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RESEARCH ARTICLE

RESPONSE OF COMMON BEAN CULTIVARS TO MINERAL FERTILISATION IN THE COLLINES DEPARTMENT OF BENIN

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ABSTRACT

The present work was undertaken with the aim of evaluating the influence of mineral fertilizers and local varieties on the yield and economic profitability of common bean in order to identify cultivars of the species presenting interesting agronomic potential for fixation and the conversion of atmospheric nitrogen. An experimentation was conducted in Ouèdèmè in the commune of Glazoué (Benin), with tretments including15bean varieties and fertilisation (NPK 14-18-18 and Urea 46% N), applied in a split-plot arrangement. Results showed that production of dry bean seeds depended on the variety and fertiliser used. Variety MSCn3 gave a yield of 2264.925 kg. $ha^{-1}$with fertilisationused. The unfertilised: 1170.32 Kg. ha^{-1} versus fertilised plots: 1573.94 $Kg.ha^{-1}$, a gain of 44%). (unfertilised: 1170.32 Kg $.ha^{-1}$ versus fertilised plots: 1573.94 $kgha^{-1}$, a gain of 44%). The analysis of the RVC indicated, however, that the application of fertilisers to common beans was generally less profitable, apart from the local varieties HZZZn3 and GOLn6, whose RVCs were, respectively above 2. At the end of this study, the local cultivars LSCn3, SDCn5 and AOGn1 which gave a small increase in yield in $kgha^{-1}$ are those which showed a strong increase in leaf biomass. Therefore, subject to further studies, they could be recommended as cultivars predisposed to good fixation and conversion of mineral nitrogen to ammonia.

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INTRODUCTION

Phaseolus vulgaris L., also known as common bean, is native to Central America and the Andes region (Debouck *et al*.,1987). It was domesticated in its centers of origin around 4000 years before Christ and it was only in the 16th century that it was introduced by the Portuguese to other continents of the world (Delgado, 1988; Debouck and Smartt, 1995). The *Phaseolus* genus belongs to the family Fabaceae and the subfamily Papilionaceae (Kaplan and Lynch, 1999). *Phaseolus vulgaris* is an annual herbaceous plant with determinate or indeterminate growth. It is generally characterized by a taproot but which subsequently forms long secondary roots developing throughout the main root bearing nodules (Baudouin *et al*., 2001). At the end of germination, two simple opposite leaves then trifoliate leaves with triangular leaflets form on an angular stem. When flowering, petals of various colors are observed, including white, mauve or violet (Milognon *et al.,* 2019and Milognon *et al*., 2022). It is a zygomorphic flowering of the papilionaceous type with 5 united sepals, 5 petals, 10 stamens and a multiple ovarian sac. In most cases, the flower self-fertilizes and develops a straight or slightly curved fruit or pod. The seeds are round, somewhat flattened ellipsoid or rounded (Broughton, 2003; Milognon *et al*.,2020; Milognon *et al*.,2022). Thus, described, *Phaseolus vulgaris* L., is a plant whose seeds are rich in polyphenols, vitamins, minerals and fibers which are natural antioxidants with beneficial effects on human health. Indeed, several epidemiological studies have demonstrated that a high consumption of beans is attracting more and more interest for the prevention and treatment of inflammatory, cardiovascular, neurodegenerative diseases, obesity, diabetes (Barkat and Kadri, 2011, Mehinagic *et al*., 2011), but is also inversely associated with certain types of cancers, such as prostate, breast and colon cancers (Minussi *et al*., 2003; Turkmene *et al*., 2005; Lenoir *et al* ., 2011). These micronutrients constitute a sort of nutritional pharmacopoeia for the body (Bravo, 1998; Valdés *et al*., 2011). In addition, the common bean represents one of the most important components of the human diet, due to its high content of protein and other micronutrients such as iron, calcium, magnesium and folic acid, but also for its dry seeds as a nutritional supplement, essential for diets based on cereals or starchy tubers (Nzungize, 2012; Pujolà *et al*, 2007). Economically, it is also one of the most important crops in Latin America and the Great Lakes Regions of Africa because it provides a source of income for small farmers (Bargaz, 2012; Pachico 1989). It is also essential to emphasize that alongside these health, nutritional and economic importance, legumes in general have an important agronomic interest. They enrich the soil with nitrogen, thanks to the nodules present on their roots containing symbiotic bacteria capable of fixing and converting atmospheric nitrogen into organic nitrogen easily assimilated by plants. As a result, they constitute a considerable agricultural interest group in crop rotations and associations (N'gbesso *et al*., 2013). In recent years, several studies have shown that soil degradation and the resulting low agricultural yields in most countries of the world; and particularly in sub-Saharan Africa (SSA), are largely due to demographic pressure, erosion and poor management. cultural technics (Amonmédé *et al.*, 2019; Baboy *et al*., 2015). This reduction in crop productivity constitutes one of the major problems of the Beninese agricultural system to which agricultural research must provide solutions as quickly as possible (Igué *et al*., 2013). However, in Benin, research institutions and decentralised agricultural extension services for the most part focus their research on cash crops (cotton, cashew nuts), cereals (maize, rice, etc.), roots and tubers such as yam and cassava (Aho and Capo-Chichi, 2017) and therefore have very little data on the production of beans of the *Phaseolus* genus and by extension on the *Phaseolus vulgaris* species (Milognon, 2017; Milognon *et al* ., 2019). Thus, the national situation on the area sown and annual productivity still remain undocumented. But according to the work carried out by Milognon *et al.* (2020) on species of the *Phaseolus* genus in Benin, local populations exploiting the genetic resources of this genus have mostly reported cases of genetic erosion and a drastic drop in the yields of their local varieties that they adopt one year to another. This reduction in yield observed from year to year is due to biotic constraints of production, to the great edaphic and climatic variations of recent years, thus leading farmers into an infernal cycle of poverty and food insecurity (Mbukula *et al*., 2018; Milognon *et al*., 2020) but also to the high request for food needs due to galloping demographics. In such a situation, food production must increase to meet population request. However, the increase in the surface area of cultivable land, which is a plausible alternative for increasing productivity, is restricted by population growth and urbanization. Thus, in the current context, the use of fertilizers to improve crop yields on already available agricultural land and/or the identification and introduction of efficient genotypes of certain species to restore and increase the content of soil nutrients in subsistence agriculture prove to be essential (Kanyenga, 2016; Miklas *et al*., 2006, Smaling *et al*., 1997; Amonmidé *et al*., 2019). It is in this context that this study generally aims to increase the production and consumption of beans of the *Phaseolus* genus within households in order to make nutritional and food security sustainable in Benin. Specifically, the study aims to evaluate the effect of mineral fertilizers on the yield and economic profitability of local varieties of common bean (*Phaseolus vulgaris* L.) on the one hand and on the other hand identify the genotypes presenting agronomic potential for the proper fixation and conversion of atmospheric nitrogen into organic nitrogen.

MATERIALS AND METHODS

A field experiment was conducted from June to November 2020 for the first season and from July to December 2022 for the second season in a natural environment in Ouèdèmè in the commune of Glazoué, Collines department, in Benin. Ouèdèmè is located between the parallels 8°00'993" of southern latitude and 02°10'191" of eastern longitude at an altitude of 818m. It is a transition zone between the Subequatorial and Sudanian zones, where the Sudano-Guinean climate reigns with the alternation of a dry season and a rainy season (Akouègninou *et al*., 1979). The rainy season generally starts in April and ends around mid-November or mid-December; while the dry season goes from November to March. Annual rainfall varies between 800-1200 mm, with a large variation in annual temperatures, oscillating between 22 and 36°C (MEPN, 2008). The soil types in the study area are mainly Ferruginous and Ferralitic. The choice of Ouèdèmè for thiswas due to the low levels of nitrogen in the soil. Tratments included 15 local bean varieties and fertilisation (NPK 14-18-18 and Urea 46% N), applied at rates of 0 and 531 kg fertilizer ha^{-1}.

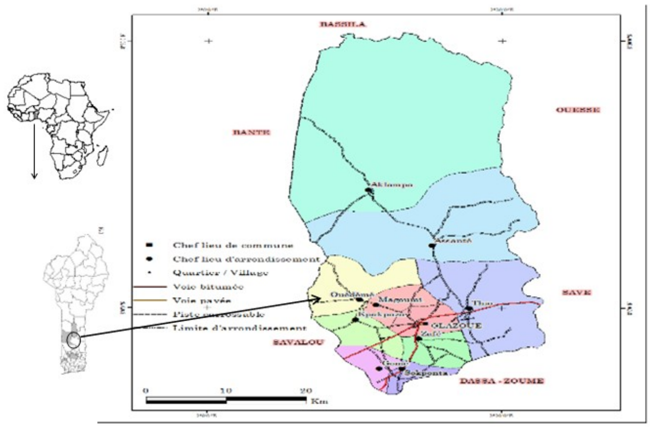

Figure 1. Location of the study site in Benin

The experimental was laid out in a randomised complete design, with split-plot arrangement. The vaireties constituted the main plots, while the fertiliser rates were the subplots. Each plot measured 10 m in length and 7.5 m in width. Paths of 3m separated the subplots. The land was prepared manually and the different local bean varieties were sown at spacings of 2 m × 2.5 m, placing one seed per pocket with a seeding density of 2000 plants ha^{-1}. Each plot contains five local varieties, each of which was replicated three times in an under plot. In total, each block contains the fifteen local varieties tested. The choice of the 15 local common bean cultivars was based on results of the agro-morphological study (Milognon *et al*., 2022), and the phylogenetic classification (Milognon *et al*., 2019); while taking into account the preference criteria of producers/consumers. The agronomic characteristics of local varieties of common bean measured during this study during the two seasons are presented in Table 1.

Table 1. Agronomic parameters measured in the study

Performance parameters	Coded
Pod length (Average of 10 pods selected per variety)	LOG
Number of seeds per pod (Average of 10 pods selected per variety)	NGG
Flowering time	TAF
Pod appearance time	TAG
Average weight of 1000 seeds	P1000G
Yield in k ha^{-1}	REPHa

The harvest was done manually in two stages namely on the 127th day for early varieties and on the 149th for late varieties; as soon as the leaves yellowed and the pods dried out for the two seasons. The growth rate of the plants was evaluated between the period of germination (8th day on average after sowing) until the stage of residence of the cotyledons on the plants (15th day on average) by the ratio number of plants growth/number of seeds sown. After harvest, grain yield was adjusted to 14% moisture. The humidity is determined after drying the beans in the sun for a period of one month. The moisture content (H) is expressed as a percentage and calculated by the following formula (AFSCA, 2013):

$$H (\%) = (M1-M2)/M1 \times 100$$

Where M1= weight in grams before drying; and M2= weight in grams after drying. Finally, the profitability of fertilizer use in bean production was computed using the Value/Cost ratio (VCR), in order to determine whether mineral fertilizer applied to the plant could be profitable for producers. This ratio was obtained by dividing the value of the increase in bean grain yield for each treatment by the total cost incurred following the use of the fertilizer. In the village groups (GV) of the study area, 50kg bags of NPK (14-18-18) and urea cost respectively,cost US$25 and 29.50; and the labour for fertilisation and transport together cost US$65 (USD) per hectare. As for the price of common beans, 4kg of bean grains cost on average between 3 and 5 United States dollars, depending on the varieties; at the Glazoué international market. Thus, depending on the variety, the price of a kilogram can vary between US$0.750 and 1.25.

Data analysis. Regarding data analysis, data from both seasons were compiled and an average was obtained for each local variety for the measured variables.An analysis of variance was carried out on the different yield parameters, using the XLSTAT software, in order to identify the effects of each factor studied on the yield differences observed between treatments. Means were compared using the Tukey HSD test. The growth rate was determined by the ratio of number of plants grown/number of seeds sown. Economic profitability was assessed according to Mufind *et al.*(2017).

RESULTS

Response of mineral fertilization on the measured yield characteristics. Table 2 presents both the average values obtained following the application of fertilizers and those obtained without fertilizers on yield parameters such as growth rate, pod length, flowering times and pod appearance, the number of seeds per pod, the weight of 1000 seeds and the grain yield per hectare of the local varieties of *P. vulgaris* tested. It appears from the analysis of this table that all the measured yield parameters showed highly significant differences (p = 0.005 or p<0.0001) with the exception of the emergence rate parameter which showed a non-significant difference (p = 0.114). The average yield obtained on unfertilized plots is 1170.32294 Kg.ha^{-1} while that of fertilized plots is approximately 1573.93824 Kg.ha^{-1}. Thus, the use of mineral fertilizers provides a yield gain of approximately 44% compared to unfertilized plots.

Influence of local varieties of common bean (P. vulgaris) on the measured yield parameters. As a result of the analysis of variance, highly significant differences (p<0.0001) are noted in Table 3. Thus, all the yield parameters measured during this trial are significantly influenced by the tested varieties. Highly significant differences are therefore observed on characters such as the length of the pods, the number of seeds per pod, the flowering and appearance times of the pods, the weight of 1000 seeds as well as the yield per hectare of the common bean. Furthermore, on the growth rate, we note non-significant differences between varieties tested (p>0.05). The MSCn3 variety gave the best yield per hectare (2264.925 Kg.ha^{-1}) and the lowest yield was observed in the SDCn5 variety (894.145 Kg.ha-1). Let us also remember that it is the GOLn6 variety which, in addition to the best growth rate (94.70%), gave the greatest length of pods (8.808) as well as the greatest number of seeds per pod (4.750). Its yield per hectare is also not negligible (1794.250 Kg.ha^{-1}). Finally, the best weight of 1000 seeds (518.950g) is observed in the GACn2 variety. During this test, we can also remember that there are varieties in the collection (MSCn7; DBZn3; LSCn3 and AOGn1) whose flowering and pod appearance times are short but whose average yields per hectare are moderate.

Influence of mineral fertilizers and local varieties of common bean (*P. vulgaris*) on the measured yield parameters. As for the evaluation of the combined effect of mineral fertilizers and common bean tested varieties, Table 4 presents the results of the analysis of variance on the measured yield parameters. From this table, highly significant differences were noted on the length of the pods, the weight of 1000 seeds, the times of flowering and appearance of the pods (p < 0.00001) and a significant difference on the number of seeds per pod (p=0.0044). It is also important to emphasize that the fertilizer-variety combination has a highly significant effect (p <0.00001) on bean seed yield. Furthermore, apart from local varieties such as GOLn2, KDCn5 and AAZn1 where the number of seeds per pod showed a significant difference between varieties having received fertilizer and those not fertilized, all the other varieties tested with mineral fertilizer did not showed no significant difference for this trait.

Effect of chemical fertilizer on the economic profitability of *Phaseolus vulgaris* L. Table 5 reports the varieties of common bean that have shown benefit after the use of chemical fertilizer. In total, two local varieties of beans tested with mineral fertilizers gave a value for the cost value ratio greater than or equal to 2. In fact, the local varieties HZZZn3 and GOLn6 are the only ones whose value in increasing the seed yield of common bean after the use of mineral fertilizers made it possible to offset the expenses linked to the use of fertilizer, and to produce a gain in return. It is important to emphasize that the SSCn3 variety gave a value for cost ratio very close to 2, that is to say 1.906 and could be considered as a variety having an almost positive effect with regard to mineral fertilizers. . Furthermore, other local varieties such as MSCn3, AAZn1, HDDCn3 and K1DCn3 have given a very satisfactory increase in yield in Kg.ha^{-1} but whose cost price per kilogram on the market is low, thus leading them to be unable to balance the expenses linked to the use of fertilizer, and create a relative profit while the local cultivars (LSCn3, SDCn5 and AOGn1) gave a significant biomass with a small increase in yield in Kg.ha^{-1} after the use of mineral fertilizers. Finally, let us note that varieties such as GACn2, GOLn2, KDCn5, DBZn3 and MSCn7 remained almost insensitive to mineral fertilizers.

DISCUSSION

In Benin, despite the substantial efforts made by the government to increase food production, malnutrition persists and food insecurity continues to affect households, particularly in rural areas (Chikou *et al.*, 2016, Sodjinou et *al. al.,* 2016). Over the past three decades, food and nutritional security have been threatened despite the sharp increase in imports of agricultural products (Kogbéto, 2010). Face to all these challenges, agricultural research in developing countries cannot neglect cropping systems, because traditional crops in tropical regions do not always allow plants to express their real production potential. This situation consequently requires the development of more efficient phytotechnics in pure or associated cultivation where the selection of new varieties responding to current challenges in subsistence agriculture (Baudoin, 2001) is necessary in order to guarantee food self-sufficiency for populations. Due to the complexity of the factors involved in mastering cultivation techniques in agriculture, authors have shown that the use of mineral fertilizers often makes it possible to double and even triple agricultural yields (Sanginga & Woomer, 2009, pypers *et al.,* 2010). However, increasing the productivity of beans would contribute to the reduction of malnutrition and indeed guarantee food security due to the nutritional status of these resources (Marilyn *et al.,* 2011). It is with this in mind that this study focused on the effect of mineral fertilizers on the yield and economic profitability of beans grown in Benin for sustainable food security. The results obtained on the bean cultivars used showed that the yield components measured during this experiment are all influenced by the varieties. Indeed, the highly significant differences observed on the length of the pods, the number of seeds per pod, the flowering and appearance times of the pods, the weight of 1000 seeds as well as the yield per hectare of the common bean could be explained by the genetic heritage of the different tested cultivars. As a result, not all varieties have the same potential for absorption of nutrients from the soil and/or production, due to the wide variability that exists within the same species (Okii *et al.,* 2014; Milognon *et al.,* 2022). These observations are similar to the results of research carried out on different varieties of beans by several authors (Mufind *et al.,* 2016; Lubobo *et al.,* 2016; Ntamwira *et al.,* 2017). Apart from genetic variability which would justify the differences in yields, Lubobo *et al.* (2016) also demonstrated that the photoperiod and the physical environment are also factors that condition the differences in yields between the same bean variety. Indeed, the same variety grown in two different environments can show variations in yield. The results of our study confirm those of Lubobo *et al.* (2016) because the cultivars MSCn3, GACn2 and GOLn6, all collected in the agro-ecological zone where the experiments took place, proved to be the most productive. This could be due to the fact that these cultivars have already adapted to the agro-ecological conditions of the environment. This is why any breeder, in order to have cultivars that are both productive and stable, must first take care to choose the species or cultivated variety that best suits local ecological requirements (Milognon *et al.,* 2022). Thus, we recommend with the same cultivars, the resumption of this experiment in the other agro-ecological zones of Benin where the collection of other cultivars used

Table 2. Response of local varieties of common bean (*P. vulgaris*) to mineral fertilization

Fertilizers	Agronomic	characters	measured				
	TL	LOG	TAF	TAG	NGG	P1000G	REPHa
Fertilized	85.65±6.32a	7.69±0.98a	63.59±10.01b	75.62±10.16b	3.79±0.76a	343.88±79.20a	1573.94±341.01a
No Ferti	89.33±5.40a	7.26±0.89b	67.44±10.35a	77±11.49a	3.53±0.50b	333.46±77.29b	1170.32±354.15b
p-Value	0.114	<0.0001	<0.0001	<0.0001	0.005	<0.0001	<0.0001

TL= Lift rate; LOG= Pod length; TAF= Flowering time; TAG= Pod appearance time; NGG= Number of seeds per pod; P1000G= Weight of 1000 seeds; REPHa = Yield per hectare.

Table 3. Influence of common bean varieties on the measured parameters

Varieties	**Agronomics**	**characters**	**measured**				
	TL	LOG	NGG	TAF	TAG	P1000G	REPHa
GACn2	91.56±2.49a	7.93±1.11bc	3.75±0.07ab	83.25±11.33a	92.50±9,67a	518.95 ±70.55a	1855.83 ±205.63b
MSCn3	86.41±5.36a	8.00±1.09b	3.75±0.02ab	76.75±8.56b	89.25±9.97a	478.00 ±62.88b	2264.93 ±523.69a
KDCn5	82.68±4.55a	8.73±0.84a	4.50±0.10a	72.50±6.23bc	87.75±8.64a	307.15 ±56.98gh	1180.90 ±200.05fgh
GOLn2	89.40±6.87a	8.33±1.43ab	4.25±0.05ab	62.25±7.48e	71.50±6.78c	449.15 ±74.12c	1542.68 ±190.77c
AAZn1	90.31±4.66a	8.90±1.00a	3.25±0.23ab	66.50±4.43de	77.50±5.28b	311.95 ±63.21gh	1390.00 ±188.61d
HZZZn3	93.00±3.78a	7.30±0.33cde	3.75±1.00ab	76.25±12.71b	92.00±8,31a	317.00 ±74.00g	1245.25 ±164.23ef
LSCn3	81.54±7.32a	7.33±0.16cde	3.50±0.45ab	54.00±3.88f	63.75±7.75d	252.75 ±34.76k	1834.43 ±308.52b
SSCn3	85.90±6.08a	7.19±0.47def	3.75±0.70ab	66.75±5.21de	77.25±6.44b	360.98 ±71.04e	1258.38 ±236.22ef
HDDCn3	87.36±8.61a	7.80±0.00bcd	4.00±0.12ab	70.00±8.06cd	79.75±4.23b	264.75 ±45.73j	1183.60 ±171.55fgh
SDCn5	88.54±2.13a	7.95±0.38bc	3.25±0.56ab	63.25±5.98e	72.25±3.60c	229.74 ±50.09m	894.15 ±101.07j
GOLn6	94.70±3.69a	8.81±0.89a	4.75±0.78a	69.25±6.11cd	80.00±9.29b	385.95 ±81.35d	1794.25 ±188.03b
AOGn1	87.51±6.82a	6.58±0.08f	3.50±0.40ab	55.75±5.38f	65.00±4.89d	270.75 ±49.32j	1155.25 ±103.27gh
K1DCn3	80.76±7.11a	6.89±0.29ef	3.25±0.02ab	74.00±9.66bc	81.50±6.22b	285.50 ±43.73i	1317.70 ±121.68e
DBZn3	83.92±3.47a	5.38±1.55g	3.00±0.04b	54.75±4.02f	65.25±3.79d	317.50 ±39.98g	1581.35 ±208.91c
MSCn7	82.00±2.46a	6.96±0.23ef	3.25±0.08ab	47.00±5.74g	58.00±5.53e	234.00 ±36.52l	1307.73 ±148.45e
Pr > F(Model	0.386	<0.0001	0.005	<0.0001	<0.0001	<0.0001	<0.0001
Significant)	No	Yes	Yes	Yes	Yes	Yes	Yes

The different letters next to the means indicate a significant difference and the same letters indicate non-significant differences after comparison of the means by the Tukey Test (HSD) at the 5% threshold.

Table 4. Influence of common bean varieties and mineral fertilizers on the measured parameters

Varieties Fertilization	LOG	NGG	TAF	TAG	P1000G	REPHa	Lift rate
GACn2 Fertilized	8.10±1.30abcdef	3.50±0.67ab	84.00±6.20a	94.00±5.67a	523.50±67.98a	2011.65±508,78b	89.35±5.23a
No fertilized	7.75±0.32cdefgh	4.00±0.96ab	82.50±4.01ab	91,00±11.36ab	514.40±56.28a	1700.00±421.87d	91.56±2.49a
MSCn3 Fertilized	8.15±0.82abcdef	3.50±0,58ab	72.50±8,61def	87.50±7.43abcd	490.00±43.65b	2490.45±608.35a	83.11±2.23a
No fertilized	7.85±1.00bcdefg	4.00±0,71ab	81.00±9,23abc	91.00±9.45ab	466.000±32.16c	2039.40±585.63b	80.73±4.98a
GOLn2 Fertilized	8.75±1.60abc	3.50±0.21ab	61.50±3.65hij	73.00±4.21ghijk	451.80±36.81cd	1741.15±306.56d	76.65±8.32a
No fertilized	7.90±0.96bcdefg	5.00±1.20a	63.00±5.47ghij	70.00±7.88ijkl	446.50±28.89d	1344.20±202.62gh	78.46±9.87a
KDCn5 Fertilized	9.20±0.93a	4.50±0.00ab	67.50±11.30efghi	86.00±0.78abcde	310.80±15.16hij	1345.30±127.32gh	84.26±5.68a
No fertilized	8.25±1.11abcde	5.000±0.26a	77.50±6.51bcd	89.50±2.77abc	303.50±13.23ijk	1016.50±98.83ijk	87.12±6.56a
AAZn1 Fertilized	9.04± 0.71a	2.50±1.40b	65.50±7.56fghi	76.50±10.56fghij	369.00±8.77ef	1706.00±78.64d	72.71±9.42a
No fertilized	8.75±0.62abc	3.00±0.79ab	67.50±8.33efghi	78.50±14.67efghi	304.50±12.54ijk	1074.000±54.69ij	80.31±6.09a
SSCn3 Fertilized	7.30±0.88defghij	3.50±0.05ab	65.50±2.20fghi	75.50±6.66fghij	358.83±41.22f	1524.50±100.08ef	92.86±6.54a
No fertilized	7.08±1.00efghij	4.00±0.46ab	68.00±4.31efghi	79.00±9.10efgh	245.00±26.09op	992.25±87.87ijkl	90.03±8.01a
SDCn5 Fertilized	8.15±1.4abcdef	3.00±0.12ab	60.00±9.16ijk	70.50±4.46hijkl	336.00±51.34g	999.90±58.31ijkl	73.39±5.20a
No fertilized	7.75±0.89cdefgh	3.50±0.49ab	66.50±4.12fghi	74.00±8.23fghij	259.30±42.18no	788.39±32.56m	71.66±4.04a
LSCn3 Fertilized	7.40±0.04defghi	3.50±043ab	57.50±6.97jkl	69.00±3.14jkl	260.50±27.80no	1723.95±303.68d	97.90±1.06a
No fertilized	7.25±0.50defghij	3.50±0.62ab	50.50±9.76lm	58.50±7.56mn	283.50±15.05klm	1544.900±289.42e	94.05±1.88a
HZZZn3 Fertilized	7.61±0.77defgh	3.50±0.36ab	76.50±3.44bcd	92.00±15.78ab	330.00±34.75gh	1551.00±278.65e	88.58±3.13a
No fertilized	7.00±0.82fghij	4.00±0.53ab	76.00±5.94bcd	92.00±14.22ab	299.25±27.33jk	939.50±219.96kl	81.16±6.07a
DBZn3 Fertilized	5.45±1.20k	3.00±0.72ab	52.50±7.76lm	65.50±5.17klm	315.00±31.13ghij	1747.40±288.95d	93.06±1.00a
No fertilized	5.30±0.97k	3.00±0.48ab	57.00±4.19jkl	65.00±3.11klmn	305.00±24.72ijk	1415.30±206.09fg	91.44±1.27a
HDDCn3 Fertilized	8.10±0.47abcdef	3.50±0.90ab	65.00±6.00fghi	77.50±9.42efghij	293.50±19.41jkl	1476.20±205.06ef	71.48±9.89a
No fertilized	7.50±1.00 defgh	4.50±0.59ab	75.00±4.93cde	82.00±11.16cdef	270.20±13.76 mn	891.00±112.32l	77.15±9.30a
GOLn6 Fertilized	6.96±2.30fghij	3.50±0.38ab	67.00±11.85efghi	75.00±8.36fghij	304.00±47.86ijk	1865.50±402.04c	86.01±7.05a
No fertilized	6.20±0.63j	4.00±0.57ab	71.50±9.28def	85.00±14.67bcde	258.000±31.76no	1273.00±309.84h	84.70±5.06a
K1DCn3 Fertilized	6.95±0.25fghij	3.00±1.10ab	71.00±3.27defg	81.50±1.02cdefg	293.50±21.71jkl	1567.00±104.69e	83.30±1.56a
No fertilized	6,82±0.00ghij	3.50±0.78ab	77.00±8.10bcd	81.50±2.00defg	277.50±13.08lmn	1068.40±85.66ijk	82.02±3.14a
MSCn7 Fertilized	7.08±0.56efghij	3.50±0.64ab	43.50±8.23n	57.00±4.75n	238.00±16.12p	1520.90±247.11ef	90.44±1.64a
No fertilized	6.83±0.78ghij	3.00±0.92ab	50.50±6.25lm	59.00±5.48mn	230.000±13.68p	1095.55±193.86ij	88.22±2.31a
AOGn1 Fertilized	6.85±1.88ghij	3.50±0.09ab	53.50±10.32klm	65.00±6.33klmn	283.50±42.84klm	1278.20±121.07h	81.70±4.87a
No fertilized	6.30±1.31ij	3.50±0.41ab	58.00±11.81jkl	65.00±5.89klmn	258.00±36.04no	1032.30±97.88ijk	78.01±3.83a
Pr > F(Model)	<0.0001	0.0045	<0.0001	<0.0001	<0.0001	<0.0001	0.877
Significant	Yes	Yes	Yes	Yes	Yes	Yes	No

in the study was made in order to observe the stable or not behavior of the cultivars which are found to be the most productive in this study compared to those who showed lower returns than the latter. Regarding the effect of fertilizers, the results of this study show that mineral fertilizers produced a compensatory relationship between certain yield traits. Indeed, apart from the local variety LSCn3, for all the other local tested varieties, the reduction in the number of seeds per pod observed on the fertilized plots causes an improvement in the average weight of 1000 seeds. This could be explained by the absence of competition between the seeds of the same pod, which certainly favored the filling conditions of the pods by increasing the size of the seeds and consequently the weight of the seed, thus making it weak the number of seeds per pod. These results confirm those obtained by Laupretre and Benoît (1989); Mbukula *et al.* (2018) which indicate

Table 5. Influence of mineral fertilizers on the economic profitability of common bean varieties

Variéties Fertilization	Total fertilizer cost in $	Yield in $Kg.ha^{-1}$	Increase in yield in $Kg.ha^{-1}$	Price of a Kg of the variety on the market	Value of de yield increase in $	Value Cost Ratio
GACn2 Fertilized	348.995	2011.650	311.65	0.920	286.718	0.821
No fertilized	------	1700.000	------	0.920	------	
MSCn3 Fertilized	348.995	2490.450	451.05	0.875	394.668	1.130
No fertilized	------	2039.400	------	0.875		
GOLn2Fertilized	348.995	1741.150	396.95	0.750	297.712	0.853
No fertilized	------	1344.200	------	0.750		
KDCn5 Fertilized	348.995	1345.300	328.8	1.100	361.680	1.036
No fertilized	------	1016.500	------	1.100		
AAZn1 Fertilized	348.995	1706.000	632	0.920	581.440	1.666
No fertilized	------	1074.000	------	0.920		
SSCn3 Fertilized	348.995	1524.500	532.25	1.250	665.312	1.906
No fertilized	------	992.250	------	1.250		
SDCn5 Fertilized	348.995	999.900	211.51	0.950	200.934	0.575
No fertilized	------	788.390	------	0.950		
LSCn3 Fertilized	348.995	1723.950	179.05	1.250	223.812	0.641
No fertilized	------	1544.900	------	1.250		
HZZZn3Fertilized	348.995	1551.000	611.5	1.250	764.375	2.190
No fertilized	------	939.500	------	1.250		
DBZn3 Fertilized	348.995	1747.400	332.1	1.100	365.310	1.046
No fertilized	------	1415.300	------	1.100		
HDDCn3Fertilized	348.995	1476.200	585.2	0.920	538.384	1.542
No fertilized	------	891.000	------	0.920		
GOLn6Fertilized	348.995	1865.500	592.5	1.250	740.625	2.122
No fertilized	------	1273.000	------	1.250		
K1DCn3Fertilized	348.995	1567.000	498.6	1.000	498.600	1.428
No fertilized	------	1068.400	------	1.000		
MSCn7 Fertilized	348.995	1520.900	425.35	0.900	382.815	1.096
No fertilized	------	1095.550	------	0.900		
AOGn1Fertilized	348.995	1278.200	245.9	0.875	215.162	0.616
No fertilized	------	1032.300	------	0.875		

that any water and mineral restriction during the period of elongation and filling of the pods has a negative impact on the average weight of the seed and that there is therefore an interaction between the different yield components, namely the number of seeds per pod, the number of pods per plant and the average weight of seeds depending on the availability of mineral elements during reproduction. Furthermore, local cultivars (LSCn3, SDCn5 and AOGn1) gave a slight increase in yield in $Kg.ha^{-1}$ after the use of mineral fertilizers. This could be explained by an increase in leaf biomass observed in the latter. Thus, during this study, these cultivars underwent excessive growth in their vegetative apparatus to the point where the few pods produced under the shade of the leaves and in the axils of the stems were damaged by rot; which justifies the low yields observed per hectare for these cultivars because rotten seeds were not taken into account when evaluating the yield in $Kg.ha^{-1}$. Consequently, at the level of these cultivars, in the event of an abundant mineral supply, it is the biomass which benefits from an increase in production rather than the seeds.

Referring to the role of nitrogen for plants (Witham and Devlin, 1983, Newton, 2007), we could retain that the excess growth of vegetative organs, in particular that of stems and leaves (biomass) observed in level of these cultivars would be the consequence of an additional supply of nitrogen due to the fixation and conversion of atmospheric nitrogen into ammonia by the rhizobia of these plants. Thus, subject to in-depth study, these cultivars would present interesting agronomic potential for the fixation and conversion of atmospheric nitrogen into organic nitrogen easily assimilated by plants and could therefore be recommended in crop rotations. The use of mineral fertilizers in this study resulted in an overall increase in yield of around 44%. These results are in agreement with those of Mufind *et al.* (2017) and Baert (1988); who used respectively 611Kg of mineral fertilizer per hectare and different doses of Diammonium Phosphate on common bean and could be explained by the fact that the yield per unit area of crops depends largely on soil fertility (Mbukula *et al.,* 2018, Pypers, 2010). It is here that it must be emphasized that the addition of fertilizer always produces a gain for the plants, either in seed yield or in leaf biomass. It is therefore appropriate to study in future studies the optimal doses for which each cultivar of common beans from Benin would produce a limit increase in seed or biomass. The HZZZn3 cultivar gave the highest increase in seed yield (around 65.08%) after the application of mineral fertilizers during this experiment; this observation could be explained by the area of origin of the latter. Indeed, the locality of Lama was already identified more than two decades ago by the Ministry of Agriculture, Livestock and Fisheries (MAEP) of our country as being an area of great fertility after the Ouémé Valley and is reserved for the National Office of Wood (ONAB) for the reforestation of the Zogbodomey forest. Consequently, HZZZn3 collected in this area is accustomed to fertile soils, hence this remarkable increase in yield noted for this cultivar on fertilized plots compared to unfertilized plots. Baert, (1988) in similar studies reached the same result and concluded that there are cultivars which only express their genetic potential on fertile soils. From the above, we can conclude that cultivars having shown a large difference in yield between fertilized plots and those not fertilized would be able to express their genetic potential only in fertile environments. These differences in yields obtained with these cultivars have a direct consequence on economic profitability. Indeed, out of the fifteen (15) tested cultivars, 10 showed a CVR (Cost Value Ratio) value strictly greater than 1. Which means that the addition of mineral fertilizers to bean cultivars is moderately profitable because for these 10 cultivars, the expenses related to the application of fertilizers were ensured and a profit was noted. But this is not enough for local producers to launch into the production of beans based on mineral fertilizers. According to the standard established by Kelly and Murekezi (Kelly and Murekezi, 2000) supported by the FAO (FAO, 2005); a variety would be profitable if and only if, the potential profit obtained after strengthening the productivity of the variety with fertilizer is at least double the expenses incurred in the fertilizer application. In these conditions, small farmers with limited financial resources and who are, moreover, the guarantors of the sustainability, promotion and conservation of beans of the *Phaseolus* genus in Benin (Milognon, 2017; Milognon *et al.*, 2020) could invest without major risks in the use of fertilizers to improve the yield of beans because the expected profit is much greater than the investment and could therefore cover the risks of possible climatic hazards and fluctuations in the price of the Kilogram on the market. In the case of our study, the cultivars HZZZn3 (CVR = 2.190), GOLn6 (CVR = 2.122) and SSCn3 (CVR = 1.906) are models that seem to meet the FAO standard (2005). From all of the above, the use of fertilizers remains less profitable for local populations. Furthermore, other local varieties such as MSCn3, AAZn1, HDDCn3 and K1DCn3 have given a very satisfactory increase in yield in $Kg.ha^{-1}$ but whose cost price per kilogram on the market is low, thus leading them to be unable to balance the expenses linked to the use of fertilizer, and create a related profit. Which shows that these varieties, although being productive, their seeds present culinary characteristics (too hard seed coat implying late cooking, bitter taste after cooking, etc.), morphological characteristics (black or carmine red colors of the seed coats, bulky seed, etc. .) which cause them to be depreciated on the market by consumers. Crosses could be considered between these genotypes and those preferred by populations whose yields are often low while the cost per kilogram is high on the market, to improve both their productivity and their economic profitability.

CONCLUSION

At the end of this study, which aimed to evaluate the response of mineral fertilizers (NPK and urea 46% N) on the yield and economic profitability of common bean cultivars (*Phaseolus vulgaris* L.), it should be noted that the obtaining of a high yield from these genetic resources depends both on the type of cultivar and mineral fertilizers. Thus, highly significant differences in yield were noted on the one hand between the used cultivars and on the other hand, between the fertilized plots and those not fertilized. In addition, the use of mineral fertilizers produced an increase in yield of around 44% with only three (03) cultivars whose CVR are greater than or equal to 2 (CVR≥2) showing that the use of mineral fertilizers is not as profitable for small farmers in the edapho-climatic conditions of Ouèdèmè/Glazoué in the hills department of Benin. This lackluster response from fertilizers is particularly due to the fact that certain cultivars having shown a favorable response after the use of mineral fertilizers are sold less expensively on the market due to the depreciation of certain characteristics of their seeds; or that the dose of fertilizers applied in the present study is either too little or slightly higher than the demand of certain cultivars. This situation urgently calls for a research effort to improve the physical characteristics of the seeds of certain cultivars according to consumer taste and on the optimal doses of fertilizer for which each common bean cultivar of Benin is profitable for local populations. We also recommend testing the effectiveness of other fertilizers such as DAP (Diammonium Phosphate) and *Jatropha curcas* cake on common bean cultivars grown in Benin.

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