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Research Article

Agrophysiological Performance of Mungbean Accessions (*Vigna radiata* (L.) R. Wilczek) and Nitrogen Balance under Mungbean in Burkina Faso

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Mungbean (*Vigna radiata* (L.) Wilczek) is a seed legume that is not well known in the cropping systems and dietary habits of Burkina Faso. The objective of this study was to evaluate the physiological and agronomic performance of fifteen mungbean accessions from a collection of the World Vegetable Center in Mali under rainfed conditions in Burkina Faso. The experimental design was a Fischer block with three replications, and the measurements focused not only on the growth, development cycle, and yield parameters of the plants but also on the total nitrogen balance in the soil at harvest. The results show that growth parameters such as the plant height at the beginning of flowering (HP), stem neck diameter (SCD), and number of branches per plant (NBrP) significantly discriminate between dealerships. The same was true for all the developmental parameters. The tallest plants with a higher crown diameter and number of branches were those of accession A3. The early flowering cycle varied from very early (29 days) to medium (41 days), with an average of about 34 days. On the other hand, the cycle at harvest varied from 82 days to 93 days depending on the accessions, with an average of about 88 days. The best performances in terms of yield were expressed by the accessions A3, A2, and A12 with $850.50\,kg{\cdot}ha^{-1}$, $625.2\,kg{\cdot}ha^{-1}$, and $544.8\,kg{\cdot}ha^{-1}$, respectively. At harvest, the soil nitrogen balance was generally positive with an increase of $0.326\,g{\cdot}N{\cdot}kg^{-1}$ of soil, which represents a nitrogen input from the mungbean contributing to the improvement of the soil nitrogen status. As nitrogen is an essential nutrient that is often lacking, limiting plant growth, farmers are obliged to supply this nutrient in the form of fertiliser; with mungbean's ability to supply nitrogen to the soil, it could therefore be used in crop rotations as a solution to make up for the lack of nitrogen.

1. Introduction

Burkina Faso, like other countries of sub-Saharan Africa, is experiencing significant population growth. This strong population growth leads to an increase in food needs, thus inducing a prevalence rate of undernourishment estimated at 19.2% in Burkina Faso [1]. In addition, increasingly severe climatic hazards have contributed to weakening the food situation of peasant populations, thus compromising numerous development initiatives [2]. Moreover, the degradation of land fertility [3] and the low level of crop diversification in Burkina Faso limit agricultural production. In view of this situation, it is not only necessary to diversify agricultural production but also and above all to identify crops that are resilient to difficult climatic conditions and that meet the nutritional needs of the population.

The cultivation of seed legumes is recognised as one of the best and least expensive options for addressing malnutrition and particularly protein deficiencies in sub-Saharan Africa [4]. Mungbean (*Vigna radiata* (L.) Wilczek) is an annual seed legume that is a major source of dietary protein and minerals for urban and rural populations as well as for livestock [5]. As a result, mungbean is a legume with high protein potential that can substitute animal protein, which is not easily accessible to the poor. Moreover, this legume has specific properties with regard to the nitrogen cycle through its capacity to fix atmospheric nitrogen. To this end, the integration of mungbean (*Vigna radiata* (L.) Wilczek) into cropping systems could be an alternative towards achieving food and nutritional security in Burkina Faso and also for improving soil fertility through its contribution of nitrogen, which is an essential element generally lacking in soils. According to the authors in [6], *V. radiata* could contribute significantly to food and nutritional security and to generate substantial income for the households that produce it. Unfortunately, mungbean remains a very little cultivated species in Burkina Faso. Thus, this study was initiated with the objective of evaluating the physiological and agronomic parameters of mungbean accessions under the climatic conditions of the Sudano-Sahelian zone of Burkina Faso.

2. Materials and Methods

2.1. Experimental Site. The experiment was conducted under rainfed conditions at the experimental station of the Institut du Développement Rural (IDR) based in Gampèla, about 20 km east of the city of Ouagadougou, not far from the national road (RN) n°4 (Figure 1).

Established in 1975, with an area of about 490 hectares, the Gampèla experimental station is located between parallels 12°24.613′ and 12°25.413′ north latitude and meridians 1°20.464 and 1°21.652 west longitude [8]. The climate in the area of the station is of the Sudano-Sahelian type characterised by a rainy season from June to October with the maximum rainfall in August and a long dry season from November to May [9]. The average rainfall varies between 700 mm and 900 mm.

The soil of Gampèla is of low chemical fertility and predominantly sandy loam texture [10].

2.2. Plant Material. The plant material consists of 15 mungbean accessions from the World Vegetable Center collection in Mali. These accessions differ essentially in seed colour, which varies from light to dark green, in pod colour at maturity, and in the state of pubescence of the pods (Table 1).

Accessions have been assigned symbols from A1 to A15 to facilitate the processing of data with regards to long names.

2.3. Experimental Device. The experimental setup was a Fischer block with three replicates, oriented from East to West (Figure 2), covering a total area of 907.5 m^2 (75 m × 12.1 m). A total of forty-five (45) elementary plots were used for the experiment, each replication comprising one elementary plot per accession, i.e., 15 elementary plots per replication. The elementary plot had 7 lines of 2.7 cm each. The spacing between the replicates was 2 m, and the distance between the elementary plots in a block was 1.5 m. The rows were spaced at 0.6 m apart, and in each row, the pits were 0.3 m apart. The seedlings were sown at one seed per cluster. Each accession was sown on three elementary plots comprising seven (07) lines each. Measurements were made on 5 plants in the 3 middle rows in each plot.

2.4. Data Collection and Statistical Analysis. Measurements were made on growth, development, yield, and total soil nitrogen.

For growth, plant height (HP) in centimetres and diameter at stem collar (DSC) in millimetres were measured weekly from 21^{st} days after sowing until fruiting. The length of the terminal leaf (LTL) in centimetres determined at flowering, the length of the petiole (LPt) in centimetres determined at the fourth node, the length of the peduncle (LPd) in centimetres measured at the ripening of the first pod, and the number of branches per plant (NBrP) counted at the pod ripening stage were considered.

The development cycle of the accessions was assessed through the number of days at the beginning of flowering (NDBFl), the number of days to 50% flowering (ND50Fl), the number of days to 50% pod maturity (ND50MatG), and the cycle length (CL) in days.

Yield components such as the number of pods per plant (NPoP), pod length (LPo) in centimetres, number of seeds per pod (NSePo), number of seeds per plant (NSeP) using a Tripette & Renaud seed counter, and 1000-seed weight (WTSe) using a 0.01 g precision balance were assessed.

The seed yield (YSe) in kg/ha was estimated from the following formula:

$$\text{YSe}\left(\frac{\text{kg}}{\text{ha}}\right) = \left(\frac{\text{seed weight} \times 10000}{\text{area}}\right), \quad (1)$$

where kg: kilogram and ha: hectare.

The total nitrogen balance of the crop soil was determined on the basis of the difference between the nitrogen available in the soil at sowing and that available at harvest. To do this, three samples were taken at three levels along the diagonal in each replication using an auger before sowing and then mixed to obtain a composite sample. The same operation was repeated at harvest for each elemental plot, and the crop soil samples from the same accession were mixed to obtain composite samples. The total N content of the composite samples was measured according to the Kjeldhal method as described by [12]. The total nitrogen balance was determined according to the following formula:

$$\text{TNB} = \text{QNS} - \text{QNH}, \quad (2)$$

where TNB: total nitrogen balance, QNS: quantity of nitrogen before sowing, and QNH: quantity of nitrogen at harvest.

For data processing and analysis, the Microsoft Excel 2016 spreadsheet program was used to build the database.

The analysis of variance (ANOVA) and the calculation of means and standard errors were carried out with the GenStat 2015 software. The Newman–Keuls test at the 5% threshold was also used to compare the means and to produce the graphs. The Newman–Keuls test was used to separate means

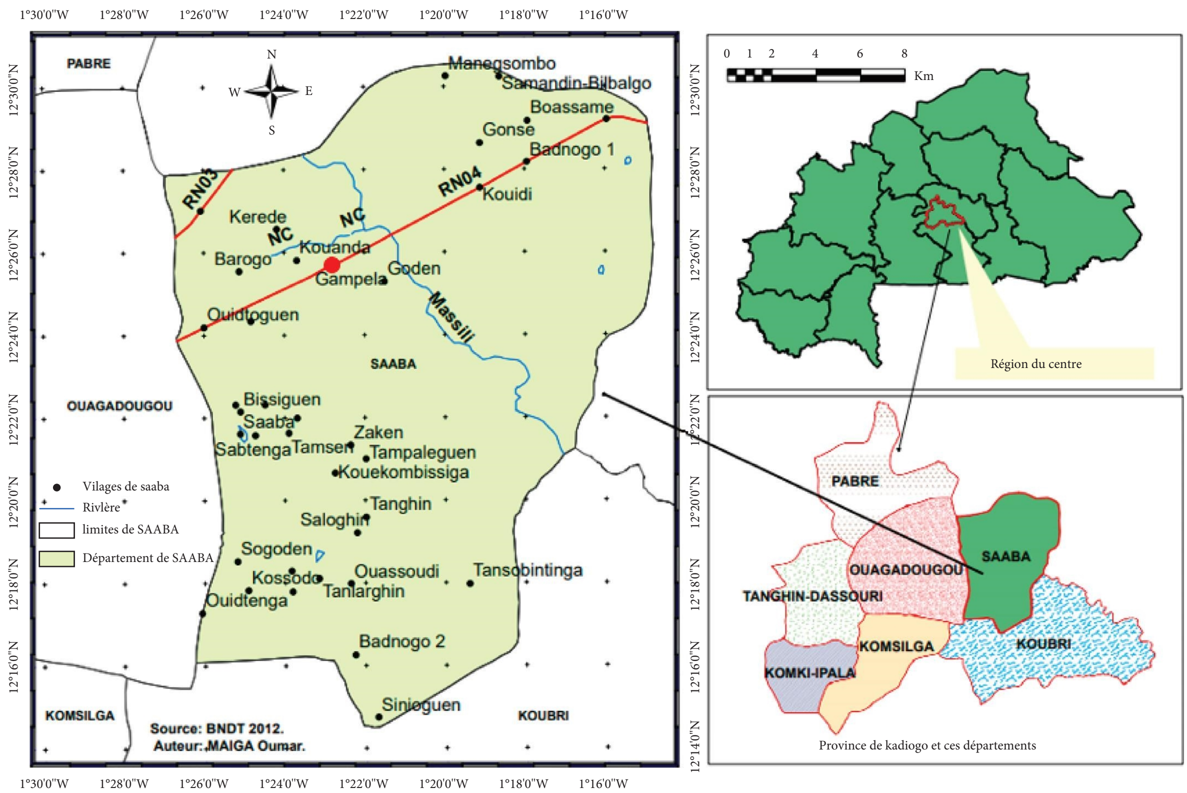

Figure 1: Map of the geographical location of the study area, source: [7].

Table 1: Characteristics of the accessions studied.

Symbols	Accessions	Colour of the flowers	Colour of young pods	Colour of pods at maturity	Pubescence of pods	Seed colour
A1	AVMU1654-VR-2013-5-2-1-1	Pale yellow	Green	Black	Intermediate	Green
A2	AVMU1656-VR-2013-6-1-1-3	Pale yellow	Green	Black	Intermediate	Green
A3	AV MU1614-VR-2012-5-69-26-1-1	Pale yellow	Green	Black	Very pubescent	Dark green
A4	AVMU1643-R-2012-81-1-3	Pale yellow	Green	Brown	Intermediate	Green
A5	AVMU1650-VR-2013-2-3-13	Pale yellow	Green	Black	Very pubescent	Light green
A6	AVMU1646-VR-2013-1-1-1-2	Pale yellow	Green	Black	Very pubescent	Dark green
A7	AVMU1657-VR-2013-6-3-1-4	Pale yellow	Green	Black	Intermediate	Light green
A8	AVMU1655-VR-2013-5-3-1-2	Pale yellow	Green	Brown	Intermediate	Light green
A9	AVMU1621-VR-2012-5-93-12-1-1	Pale yellow	Green	Black	Intermediate	Dark green
A10	AVMU1626-VR-2012-9-7-3-3-1-1	Pale yellow	Green	Black	Intermediate	Green
A11	AVMU1627-VR-2012-9-7-3-4-1-1	Pale yellow	Green	Brown	Intermediate	Green
A12	AVMU1645-VR-2012-12-140-1-2	Pale yellow	Green	Black	Intermediate	Light green
A13	AVMU1636-VR-2012-12-45-1-2	Pale yellow	Green	Brown	Intermediate	Green
A14	AVMU1642-VR-2012-12-81-1-2	Pale yellow	Green	Brown	Intermediate	Green
A15	AVMU1641-VR-2012-81-1-1	Pale yellow	Green	Brown	Intermediate	Green

Source: [11].

in order to determine significant differences between the group means.

The results were presented in the form of tables with average ± standard errors and in the form of box plots in order to best observe the variability of yields according to the accessions.

3. Results

3.1. Plant Growth. The Newman–Keuls mean separation test from the analysis of variance revealed that the plant height at flowering (HP), diameter at stem collar (DSC), peduncle length (LPd), and number of branches per plant (NBrP)

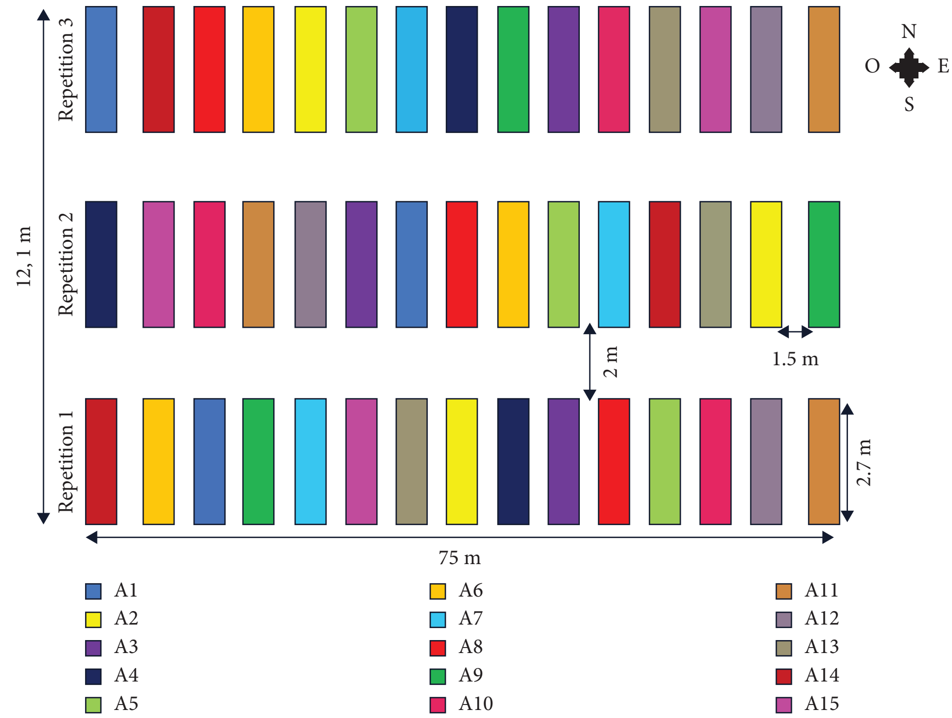

Figure 2: Schematic of the experimental setup.

significantly discriminate the 15 accessions studied with respective means of 14.73 ± 0.96 cm, 2.40 ± 0.23 cm, 10.97 ± 1.48 cm, and 1.98 ± 0.55 (Table 2). Indeed, accession A3 presented taller plants (18.53 cm) with larger diameters (2.91 cm), longer peduncles (14.09 cm), and a higher number of branches than the other accessions. However, the lowest plant height at flowering (11.65 cm) was recorded by accession A14, and the shortest peduncle (7.95 cm) was noted on accession A5.

Overall, all accessions showed plants with low branching ranging from about 1 to 3.

3.2. Development Cycle of Accessions. The analysis of variance showed a significant difference ($P < 0.001$) between the accessions in the number of days at the beginning of flowering (NDBFl), the number of days to 50% flowering (ND50Fl), the number of days to 50% pod maturity (ND50MatPo), and the cycle length (CL). Indeed, the number of days at the beginning of flowering varied from 29.33 days to 41.33 days depending on the accessions with an average of 33.75 days (Table 3). The number of days to 50% flowering and the number of days to 50% pod maturity varied, respectively, from 33.67 to 47.33 days and from 51.33 to 64.33 days depending on the accessions with an average of 39.38 days and 56.84 days, respectively. Accession A10 had a relatively short flowering start, days to 50% flowering, and days to 50% pod maturity, with about 29 days, 33 days, and 51 days, respectively. However, accession A7 had a longer flowering onset, days to 50% flowering, and days to 50% pod maturity than the other accessions at about 41 days, 47 days, and 64 days, respectively.

The cycle length also varied between accessions from 82 days to 93 days, with an average of about 88 days. Thus, accessions A10 and A11 showed a relatively short cycle (82 days), while the long cycle (93 days) was observed on accession A7.

3.3. Yield and Its Components. The results showed that the seed yield of accession A3 was significantly higher (850.50 kg·ha^{-1}) than that of the other accessions, followed by those of accessions A2 and A12 with 625.2 kg·ha^{-1} and 544.8 kg·ha^{-1}, respectively (Figure 3). However, the distributions of values for accessions A3 and A12 showed higher ranges. The accessions that expressed significantly low seed yields were A14, A13, and A11 with 151.2 kg·ha^{-1}, 240.7 kg·ha^{-1}, and 243.8 kg·ha^{-1}, respectively.

The analysis of variance revealed very highly significant differences ($P = 0.008$) between the accessions with the constitution of 3 statistical groups, namely, group 1 with accession A3, group 2 composed of accessions A4, A8, A9, A15, A7, A12, and A2, and group 3 composed of accessions A14, A13, A11, A6, A1, A10, and A5.

The number of pods per plant (NGop), pod length, number of seeds per plant (NSeP), and 1000-seed weight (WTSe) significantly ($P < 0.001$) discriminate between accessions (Table 4). Indeed, the average number of pods and seeds per plant was 58.80 and 566.27, respectively. Accession A14 recorded a lower number of pods per plant (NPoP) and number of seeds per plant (NSeP) with values of 29 pods per plant and 259 seeds per plant, respectively. However, the high number of pods (149 pods) and seeds per plant (1694) was noted in accession A3. The results also revealed the 1000-seed weight (WTSe) varying between 26.90 g and

Table 2: Growth parameters of mungbean accessions.

Accessions	HP (cm)	DSC (mm)	LTL (cm)	LPt (cm)	LPd (cm)	NBrP
A1	15.23 ± 0.44^{bc}	2.39 ± 0.08^{ab}	8.88 ± 0.70^{a}	7.51 ± 0.81^{a}	10.11 ± 1.16^{ab}	1.20 ± 0.13^{a}
A2	16.40 ± 1.37^{bc}	2.74 ± 0.23^{ab}	10.01 ± 0.28^{a}	7.47 ± 0.84^{a}	10.32 ± 1.64^{ab}	1.56 ± 0.50^{ab}
A3	18.53 ± 0.88^{d}	2.91 ± 0.75^{b}	9.84 ± 1.36^{a}	8.51 ± 2.24^{a}	14.09 ± 3.77^{b}	2.98 ± 1.74^{b}
A4	13.07 ± 1.65^{a}	2.38 ± 0.24^{ab}	9.72 ± 1.10^{a}	9.29 ± 3.35^{a}	11.34 ± 1.45^{ab}	1.64 ± 0.78^{ab}
A5	14.73 ± 1.04^{b}	2.47 ± 0.07^{ab}	9.71 ± 1.28^{a}	6.75 ± 0.34^{a}	7.95 ± 0.67^{a}	2.02 ± 0.71^{ab}
A6	15.15 ± 0.32^{bc}	2.29 ± 0.03^{ab}	8.87 ± 0.79^{a}	6.88 ± 0.69^{a}	8.27 ± 1.50^{a}	1.61 ± 0.55^{ab}
A7	15.157 ± 1.42^{bc}	2.42 ± 0.16^{ab}	7.11 ± 2.71^{a}	8.13 ± 1.63^{a}	13.15 ± 1.33^{b}	2.92 ± 0.50^{b}
A8	16.37 ± 1.41^{bc}	2.24 ± 0.14^{ab}	10.03 ± 0.67^{a}	8.82 ± 0.81^{a}	10.37 ± 1.05^{ab}	2.02 ± 0.67^{ab}
A9	15.76 ± 1.08^{bc}	2.08 ± 0.11^{a}	10.19 ± 0.57^{a}	5.70 ± 2.89^{a}	11.80 ± 2.41^{ab}	2.16 ± 0.37^{ab}
A10	16.72 ± 0.56^{c}	2.38 ± 0.24^{ab}	10.56 ± 0.71^{a}	7.35 ± 1.21^{a}	9.59 ± 1.48^{ab}	1.40 ± 0.24^{ab}
A11	15.15 ± 0.72^{bc}	2.20 ± 0.24^{a}	10.56 ± 0.64^{a}	7.19 ± 0.84^{a}	10.12 ± 0.60^{ab}	1.63 ± 0.35^{ab}
A12	11.73 ± 0.48^{a}	2.33 ± 0.33^{ab}	8.77 ± 1.27^{a}	5.84 ± 1.07^{a}	11.34 ± 1.63^{ab}	1.87 ± 0.66^{ab}
A13	12.30 ± 1.21^{a}	2.46 ± 0.40^{ab}	9.01 ± 1.99^{a}	6.97 ± 1.46^{a}	12.25 ± 2.32^{abc}	2.13 ± 0.69^{ab}
A14	11.65 ± 0.25^{a}	2.32 ± 0.10^{ab}	8.87 ± 1.87^{a}	6.54 ± 1.06^{a}	11.34 ± 1.08^{ab}	1.73 ± 0.25^{ab}
A15	13.03 ± 1.52^{a}	2.42 ± 0.38^{ab}	8.61 ± 0.89^{a}	7.97 ± 0.92^{a}	12.49 ± 0.15^{ab}	2.13 ± 0.18^{ab}
Average	14.73 ± 0.96	2.40 ± 0.23	9.38 ± 1.12	7.39 ± 1.34	10.97 ± 1.48	1.98 ± 0.55
CV (%)	4.5	9.5	12.8	18.9	14.1	29.0
P	<0.001	0.027	0.105	0.138	0.002	0.024
Meaning	S	S	NS	NS	S	S

HP: height of the plant at flowering; DSC: diameter at stem collar; LTL: length of terminal leaf; NBrP: number of branches; LPt: petiole length; LPd: peduncle length; CV: coefficient of variation (%); P: probability; S: significant; NS: not significant; mm: millimetre; cm: centimetre. Numbers followed by the same letters are not significantly different.

Table 3: Development cycle parameters of mungbean accessions.

Accessions	Cycle parameters			
	NDBFl	ND50Fl	ND50MatPo	CL (d)
A1	33.33 ± 0.58^{cd}	38.33 ± 0.58^{cd}	56.67 ± 0.58^{bc}	87.33 ± 4.62^{cd}
A2	32.33 ± 1.15^{bc}	36.67 ± 0.58^{b}	56.33 ± 0.58^{bc}	85.67 ± 3.79^{abc}
A3	33.33 ± 0.58^{cd}	39.33 ± 0.58^{df}	57.00 ± 0.00^{bc}	89.00 ± 3.61^{cd}
A4	34.33 ± 0.58^{d}	41.33 ± 0.58^{h}	58.00 ± 0.00^{c}	89.33 ± 1.12^{cd}
A5	33.67 ± 0.58^{cd}	37.67 ± 0.58^{bc}	56.67 ± 0.58^{bc}	89.67 ± 0.58^{cd}
A6	33.33 ± 0.58^{cd}	39.33 ± 0.58^{df}	55.33 ± 1.15^{b}	85.33 ± 2.31^{abc}
A7	41.33 ± 0.58^{f}	47.33 ± 0.58^{j}	64.33 ± 1.18^{d}	93.00 ± 0.00^{d}
A8	33.33 ± 0.58^{cd}	37.67 ± 0.58^{bc}	57.33 ± 1.15^{bc}	88.33 ± 2.08^{cd}
A9	35.67 ± 0.58^{e}	41.33 ± 0.58^{h}	58.00 ± 0.00^{c}	91.00 ± 0.00^{cd}
A10	29.33 ± 0.58^{a}	33.67 ± 0.58^{a}	51.33 ± 0.58^{a}	82.00 ± 0.00^{a}
A11	31.67 ± 1.54^{b}	37.33 ± 0.58^{bc}	52.33 ± 0.58^{a}	82.00 ± 0.00^{a}
A12	36.33 ± 0.58^{e}	41.33 ± 0.58^{h}	57.67 ± 0.58^{c}	87.33 ± 2.31^{cd}
A13	32.33 ± 0.58^{bc}	40.33 ± 0.58^{fh}	57.00 ± 0.00^{bc}	85.33 ± 1.16^{abc}
A14	33.33 ± 0.58^{cd}	40.67 ± 0.58^{h}	57.67 ± 0.58^{c}	88.67 ± 1.16^{cd}
A15	32.67 ± 0.58^{bc}	38.33 ± 0.58^{cd}	57.00 ± 1.00^{bc}	90.00 ± 2.00^{cd}
Average	33.75 ± 0.65	39.38 ± 0.58	56.84 ± 0.70	87.60 ± 1.65
CV (%)	1.8	1.4	1.3	2.4
P	<0.001	<0.001	<0.001	<0.001
Meaning	S	S	S	S

NDBFl: number of days at the beginning of flowering; ND50Fl: number of days at 50% flowering; ND50MatPo: number of days to 50% pod maturity of pods; CL: cycle length; d: date; DCV%: coefficient of variation; P: probability; S: significant. Numbers followed by the same letters are not significantly different.

41.47 g depending on the accessions with an average of 31.92 g. Regarding the pod length (LPo), accession A7 produced longer pods (9.90 cm), while accession A15 produced shorter pods (6.15 cm).

3.4. Relationships between Parameters. The Pearson correlation matrix at the 5% threshold (Table 5) revealed positive correlations between the number of branches and yield-related parameters, notably the number of seeds per plant

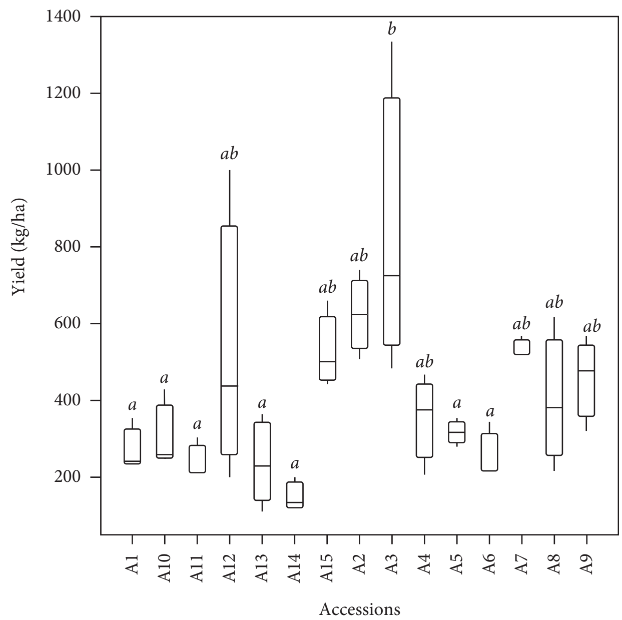

Figure 3: Variability of seed yields according to accessions. Numbers followed by the same letters are not significantly different, and the central horizontal bar of the box plot represents the median.

Table 4: Yield components of mungbean accessions.

Accessions	Yield components			
	NPoP	LPo	NSeP	WTSe (g)
A1	49.56 ± 3.62[ab]	6.53 ± 0.32[abc]	404.70 ± 15.64[abc]	36.17 ± 3.80[bdef]
A2	48.11 ± 15.68[ab]	9.60 ± 0.62[gh]	462.70 ± 23.41[abc]	41.47 ± 2.48[f]
A3	149.33 ± 20.92[c]	8.83 ± 0.42[fgh]	1693.90 ± 56.76[d]	31.70 ± 3.86[abcde]
A4	61.33 ± 18.19[ab]	8.12 ± 0.49[def]	615.70 ± 54.10[abc]	27.37 ± 2.30[abc]
A5	48.44 ± 9.08[ab]	9.00 ± 0.56[fgh]	369.9 ± 15.22[abc]	39.63 ± 2.98[ef]
A6	44.89 ± 9.37[ab]	7.80 ± 0.70[cdef]	267.30 ± 12.48[a]	38.23 ± 8.44[def]
A7	62.22 ± 9.13[ab]	9.90 ± 0.44[h]	736.20 ± 26.00[bc]	37.23 ± 2.49[def]
A8	48.56 ± 9.20[ab]	7.17 ± 0.61[abcd]	464.90 ± 19.20[abc]	27.30 ± 0.80[abc]
A9	49.67 ± 9.72[ab]	8.60 ± 0.87[efg]	630.60 ± 54.88[abc]	26.90 ± 0.82[ab]
A10	55.11 ± 6.77[ab]	7.53 ± 0.25[bcde]	408.30 ± 7.84[abc]	30.50 ± 2.10[abcd]
A11	50.56 ± 7.00[ab]	7.43 ± 0.58[abcde]	335.40 ± 11.40[ab]	30.47 ± 0.76[abcd]
A12	71.56 ± 4.05[b]	6.80 ± 0.00[abcd]	557.20 ± 29.70[abc]	32.17 ± 4.03[abcde]
A13	52.78 ± 2.91[ab]	7.13 ± 0.53[abcd]	494.00 ± 5.78[abc]	25.43 ± 1.35[a]
A14	29.33 ± 3.57[a]	6.40 ± 0.26[ab]	259.30 ± 12.16[ab]	27.17 ± 2.40[ab]
A15	75.58 ± 20.88[b]	6.13 ± 0.12[a]	794.00 ± 45.76[c]	27.00 ± 2.82[ab]
Average	58.80 ± 10.01	7.80 ± 0.46	566.27 ± 27.51	31.92 ± 2.76
CV (%)	22.8	6.7	27.2	10.7
P	<0.001	<0.001	<0.001	<0.001
Meaning	S	S	S	S

NPoP: number of pods per plant; LPo: pod length; NSeP: number of seeds per plant; WTSe: 1000 seed weight; g: gram; CV%: coefficient of variation in percent; P: probability value. Numbers followed by the same letters are not significantly different.

($r = 0.62$), the number of pods per plant ($r = 0.59$), and seed yield ($r = 0.6$). The seed yield was itself positively correlated with the number of pods per plant ($r = 0.96$) and the number of seeds per plant ($r = 0.96$). Strong positive correlations were also noted between the number of days to start flowering and the number of days to 50% flowering ($r = 0.90$) and between the number of days to 50% pod maturity and the cycle length ($r = 0.74$).

3.5. Nitrogen Balance in the Soil after Cultivation. The results show that, at the end of the experiment, the total nitrogen balance in the cultivation soil of most accessions is positive. Indeed, initial nitrogen in the soil was 0.062 g·N·kg^{-1} of soil, but at the end of the experiment, we noted on average 0.326 g of nitrogen/kg of soil, i.e., an increase of 26.6% in the initial nitrogen in the soil. The significance test of the means from the analysis of variance (Table 6) showed a significant

Table 5: Pearson correlation between parameters.

Variables	NBrP	LTL	LPt	DSC	LPo	ND50Fl	ND50MatPo	NDBFl	CL	NSeP	WTSe	NPoP	LPd	HP	SeY
NBrP	1														
LTL	0.034	**1**													
LPt	0.423	0.275	**1**												
DSC	**0.507**	0.285	0.461	**1**											
LPo	0.391	0.022	0.039	0.317	**1**										
ND50Fl	0.400	−0.483	0.038	−0.053	0.201	**1**									
ND50MatPo	0.384	**−0.504**	0.104	0.009	0.320	**0.847**	**1**								
NDBFl	0.391	−0.416	0.038	−0.067	0.385	**0.908**	**0.862**	**1**							
CL	0.469	−0.236	0.141	0.020	0.264	**0.595**	0.740	**0.632**	**1**						
NSeP	**0.623**	0.203	0.402	**0.659**	0.260	0.075	0.114	0.092	0.313	**1**					
WTSe	0.000	−0.143	−0.006	0.240	0.473	−0.023	0.057	0.156	0.037	−0.044	**1**				
NPoP	**0.597**	0.237	0.404	**0.684**	0.215	−0.027	0.011	−0.006	0.203	**0.982**	−0.012	**1**			
LPd	**0.699**	−0.044	0.338	0.433	0.168	0.407	0.383	0.284	0.418	**0.616**	−0.245	**0.558**	**1**		
HP	0.364	0.447	0.272	0.485	**0.586**	−0.176	−0.181	−0.045	−0.089	0.459	0.215	0.469	0.219	**1**	
SeY	**0.600**	0.191	0.400	**0.703**	0.355	0.037	0.111	0.073	0.313	**0.966**	0.124	**0.960**	**0.570**	0.495	**1**

NBrP: number of branches; LTL: length of terminal leaf; LPt: petiole length; DSC: diameter at stem collar; LPo: pod length; ND50Fl: number of days at 50% flowering; ND50MatPo: number of days to 50% pod maturity of pods; NDBFl: number of days at beginning at flowering; CL: cycle length; NSeP: number of seeds per plant; WTSe: 1000 seed weight; NPoP: number of pods per plant; LPd: peduncle length; HP: height of the plant at flowering; SeY: seed yield.

Table 6: Total nitrogen balance in the soil.

Accessions	Initial nitrogen	Final nitrogen	Nitrogen balance (g/kg soil)
A1		0.145	0.83[b]
A2		0.067	0.05[f]
A3		0.156	0.94[a]
A4		0.103	0.41[c]
A5		0.105	0.43[c]
A6		0.104	0.42[c]
A7		0.106	0.44[c]
A8	0.062	0.103	0.41[c]
A9		0.101	0.39[c]
A10		0.089	0.27[d]
A11		0.056	−0.02[fg]
A12		0.078	0.16[e]
A13		0.089	0.27[d]
A14		0.06	−0.05[g]
A15		0.057	−0.06[g]
Average (g/kg of soil)			0.326
CV (%)			0.88
P			0.0001

CV: coefficient of variation; P: probability. Numbers followed by the same letters are not significantly different.

difference ($P < 0.0001$) between the accessions' crop plots. Thus, on the A3 and A1 accessions, the amount of total nitrogen at harvest was higher than on the other accessions, with 0.94 g·N·kg^{-1} of soil and 0.83 g·N·kg^{-1} of soil, respectively. However, the N balance in the crop soils of accessions A11, A14, and A15 was negative.

4. Discussion

The average seed yield per hectare varied between 151.20 and 850.50 kg depending on the accessions with an average of 407.16 kg/ha. Considering this average yield expressed by all the accessions, we note that it is largely below the average yield reported by [13] on mungbean, which was 721 kg/ha. This low yield could be explained by the fact that the cultivation plots of these accessions did not benefit from fertiliser applications. However, the same authors pointed out that mungbean yields are generally low, varying between 0.5 and 1.5 t/ha in most countries. Thus, each of the five accessions studied (A2, A3, A7, A12, and A15 expressed a yield within this range.

On the other hand, accession A3 expressed a higher yield (850.50 kg/ha). The higher yield of this accession is attributable to its branching, number of pods per plant, and number of seeds per plant. Indeed, accession A3 produced taller plants with a larger diameter at flowering and a higher number of branches, pods per plant, and seeds per plant than the other accessions. The expansion of the aerial organs of the plants of this accession would have induced good carbon nutrition and a production of an important quantity of photoassimilates which would be exported towards the formation of pods and seeds which are metabolic sinks. Thus, according to [14], most of the useful yield comes from actual photosynthetic assimilation. However, the authors in [15] pointed out that the yield problem is not only a photosynthetic problem because in many cases, it is difficult to define which of the source (photosynthesis) or the sink (storage capacity) played the determining role.

Variability was observed between accessions for parameters related to the development cycle. Indeed, the number of days to 50% flowering varied between 33.67 and 47.33 days with an average of about 40 days for all accessions. However, the authors in [16] found that the number of days to 50% flowering varied between 29 and 48 days with an average of 34.46 on mungbean accessions evaluated in Burkina Faso. Furthermore, the cycle of the 15 accessions studied varied from 82 to 93 days with an average of 88 days.

Seed legumes have enormous agronomic potential, including the provision of nitrogen to the soil. Thus, the authors in [17] reported that mungbean is able to improve soil fertility and increase crop production. At the end of our experiment, the total nitrogen balance varied according to the mungbean accessions. The work of [18] showed that, in cowpea, the capacity to fix nitrogen from the air varies according to the variety, fertilisation conditions, and climatic conditions. The authors in [19] found a negative partial nitrogen balance under cowpea cultivation without fertilisation. However, in our case, the overall nitrogen balance under mungbean was positive with an average increase of 0.326 g·N/kg soil. If this balance was positive, this indicates the capacity of symbiotic fixation of atmospheric nitrogen (N_2) by mungbean. The authors in [20] showed that variations in fixation between species depend on both the species-specific N accumulation potential and climatic conditions. As our experiment was conducted without fertilisation, fixed nitrogen would have contributed to the mungbean's own nitrogen requirements and thus to the yield obtained because according to [21], the triggering of symbiotic fixation occurs when the level of mineral nitrogen availability becomes insufficient to meet the plant's nitrogen requirements. Furthermore, the authors in [22, 23] reported that mungbean is mainly grown in rotation with cereals and can be in symbiosis with rhizobium, fixing up to 110 kg·N per hectare, which could help meet its own and the associated or following crop's N requirements.

5. Conclusion

This study increased our scientific knowledge of mungbean. To that goal, it demonstrated the variation between mungbean accessions in terms of development and yield, as well as nitrogen supply to the soil. The findings demonstrate accessions-to-accessions variation in growth characteristics, development cycle, and yield. Nevertheless, accession A3 showed better growth with a higher plant height at flowering, number of branches, and stem neck diameter than the other accessions. On the other hand, accessions A3, A2, and A12 showed better agronomic performance with, respectively, 850.50 $kg{\cdot}ha^{-1}$, 625.2 $kg{\cdot}ha^{-1}$, and 544.8 $kg{\cdot}ha^{-1}$. The number of days to flowering, the number of days to 50% flowering, and the length of the cycle to harvest also varied between accessions, with an early flowering (29 days) observed in A10 and a relatively short number of days to 50% flowering in A10 and A2. In addition, the cycle at harvest ranged from 82 to 93 days with an average of 88 days.

The total soil nitrogen balance at harvest was positive with an increase of 0.326 $g{\cdot}N{\cdot}kg^{-1}$ of soil, and therefore, mungbean cultivation could be of great benefit in agricultural systems for its atmospheric nitrogen fixing capacity. This seed legume should be encouraged in the cropping systems in Burkina Faso not only as a diversification crop but also as an intercrop with cereals for its nitrogen supply to the soil through its symbiotic nitrogen fixation, and nitrogen being one of the macroelements likely to be depleted in the soil with the removal of crops.

Data Availability

The data collected during the experimentation to write this scientific article are available and can be made available to readers.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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