seeds (11.11%). Figure 3 present photographs of non-variable qualitative characteristic of tépary bean lines.

Table 2 Distribution of the 9 tepary bean lines for quantitative characteristics

Characters	Modalities	Frequencies in percent
Type of plant	Semi-dry	100
Flower colour in full bloom	Blanche	100
Colour of mature pods	Yellow	100
Pod dehiscence	No	100
Creeping stem	Presence	100
Leaflet shape	Lancéolée	88.89
	Oval-lanceolate	11.11
Seed colour	Blanche	88.89
	Brown	11.11

Legend: A: oval-lanceolate; B: lanceolate.

Figure 1 Leaflet shape of tepary bean lines

Legend: A: brown seeds; B: white seeds

Figure 2 Seed colours of tepary bean lines

Legend: A: creeping stem; B: yellow pods; C: white flower.

Figure 3 Photographs of non-variable qualitative characteristics of tepary bean lines

3.2. Phenology

Emergence occurred between the 2nd and 3rd day after sowing. The tepary bean line 13IS-7594 emerged first. On the 2nd day after sowing (DAS) while the other lines emerged on the third day. The results of the analysis of variance (Table 3) revealed a significant difference between the lines at the 5% level ($p<0.05$). However. the analysis of variance at the 5% level was not significant for chlorophyll content. flowering and maturity.

Table 3 Result of the analysis of variance of phenological traits

Lines	Emergence (JAS)	Chlorophyll content	50Flowering % (JAS)	95%Maturity (JAS)
13IS-7500	3.000 [a]	0.422 [a]	32.001 [a]	57.668 [a]
13IS-7520	2.999 [a]	0.401 [a]	31.676 [a]	57.670 [a]
13IS-7506	3.000 [a]	0.444 [a]	31.004 [a]	58.003 [a]
13IS-7594	2.334 [b]	0.489 [a]	29.662 [a]	60.999 [a]

13IS-7525	2.998 [a]	0.393 [a]	30.680 [a]	58.337 [a]
13IS-7528	3.000 [a]	0.384 [a]	31.665 [a]	57.668 [a]
13IS-7599	3.000 [a]	0.427 [a]	30.667 [a]	58.336 [a]
Local	3.004 [a]	0.429 [a]	32.297 [a]	59.650 [a]
13IS-7527	2.998 [a]	0.398 [a]	31.014 [a]	57.336 [a]
Minimum	2.000	0.311	29.000	56.000
Maximum	3.000	0.540	34.000	69.000
Average	2.926	0.421	31.185	58.407
CV%.	9.12	13.82	4.08	3.95
Pr > F	0.022*	0.648	0.395	0.760

Means with the same letter in the same column are not significantly different at the 5% level. CV%: covariance. JAS: day after sowing.

3.3. Performance and components

The pod weight ranged from 0.59 g to 0.98 g with an average of 0.75 g. The highest value of pod weight was obtained by line 13IS-7500 while the lowest value was observed in line 13IS-7599 (P-value = 0.022). The analysis of variance showed a significant difference between lines at the 5% level (p = 0.027; table 4).

The variation in pod length ranged from 6.74 cm to 7.9 cm with an average of 7.32 cm. The longest pods (7.83 cm) were harvested on line 13IS-7500 and the shortest (6.87 cm) on line 13IS-7528. The analysis of variance for this characteristic was significant at the 5% level (p = 0.028).

Table 4 Result obtained for the performance variables

Lines	Seed yield Kg/Ha	Fodder yield Kg/ha	Pods/ plant	Number seeds /pod	Leaflet width (cm)	Pod length (cm)	Pod weight (g)	Seed length (mm)	Seed width (mm)	Weight 100 seeds (g)
13IS-7500	1584.7 [a]	2712.9 [a]	23.5 [a]	5.0 [a]	3.4 [a]	7.8 [a]	0.8 [a]	9.3 [a]	9.3 [a]	15.0 [a]
13IS-7520	1408.3 [a]	2765.6 [a]	35.9 [a]	5.4 [a]	2.5 [b]	7.4 [ab]	0.7 [ab]	8.1 [b]	5.5 [b]	12.0 [bc]
13IS-7506	1675.1 [a]	3484.5 [a]	27.8 [a]	5.2 [a]	2.6 [b]	7.4 [ab]	0.7 [ab]	8.1 [b]	5.6 [b]	11.6 [bc]
13IS-7594	671.2 [a]	4639.5 [a]	25.0 [a]	5.2 [a]	2.8 [b]	7.1 [ab]	0.7 [ab]	8.0 [b]	5.7 [b]	12.4 [bc]
13IS-7525	1105.9 [a]	4742.6 [a]	38.0 [a]	5.1 [a]	2.6 [b]	7.3 [ab]	0.7 [b]	8.0 [b]	5.3 [b]	11.6 [bc]
13IS-7528	914.8 [a]	4548.6 [a]	27.4 [a]	5.1 [a]	2.5 [b]	6.8 [b]	0.7 [ab]	8.0 [b]	5.7 [b]	13.4 [b]
13IS-7599	1424.0 [a]	3284.4 [a]	24.3 [a]	5.1 [a]	2.9 [b]	7.3 [ab]	0.6 [b]	7.9 [b]	5.3 [b]	10.6 [c]
Local	991.1 [a]	1771.7 [a]	22.7 [a]	5.5 [a]	2.7 [b]	7.1 [b]	0.7 [b]	7.5 [c]	5.0 [b]	10.7 [c]
13IS-7527	1027.08 [a]	2646.3 [a]	25.5 [a]	5.1 [a]	2.3 [b]	7.2 [ab]	0.6 b	7.8 [b]	5.3 [b]	11.3 [bc]
Minimum	210	1357.81	9.83	4.83	2.2	6.7	0.5	7.3	4.9	9.9
Maximum	2029.5	9859.38	58.1	5.75	3.8	7.9	0.9	11.1	9.5	16
Average	1200.27	3399.61	27.83	5.23	2.7	7.3	0.7	8.1	5.9	12.1
CV%.	43.93	40.65	37.33	4.33	14.27	4.36	10.6	6.28	25.2	12.5
Pr > F	0.87 ns	0.83 ns	0.73 ns	0.18 ns	0.028*	0.028*	0.027*	0.0001**	0.005**	0.001**

Means with the same letter in the same column are not significantly different at the 5% level. CV%: covariance; cm: centimeter; mm: millimeter; g: gram

The length of the seed varied from 7.39 mm to 11.17 mm with an average of 8.12 mm. The analysis of variance showed a significant difference (p = 0.0001) for this parameter. The line that obtained the longest seeds was the line 13IS-7500 with 9.36 mm and the shortest were presented by the seeds of the local line with 7.50 mm.

Seed width varied from 4.92 mm to 9.56 mm with an average of 5.90 mm. The smallest seed width was measured on seeds of the local line with 5 mm and the highest (9.35 mm) on the line 13IS-7500. The results of the analysis of variance showed a significant difference at the 5% level (P=0.005).

The 100-seed weight ranged from 10.71 g to 15.01 g with an average of 12.11 g. Line 13IS-7500 had the highest 100-seed weight with 15.028 g and line 13IS-7599 had the lowest 100-seed weight with 10.644 g. The result of the analysis of variance for 100-seed weight was significant (p=0.001).

The results of the analysis of variance for the variables number of pods per plant. number of seeds per pod. fane yield. seed yield.

The difference is not significant for the other variables; however. it varied from 9.833g to 58.100g with a mean of 27.839g; which varied from 4.83 and 5.70 with a mean of 5.23; which varied from 1357.813 kg/ha to 9859.375 kg/ha with a mean of 3399.609 kg/ha and with a minimum of 210.000. a maximum of 2029.583 kg/ha and a mean of 1200.278 kg/ha.

4. Discussion

Agronomic and morphological evaluation of the 9 lines revealed the existence of variability for some qualitative and quantitative traits. For [15]. the evaluation of the morphological trait is the first step in the characterisation of the germplasm. This is very important for a breeder because breeding programmes are generally based on the wide phenotypic variability of the crops [16].

The qualitative characteristics presented two or more modalities. Thus, reflecting a morphological diversity within the material studied. All the lines had semi-erect stems characteristic of cultivated forms of tepary bean [17].

The non-significant differences in quantitative variables related to phenology. number of pods per plant. number of seeds per pod. fane yield. seed yield indicates a low level of variability between the selected lines. This suggests that the accessions are agronomically similar. These results are in agreement with the lower tepary diversity observed by [18] when 55 wild and 8 cultivated tepary were analysed by polyacrylamide gel electrophoresis. These results could be explained by the small number of lines or by duplication of material. Nevertheless. this duplication could perhaps be tested during molecular analysis work. These analyses are better suited to identify duplicates of accessions than analyses of morphological traits that are highly influenced by environmental effects [19].

Although the cycle (flowering and maturity) was not significant. it was found that all lines showed a fairly early tepary bean cycle on average (58.407 JAS). This is an intrinsic characteristic of the tepary bean [18]. Early selection is important for any species. as breeders and farmers still need early maturing genotypes to adapt the crop to the short rainy season as a consequence of climate change [20].

Also, the number of seeds per pod did not vary. It ranged from 4 to 6. These results confirm those obtained by [21] who stated that the number of seeds per pod is a low variable trait. Similarly. the tepary bean is known as a plant that does not have a high number of seeds per pod. For yield improvement. breeders will have to focus on increasing the number of pods per plant. as it is difficult to influence the number of seeds per pod. Thus, lines 13IS-7520 and 13IS-7525 with pod numbers above 30 could be identified as a cross parent for increasing the number of pods per plant.

The lack of significant difference in haulm and seed yields does not exclude the fact that some lines showed good seed (above 1.5 tons) and haulm yields (above 3 tons). These lines with good seed and haulm yields can be offered for seed consumption and those with good haulm yields for animal fodder consumption. Also, these lines can be used as crossing parents for the improvement of this crop. The line 13IS-7506 with a very good seed and haulm yield can be used as a dual purpose tepary bean (human consumption and livestock).

The traits with the greatest variation were hundred seed weight. seed length and seed width. The higher variation suggests that there is potential for improvement in this crop. The average 100-seed weight ranged from 10.6 to 15.5 g and the line 13IS-7500 had the best 100-seed weight value (15.028 g). These differences in seed weight could be based on the time of accumulation of reserves in the seeds or on the genetic composition of different genotypes. The climatic adaptation factor could also be responsible for the higher seed weight [22]. The interest of this parameter in breeding is that the consumer prefers large seeds and it is in this sense that the breeder chooses plants with larger seeds and at the same time with good morphological traits that are likely to give good yields.

5. Conclusion

This study has shown that there is variability within the nine tepary bean lines and. above all. has identified lines with characteristics of agronomic interest. It has made it possible to highlight lines with characteristics of agronomic interest. The line 13IS-7500 obtained the best results on yield components: pod length. pod weight. seed length. seed width and weight of 100 seeds. We can therefore suggest this line to producers who want to start producing tepary beans. We can also recommend the line 13IS-7527 for its white seed colour and for its performance. which is very similar to 13IS-7500.

Overall. the best performance was recorded for all lines tested either for a given parameter or for all the parameters that were considered in the evaluation. i.e. the agronomic traits.

These very interesting results will serve to improve knowledge of the tepary bean and help to advocate for its popularisation and adoption by farmers in Burkina Faso.

Compliance with ethical standards

Acknowledgments

We would like to thank the site wardens for securing the experiment, as this made it easier to achieve our objectives.

Disclosure of conflict of interest

All authors have no conflict of interests to declare

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