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RESEARCH ARTICLE

ASSESSING FERTILIZATION AND PLANTING DENSITY EFFECTS ON AGRONOMIC PERFORMANCE OF MUNG BEAN (VIGNA RADIATA (L.) WILCZEK) IN BURKINA FASO

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ABSTRACT

Crop agronomic performance are mostly related to the agricultural practices used for production. Study was carried out at Kamboinsin, in Burkina Faso, with aim to evaluating the effects the fertilization and planting density on mung bean (*Vigna radiata*) agronomic performance. The fertilization was at three (03) levels of treatment (control, NPK (14-23-14) and poultry manure), the planting density at three levels ($D_{1:}$177,777; D_2: 133,333 and $D_{3:}$106,666 plants ha^{-1}) and the genotype at two (02) levels (Beng tigre, M3). The experimental design was a split-split-plot replicated thrice. Growth, yield components and yield related data were collected and subjected to amultifactorial analysis using JMP 16.1.0 version software. Significant means were separated using Student Newman Kheuls's test at 5% threshold. The results showed that fertilizing with organic matter resulted in the highest number of branches per plant, leaf chlorophyll content, number of pods per plant, pod weight per plant, pod yield per hectare, number of grain per pod, hundred grains weight, grain weight per plant, grain yield per hectare and harvest index. The mineral fertilization (NPK) was more favorable to a high aerial biomass. The lowest performance were registered from the control. Plants were highly performing under the planting density D_1 (177,777 plants ha^{-1}). Decreasing plant population densities led to a progressive decrease in agronomical performance of mung bean. Beng-tigre is the most grain productive and recommendable compared to the M3 genotype. The type of fertilizer, the planting density and the genotype have significant influence on mung bean production.

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INTRODUCTION

Food insecurity remains a major handicap to the development of many households in sub-Saharan Africa (Ilunga & et al., 2018). This situation leads to a nutritional deficit and accentuated undernourishment of populations (Dembélé, 2001). According to (Ezeh Alex et al., 2012) and (Lutz et al., 2001), given the exponential population growth in this part of Africa, the food insecurity could worsen by 2050. Food insecurity in the Sahelian zone of Africa is partly linked to substantial decrease in crop yields due to recurrent rainfall deficits following the global climate change (FAO, 2015). The diversification of agricultural productions and the use of adapted crops to climatic variability remains the ideal alternative in the fight against food insecurity (Ilunga & et al., 2018). In Burkina Faso, one of the Sahelian countries, the agricultural sector is the main backbone of the national economy, and efforts are continuously made through research to mitigate the food unavailability. Introductions of crop species including legumes such as mung bean (*Vigna radiata* (L.)) are being made in order to boost seasonal productions for increasing food availability. Mung bean is a legume species (Degefa, 2016) belonging to the Vigna genus comprising around 80 species (Jansen, 2006; Mogotsi, 2006). It is widely cultivated in subtropical and tropical regions of Asia (China, India, Bangladesh, Pakistan, and some Southeast Asian countries), in dry regions of Southern Europe and in the warmer environments of United States and Canada (Dahiya et al., 2015; Kumari et al., 2012). In Africa, mung bean is mainly cultivated in Gabon, the Democratic Republic of Congo, Kenya, Mozambique, Ethiopia, South Africa, Madagascar and Mauritius (Jansen, 2006; Mogotsi, 2006). It is relatively drought tolerant (AVRDC, 2015) with better adaptation to fertile, sandy clay soils characterized by a good internal drainage and a pH ranging between 6.3 and 7.2. Mung bean has high nutritive value (Karamany, 2006). Among the legumes, mung bean is one the main sources of amino acid and protein (Imrie, 2005). It also has a high digestibility and less flatulence effects as well as bioactive compounds (Fery, 2002; Gan et al., 2017; Kumar Dahiya et al., 2014). Many studies recommended mung bean as a supplement for infant's weaning food regarding its high protein content and hypo-allergic properties (Ali et al., 2016; Bazaz et al., 2016). Elsewhere, owing to its antidotal activity, mung bean is formerly used as medicinal or cosmetic product (Sharma & Mishra, 2009). In Chinese traditional medicine, mung beanis used in the detoxification activities and in recuperation of mentality (Dianzhi et al., 2019). It also has ability in alleviating heat stroke and regulation of gastrointestinal upset (Dianzhi et al., 2019). Beyond its basic nutritional interest, many potential benefits were identified. Mung bean possesses antihypertensive, antidiabetic and hypolipidemic effects as well as anticancer, anti-melanogenesis, hepato-protective and immunomodulatory properties (Liyanage et al., 2018; Lopes et al., 2018; Yang et al., 2008). Likewise, mung bean plays an important agronomic role in improving soil fertility through its capacity of fixing atmospheric nitrogen (Pataczek et al., 2018). Acoording to (Yehuala, 2018), improved mung bean varieties have better yield potential and this pulse crop is considered the most important legume by low income farmers in drier marginal environments (Itefa, 2018). However, despite its importance, the cultivation of mung bean has gained little importance outside Asia, mainly in Africa. (Umata, 2018) in Ethiopia, reported that despite the better yield advantage revealed, further promotion of mung bean is to be done as the crop is lowly adopted by farmers. In Burkina Faso, only one variety is listed in the national catalog, making mung bean a crop less known by the majority of producers despite the proven nutritional and therapeutic virtues of its seeds and its economic and agronomic importance. In addition, official statistics on mung bean production in Burkina Faso are almost non-existent due to the lack of awareness of it by most of the farmers. Scientific studies on mung bean species that could lead to its large-scale promotion and adoption still remain at embryonic stage despite the introduction of foreign species. Crop species agronomic performance are mostly related to agricultural practices such as the soil preparation method, plant maintenance, fertilization and planting density used for production. Therefore, studies on mung bean spawning these aspects are necessary and part of the preliminary steps in the process of its popularization, promotion and adoption by producers. This study aims at contributing to the use of adapted cultivation techniques in mung bean production in Burkina Faso. The specific objectives are: (i) to determine the effect of poultry manure and NPK (14-23-14) on the agronomic performance of mung bean (ii) to identify an adequate planting density in mung bean production (iii) to evaluate the agro-morphological parameters of the M3 genotype and the Beng-tigré variety.

MATERIALS AND METHODS

Site of the study: The experiment was conducted in Burkina Faso during rainy season of 2021 at Kamboinsin in the Centre of Environmental and Agricultural Research and Training (CREAF), located at 12 °28' north and 01 °33' West at 300 m above sea level. The station is located in the northeast Ouagadougou, at 12°28' north and 01 °33' west at 300 m above sea level. The climate is of north-soudanian type characterized by a long dry season from November to May and a rainy season from June to October. The rainfall varies from a year to another.

Factors, treatments and experimental design: Three factors were involved in this study (fertilization, planting density and genotype). The fertilization was at three (03) levels of treatments (control, NPK (14-23-14) and poultry manure (PM)). The planting density was at three levels (177,777; 133,333 and 106,666 plants ha^{-1} designed as D_1, D_2 and D_3). The genotype was at two (02) levels of variation (Beng tigre, M3). The experimental design was a split-split-plot design with three replicates. The spacing between two consecutives replications was of 1.5 m. The fertilization was assigned in the main plot, the planting density in the sub-plot and the genotype in the sub-sub-plot. A spacing of 3 m was left between two consecutive levels of fertilization in order to minimize the interaction effects.

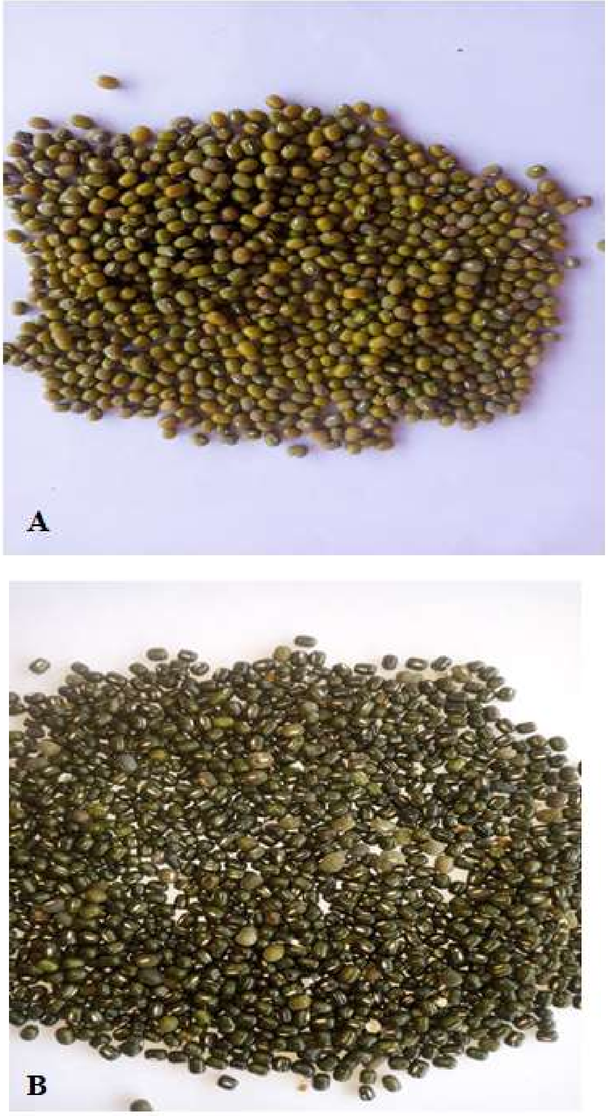

Figure 1. Plates of the mung bean genotypes used for the study : Beng-tigre (A) and M3 (B)

Soil preparation and sowing: Soil preparation consisted of a ploughing using a tractor, followed by a levelling. Two seeds were sown per sowing hole, following lines of 3 m length. The spacing was of 0.75 m between two consecutive lines and of 0.30, 0.40 and 0.50 m between two consecutive sowing holes respectively for the three planting densities (D_1, D_2 and D_3).

Plants maintenance: Plants maintenance consisted of weedings, fertilizations respective to the levels of treatments involved, and pesticide application for protecting plants against crop pests. The poultry manure representing the organic fertilizer was applied 3 days before sowing operation, at the rate of 3 tons per hectare, while the NPK (14-23-14) (mineral fertilizer) was used at the rate of 100 kg per hectare two weeks after sowing. The insecticide application was done using K-optimal and Delta cal at the rate of 20 ml for 2 l of water, respectively during flowering and pods formation.

Data collection: Growth data, yield components and yields related data were collected. The growth data were : number of days to first flowering, number of days to 50% flowering, number of days to 95% maturity, number of branches per plant, plant height, leaflet length, leaflet width, leaf chlorophyll content ; Yield components : number of pods per plant, pods weight per plant, number of grain per pod, hundred grains weight, grain weight per plant ; Yields : grain yield per hectare, pod yield per hectare, haulm yield per hectare. The following formulas were used for yield calculation.

$$\text{Yield ha}^{-1} = \frac{\text{Yield per net plot (kg)}}{\text{Area of the net plot (m}^2)} * 10000\ \text{m}^2$$

The harvest index was calculated using the following formula:

$$\text{HI} = \frac{\text{Grain yield (kg } ha^{-1})}{(\text{Grain yield} + \text{haulm yield})\ (\text{kg ha}^{-1})}$$

Data analysis: A multifactorial analysis of the variance of the collected data was performed using the JMP 16.1.0 version software. Significant means were separated using Student Newman Kheuls test at 5% threshold.

RESULTS

Effects of fertilization, planting density and genotype on growth and morphological characters of mung bean: The results of the analysis of the variance of the growth and morphological characters are presented in Table 1.

Number of days to first flowering: The type of fertilizer had significant effects on number of days to first flowering of the studied mung bean genotypes (P5%=0.008). Plants were early flowering in the plots fertilized with the NPK and Poultry manure and late flowering in the control. However, planting density and genotype had non-significant effects on days to first flowering (P=0.69 and P=0.56). The interaction between factors (fertilization * density * génotype) significantly affected the date of the first flower appearance.

Number of days to 50% flowering: The level of fertilization significantly affected the number of days to 50% flowering (P=0.01). Similarly to the days to first flowering, plants reached early the 50% flowering stage when fertilized with NPK and poultry manure and lately in the control. Planting density and genotype had no-significant effects on plants flowering period. However, the interaction between all the factors (fertilization*planting density * genotype) significantly affected the number of days to flowering of the genotypes (Table 2). Greater number of days to 50% flowering were recorded in the control. Shorter days to flowering were registered under the mineral fertilization in more than 60% of the cases.

Number of days to 95% maturity: The analysis of the variance showed that the type of fertilizer, the planting density as well as the genotype had non-significant influence on days to maturity of the plants (P=0.32 ; P=0.81 and P=0.32).Likewise, non-significant effect of the interaction between factors was observed.

Number of branches per plant: Of all the factors (fertilization, planting density and genotype), only planting density had significant influence on number of branches per plant. The planting density 0.75 x 0.40 m (D_2:133,333 plants ha^{-1}) resulted in the greatest number of branches per plant (3.97), followed by the density 0.75 x 0.50 m (D_3 :106,666 plants ha^{-1}) (3.72). The smallest number of branches per plant was registered from the planting density D_1 (177,777 plants ha^{-1}, spacing 0.75 x 0.30 m) (3.06). The interaction between planting density and genotype had significant effects on number of branches per plant (Table 2). For the genotype Beng-tigre, smaller number of branches per plant was recorded under the planting density D_1 (177,777 plants ha^{-1}) (2.53), while greater number of branches per plant was registered from the decreasing sowing densities, with average values of 4.05 and 4.11 for D_2 (133,333 plants ha^{-1}) and D_3 (106,666 plants ha^{-1}) respectively. For the genotype M3, the greatest number of branches per plant was recorded from the planting density D_2 (3.88), while the lowest was registered from D_3 (3.33).

Plant height: The analysis of the variance revealed that the fertilization and the genotype had highly significant influence on plant height (P=0.0006 and P=0.0001). The tallest plant was recorded from plots fertilized with NPK, with an average height of 48.18 cm. The shortest plant was recorded from the control (40.96 cm). The genotype Beng-tigre presented the tallest height (49.94 cm) compared to the genotype M3 (39 cm). Non-significant influence of the planting density as well as of the interaction between factors on plant height was observed.

Leaflet length: The type of fertilizer and the genotype had significant effects on leaflet length (P=0.0002 and P=0.0007). However, planting density had no significant effects on leaflet length (P=0.26). Fertilizing with NPK (14-23-14) resulted in the longest leaflet (9.31 cm), while the control led to the shortest (7.19 cm). Beng-tigre had longer leaflet comparatively to the genotype M3. The interaction between factors had no significant effects on leaflet length.

Leaflet width: The fertilization as well as the planting density had non-significant influence on leaflet width. However, significant effect was observed at the genotype level. Beng-tigre showed the widest leaflet (7.25 cm), while narrower leaflet was registered from the genotype M3 (5.76 cm).

Leaf chlorophyll content: None of the factors had significant effect on leaf chlorophyll content. Leaf chlorophyll content varied from 56% to 59%, from 52.38% to 62.72% and from 56.52% to 60.47%, respectively for fertilization, planting density and genotype.

Effects of fertilization, planting density and genotype on yield components and yield of mung bean: Table 2 shows the results of the analysis of the effects of fertilization, planting density and genotype on yield and yield components of mung bean.

Tableau 1. Effects of fertilizer, planting density and genotype on morphological characters of mun bean

TREATMENTS	DFF	50%F	95%M	NPB/P	PH (cm)	LeL (cm)	LeW (cm)	LCC (SPAD value)
FERTILISER (F)								
Control	31.66a	41.66a	59.77	3.16	40.96c	7.19b	6.10b	58.87
NPK	30.22b	40.27b	59.66	3.85	48.17a	9.31a	7.26a	56.63
Poultry manure	30.44b	40.44b	59.00	3.74	44.38b	8.10b	6.16ab	59.98
P-value (5%)	0.008	0.01	0.32	0.10	0.0006	0.0002	0.08	0.83
ES±	0.331	0.333	0.392	0.236	1.189	0.318	0.400	4.001
PLANTING DENSITY (PD) (plants ha^{-1})								
177,777	30.94	40.94	59.61	3.06	43.15	**7.88**	6.11	52.38
133,333	30.50	40.55	59.55	3.97	46.01	8.61	6.67	60.37
106,666	30.83	4088	59.27	3.72	44.35	8.11	6.73	62.72
P-value	0.69	0.67	0.81	0.02	0,24	0.26	0.49	0.17
SE±	0.331	0.333	0.392	0.236	1.189	0.318	0.400	4.001
GENOTYPE (G)								
Beng-tigré	30.66	40.66	59.29	3.56	49.94a	8.88a	7.25a	60.46
M3	30.88	40.92	59.66	3.60	39.06b	7.52b	5.76b	56.52
P-value (5%)	0.56	0.50	0.41	0.89	<0001	0.0007	0.002	0.39
ES±	0.270	0.272	0.320	0.192	6.971	0.260	0.326	3.267
Interactions								
F*PD	0.92	0.88	0.70	0.76	0.77	0.64	0.98	0.97
F*G	0.64	0.57	0.83	0.47	0.83	0.78	0.42	0.83
PD*G	0.18	0.17	0.72	0.029	0.63	0.65	0.49	0.91
F*PD*G	0.032	0.023	0.,75	0.57	0.69	0.40	0.62	0.95

DFF : Number of daysto first flowering ; 50%F : Number of days to 50% flowering ; 95%M : Number of days to 95% maturity ; NPB/P : Number of primary branches per plant ; NSB/P : Number of secondary branches per plant ; PH : Plant heiight ; LeL : Leaflet length ; LeW : Leaflet width ; LCC : Leaf chlorophyll content ; F ; Fertiliser ; PD :Planting density ; G ; Genotype.

Table 2. Interaction between fertilizer, planting density and genotype on number of days to 50% flowering and between planting density and genotype on number of branches per plant

Fertilizer	Interaction between fertilizer, planting density and genotype on number of days to 50% flowering					
	Genotype					
	Beng-tigre			M3		
	Planting density			Planting density		
	D_1	D_2	D_3	D_1	D_2	D_3
Control	42ab	41.66ab	41.66abc	42.33a	41abcd	42.33a
NPK	41abcd	39.66bcd	39.33cd	39d	40.33abcd	40abcd
Poultry manure	41abcd	39d	41abcd	40abcd	41.66ab	41.33abcd
SE±		0.816			0.816	
	Interaction between planting density and genotype on number of branches per plant					
	D_1	D_2	D_3			
Beng-tigre	2.53b	4.05a	4.11a			
M3	3.59a	3.88a	3.33b			
SE±		0.578				

D_1 : 177,777 plants ha^{-1} ; D_2 : 133,333 plants ha^{-1} ;D_3 :106,666 plants ha^{-1}

Tableau 2. Effects of fertilizer, planting density and genotype on yield components, pod yield and fodder yield of mun bean

Treatment	NPP	PWP (g)	PYH (kg ha^{-1})	NGP	100GW (g)	GWP (g)	AGBP (g)	HYH (kg ha^{-1})	HI
FERTILIZER (F)									
Control	36.69a	16.76	1150.52b	11.70	4.03	10.36b	9.46b	681.98b	0.48a
NPK	37.39a	18.71	1355.94ab	12.07	3.95	12.84ab	18.59a	1936.37a	0.37b
Fiente de poules	45.21a	22.26	1649.61a	11.85	4.30	15.51a	11.73b	850.63b	0.55a
P-value (5%)	0.34	0.10	0.05	0.50	0.52	0.019	0.001	0.003	0.001
ES±	4.507	1.817	138.970	0.217	0.227	1.228	1.115	264.977	0.031
PLANTING DENSITY (PD) (plants ha^{-1})									
177,777	45.07a	26.16ab	1758.31a	12.20	4.27	13.44ab	15.44	1372.79ab	0.46
133,333	45.84a	22.12a	1573.57a	11.73	4.02	15.08a	12.56	1467.67a	0.49
106,666	28.38b	15.43c	824.20b	11.70	4.00	10.19b	11.78	628c	0.45
P-value	0.01	0.03	<00001	0.20	0.64	0.024	0.06	0.04	0.53
SE±	4.507	1.817	138.97	0.217	0.227	1.228	1.115	264.977	0.031
GENOTYPE (G)									
Beng-tigré	29.14b	20.69	1477.24	11.82	5.77a	14.58a	13.42	1204.09	0.50
M3	50.39a	17.86	1293.47	11.93	2.51b	11.23b	13.10	1108.55	0.43
P-value (5%)	0.0002	0.17	0.25	0.65	<0001	0.023	0.80	0.75	0.06
ES±	3.680	1.484	113.468	0.177	0.185	1.003	0.911	216.352	0.025
Interactions									
F*PD	0.10	0.32	0.16	0.55	0.23	0.38	0.31	0.30	0.39
F*G	0.6	0.50	0.53	0.79	0.64	0.40	0.23	0.67	0.99
PD*G	0.17	0.76	0.93	0.73	0.65	0.61	0.98	0.94	0.40
F*PD*G	0.56	0.58	0.52	0.71	0.37	0.32	0.70	0.99	0.34

NPP : Number of pods per plant ; PWP : Pods weight per plant ; PYH : Pod yield per hectare ; NGP : Number of grains per pod ; 100GW : Hundred grains weight ; GWP : Grain weight per plant ; AGBP ; Above ground biomass per plant ; HYH : Haulm yield per hectare ; HI : Harvest index ; F ; Fertiliser ; SD : Sowing density ; G ; Genotype.

Tableau 3. Coefficients of correlations and their significance between the studied characters

Variables	DFF	50%F	PH	LeL	LEW	NPP	PWP	PYH	GWP	100GW	GYH	HYH	HI
DFF	1												
50%F	0.9963**	1											
PH	-0.4441	-0.4366	1										
LeL	-0.2461	-0.2357	0.6860*	1									
LeW	-0.2368	-0.2292	0.5404*	0.6893*	1								
NPP	-0.0831	-0.0855	-0.1944	-0.0605	-0.2941	1							
PWP	-0.2194	-0.2257	0.3518	0.3527	0.0841	0.6867*	1						
PYH	-0.2263	-0.2347	0.2845	0.2597	0.0443	0.6902*	0.9305**	1					
GWP	-0.3126	-0.3203	0.4790	0.4745	0.2198	0.5273*	0.9317**	0.8755**	1				
100GW	-0.0415	-0.0502	0.5719*	0.2515	0.2775	-0.3567	0.2148	0.1871	0.3039	1			
GYH	-0.2713	-0.2809	0.3709	0.3493	0.1292	0.5743*	0.8920**	0.9622**	0.9319**	0.2737	1		
HYH	-0.2738	-0.2750	0.1544	0.2710	0.1955	0.0953	0.1855	0.2470	0.1970	-0.0224	0.2557	1	
HI	-0.0848	0.0925	0.2686	0.1397	-0.0067	0.3559	0.6291*	0.5382*	0.6444*	0.2914	0.5586*	-0.5088*	1

DFF : Number of days to first flowering ; 50%F : Number of days to 50% flowering ; 95%M : Number of days to 95% maturity ; NBP : Number of branches per plant ; PH : Plant heiight ; FoL : Foliole length ; FoW : Foliole width ; NPP : Number of pods per plant ; PWP : Pods weight per plant ; PYH : Pod yield per hectare ; NGP : Number of grains per pod ; GWP : Grain weight per plant ; 100GW : Hundred grains weight ; GYH : Grain yield per hectare ; HYH : Haulm yield per hectare ; HI : Harvest index.

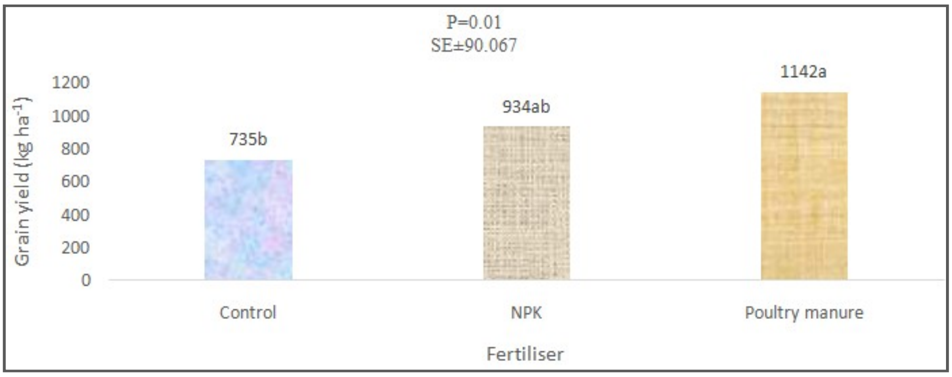

Figure 2. Grain yield (kg ha^{-1}) of mung bean under mineral (NPK)and organic (poultry manure) fertilization

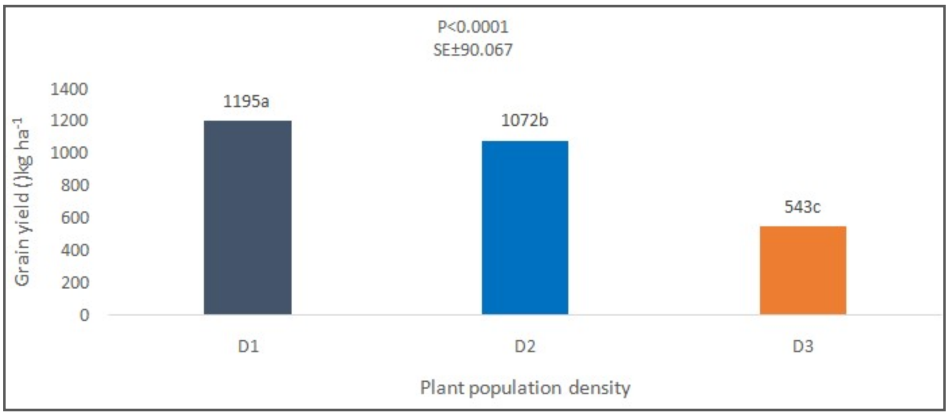

Figure 3. Grain yield (kg ha^{-1}) of mung bean depending on planting density (D_1 :177,777 plants ha^{-1}, D_2 :133,333 plants ha^{-1}, D_3 :106,666 plants ha^{-1})

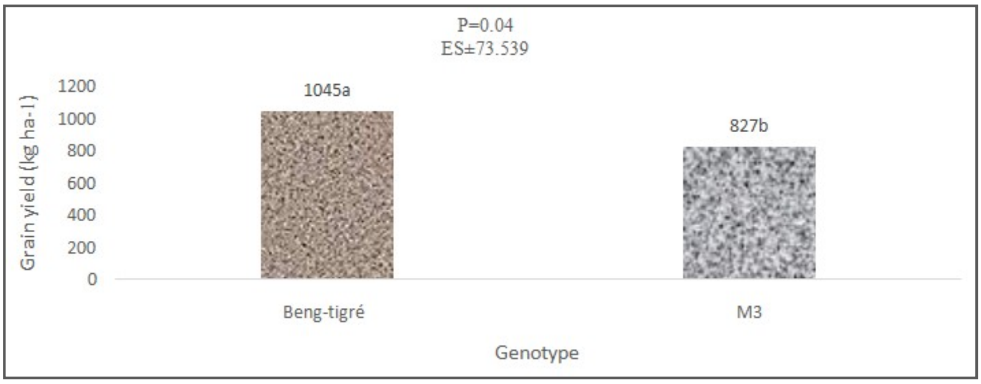

Figure 4. Grain yield (kg ha^{-1}) of mung bean depending on the genotype

Number of pods per plant: The analysis of the variance revealed non-significant effects of the fertilization on number of pods per plant (P=0.34). Globaly, the number of pods per plant varied from 36.69 to 45.21 among the treatments of fertilization. However, planting density and genotype had significant effects on number of pods per plant (P=0.01 and P=0.0002). The greatest number of pods per plant was recorded from the planting density D_1 (177,777 plants ha^{-1}; spacing 0.75 x 0.30 m) (45.07 pods). The smallest was registered from the planting density D_3 (106666 plants ha^{-1}; spacing of 0.75 x 0.50 m) (28.38 pods). At genotype scale, Beng-tigre presented greater number of pods per plant (50.39), while the M3 accession showed the lowest (29.14). Interactions between factors had non-significant effects on number of pods per plant.

Pods weight per plant: The fertilization and the genotype had non-significant influence on pod weight per plant. However, planting density significantly affected the pod weight per plant (P=0.03). The lowest average pod weight per plant (15.45 g) was registered from the planting density D_3 (106,666 plants ha^{-1}; spacing of 0.75 x 0.50 m). D_2 (133,333 plants ha^{-1}; spacing of 0.75 x 0.40 m) resulted in the highest pod weight per plant (22,12 g). Intermediate average values was recorded from D_1 (177,777 plants ha^{-1}; spacing 0.75 x 0.30 m) (20.16 g).

Pod yield per hectare: Panting density had significant effects on pod yield per hectare. Pod yield increased with increasing planting density. Pod yield was higher in the planting density D_1 (177,777 plants ha^{-1}) followed by D_2 (133,333 plants ha^{-1}), with respectively 1758.31 kg ha^{-1} and 1573.57 kg ha^{-1}. The lowest average pod yield per hectare was recorded from the planting density D_3 (106,666 plants ha^{-1}) (824.20 kg ha^{-1}). The genotype as well as the interaction between factors had non-significant effects on pod yield.

Above ground biomass per plant: The type of fertilizer significantly affected the plant above ground biomass (P=0.001). Plants were high biomass productive when fertilized with NPK, compared with organic fertilization (poultry manure) and the control. However, the plant population density, the genotype and the interaction between factors had non-significant influence on above ground biomass.

Number of grains per pod: The fertilization, the planting density as well as the genotype had non-significant influence on number of grains per pod. The number of grains per pod ranged from 11.70 to 12.07 between fertilizer treatments, from 11.70 to 12.20 between the plant population densities and from 11.82 to 11.83 between the genotypes. Likewise, the interaction between factors had non-significant effects on number of grains per pod.

Hundred grains weight: The fertilization and the planting density had non-significant influence on hundred grains weight (P=0.52 and P=0.64). However, at genotype level, significant effect was observed (P<0.0001). The highest hundred grains weight was obtained from Beng-tigre (5.77 g), while the lowest was registered from the M3 accession (2.51 g). Non-significant influence of the interaction between the involved factors was observed.

Haulm yield per hectare: The results showed that the type of fertilization and the planting density significantly affected the haulm yield per hectare of the genotypes (P=0.003 and P=0.04). Fertilizing with NPK resulted in the highest haulm yield (1936.37 kg ha^{-1}), compared to the other treatments. Planting density D_2 (133,333 plants ha^{-1} ;s pacing 0.75 x 0.40 m) gave the highest haulm yield per hectare (1467.67 kg ha^{-1}), followed by D_1 (177,777 plants ha^{-1} ; spacing0.75 x 0.30 m) (1372.79 kg ha^{-1}). The lowest planting density, D_3 (106,666 plants ha^{-1} ; spacing0.75 x 0.50 m) resulted in the lowest haulm yield per hectare (628 kg ha^{-1}). Non-significant effects of the genotype as well as of the interaction between factors was registered.

Grain yield per hectare: The results of the analysis of the variance of the grain yield depending on the type of fertilizer, the plant population density and the genotype are respectively presented in Figure 1, 2 and 3. The type of fertilizer, the planting density as well as the genotype had significant effects on grain yield per hectare (P=0.01, P<0,0001 and P=0.04). The highest grain yield per hectare was recorded from the plots fertilized with poultry manure (organic fertilization), with a mean yield of 1142.07 kg ha^{-1}. Fertilizing with NPK (mineral fertilization) resulted in intermediate grain yield (934.53 kg ha^{-1}), while the lowest grain yield was registered from the control (735.14 kg ha^{-1}). At planting density scale, the sowing density D_1 (177,777 plants ha^{-1}) resulted in the highest grain yield per hectare (1195.51 kg ha^{-1}). D_2 (133,333 plants ha^{-1}) gave intermediate average grain yield (1072.47 kg ha^{-1}). The lowest grain yield per hectare was recorded from the planting density D_3 (106,666 plants ha^{-1}) (543.76 kg ha^{-1}). Regarding the genotypes, Bemg-tigre presented the highest grain yield per hectare (1046.55 kg ha^{-1}), while the M3 genotype showed the lowest (827.94 kg ha^{-1}). The interaction between factors had non-significant influence on the grain yield per hectare.

Harvest index: The type of fertilizer significantly affected the harvest index (P=0.0001). Fertilizing with poultry manure (organic fertilization) exhibited the highest harvest index (0.55), followed by the mineral fertilization (NPK) (0.48). The control resulted in the lowest harvest index (0.37). Non-significant effects on harvest index was observed at planting density and genotype scale. The interaction between factors had no influence on harvest index likewise.

Correlations between characters: Correlations analysis revealed the existence of significant correlations between some studied parameters. High and positive correlations were observed between the variables number of days to first flowering and number of days to fifty percent flowering (0.9963), pods weight per plant and pod yield per hectare (0.9305), pods weight per plant and grains weight per plant (0.9317), pods weight per plant and grain yield per hectare (0.8920), pod yield per hectare and grain yield per hectare (0.9622) and between grain weight per plant and grain yield per hectare (0.9319). Significant positive correlations were as well noted between the variables plant height and leaflet length, leaflet width and hundred grains weight, leaflet length and width (0.6860). The number of pods per plant was positively correlated with the variables pods weight per plant, pod yield per hectare, grains weight per plant and hundred grains weight. The harvest index was significantly and positively correlated with pods weight per plant, pod yield per hectare, grains weight per plant and grain yield per hectare. Significant negative correlation was observed between the variables harvest index and haulm yield per hectare (-0.5088).

DISCUSSION

Effects of the fertilization on agro-morphological characters of mung bean: The analysis of variance showed a significant difference between the different fertilizer treatments. Under the mineral fertilization, plants were early flowering, while the organic fertilization resulted in intermediate values of number of days to flowering. In the control (no fertilizer application), flowering occurred lately. Similar trend was observed for the plant height, leaflet length, aerial biomass and grain yield. These results show that the soil fertilization has positive impact on mung bean development. However, the mineral fertilization (NPK) allows a rapid development of plants and a massive aerial biomass production compared to the use of organic matter. In fact, the NPK amendment (mineral fertilization) provides nutrients directly assimilable by the plants. This is favorable to a good photosynthetic activity, leading to an optimal growth and development of plants and consequently an early flowering and a significant biomass production. The late flowering and the low fodder yield registered from the organic fertilizer treatment compared to those from the mineral fertilization could be explained by the fact that although chicken droppings (organic matter) are rich in nutrients, the decomposition of these elements into an easily absorbable state by the plant requires a minimum of time. The late flowering of plants in unfertilized plots would show that the deficiency of nutrients in the soil leads to a delay in the establishment of the different phenological stages of the plants and a slowdown in the growth and biomass production by the plant.

However, for most of the yield components (number of pods per plant, pods weight per plant, number of grains per pod, grains weight per plant, hundred seeds weight, pod yield per hectare), grain yield and harvest index, the organic fertilization (chicken droppings) exhibited the highest averages values. Intermediate mean values were registered from the mineral fertilization, while the lowest were consistently recorded from the control. This shows that organic matter has much more an inductive effect in increasing plants productivity comparatively to the mineral fertilizer (NPK) that is more favorable to aerial biomass production. Indeed, the high grain yield and harvest index show that fertilizing with organic matter promotes mung bean seed production to the detriment of aerial biomass. NPK is a fertilizer of mineral origin which provides plants with essential nutrients in a directly obsorbable form. But, beyond nutrients intake, according to the findings of (Yerima *et al.*, 2014), chicken droppings significantly improve soil properties, making them more fertile and favorable for crop production. Indeed, the contribution of poultry droppings added to mineral fertilizers contained in the soil greatly increases the availability ofnutrients and promotes water accumulation. This reduces nutrient losses and increase the efficiency of nitrogen fertilizers in the soil. Furthermore, (Nyembo *et al.*, 2015) argued that poultry manures have great potential in improving soil nutrient availability and providing nutrients needed for maize cultivation. These hypothesis could explain the substantial increase in grain yield observed with organic matter treatments in this study.

Effects of the planting density on agro-morphological characters of mung bean: The results showed that the highest average values of pod yield, grain yield and yields attributes were recorded under the density D_1(177,777 plants ha^{-1} ; 0.75 x 0.30 m), while the highest number of branches per plant, plant height, foliole length, foliole width as well as haulm yield where recorded from the planting density D_2. However, the lowest average values for all the parameters, were consistently registered from the lowest planting density D_3 (106,666 plants ha^{-1}, spacing 0.75 x 0.50 m). These results show that increased planting density increase mung bean yield performance, while too low planting densities have negative incidence on plants productivity. This could be attributed to the fact that lower sowing densities lead to a reduced number of plants per hectare, which may negatively and considerable reduce the grain yield. Meanwhile, high planting densities result in higher number of plants per hectare creating competition among plants for light, soil moisture, carbon dioxide and nutrients(Ahmed & Abdelrhim, 2010). This competition among plants positively affects plants final yields. According to (Ahmed & Abdelrhim, 2010), increasing plant population density increases final grain yield. The highest number of branches per plant, plant height, foliole length, foliole width as well as haulm yield recorded from the planting density D_2suggests that very high densities is not conducive for aerial development and fodder production. This is in discordance with findings of (Mohamed, 2002)who reported that plant population density had no significant effects on plant height, but in concordance with (Alege & Mustapha, 2007), who, respectively depicted that increasing planting density results in lower number of leaves per plant and plant height. Regarding the consistent performance of plants in the planting density D_1 (177,777 plants ha^{-1};0.75 x 0.30 m) for yield components and yield, it can be retained that this sowing density would be the optimal planting density in the cultivation of mung bean in the agro-ecological context of Burkina Faso. Lower densities have negative impacts on mung bean agronomical performance.

Effects of the genotype on agro-morphological characters of mung bean: The genotype Beng-tigre presented the best agronomic performance compared to the M3 accession. These differences can be attributed to the intrinsic properties of the genotypes, particularly the varietal characteristics. Morphologically, Beng-tigre presented the highest plant height, foliole length and width, which can explain its high productivity compared to M3 genotype. Indeed, according to (Mohammadi *et al.*, 2003), the increase in plant height can induce a high grain yield production. In addition, Beng-tigreis the only genotype already vulgarized and used in Burkina Faso by producers as a mung bean variety. It would therefore have much more fixed or stable characteristics. However, the M3 genotype is a newly introduced accession in the country and would have low stability and agronomic performance in the agro-climatic context of Burkina Faso. The large-scale use of the Beng-tigre variety should then be recommended given that in this study it was the high grain yielding genotype.

CONCLUSION

Fertilization, planting density and genotype significantly affect mung bean agronomic performance. The non-application of fertilizer leads to very low yields. Fertilizing with organic matter results in the highest grain yields in mung bean production compared to mineral matter (NPK), which is much more favorable to high aerial biomass production. The planting density 177,777 plants ha^{-1}, with spacingof0.75 x 0.30 m is the most appropriate in mung bean production. Decreasing plant population densities lead to decrease in plants performance. Of the two genotypes used, Beng-tigre is the most productive and recommendable compared to the M3 genotype. The results of this study can serve as a basis for guiding initiatives aiming at increasing seasonal yields in mung bean production in Burkina Faso. However, research involving a large number of genotypes, planting densities and various doses of mineral and/or organic fertilizer would be necessary in order to strengthen knowledge on the technical route of mung bean production.

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