*Short Research Article*

# Agronomic performance of corn genotypes in a consortium with the bean variety IAC Alvorada


## ABSTRACT

The corn crop is among the most important activities in Brazil, as one of the main export products. The objective of this work was to analyze agronomic performance of maize genotypes in a consortium with the bean variety IAC Alvorada. The experiment was conducted in 2014 in the months from August to December in the experimental area of the Federal University of Alagoas in Rio Largo city, and used a randomized block design in a factorial scheme (4x2) four corn genotypes: Alagoano, Viçosense, Nordestino and BRS 5037 (Cruzeta) in two production systems, plus a complementary treatment. We evaluated the following variables for corn: plant height, stem diameter, the first ear height, weight hundredfold, number of grain row, yield and equivalent production of corn. For beans was evaluated grain yield. The polyculture showed higher equivalent corn yield, 21,270 kg $ha^{-1}$. He Viçosense, Nordestino and Alagoano genotypes (4640 kg $ha^{-1}$) showed the highest production yields. The consortium did not influence in any of corn agronomic characteristics. The genotypes showed favorable rates of cropping systems.



*Keywords: intercropping, equivalent production, consortium, Zea mays L.*




## 1. INTRODUCTION

The corn crop is one of the most important activities for Brazil, being one of the main export products because it is one of the main food sources in the world [1], exporting in 2015 around 30% of its production, which in the 2014/2015 harvest was about 84.7 million tons [2].

The average grain yield of this crop in Brazil is 5370 kg $ha^{-1}$, ranging from 290 kg $ha^{-1}$ in Pernambuco to 8090 kg $ha^{-1}$ in the Federal District [2], as a result of cultivation conditions were varied, possessing since cultivation with high level of technification up until typical subsistence cultivation [3]. This productivity when compared to other producing countries is considered low due to numerous factors, among them the use of genetic material and inappropriate management techniques in the production system in which the crop is submitted [4].

High yields with lower production costs is one of the main objectives of agricultural research. However, in the case of low-income producers with little cultivation area, maximum attention should be given to the cost of production and the more efficient use of land. Thus, polyculture can become a crucial practice [5].

The consortium is a planting system in which the different plant species live in part or all of their life cycle, having with this association several advantages, among which less need of use of inputs and labor depending on the characteristics of both species are completed [3,6,7], however, because it is a technique commonly used by small farmers, management is

not adequate for both crops to have good yields, mainly in relation to the arrangement and by the scarcity of genotypes adapted to this system [8,9].

The development of superior genotypes for each type of crop is critical to agricultural success, considering that in general the genotype contributes 50% of the phenotype, and the other 50% are the contribution of edaphoclimatic and management conditions [10]. Thus, in order for the consortium system to succeed it is necessary that the cultivated varieties are adapted to the competitive management of the system [11], mainly in relation to the main culture, being the secondary as additional productive [12].

The objective of this work was to analyze agronomic performance of maize genotypes in a consortium with the bean variety IAC Alvorada.

## 2. MATERIAL AND METHODS

The experiment was conducted in the year 2014 during the months of August to December in the experimental area of the Agricultural Sciences Center of the Federal University of Alagoas (CECA / UFAL) - Delza Gitaí Campus, BR 104 North, km 85, located in the Municipality of Rio Largo, State of Alagoas, located at 9 ° 27 'south latitude and 35 ° 27' west longitude and 127 m altitude. The region presents hot and humid climate, high total annual rainfall (1,500 - 2,000 mm), with the rainy season concentrated in autumn-winter, where rainfall equals 70% of the annual total, and the dry period in spring-summer with high water deficits. The average temperature and the relative humidity of the air are of 26 ℃ and 80 %, respectively [13]. The soil is classified as Yellow Latosol cohesive argisolico, of sandy frank texture [14].

Before planting a sampling was carried out and soil analysis of the chemical conditions and by means of which fertilization is performed to supply the needs of the crops, having the following results: pH - 5.4; Na - 23 ppm; P - 55 ppm; K - 37 ppm; Ca+Mg 5.6 meq/100ml; Ca - 3.2 meq/100; Mg - 2.4 meq/100; Al - 0.03 meq/100; H+Al - 3.6 meq/100; S.B. - 5.8 meq/100; CTC - 9.4 meq/100; V - 61.7%; m - 0.5% and M.O. - 2.13%. Also manure analysis was performed sheep-goat used in the fertilization of foundation at the time of planting, with the following results: pH = 7.9; Humidity (65 ℃) - 8.7 %; Organic carbon - 34.7; N total - 1.80 %; Relationship C: N – 20 %; Total P2O5 - 1.40 %; K2O = 2.24 %; S - 0.23 %; Ca = 0.9 meq/100; Mg - 0.4 meq/100.

The meteorological data of the cultivation period were: Precipitation: 153.7; 135.9; 229.4; 48.36 and 128.01 mm, from August to December 2015, mean temperature in the months of 23.62 ℃, minimum of 18.82 ℃, maximum of 30.10 ℃ and relative humidity of 75.2 %.

The experimental design was a randomized complete block in the factorial scheme (4x2) + 1, with three replications, totaling 27 experimental plots. Four maize genotypes were evaluated in this experiment, of which three developed by the Plant Genetic Improvement Sector (SMGP) of the CECA/UFAL: Alagoano, Viçosense and Nordestino, and a commercial variety developed by EMBRAPA, BRS 5037 (Cruzeta), in two systems of planting, monoculture and in consortium with beans (*Phaseolus vulgaris* L.), variety IAC Alvorada, plus a complementary treatment (beans in monoculture).

The plots with corn in monoculture had 4 rows of plants with 5.0 m in length, spaced at 1.0 m between rows and 0.2 m between plants, with one plant per pit, constituting a corn population of 50,000 plants $ha^{-1}$. The consorted parcels had the same dimensions, but in the lines of maize had two rows of bean plants 5.0 m long, spaced 0.4 m between rows and 0.3 m between plants, with two plants per pit, constituting a bean population of 113,333 plants

$ha^{-1}$ plus 50,000 maize plants. The bean monoculture plots consisted of 15 rows of beans spaced at 0.4 m between rows and 0.3 m between plants, with two plants per pit, totaling a population 166,667 plants $ha^{-1}$.

In the plots of corn in monoculture and in consortium were considered as useful area to the two central rows, being removed from the two plants at each end. In the monoculture bean plots were considered the nine central rows as useful area, being eliminated from these two plants at each end. For the plots of the consortium, no bean plants were eliminated.

Soil preparation occurred manually with hoe and soon after the grooves were opened with about 10 centimeters of depth, where the manure was applied sheep-goat and incorporated into the furrow, in which it was applied 10 Mg $ha^{-1}$ for corn and 8 Mg $ha^{-1}$ for beans.

The planting took place on August 20, 2014, being manually seeded three seeds per pit of each crop, both with depths of 3 to 4 centimeters, and 10 days after thinning was performed. The rows of plants were in the east-west direction for greater exploitation of sunlight.

Weed control was performed with two manual hoeing with hoe performed at 15 and 35 days after planting. Pest control was performed with two sprays of the insecticide Connect® (700 mL $ha^{-1}$) at 15 and 30 days, and an application of the Capaz® insecticide (500 mL $ha^{-1}$) at 50 days after planting, both being applied with costal spray with a capacity of 20 liters using the fan-type nozzle (105 °).

For the maintenance of soil water conditions and ideal crop development, a sprinkler irrigation system was installed, with 7 mm daily blade, being applied during periods of drought during the conduction of the experiment.

Maize was harvested at 120 days after (natural drying in the sun until reaching 13% moisture) the planting and for green beans (63% moisture) at 70 days after planting and after that the following variables were evaluated: Plant height (AP): measured with tape measure in meter, from ground level to the apex of the tassel; Stem diameter (DC): measured in centimeter with digital pachymeter an 0.05 m from the ground; Height of insertion of the first ear (AIPE): measured with a tape measure in meter, from the ground until the first cob is inserted; Weight of One hundred Grains (PCG): measured from the weighing of 100 grains in a precision digital scale; Number of Grain Rows (NFG): counting the number of row of grains of 10 cob; Grain yield (RG): weighed with digital scale the production per plot of 42 plants after the natural drying of the grains until reaching the recommended humidity.

The common bean variable was the Grain Yield (RGF): weighed in a digital scale heavy on digital scale and then was made the relation for productivity in kg $ha^{-1}$.

The comparison between the intercropped and monoculture plots was carried out using some parameters: Equivalent corn production (PEM) [15]: $Ye = Ym + r\ Yf$, where: Ye = Corn equivalent production; Ym = Corn grain yield (kg $ha^{-1}$); Yf = Production of bean grains (kg $ha^{-1}$); r = Bean price relation for maize, that is, r = current price of beans/current price of maize, being at the time of harvest this relation was of 8.75 [2]. Maize Productive Efficiency Index (IEPM) calculated by the following expression: IEPM = Mc/Mm [16]. Productive efficiency index of the bean (IEPF), calculated by the expression: IFPF = Fc/Fm [16]. Earth Efficiency Index (UET) [15]: The UET is calculated by the following expression: UET = Mc/Mm + Fc/Fm, where Mc and Fc represent the corn crops and beans respectively in the consortium system and Mm and Fm represent the corn and bean crops in monoculture respectively.

The statistical analysis used was the analysis of variance and the Tukey test at 5% probability for comparison of maize genotypes and of cropping systems, besides the beans in the cultivation systems, PEM, IEPM, IEPF and UET. The variables coming from counting and percentage had their data transformed into √x so that they are within the normal range, thus meeting the basic assumptions of the analysis of variance [15].

## 3. RESULTS AND DISCUSSION

For the interaction G x S there was no significant difference for the variables height of plants, stem diameter, height of insertion of the first ear, number of ears per plant and weight of one hundred grains. There was a significant difference (P <0.01) between the genotypes for these variables (Table 1).

**Table 1. Values of F with their respective significance and mean test for plant height (AP), stem diameter (DC), height of insertion of the first ear (AIPE), number of ears per plant (NEP) and weight of one hundred grains (PCG).**

| TREATMENTS | AP (m) | DC (cm) | AIPE (cm) | NEP (Ear Plant$^{-1}$) | PCG (g) |
|---|---|---|---|---|---|
| **Genotypes (G)** | | | | | |
| Alagoano | 2.40 b | 2.39 b | 1.41 bc | 1.25 b | 25.95 b |
| Viçosense | 2.23 b | 2.30 b | 1.24 b | 1.23 b | 27.28 b |
| Nordestino | 2.38 b | 2.34 b | 1.49 c | 1.24 b | 28.98 b |
| Cruzeta | 1.46 a | 2.09 a | 0.72 a | 1.00 a | 21.49 a |
| **Cultivation System (S)** | | | | | |
| Monoculture | 2.15 a | 2.30 a | 1.23 a | 1.17 a | 26.02 a |
| Consortium | 2.08 a | 2.27 a | 1.20 a | 1.19 a | 25.83 a |
| **TEST F** | | | | | |
| **G** | 94.10** | 11.20** | 64.21** | 10.71** | 11.12** |
| **S** | 2.34$^{ns}$ | 0.62$^{ns}$ | 0.38$^{ns}$ | 0.42$^{ns}$ | 0.04$^{ns}$ |
| **G*S** | 0.27$^{ns}$ | 12.60$^{ns}$ | 0.52$^{ns}$ | 2.05$^{ns}$ | 0.22$^{ns}$ |
| **CV (%)** | 5.29 | 4.30 | 8.75 | 7.51 | 9.08 |

*Means followed by the same lowercase letter in the column do not differ from each other by the Tukey test at 5% probability.*

***: significant (P <0.01); *: significant (P <0.05); ns: not significant; CV%: coefficient of variation.*

According to [17], the DC variable has a correlation with the productivity, because the larger the diameter of the stem, the greater the amount of soluble solids in the stem. According to [18] the accumulation of the reserves in the stem starts in the stage V6 (6 leaves) and goes to the V18 stadium (18 sheets); being this reserve then translocated to the ear during its formation [19]. Therefore, plants with higher heights have stalks with greater storage capacity of photoassimilates and, consequently, they will be more productive, which was observed in the Alagoano, Viçosense and Nordestino genotypes in relation to the Cruzeta variety (Table 1). In addition, higher plants have their ears inserted farther from the ground, which is advantageous in regions with rodent infestation, because make it difficult the action of the same, thus promoting lower losses.

According to [20], the number of ears per plant is directly related to grain yield, meaning a greater financial income for the farmer. Still, according to [10], the amount of grain in the ears will influence the individual yield of the plant to produce grain. These relationships were observed in the present work, because the Alagoano, Viçosense and Nordestino genotypes had 24.0% more in the number of ears and 27.5% more by weight of one hundred grains, and consequently, produced 163.6% more grains than the Cruzeta variety (Table 1).

The two cultivation systems, with respective averages of 2.12 m, 2.29 cm, 1.22 m, 1.18 ears plant$^{-1}$ and 25.93 g presented statistically the same results for the respective variables AP, DC, AIPE, NEP and PCG (Table 1).

For the interaction G x S there was no significant difference for the variables number of rows of grains, yield of grains and corn equivalent production. There was a significant difference between the genotypes for grain yield (P <0.01), while for the cultivation system there was a significant difference (P <0.01) only for corn equivalent production (Table 2).

**Table 2. Values of F with their respective significance and test of means for number of rows of grains (NFG), grain yield (RG) and corn equivalent production (PEM).**

| TREATMENTS | NFG (Number of rows of grains$^{-1}$) | RG (Kg ha$^{-1}$) | PEM (Kg ha$^{-1}$) |
|---|---|---|---|
| **Genotypes (G)** | | | |
| Alagoano | 12.98 a | 4,190 b | 11,060 a |
| Viçosense | 13.53 a | 5,490 b | 13,740 a |
| Nordestino | 13.06 a | 4,230 b | 14,010 a |
| Cruzeta | 13.06 a | 1,760 a | 11,250 a |
| **Cultivation System (S)** | | | |
| Monoculture | 13.18 a | 4,270 a | 4,270 a |
| Consortium | 13.14 a | 3,570 a | 21,270 b |
| **TEST F** | | | |
| **G** | 0.38$^{ns}$ | 15.05** | 4.16$^{ns}$ |
| **S** | 0.01$^{ns}$ | 2.98$^{ns}$ | 6.75** |
| **G*S** | 0.33$^{ns}$ | 0.08$^{ns}$ | 0.32$^{ns}$ |
| **CV (%)** | 7.53 | 25.14 | 23.76 |

*Means followed by the same lowercase letter in the column do not differ from each other by the Tukey test at 5% probability.*
***: significant (P <0.01); ns: not significant; CV%: coefficient of variation.*

For the variable NFG, the evaluated genotypes had the same behavior, with overall average of 13.16 rows of grains. The Alagoano, Viçosense and Nordestino genotypes were superior to the Cruzeta in relation to the RG variable, whose averages were: 4,190, 5,490, 4,230 and 1,760 kg ha$^{-1}$, respectively (Table 2).

For the PEM there was no significant difference, explaining an average of 12,520 kg ha$^{-1}$ (Table 2). As observed, that the genotypes present in the study presented 35.8% more productivity when compared to the Federal District (8,090 kg ha$^{-1}$), federative unit that has the highest national grain yield [2].

Two cropping systems presented statistically the same results for the variables NFG and RG, with respective averages of 13.16 rows and 3,920 kg ha$^{-1}$ (Table 2).

According to [11,21], the consortium of corn and beans is a viable alternative, because it does not cause reduction in the agronomic value of maize, besides the many advantages of the system, among which, the productive increase and greater financial profitability. In this study, the consortium system presented higher PEM with a mean of 21,270 kg ha$^{-1}$, statistically differing from monoculture which presented an average of 4,270 kg ha$^{-1}$ (Table 2), by having then the consortium about 500% more productive efficiency than monoculture.

Considering the yield of the secondary crop in the consortium system as additional productive and transforming it into corn equivalent production, the genotypes in the consortium were 3.95 times more productive than the average Brazilian corn [2].

Beans had the highest yield (5,010 kg $ha^{-1}$) in monoculture, due to greater amount of common bean per unit area and the lack of competition exerted by corn for physical space, solar radiation, carbon dioxide, water and nutrients (Figure 1). Thus, the consortium was 59% less productive than the bean monoculture. However, this relatively low production was important in this system because it is a raw material with higher value of commercialization in comparison with the corn crop, contributing to the consortium having an increase of 180.4% in the corn equivalent production.

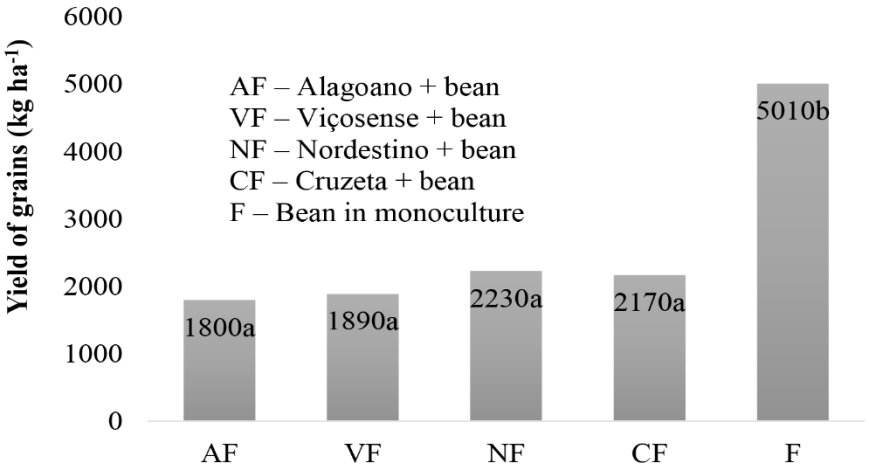


**Figure 1. Yield of bean grains in monoculture systems and consortium with maize genotypes.**

Also the IEPF did not present significant difference, with an average of 0.59, indicating that the beans in the consortium system presented 59% of productivity of the monoculture system of the bean (Table 3), also observed directly in the yield variable of bean grains. Soon the consortium system is viable, because the productivity of the main crop combined with the secondary crop overcomes the productivity of each species in the isolated crop [16].

**Table 3. Test of means for corn productive efficiency index (IEPM), bean productive efficiency index (IEPF) and land use index (UET) of maize genotypes in the cropping systems.**

| Genotypes | IEPM | IEPF | UET |
|---|---|---|---|
| Alagoano | 0.79a | 0.52a | 1.28a |
| Viçosense | 0.88a | 0.55a | 1.44a |
| Nordestino | 0.88a | 0.66a | 1.55a |
| Cruzeta | 0.63a | 0.63a | 1.40a |
| CV (%) | 28.77 | 26.86 | 23.57 |

*Means followed by the same lowercase letter in the column do not differ from each other by the Tukey test at 5% probability. CV%: coefficient of variation.*

The UET, with an overall mean of 1.42, did not differ statistically between the genotypes (Table 3), so that all they were greater than 1, indicating that in the consortium system there was a better use of environmental resources when compared with the system in monoculture [22].

## 4. CONCLUSION

The genotypes Viçosense, Nordestino and Alagoano produced more grains, with an average of 4,640 kg $ha^{-1}$.

The corn and bean consortium did not influence the agronomic characteristics of corn.

The consortium system had corn equivalent production (21,270 kg $ha^{-1}$) higher than monoculture (4,270 kg $ha^{-1}$).

The genotypes Viçosense, Alagoano, Nordestino and Cruzeta have indices of favorable cropping systems (with general averages: PEM of 12,520 kg $ha^{-1}$, IEPM of 0.79, IEPF of 0.59 and UET of 1.42), potentializing the use of these genotypes in consortium systems.

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