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Yield, Growth and Vegetative Development Parameters Response of Dry Beans to Organic and Inorganic Fertilizers and Biofertilizer

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Abstract

As part of the promotion of common bean cultivation, fertilization methods will have to be proposed to growers. The aim of this study is therefore to develop a technical itinerary for dry bean fertilization. To this end, different types of chemical and organic fertilizers were evaluated on three dry bean varieties (HARI25/GHA19, HARI35/GHA19 and HARI36/GUI21). Seven (7) doses of chemical and organic fertilizers were used, including two controls (D0 with no fertilizer and D1, the reference dose using NPK base and cover fertilizers in the form of urea). The fertilization trial was set up as a Split-Plot design, with variety as the primary factor and dose as the secondary factor. The experiment was repeated three (3) times. The results showed that vegetative development parameters and fruit set rate varied according to the variety studied. For yield and its components, the treatments had a significant effect. Indeed, the response of varieties to fertilizers was specific. For each variety used, the optimum yield was obtained with a different treatment, thus highlighting the genotype effect of the dry bean varieties studied. Among the treatments tested, D4 (5 t organic fertilizer/ha) performed best in all three varieties, generating yield increases of 20%, 46% and 91% respectively.

Keywords

Dry Bean, Variety, Chemical Fertilizer, Organic Matter, Biofertilizer

1. Introduction

The various crises in Côte d'Ivoire have accelerated the diversification of agricultural crops. As part of the 2018-2025 National Agricultural Investment Program [1], political decision-makers, notably the Ivorian government, have expressed their firm intention to step up the promotion of food crops to achieve food security and sovereignty. These crops include cereals, tubers and pulses. Pulses include crops such as groundnuts, cowpeas, common beans and soybeans. Among these food legumes is the dry bean, which, like the others mentioned above, belongs to the Fabaceae family. The common bean is widely adapted to a wide range of environments, cultivated at latitudes between 52˚N and 32˚S; in the humid tropics, in the semi-arid tropics and even in cold climatic regions [2]. By 2050, an increase in cereal supply is needed to feed the world's projected population of 9.8 billion. Dry beans are known to be rich in nutritional elements, namely vitamins, minerals, lipids and proteins. It is this nutrient richness that gives it an undeniable role in human and animal nutrition [3]. What's more, it can be used in cropping systems in association or rotation with other crops. Its after-effects can be exploited as a source of fertilizer for these crops.

Furthermore, common bean yield, like that of other crops, is affected by numerous external and internal factors (soil fertility degradation, lower fertilizer use, soil properties, irrigation, weed and pest control, genetic improvements, etc.), which reduce yield potential [4]. To combat malnutrition and ensure food sovereignty, the Ivorian government has encouraged crop diversification. Thus, the Vegetable and Protein Crops Program has undertaken the selection of high-performance bean varieties in terms of agromorphology and nutrition. The data gained from this research encouraged bean consumption as part of a healthy diet and support new breeding within the same genera with particular nutritional and health benefits [5]. The aim of this study was to evaluate the response of dry beans to different levels of organic, inorganic and biofertilizer fertilizers in order to improve their yield.

2. Materials and Methods

2.1. Hardware

The plant material used in this study consisted of three (3) dry bean varieties introduced from Ghana and Guinea Conakry (**Figure 1**).

HARI25/GHA19 HARI35/GHA19 HARI36/GUI21

Figure 1. Seeds of three (3) dry bean varieties tested for fertilization.

Table 1 indicates some traits of the tree dry bean varieties used in this trial.

2.2. Methods

- **Experimental site**

The trial was conducted at the Crop research Station in Bouaké, located in central Côte d'Ivoire at latitude 7˚46'N, longitude 5˚06'W and altitude 375 m [6]. The city of Bouaké lies in the transition zone between the forest climate of the south and the savannah climate of the north. The climate in the study area is humid tropical, with four seasons, including a long dry season (November to February), a long rainy season (March to June), a short dry season (July to August) and a short rainy season (September to October). These periods have become less marked in recent years. The vegetation consists of wooded savannah with several species of poaceae [7]. Soils are ferralitic gravelly, reworked, shallow and derived from granitic weathering material with a sandy-clay texture [8]. Average annual rainfall is 1200 mm, with an average temperature of 25.73˚C and an annual sunshine duration of 2200 h [9].

- **Experimental setup**

Numerous studies have shown the importance of improving soil fertility to increase agricultural production [10]. Fertilization can therefore be carried out in the form of organic or mineral amendment [11].

To set up the experiment, a Split-Plot factorial design was used. Dry bean variety was taken as the main factor with 3 modalities (HARI25/GHA19, HARI35/GHA19 and HARI36/GUI21). Fertilization method was taken as a secondary factor with 7 variants:

- Dose 0: no treatment (negative control)
- Dose 1: 100 kg NPK/ha before sowing
- Dose 2: 50 kg/ha Urea 2 weeks after sowing
- Dose 3: reference dose (100 kg/ha NPK before sowing + 50 kg Urea 2 weeks after sowing (positive control))
- Dose 4: 5 t organic manure/ha before sowing
- Dose 5: 10 t organic manure/ha before sowing
- Dose 6: Green Humico Biofertilizer 500 ml for 16 l of water (12 l/ha)

The Split-Plot allows the use of larger plot sizes for factors requiring it such as fertilization without greatly increasing the surface area of the experimental field.

Table 1. Agronomic and nutritional traits of tree dry bean varieties.

Bean varieties	Agronomic and nutritional traits			
	Protein content (%)	Lipids (%)	Potential seeds yield (t/ha)	Cooking time (min)
HARI25/GHA19	19.25	4.53	1.70	145
HARI35/GHA19	20.3	6.47	2.35	140
HARI36/GUI21	19.08	4.76	2.04	130

In addition, the layout on the ground is quite clear, which is interesting when the test also has a demonstration function. Also, the use of this experimental device makes it possible to better discriminate the secondary factor (fertilization) which is the subject of this study compared to the first one (variety) [12].

The plot size was 24 m^2 (6 m × 4 m). Sowing was done in 2-seed stacks spaced 0.20 m apart on the row and 0.50 m between rows. The plants were pruned 2 weeks after emergence to give one plant per bunch, *i.e.* a density of 280 plants per elementary plot. This resulted in 5880 plants for a surface area of 504 m^2 (24 m^2 × 21 plots).

2.3. Measurements and Observations

Measurements and observations focused on growth and vegetative development parameters, phenology and yield components.

To measure growth and vegetative development, plant height and collar diameter were taken into account. These two parameters were used to calculate the vegetative vigor index (VVI) using the following formula:

$$\text{VVI} = \log\left(0.785 \cdot H \cdot D^2\right)$$

With regard to phenology, flowering times were calculated when 50% of the plants in the elementary plot had flowered.

For yield components, the fruit set rate (number of open flowers/number of pods neoformed) was calculated. The number of nodules/plant was also calculated. Nodulation efficiency (NE) was calculated using the formula:

$$\text{NE} = \frac{\text{Number of functional nodules}}{\text{Total number of nodules per plant}} \times 100$$

NB: To determine the number of functional nodules, each nodule on the plant is sectioned using a new slide. Nodules with a bright red or brown interior are functional; those with a green or black coloration are non-functional.

Dry biomass was determined by weighing the organs (roots, stems and foliage) of the whole plant per elementary plot on a commercial scale. The weight of 100 seeds was also estimated using an electronic balance. Seed yield (SY) was calculated using the following formula:

$$\text{SY} = \frac{\text{Seed weight of elementary plot}}{\text{Area of elementary plot}} \times 10000$$

The rate of yield increase (RYI) was calculated using the following formula:

$$\text{RYI} = \frac{\text{Treatment yield} - \text{negative control yield}}{\text{Negative control yield}} \times 100$$

2.4. Data Analysis

The data obtained were subjected to statistical analysis using Statistica 7.1 software. Survey means were then discriminated by multiple comparison tests (LSD tests) at the 5% threshold.

3. Results

Table 2 records the height, crown diameter and vegetative vigor index (VVI) of three dry bean varieties. Analysis of variance (ANOVA) indicated that there were no significant differences between treatments applied to dry bean varieties for the vegetative parameters studied; except for plant height and vegetative vigor index, for which variability was recorded between treatments. However, it was noted that for a given variety, there was little difference between treatments

Table 2. Height, crown diameter and vegetative vigour index (VVI) of three dry bean varieties.

Accessions	Treatments	Plant heights (cm)	Neck diameters (cm)	Vegetative vigour index
HARI25/GA19	DO	17.53 ± 1.77^{bc}	0.21 ± 0.06^{a}	0.11 ± 0.17^{e}
HARI25/GA19	D1	19.07 ± 0.47^{bc}	0.25 ± 0.06^{a}	0.11 ± 0.19^{c}
HARI25/GA19	D2	21.67 ± 4.27^{bc}	0.27 ± 0.03^{a}	0.08 ± 0.14^{c}
HARI25/GA19	D3	21.07 ± 0.64^{bc}	0.29 ± 0.04^{a}	0.13 ± 0.11^{c}
HARI25/GA19	D4	19.73 ± 1.54^{bc}	0.25 ± 0.05^{a}	0.12 ± 0.15
HARI25/GA19	D5	20.60 ± 1.10^{bc}	0.25 ± 0.04^{a}	0.11 ± 0.12^{c}
HARI25/GA19	D6	22.13 ± 2.77^{bc}	0.27 ± 0.05^{a}	0.07 ± 0.19^{c}
HARI35/GA19	DO	25.67 ± 9.21^{bc}	0.29 ± 0.02^{a}	0.01 ± 0.28^{d}
HARI35/GA19	D1	26.67 ± 7.77^{bc}	0.29 ± 0.04^{a}	0.25 ± 0.38^{b}
HARI35/GA19	D2	31.87 ± 14.13^{ab}	0.30 ± 0.01^{a}	0.09 ± 0.35^{c}
HARI35/GA19	D3	45.87 ± 19.23^{a}	0.31 ± 0.01^{a}	0.26 ± 0.31^{b}
HARI35/GA19	D4	41.67 ± 10.54^{a}	0.29 ± 0.05^{a}	0.45 ± 0.22^{a}
HARI35/GA19	D5	43.53 ± 15.18^{a}	0.35 ± 0.01^{a}	0.39 ± 0.23^{a}
HARI35/GA19	D6	20.80 ± 5.60^{bc}	0.23 ± 0.03^{a}	0.46 ± 0.51^{a}
HARI36/GUI21	DO	24.73 ± 7.51^{bc}	0.26 ± 0.06^{a}	0.18 ± 0.12^{b}
HARI36/GUI21	D1	37.47 ± 16.03^{ab}	0.29 ± 0.08^{a}	0.20 ± 0.04^{b}
HARI36/GUI21	D2	26.33 ± 8.5^{bc}	0.28 ± 0.07^{a}	0.27 ± 0.21^{b}
HARI36/GUI21	D3	38.87 ± 12.79^{ab}	0.27 ± 0.06^{a}	0.47 ± 0.21^{a}
HARI36/GUI21	D4	34.53 ± 11.03^{ab}	0.35 ± 0.04^{a}	0.38 ± 0.19^{a}
HARI36/GUI21	D5	37.27 ± 11.22^{ab}	0.31 ± 0.05^{a}	0.58 ± 0.15^{a}
HARI36/GUI21	D6	29.93 ± 15.63^{b}	0.25 ± 0.08^{a}	0.05 ± 0.04^{e}
	Mean	28.90 ± 3.07	0.28 ± 0.01	0.15 ± 0.05
	Significance	0.0450	0.7280	0.0312
	CV (%)	10.62	0.057	33.33

For the same parameter, in the same column and in the same row, means followed by the same letter show no significant difference at the 5% threshold (Fisher test).

(intra-variety effect). Variability in height was observed from one variety to another (inter-variety effect). The smallest plants were found in HARI25/GHA19 and the tallest in HARI35/GHA19. For VVI, treatments D3, D4, D5 and D6 gave the highest values for varieties HARI35/GHA19 and HARI36/GUI21.

Table 3 shows flowering times and set rates for three dry bean varieties. The results show that the values for flowering time were statistically identical for the varieties used. This was in contrast to set rate, where variability was observed between treatments in dry bean varieties. The highest values were produced in

Table 3. Flowering time and fruit set in three dry bean accessions.

Accession of dry beans	Treatments	Flowering time (JAS)	Fruit set rate (%)
HARI25/GA19	DO	36 ± 00^{a}	20.13 ± 0.11^{cd}
HARI25/GA19	D1	36 ± 00^{a}	33.86 ± 0.17^{c}
HARI25/GA19	D2	36 ± 00^{a}	46.37 ± 0.06^{bc}
HARI25/GA19	D3	36 ± 00^{a}	20.84 ± 0.12^{cd}
HARI25/GA19	D4	36 ± 00^{a}	33.49 ± 0.13^{c}
HARI25/GA19	D5	36 ± 00^{a}	20.33 ± 0.11^{cd}
HARI25/GA19	D6	36 ± 00^{a}	20.84 ± 0.11^{cd}
HARI35/GA19	DO	32 ± 00^{a}	20.19 ± 0.2^{cd}
HARI35/GA19	D1	32 ± 00^{a}	40.48 ± 0.11^{c}
HARI35/GA19	D2	32 ± 00^{a}	33.27 ± 0.24^{c}
HARI35/GA19	D3	32 ± 00^{a}	53.39 ± 0.17^{ab}
HARI35/GA19	D4	32 ± 00^{a}	13.89 ± 0.06^{cd}
HARI35/GA19	D5	32 ± 00^{a}	53.73 ± 0.06^{ab}
HARI35/GA19	D6	32 ± 00^{a}	27.47 ± 0.13^{c}
HARI36/GUI21	DO	32 ± 00^{a}	47.62 ± 0.29^{bc}
HARI36/GUI21	D1	32 ± 00^{a}	60.49 ± 0.11^{a}
HARI36/GUI21	D2	32 ± 00^{a}	67.58 ± 0.13^{a}
HARI36/GUI21	D3	32 ± 00^{a}	60.19 ± 0.11^{a}
HARI36/GUI21	D4	32 ± 00^{a}	66.67 ± 0.17^{a}
HARI36/GUI21	D5	32 ± 00^{a}	53.09 ± 0.17^{ab}
HARI36/GUI21	D6	32 ± 00^{a}	53.05 ± 0.26^{ab}
	Maen	33.33 ± 0.24	41.78 ± 0.03
	Significance	0.9600	0.0316
	CV (%)	0.72	7.50

For the same parameter, in the same column and in the same row, means followed by the same letter show no significant difference at the 5% threshold (Fisher test).

HARI36/GUI21 by treatments D1, D2, D3 and D4.

Table 4 shows the number of nodules per plant and nodulation efficiency in three dry bean varieties. Statistical analysis showed that there was no variability between the number of nodules for any of the varieties studied. However, a significant difference was observed between treatments in nodulation efficiency. The highest nodulation efficiency values were obtained by treatments D6 in HARI35/GHA19, D0 and D3 in HARI25/GHA19 and D4, D5 and D6 in HARI36/GUI21.

Table 4. Number of nodules per plant and nodulation efficiency in three dry bean varieties.

Accessions	Treatments	Number of nodules/plant	Nodulation efficiency (%)
HARI25/GA19	DO	04.66 ± 2.60[a]	93.65 ± 0.07[a]
HARI25/GA19	D1	09.66 ± 7.75[a]	85.18 ± 0.08[ab]
HARI25/GA19	D2	10.33 ± 7.36[a]	80.56 ± 0.12[ab]
HARI25/GA19	D3	7.00 ± 1.73[a]	93.33 ± 0.07[a]
HARI25/GA19	D4	09.67 ± 4.63[a]	80.91 ± 0.00[ab]
HARI25/GA19	D5	09.00 ± 2.08[a]	73.53 ± 0.07[bc]
HARI25/GA19	D6	10.67 ± 0.33[a]	80.36 ± 0.12[ab]
HARI35/GA19	DO	03.67 ± 3.67[a]	33.76 ± 0.33[of]
HARI35/GA19	D1	01.00 ± 1.00[a]	40.45 ± 0.20[d]
HARI35/GA19	D2	01.67 ± 1.67[a]	27.97 ± 0.27[of]
HARI35/GA19	D3	14.33 ± 13.84[a]	60.09 ± 0.31[bc]
HARI35/GA19	D4	09.33 ± 6.98[a]	70.42 ± 0.10[bc]
HARI35/GA19	D5	14.67 ± 14.17[a]	73.13 ± 0.13[bc]
HARI35/GA19	D6	03.67 ± 3.18[a]	100.0 ± 0.00[a]
HARI36/GUI21	DO	10.00 ± 1.00[a]	42.76 ± 0.21[d]
HARI36/GUI21	D1	04.33 ± 2.03[a]	80.33 ± 0.00[ab]
HARI36/GUI21	D2	05.00 ± 5.00[a]	60.19 ± 0.31[bc]
HARI36/GUI21	D3	02.00 ± 2.00[a]	67.59 ± 0.33[bc]
HARI36/GUI21	D4	09.00 ± 4.04[a]	87.39 ± 0.07[a]
HARI36/GUI21	D5	11.33 ± 07.33[a]	87.62 ± 0.07[a]
HARI36/GUI21	D6	05.67 ± 4.18[a]	93.71 ± 0.07[a]
	Mean	7.46 ± 1.24	73.47 ± 0.04
	Significance	0.9850	0.0167
	CV (%)	16.62	5.55

For the same parameter, in the same column and in the same row, means followed by the same letter show no significant difference at the 5% threshold (Fisher test).

Table 5 shows dry biomass, 100-seed weight and seed yield for three dry bean varieties. The data recorded in the table showed a significant difference between treatments for all the agronomic descriptors studied. The highest biomass was produced by treatments D1, D2 and D6 in the HARI25/GHA19 variety. In terms of 100-seed weight, the highest values were found in the HARI25/GHA19 accession. For a fixed variety, there was no significant difference between treatments. Seed yield estimates showed that the lowest yields were generated by treatments D1 and D3 in HARI25/GHA19 and D6 in HARI36/GUI21. While the highest

Table 5. Dry biomass, 100-seed weight and yield for three dry bean varieties.

Accession of dry beans	Treatments	Dry biomass/ elemental plot (g)	Weight 100 seeds (g)	Yields (t/ha)	Rate of yield increase (%)
HARI25/GA19	DO	351.33 ± 1.05^{c}	24.33 ± 1.67^{b}	0.61 ± 0.19^{ab}	–
HARI25/GA19	D1	980.00 ± 5.31^{a}	25.33 ± 0.67^{b}	0.43 ± 0.05^{c}	−29.51 ± 9.67
HARI25/GA19	D2	821.33 ± 3.67^{a}	28.00 ± 2.00^{b}	0.72 ± 0.44^{ab}	67.44 ± 13.02
HARI25/GA19	D3	405.66 ± 0.70^{b}	25.67 ± 0.33^{b}	0.56 ± 0.23^{c}	−22.22 ± 5.98
HARI25/GA19	D4	1104.67 ± 2.75^{a}	24.67 ± 1.86^{b}	1.07 ± 0.24^{a}	91.07 ± 33.75
HARI25/GA19	D5	594.33 ± 2.42^{b}	26.33 ± 0.88^{b}	0.72 ± 0.19^{ab}	−32.71 ± 6.76
HARI25/GA19	D6	863.00 ± 3.91^{a}	25.67 ± 0.88^{b}	1.12 ± 0.09^{a}	55.56 ± 27.59
HARI35/GA19	DO	671.00 ± 0.20^{b}	25.00 ± 5.57^{b}	0.79 ± 0.31^{ab}	–
HARI35/GA19	D1	227.33 ± 0.36^{c}	18.67 ± 1.20^{bc}	0.69 ± 0.24^{ab}	−12.66 ± 3.75
HARI35/GA19	D2	310.00 ± 0.46^{c}	20.00 ± 1.15^{bc}	1.23 ± 0.106^{a}	78.26 ± 9.38
HARI35/GA19	D3	622.00 ± 3.07^{b}	21.67 ± 1.86^{bc}	0.97 ± 0.20^{a}	22.78 ± 3.87
HARI35/GA19	D4	360.00 ± 0.63^{c}	21.00 ± 1.53^{bc}	0.95 ± 0.59^{a}	20.25 ± 3.94
HARI35/GA19	D5	401.00 ± 1.25^{c}	20.67 ± 0.33^{bc}	0.96 ± 0.33^{a}	21.52 ± 4.67
HARI35/GA19	D6	333.67 ± 0.68^{c}	20.00 ± 1.53^{bc}	0.46 ± 0.17^{c}	−41.77 ± 8.23
HARI36/GUI21	DO	300.33 ± 2.26^{c}	34.33 ± 2.33^{a}	0.76 ± 0.13^{ab}	–
HARI36/GUI21	D1	374.67 ± 3.22^{c}	33.33 ± 0.88^{a}	0.920 ± 0.07^{a}	21.05 ± 2.98
HARI36/GUI21	D2	309.67 ± 1.74^{c}	34.67 ± 2.40^{a}	0.87 ± 0.42^{ab}	14.47 ± 3.01
HARI36/GUI21	D3	364.67 ± 1.64^{c}	37.33 ± 1.45^{a}	1.25 ± 0.71^{a}	64.47 ± 8.99
HARI36/GUI21	D4	431.33 ± 2.10^{c}	34.67 ± 1.45^{a}	1.11 ± 0.38^{a}	46.05 ± 8.58
HARI36/GUI21	D5	261.67 ± 1.87^{c}	37.67 ± 1.76^{a}	0.75 ± 0.27^{ab}	−1.32 ± 0.54
HARI36/GUI21	D6	234.85 ± 1.79^{c}	34.00 ± 2.00^{a}	0.91 ± 0.45^{a}	19.74 ± 5.12
	Mean	491.51 ± 0.56	27.28 ± 0.85	0.85 ± 0.06	18.21 ± 5.12
	Significance	0.0417	0.0287	0.0419	0.0322
	CV (%)	11.55	3.12	7.06	8.67

For the same parameter, in the same column and in the same row, means followed by the same letter show no significant difference at the 5% threshold (Fisher test).

values were produced by treatments D4 and D6 at HARI25/GHA19; D2, D3, D4 and D5 at HARI35/GHA19 and D1, D3, D4 and D6 at HARI36/GUI21.

Rates of increase compared with negative controls were calculated for each bean variety. For HARI25/GHA19, treatments D2, D4 and D6 produced high rates of 67.44%, 91.07% and 55.56% respectively. For HARI35/GHA19, the highest rates of increase were produced by D2, D3, D4 and D5 (78.26%; 22.78%; 20.25% and 21.52%). For HARI36/GUI21, all treatments produced positive yield rates compared with the negative control; with the exception of D5, which had a negative rate.

4. Principal Component Analysis (PCA) of Vegetative Development, Phenological Stage and Yield Parameters of Three Dry Bean Varieties

According to PCA, the first two principal axes F1 and F2, which accounted for 55.28% of total variability, were retained (**Figure 2**). The variables contributing to the formation of axes 1 and 2 were 6 and 2 respectively. Axis F1, which accounted for 35.00% of total variability, was positively characterized by phenological parameters and yield components (**Table 6**). The variables that contributed to the formation of this axis were defined by flowering time (Df), 100-seed weight (P1gr), fruit set (Tn), vegetative vigour index (VVI), dry biomass (DB) and yield (Rdt). On this axis, flowering time and dry biomass were positively correlated, while 100-seed weight (P1gr), fruit set (Tn), vegetative vigour index (VVI) and yield (Rdt) were negatively correlated.

Axis 2 (F2), describing 20.28% of total variability, was characterized by agronomic parameters linked to nodulation parameters (number of nodules/plant and nodulation efficiency). These parameters contributed positively to the

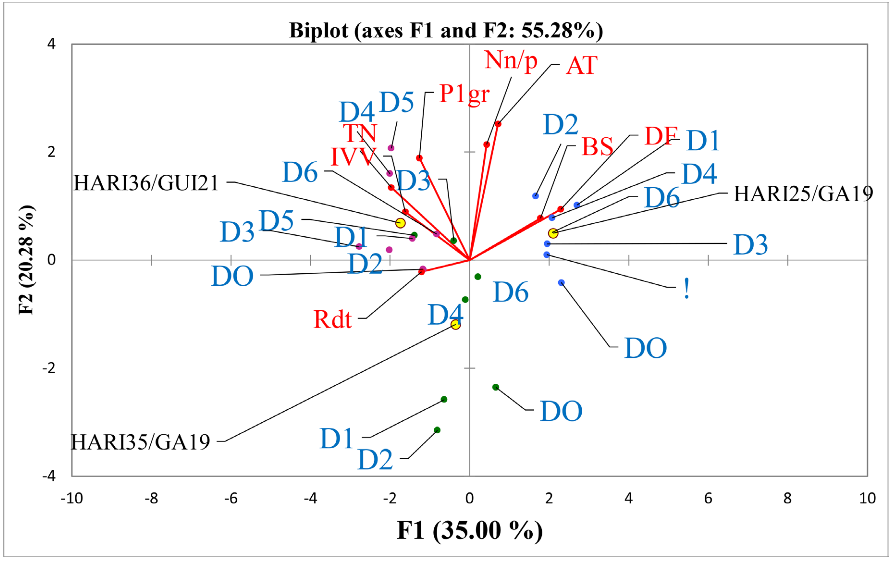

Figure 2. Principal component analysis to describe the effect of chemical and organic fertilizers and biofertilizers on three dry bean varieties.

Table 6. Matrix of eigenvalues and coordinates of agromorphological parameters of the main axes in three dry bean varieties.

Axes	F1	F2
Eigenvalue	2.966	1.650
Variability (%)	**37.071**	**20.624**
cumulative	37.071	**57.694**
Character defining axes and their eigenvalues		
Number of nodules per plant (Nn/p)	0.018	**0.469**
Nodulation efficiency (EN)	0.058	**0.574**
Vegetative Vigor Index (VVI)	**0.448**	0.101
Flowering time (DF)	**0.775**	0.091
Fruit set rate (TN)	**0.713**	0.107
Dry biomass (DB)	**0.454**	0.062
Weight of 100 seeds (P1gr)	**0.283**	0.239
Yield (Rdt)	**0.216**	0.007

formation of this axis.

The effects of treatments on accessions were highlighted by projecting variables, treatments and accessions onto the plane formed by the axes (F1 and F2). On the F1 axis, HARI35/GA19 and treatments D3 and D6 were projected. The F2 axis carried treatments D0, D1, D2, D4 and D5, as well as the varieties HARI25/GA19 and HARI36/GA21. Thus, the best flowering and biomass delays in the Hari 25/GA19 accession were induced by treatments D1 and D4. Treatments D3, D4 and D6 showed good vegetative vigour and fruit set in HARI 36/GUI21. For HARI/35/GA19, treatment D2 produced the highest yield (1.23 t/ha) compared with the others (Table 7).

5. Discussion

Measuring plant size rather revealed an inter-variety effect, *i.e.* the variability observed was established between the three varieties studied. Smaller plants were found in HARI25/GHA19 and larger plants in HARI35/GHA19. However, no intra-variety effect was noted. In other words, for a given variety, the treatments applied statistically gave the same size. According to these results, the treatments had little influence on plant height. It seems that the difference in height observed between the varieties is genetic in origin, with one variety with small plants (HARI25/GHA19) and another with large plants (HARI35/GHA19). Furthermore, when we take into account the vegetative vigor index (VVI), which is the combined expression of height and crown diameter, we find that treatments D3 (100 kg/ha NPK12-22-22 before sowing + 50 kg/ha urea 2 weeks after sowing), D4 (5 t organic fertilizer/ha before sowing), D5 (10 t organic fertilizer/ha

Table 7. Matrix of eigenvalues and coordinates for treatments and dry bean varieties.

AXES	F1	F2
Treatments		
DO	0.183	**0.421**
D1	0.038	0.170
D2	0.114	**0.367**
D3	**0.433**	0.167
D4	0.001	**0.386**
D5	0.105	**0.315**
D6	**0.198**	0.033
Bean varieties		
HARI25/GA19	**0.917**	0.072
HARI35/GA19	0.105	**0.576**
HARI36/GUI21	**0.678**	0.134

before sowing) and D6 (Green Humico 500 ml for 16 l water; 12 l/ha) gave the highest values for the HARI35/GHA19 and HARI36/GUI21 varieties. In other words, the 3 treatments significantly influenced vegetative development in these 2 varieties. It is well known that nitrogen plays a major role in plant growth and vegetative development. On this basis, it is likely that these 3 treatments released the quantity of nitrogen required for plant development in the HARI35/GHA19 and HARI36/GHA19 varieties. In contrast, work by Bernadin and Riculado [13] showed that organic fertilization boosted vegetative growth better than treatments based on synthetic chemical fertilizers.

The determination of phenological stages, in particular flowering times, revealed that the values were statistically identical for the varieties used, whatever the treatment applied. These delays were around 1 month after sowing (32 to 36 days after sowing). The results showed that the treatments had little influence on the phenology of the dry bean varieties used. It may be that bean phenology can be little influenced by certain external factors, in this case the treatments observed in this study. In contrast to flowering times, a difference was recorded between treatments in relation to fruit set rates. The highest values were produced in HARI36/GUI21 by treatments D1 (100 kg/ha NPK12-22-22 before sowing), D2 (50 kg/ha Urea 2 weeks after sowing), D3 (100 kg/ha NPK12-22-22 before sowing + 50 kg/ha Urea 2 weeks after sowing), D4 (5 t organic manure/ha before sowing). In other words, these treatments were more effective on fruit set (transformation of the ovary into fruit). These results seem similar to those of Mansouri *et al.* [14], who noted that the treatments did not influence ripening times in three (3) bean varieties, but rather favored a high number of flowers compared with the unfertilized control. Several mineral elements are involved in fruiting in plants, notably the 3 main ones: nitrogen (N), phosphorus (P) and potassium (K), with P and K playing a more active role [15]. Based on D2's N-only performance, it is likely that soil levels of P and K are sufficient to induce good fruit set.

Statistical analysis showed that there was no variability between the number of nodules for any variety and any treatment. On the other hand, a significant difference was observed between treatments with regard to nodulation efficiency. In terms of nodule number, the data from this study are at odds with those obtained by Kouassi *et al.* [16]. In fact, their work on nodulation in two legumes (*Vigna radiata* and *Vigna unguiculata*) showed that the number of nodules varied in these 2 legumes according to the treatments applied. The highest nodulation efficiency values were obtained with treatments D6 in HARI35/GHA19, D0 and D3 in HARI25/GHA19 and D4, D5 and D6 in HARI36/GUI21. Nodulation efficiency is an important concept, expressing the number of active nodules involved in symbiotic nitrogen fixation for the host plant. From the results obtained by studying nodulation efficiency, it was noted that the variability that was recorded was linked to varieties and not to treatments. This seems all the more likely as D0, which received no inputs, induced a high nodulation efficiency in the plants. What's more, efficiency values were higher overall in HARI25. This suggests that the efficient bacteria for HARI25/GHA19 were more numerous in the soil than for the other 2 varieties.

Estimated seed yields and rates of yield increase showed that the lowest yields were generated by treatments D1 and D3 at HARI25/GHA19 and D6 at HARI36/GUI21. While the highest values were produced by treatments D4 and D6 at HARI25/GHA19; D2, D3, D4 and D5 at HARI35/GHA19 and D1, D3, D4 and D6 at HARI36/GUI21. These yield values indicated that for each of the varieties used, specific treatments were identified. For HARI25/GHA19, 2 treatments were more effective, while for HARI35/GHA19 and HARI36/GUI21, 4 treatments were more effective. Among these treatments, D4 (5 t organic manure/ha before sowing) was the most effective for the 3 varieties studied, producing an average of 1 tonne of seeds and yield increases of 20%, 46% and 91% respectively for HARI35/GHA19, HARI36/GUI21 and HARI25/GHA19. The nature of this treatment, which is composed solely of organic matter, may well have favored the biological life of the bacteria and could certainly have released mineral elements for good plant growth. On this basis, treatment D5 (10 t organic manure/ha before sowing) should perform better than D4. But this is not the case; it only gave a high yield at HARI35/GHA19. It is likely that the dose of this treatment is seen as an excess in HARI25/GHA19 and HARI36/GUI21. Indeed, according to MBukula *et al.* [17], environmental conditions can influence yield components, but they are genotype-dependent.

6. Conclusion

At the end of this study, it was noted that treatments had little influence on crown diameter, the number of nodules per plant and flowering time. On the other hand, the treatments had a significant effect on the vegetative vigour index, the fruit set rate and, above all, on all yield components. Among the treatments used, the organic fertilizer-based treatment (5 tonnes of organic fertilizer per hectare) performed best in all three varieties, with yields in excess of one tonne per hectare. The results certainly showed the influence of external factors such as treatments on the behavior of the dry bean varieties studied, but a variety effect was also recorded. Indeed, for the same treatment, the varieties produced different behaviors, indicating that the notion of genotype must be taken into account in the factors influencing growth and yield in dry beans.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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