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Responses of some genotypes of bio-fortified climbing common bean *(Phaseolus vulgaris* L.) to the climatic conditions of three agro-ecological zones, southern DR Congo

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ABSTRACT

Multi local trials were carried out during the 2014-2015 cropping season simultaneously in three sites: Kasenga, Katanga and Fungurume located in the provinces of Upper Katanga and Lualaba. Five genotypes of bio-fortified climbing common bean: NUC 479, CWARENTINO, NAMULENGA, M 211, CODMLV059 were sown according to the randomized complete block design with four replications. The ecological conditions of Katanga site were more or less lenient to justify the high yield of seed, it should be noted that GWARENTINO and NAMULENGA varieties showed a high productivity. Furthermore, the combination of genotypes x environment revealed interactions on all parameters, yields were low for all genotypes due to poor rainfall distribution, but NUC479 remained least influenced by the environment. This could be exploited in varietal improvement program face to water stress, while keeping the other materials in the germplasm.

Keywords: Genotypes, rainfall, bio-fortified, sites.

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INTRODUCTION

Food and nutritional security of the DRC in general and Katanga in particular has become very worrying. The majority of the population consumes maize, cassava or sweet potato as rich staple foods in calories but poor in vitamin A and certain trace elements such as iron and zinc that can solve the problem of anemia (Mason and Garcia, 1993; World Bank, 1994; Welch et al., 1997; WHO, 1999; FAO, 2010). Furthermore, the study by Ricardo (2002) amounted to three billion people with this micronutrient deficiency as "hidden hunger" nearly two-thirds of all child deaths are associated with it. Therefore, it is important to ensure quantity and quality of foods high in energy, iron and zinc, namely the common bean (Qaim et al., 2007).

However, it carrying out to achieve good productivity is not obvious, because according to Mergeai (2010) by its climate factors especially rare or abundant rainfall does not provide favorable conditions for plants to express their productive potential and also soil poverty accompanied by high acidity and other bio-aggressors.

In DR Congo, the domestic production of common bean estimated to 115.000 t/year is lower than that of peanut 390.000 t/year, cowpea 57.730 t/year and soybean 16.000 t/year. The needs are growing for the country although large tonnages come from the Eastern Africa (FAO, 2009) compared to bush bean for the same area and micronutrient content to popularize in various areas. This aspect evaluated the behavior of these genotypes under the variability of rainfall conditions characterizing the areas. So this study verifies following hypotheses:

1. Would be the common bean productivity influenced by sites?
2. Would be grain yield influenced by genotypes?
3. Does genotypes and sites combination influence on common bean yield?

MATERIALS AND METHODS

Study areas

The tests were conducted at three sites: Kasenga, Katanga and Fungurume located in Upper Katanga and Lualaba provinces and whose geographical coordinates are listed in Table 1 and Figure 1.

Table 1. Geographical coordinates of the sites.

Sites	Altitude (m)	South latitude	East longitude
Fungurume	1210	10° 34' 08.5"	26° 19' 49.2"
Katanga	1173	11° 06' 33.4"	27° 07' 18.7"
Kasenga	1167	11° 27' 12.3"	27° 44' 27.4"

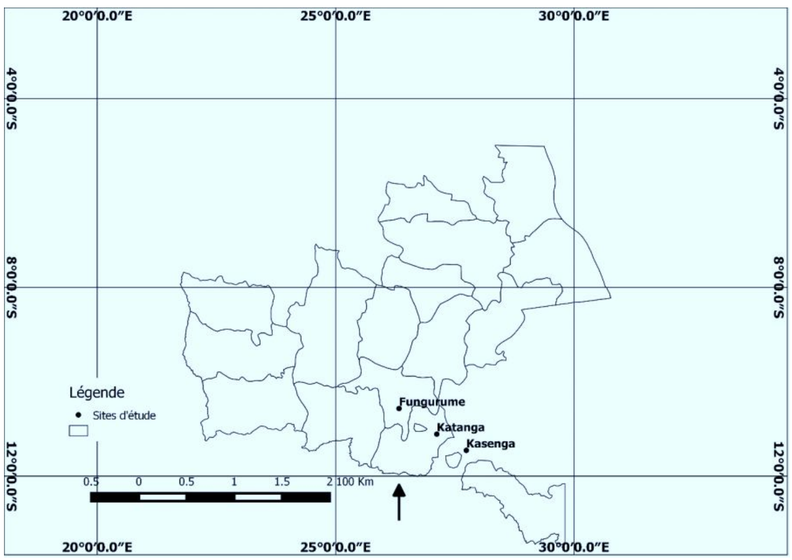

Figure 1. Location of the experimental sites.

Vegetation, soils and rainfall

Katanga forest experienced a regression resulted in a fragmentation caused largely by human activities mainly agriculture and mining. However, it should be noted that different plant communities experiencing these changes to varying degrees, as secondary forest and rainforest are strongly affected over Miombo woodland which is the most dominant class of the landscape (Kabulu et al., 2008). The herbaceous flora before opening the experimental sites was dominated by therophytes.

Soils of Upper Katanga province are usually old because having reached the stage of ultimate alteration, but it should be noted that their physical properties are good unlike chemical and biological properties. The low pH 4-4.5 makes it unavailable to plants and increases phosphorus and aluminum toxicity (Tshamala, 2008).

Ngongo et al. (2009) reported the existence of different groups reference soils: ferralsols, Acrisols, Lixisols, Arenosols, Regosols, Cambisols, Vertisols, Fluvisols and Gleysols.

Rainfall has been disrupted in recent decades and is characterized by irregular distributions during different the crop season of common bean. According to Kanyenga et al. (2016), this situation is a consequence of climate change. The results in Table 2 illustrate these rainfall disturbances.

Experimental device and conducting the test

Tests were conducted in a randomized complete block device with five bio-fortified genotypes of climbing common bean repeated four times whose characteristics are listed in Table 3. The preparation work consisted an opening of the field after delimitation, mechanical plowing and harrowing by hoe. Sowing intervened simultaneously in all sites on February 2, 2015 with two seeds per hole and spacing of 60 cm × 20 cm. During cultivation, the maintenance operations consisted staking 15 days after sowing andmanual weeding from the 15th day according to weed density. To overcome the poor soil problems in major macronutrients, an initial nutrient NPK (10-20-10) with 200 kg/ha have been applied.

Data collection was made on 10 plants located on two central lines of each plot and for each treatment and focused on the

Table 2. Rainfall data experimental sites 2014-2015.

Month and growing season	Experimental sites		
	Katanga	Kasenga	Fungurume
2014-2015	Rainfall (mm)		
February	200.5	415.7	162
March	307.6	180.95	46
April	85.1	77.3	0
May	0.3	0	0
Total rainfall	593.5	673.95	208

Sources: Weather Stations of Mangombo (Katanga), Luano (Kasenga) and Kwatebala (Fungurume).

Table 3. Characteristics of used common bean genotypes.

Genotypes	Origin	Color	Type	Weight of 100 seeds (g)	Form
M 211	INERA Mulungu	White	IVa	24	Round
CWARENTINO	INERA Mulungu	Pure white	IVa	24	Oval
NAMULENGA	INERA Mulungu	White with black stripe	IVa	32	Cuboid
CODMLV059	INERA Mulungu	Red white streak	IVa	42	Truncated
NUC 479	CIAT	Red	IVa	32	Kidney

following parameters:

1. Lifting rate (LR) evaluated 15 days after sowing (Pamo et al.,2005): LR (%) = (NGS / NSS) * 100, with NGS: Number of germinated seeds; NSS: Number of sowed seeds in the plot;
2. Plants heights (mm) to harvest (PH);
3. Number of nodes (NN);
4. Number of pods per plant (NP / P) and grain per pod (NG /P);
5. 100 seed weight (g) (100GW);
6. Yield per hectare (t) (CY).

Statistical analysis

The one factor analysis of variance (ANOVA) was performed to highlight the influence of varieties or sites on the parameters defined above, then the two-factor ANOVA allowed to highlight the likely interactions that can be generated by combining genotypes and sites, the Tukey HSD followed to separate and compare the averages of different factors. The data processing software *R i 386 2.15.0* was used.

RESULTS AND DISCUSSION

Results in Table 4 show that the sites have induced effects on the following parameters: lifting rate, plant height at harvest, number of seeds per pod, number of pods per plant, number of nodes and grain yield.

Lifting rate was similar in Katanga and Kasenga, however low value for this parameter was obtained at Fungurume (41.9%).

The small size of plants was observed at Kasenga (160.7 cm) in contrary to those of Fungurume and Katanga. The same observation was made about the number of seeds per pod, the high production in terms of pods per plant was registered in the sites of Fungurume and Katanga, the high number of nodes characterized the plants of Katanga site. Katanga site stood out from others regarding grain yield.

Genotypes showed different behavior on the observed parameters as shown in Table 4. Therefore, varietal similarities were revealed for germination rate, plant height, number of nodes, number of pods per plant and number of seeds per pod.

However, the high weight of 100 seeds was expressed by CODMLV059 variety (35.2 g) and the lowest by NUC479 variety (11.7 g), a similarity according to the Tukey HSD was cleared for grain yield M 211, two genotypes (0.498 t/ha) and CWARENTINO (0.477 t/ha) showed a high potential when the decision was taken at the threshold ($\alpha \leq 0.01$) but that is low in grain yield for NAMULENGA (0.295 t/ha) and NUC479 (0.240 t/ha). It is noted the existence of a similarity between these varieties.

The results in Table 5 showed the lack of interaction of factors ($p \geq 0.05$) on plant height. However, the presence of interactions was reported for lifting rate, number of seeds per pod, the number of seeds per pod, weight of 100 grains and grain yield ($p \leq 0.05$). To this end, it was found that the sites have little influence on the variety NUC 479, but overall productivity of the studied genotypes was not satisfactory for all parameters following the rainfall conditions (water stress) observed during the growing season (Table 6).

Results of this study showed that when genotype and sitefactors taken in isolation induced different effects on

Table 4. Influence of the sites on the common bean behavior, Average ± standard deviation.

Sites	LR (%)	PH	CY	100GW	NP/P	NG / P	NN
Fungurume	41.9 ±12.4[b]	192.9 ± 26.8[a]	0.348 ± 0.15[ab]	21.5 ± 11.4[a]	5 ± 0.74[a]	10 ± 2.37[b]	21 ± 2.23[b]
Katanga	71.4 ±13.5[a]	219.1 ± 34.0[a]	0.491 ± 0.30[a]	23.7 ± 13.0[a]	6 ± 0.75[a]	9 ± 1.61[b]	23 ± 2.98[a]
Kasenga	62.1 ±19.4[a]	160.7± 29.3[b]	0.263 ± 0.20[b]	2.3 ± 12.9[a]	4 ± 1.28[b]	4 ± 2.96[a]	20 ± 1.82[b]
p ≤0.05	0.000	0.000	0.031	0.815	0.000	0.000	0.001

The same letters next averages indicate no significant differences according to Tukey HSD (p ≤ 0.05).

Table 5. Influence of genotypes on the common bean behavior, average ± standard deviation.

Genotypes	LR (%)	PH	CY	100GW	NP/P	NG / P	NN
NUC479	53.6 ± 11.2[a]	186.5 ± 5.89[a]	20 ± 0.31[a]	0.240 ± 0.015[b]	11.7 ± 0.45[c]	5 ± 0.26[a]	8 ± 0.17[a]
CWARENTINO	66.3 ± 23.9[a]	189.7 ± 35.7[a]	23 ± 3.22[a]	0.477 ± 0.393[a]	28.1 ± 3.82[b]	5 ± 1.54[a]	7 ± 3.97[a]
NANULENGA	55.0 ± 24.1[a]	193.4 ± 50.8[a]	22 ± 2.46[a]	0.295 ± 0.131[b]	27.2 ± 4.05[b]	4 ± 1.36[a]	7 ± 4.16[a]
M 211	62.1 ± 16.1[a]	182.6 ± 37.9[a]	20 ± 2.70[a]	0.498 ± 0.288[a]	24.2 ± 3.32[b]	5 ± 1.15[a]	8 ± 3.94[a]
CODMLV059	55.3 ± 20.8[a]	202.3 ± 49.1[a]	22 ± 3.37[a]	0.328 ± 0.111[ab]	35.2 ± 5.66[a]	5 ± 1.14[a]	7 ± 3.77[a]
p ≤0.05 or 0.01	0.604	0.856	0.149	0.09	0.000	0.478	0.81

The same letters next averages indicate no significant differences according to Tukey HSD (p ≤ 0.05 and p ≤ 0.01).

common bean behavior. Further, such an observation was made when both factors are combined. To this end, the lifting rate is not totally dependent on genotypes or seed viability, but rather to the climatic conditions of the sites that have proven conducive after the sowing as shown in Table 2. In contrast, the weight of 100 grains and grain yield are influenced by the genotypes.This was also revealed by Raveneau (2012), who emphasizes that the seeds of most legumes are able to germinate between 20 and 25°C. It was completed by Munakamwe et al. (2008) who also revealed the importance of soil temperature as a primary factor determining not only seedgermination, but also plant survival.

The different genotypic behavior observed partly reflects the adaptive potential or inadequacy in relation to different agro-ecosystem factors. This observation was also revealed by Mirindi et al. (2015) who showed the existence of certain varieties of high plasticity to adapt to various environmental conditions without affecting the productivity.

Typically, the poor results for all cases studied were due in part to the poor distribution of rainfall since it was obvious to collect in a short time large amount of rain that normally would take several days and so affect the crop. Morton (2007) reported that rainy agriculture characterizes the majority of developing countries and is strongly affected either by the scarcity or abundance of sometimes poorly distributed rainfall relative to crop needs.This remains a handicap for crop production as in most African countries the rains whatever period dictates the start of the growing season (Nasser, 2009). Indeed, the choice on best sowing date for various crops is not easy for farmers, because according Dapaah et al. (2000) the choice of optimal sowing date is very important for a better growing and development of crop. Moreover, beyond optimal date, culture gradually loses its ability to produce better. The results of Kamara (1981) argue that the sowing date must be adapted not only not the conditions of the region, but also the types of crops.

Genotypes under evaluation are very sensitive to water stress, the effects are observed on the growth and productionparameters. This opinion is shared by Kanyenga et al. *(*2016) who revealed that water stress causes dramatic decline in common bean productivity and this depends on the time of its appearance in relation to the phenological stage and also the effects microclimatesspecific to each site. Brahim et al. (1998) also highlighted on the subject by showing that water stress affects more floral line with the abortion of flower buds and floral post with the reduced number of pods per plant. Moreover, another aspect has been highlighted to explain the varietal behavior to stress, this is due according to Simango and Lungu (2010) to morpho-physiological traits including low stomatal conductance and high chlorophyll density are desirable because genotypes confer the ability to resist or tolerate water stress.

Conclusion

This work clearly demonstrated the environmental effects all observed parameters, the highestgrain yield was observed in Katanga site (0.491 t/ha). However, the high 100GW (35.5 g) was obtained with CODMLV059 variety and highest was simultaneously obtained with CWARENTINO (0.477) and M 211 (0.499) varieties.

Furthermore, the combination of environment and

Table 6. Site and genotypes influences on the common bean behavior, average ± standard deviation.

Sites	Genotypes	LR(%)	CY	NG/P	100GW	NG/P	NEN	PH
	NUC 479	53.6 ±12.9^{b}	0.240 ± 0.01^{a}	5 ± 0.30^{a}	11.7 ± 0.52^{a}	8 ± 0.20^{a}	20 ± 0.36^{b}	186.5 ± 6.81^{a}
	Cwarentino	37.8 ± 11.3^{a}	0.187 ± 0.004^{a}	4 ± 0.50^{a}	32.6 ± 1.52^{bc}	9 ± 3.93^{a}	21 ± 2.02^{bc}	182.9 ± 18.3^{a}
Fungurume	Namulenga	37.7 ± 4.77^{a}	0.312 ± 0.04^{b}	6 ± 0.86^{b}	23.6 ± 2.31^{ab}	12 ± 2.48^{b}	24 ± 1.67^{bc}	225.1 ± 42.6^{a}
	M 211	45.3 ± 11.5^{b}	0.590 ± 0.11^{c}	6 ± 0.32^{b}	22 ± 5.29^{ab}	11 ± 1.15^{ab}	20 ± 1.86^{b}	185.8 ± 14.5^{a}
	COMLV059	34.9 ± 16.7^{a}	0.413 ± 0.037^{bc}	5 ± 0.55^{a}	28.3 ± 1.15^{b}	9 ± 2.12^{a}	19 ± 1.56^{a}	184.2 ± 26.0^{a}
	NUC 479	53.6 ± 12.9^{a}	0.240 ± 0.01^{a}	5 ± 0.30^{a}	11.7 ± 0.52^{a}	8 ± 0.20^{a}	20 ± 0.36^{b}	186.5 ± 6.81^{a}
	Cwarentino	78.8 ± 2.36^{b}	0.797 ± 0.42^{cd}	7 ± 0.11^{ab}	25.0 ± 1.37^{ab}	8 ±1.99^{a}	26 ± 4.05^{ab}	229.1 ± 18.0^{a}
Katanga	Namulenga	84.8 ± 4.25^{bc}	0.395 ± 0.14^{ab}	5 ± 0.37^{a}	26.7 ± 1.33^{ab}	8 ± 0.75^{a}	22 ± 2.06^{b}	215 ± 36.6^{a}
	M 211	72.6 ± 9.57^{b}	0.752 ± 0.15^{c}	6 ± 0.20^{b}	25.6 ± 1.74^{ab}	10 ± 2.74^{b}	23 ± 1.05^{b}	211.4 ± 34.2^{a}
	CODMLV059	67.3 ± 12.2^{ab}	0.270 ± 0.083^{a}	5 ± 0.40^{a}	39.9 ± 2.01^{c}	10 ± 0.55^{b}	26 ± 2.60^{ac}	253.9 ± 39.7^{a}
	NUC 479	53.6 ± 12.9^{ab}	0.240 ± 0.01^{a}	5 ± 0.30^{b}	11.7 ± 0.52^{a}	8 ± 0.20^{c}	20 ± 0.36^{ab}	186.5 ± 6.81^{a}
	Cwarentino	82.5 ± 17.5^{d}	0.440 ± 0.39^{ab}	4 ± 1.35^{ab}	26.6 ± 2.38^{b}	2 ± 0.23^{a}	22 ± 1.51^{b}	157.3 ± 22.1^{a}
Kasenga	Namulenga	42.5 ± 16.5^{a}	0.176 ± 0.10^{a}	3 ± 1.15^{a}	31.3 ± 3.67^{bc}	3 ± 0.20^{a}	19 ± 0.86^{a}	140.3 ± 27.2^{a}
	M 211	68.4 ± 12.7^{bc}	0.153 ± 0.077^{b}	5 ± 1.80^{b}	25.2 ± 1.08^{b}	5 ± 4.63^{ab}	18 ± 2.08^{a}	150.6 ± 39.8^{a}
	CODMLV059	63.8 ± 18.9^{bc}	0.300 ± 0.157^{d}	3 ± 0.98^{a}	37.4 ± 3.38^{c}	2 ± 0.49^{a}	21 ± 1.60^{ab}	169.1 ± 35.6^{a}
Sites*Génotypes	p ≤0.05	0.011	0.021949	0.013	4.84 e-06	0.0162	0.0108	0.0687

The same letters next averages indicate no significant differences according to Tukey HSD (p ≤ 0.05).

genotype factorsledin interactions on all parameters except plant height at harvest, while productivity differences have characterized these combinations for which only the variety NUC479 had little variability in all sites (0.240 t/ha).

In general, the poor distribution of rainfall during the growing season did not allow the crop to better benefit compared to different phenological phases. Which subsequently led to the recorded yield loss, but it should be noted that despite this constraint, some varieties have proved interesting and could be a genetic improvement, by increasing stress tolerance trait water. Given these results and given the dynamism of climate change, it would be interesting to spread the study over a long period and several agro-ecological zones to reproduce an agricultural calendar of climbing beans adapted to new climate conditions.

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