Colegio de Postgraduados

Biostimulants on yield and its components in common bean (*Phaseolus vulgaris* L.)

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ABSTRACT

Objective: To study the effect of biostimulants on yield and its components in Azufrado Higuera beans in northern Sinaloa.

Design/Methodology/Approach: Randomized complete block design with three repetitions, a common bean variety, and five treatments (four biostimulants and one control). Assessed variables: plant height, yield, and its components.

Results: The seaweed-based (*Ascophyllum nodosum* and *Macrocystis pyrifera*) Fia Kelp® biostimulant caused a remarkable increase in plant height, seed yield, number of seeds per pod, and 100-seed weight.

Study Limitations/Implications: The study was carried out during a single crop cycle. Therefore, an ongoing assessment of the biostimulants used must be carried out during more consecutive cycles to prove their effect on the aerial biomass characteristics, harvest index, and number of pods per m^2.

Findings/Conclusions: Foliar application of biostimulants had a positive effect on seed yield and some of its components with respect to the control. The number of normal pods per m^2 was the variable with the highest correlation percentage regarding seed yield.

Keywords: plant nutrition, foliar application, sustainable production.

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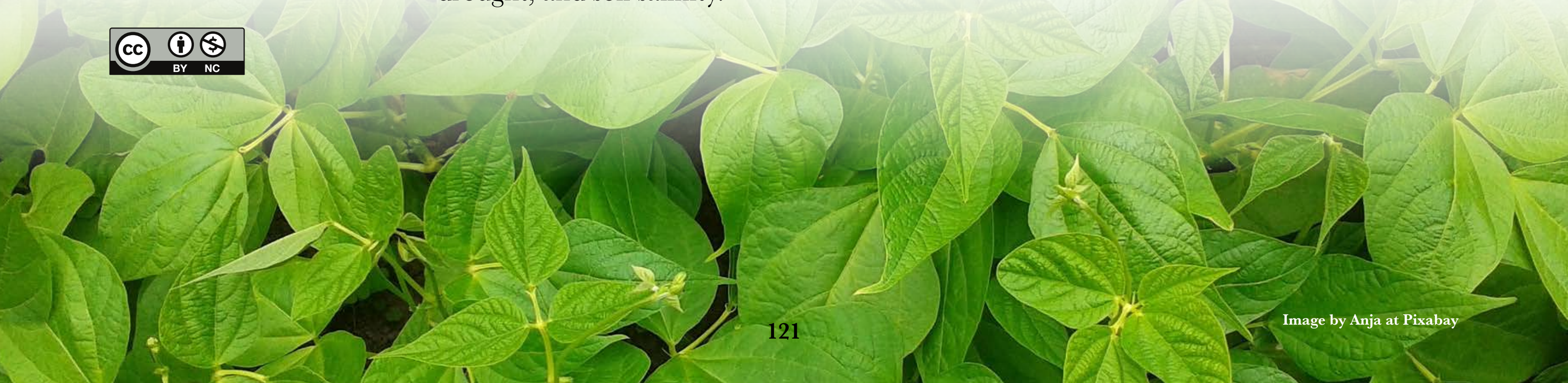
INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) (Fabaceae) is a socioeconomically important crop in Mexico and it is an important source of minerals, protein, vitamins, and fiber (Martirena-Ramírez *et al.*, 2019). The state of Sinaloa contributes 15% of the national production, it has a sowing area of 83,477 ha, produced 140,730 t in 2020, obtaining a 1.72 t ha^{-1} average yield. The state holds the second place in the country, while the municipalities of Guasave and Ahome recorded the highest yields (SIAP, 2020). However, the quantity and quality of bean production is affected by abiotic factors, such as increased temperature, drought, and soil salinity.



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Therefore, the use of biostimulants —that include products that promote tolerance to the abovementioned factors— is being implemented to mitigate these problems. Biostimulants are defined as substances or microorganisms whose application has positive effects on plant growth, promote tolerance to salt stress, drought, and extreme temperatures, improving the quality of crops and the efficiency of their nutrition (Du Jardin, 2015).

The application of products with biostimulant effect can be considered as a strategy to obtain high yields in crops with nutritional value and to reduce environmental impact (Parađiković *et al.*, 2011). Biostimulants are mainly classified as seaweeds, protein hydrolysates (amino acids), growth-promoting microorganisms, and humic and fulvic acids (Halpern *et al.*, 2015; Du Jardin, 2015).

Recently, biostimulants have become popular in the agricultural industry, because they increase crop yields in a sustainable way. An increase in the number of pods (El-Sawy *et al.*, 2020), aerial biomass (Calero-Hurtado *et al.*, 2016), and number of seeds per pod in beans has been documented (Vuelta-Lorenzo *et al.*, 2017).

Regarding yield, Ortiz-Enriquez *et al.* (2022) assessed different biostimulants in Bill Z common bean, determining a 48% increase in seed yield compared to the control, when amino acids were added. Greater plant height, stem diameter, number of leaves per plant, dry matter, grains per pod, seed weight, and seed yield in common bean were determined by Quintero-Rodríguez *et al.* (2018), through the foliar application of beneficial microorganism-based biostimulants.

Therefore, the use of biostimulants can be considered as a more environmental-friendly production strategy to obtain high yields in crops with high nutritional value. Based on this background, the purpose of the present work was to assess the effect of four commercial biostimulants on the production of common bean Azufrado Higuera under field conditions.

MATERIALS AND METHODS

Location and conditions of the experiment

The study was carried out at the Campo Experimental Valle del Fuerte (CEVAF), National Institute of Forestry, Agriculture and Livestock Research (INIFAP), Juan José Ríos, Guasave, Sinaloa (25° 45’ 47” N, 108° 49’ 46” W and 14 m.a.s.l.) in the 2020-2021 autumn-winter cycle. The prevailing climate is very dry and warm BW (h’) (Garcia, 2004), with an annual rainfall of 383.1 mm and an average temperature of 25.9 °C (Station 25048 Juan José Ríos, CONAGUA-DGE, Cuenca de Bahía Lechuguilla-Ohuira-Navachiste). Seeds of common bean (Azufrado Higuera variety) were used. This variety is characterized by its adaptability to irrigation areas and reaches acceptable production levels under residual moisture conditions —for example, it has obtained high yields in northern Sinaloa. Plants can reach a height of 40 cm, they have a specific growth habit, and their seed coat is yellow (Salinas-Pérez *et al.*, 1995).

The experiment had five treatments (four commercial biostimulants and a control): 1) Fia Kelp® (S), which contains seaweed extract (18.4% of *Ascophyllum nodosum* and 7.2% of *Macrocystis pyrifera*; 2) Agrimin 200® (AA) with 20% free amino acids; 3) BioBravo® (BM), a consortium of growth-promoting microorganisms and nutrient solubilizers based on mycorrhizal fungi of the genus *Glomus* spp (10,000), *Trichoderma* spp. 1×10^{8}, and *Azospirillum brasilense* 2×10^{11}; 4) Humiphy® (HFA) with 26.02% of humic substances derived from leonardite and 12.02% of fulvic acids, and 5) control, did not receive biostimulant application. Fia Kelp and Agrimin 200 were applied on the leaves, while BioBravo and Humiphy were applied at the base of the stem. Treatments were applied at 39, 49, 60, 75, and 89 days after sowing (das), using a dose of 5 mL L^{-1}. Treatments were established under a randomized complete block design with three repetitions per treatment; the experimental unit consisted of three 5.50-m long furrows established 80 cm apart from each other, with a density of nine plants per linear meter. The useful plot in each experimental unit was represented by the central furrow. On October 30, 2020, sowing was carried out in humid soil. Previously, 200 kg ha^{-1} of urea had been applied as a source of nitrogen, while 100 kg ha^{-1} of diammonium phosphate was used as a source of nitrogen and phosphorus. Irrigation was carried out before the beginning of flowering (38 das) and during grain filling (67 das). A dose of 0.3 L ha^{-1} of the insecticide Imidacloprid (68 das) was used to control whitefly (*Bemisia tabaci*) and aphid (*Aphis fabae*). A dose of 1 L ha^{-1} of the herbicide Fomesafen® was applied at 19 and 89 das to control bindweed (*Convolvulus arvensis* L.).

Response variables

Plant height (PH, cm): the length of the longest stem or branch was measured from the soil surface to the terminal apex, with a graduated ruler in three physiologically mature plants per experimental unit.

Seed yield (SY, g m^{-2}): it was established by weighing normal seeds and dividing seed weight by the harvested area.

Aerial biomass at physiological maturity (AB, g m^{-2}): it was obtained by harvesting and establishing the dry weight of the plants in each useful plot.

Harvest index (HI, %): it was calculated by dividing the SY by the AB $\left[HI=\left(SY\ /\ AB\right)*100\right]$.

Normal pods (NP m^{2}): it was calculated by counting the total number of total pods in each useful plot. For the purposes of this experiment, a normal pod had at least one normal seed with the size and color of the Azufrado Higuera variety. Seeds per pod (SP): the average number of seeds per pod was counted in 20 normal pods, randomly selected from the sample used to establish seed yield. 100-seed weight (SW, g): it was obtained by weighing 100 seeds —randomly selected from the sample used to establish seed yield— with a Sartorius CP224S analytical balance.

Statistical Analysis

The assumption of normality (Shapiro and Wilk, 1985) was established and an analysis of variance (ANOVA) was applied to the response variables that met this assumption. ANOVA was performed with the SAS statistical software (2009), version 9.1 for Windows, and Tukey's test ($P\leq0.05$) was used for the comparison of means. A 5% Pearson correlation coefficient was performed for all the variables assessed.

RESULTS AND DISCUSSION

A wide variation in the maximum and minimum air temperature (°C) was observed, with a weekly maximum and minimum average temperature of 26 and 9 °C, respectively. During the reproductive phase of the crop, a high temperature prevailed. After the flowering stage, a weekly average value above 25 °C and a variable minimum temperature with mean values of >10 and 7 °C were recorded (Figure 1).

The cumulative weekly rainfall during the crop cycle (624 mm) also showed strong variations. Figure 1 shows that the scarcity of rainfall during the reproductive phase of the crop affected the reproductive stage, considered the most sensitive to water scarcity (Nielsen and Nelson, 1998).

Table 1 shows the comparison of means for the PH variables, yield, and its components. The S treatment showed significant differences and was superior to the rest of the treatments in SY, SP, SW, and PH. Additionally, NSP was higher with the AA treatment, while SW and PH were higher with the BM and HFA treatments. AB, HI, and the number of NP m^2 were statistically equal (Table 1).

SY (50%), NSP (14%), and SW (6%) were higher when S was applied on the leaves than with the control. Although there were no significant statistical differences ($P>0.05$) between treatments for AB and the number of NP m^2 there was an upwards trend with the application of S regarding the rest of the treatments. Similar results were observed by Szparaga *et al.* (2018) who applied biostimulants in the crop of soybean cv. Atlanta and reported that the number of pods was similar in all treatments, including the control.

AA also encouraged an 11% increase in NSP, while BM and HFA promoted an increase of 4 and 5% in SW, respectively. According to the bibliography, there is evidence showing a similar trend in which yield and some of its components are positively affected by the biostimulants use.

A higher seed yield and seed weight was observed in southern Sonora by Ortiz-Enriquez *et al.* (2022) when amino acids were used in the Pinto Bill Z bean variety with respect to the

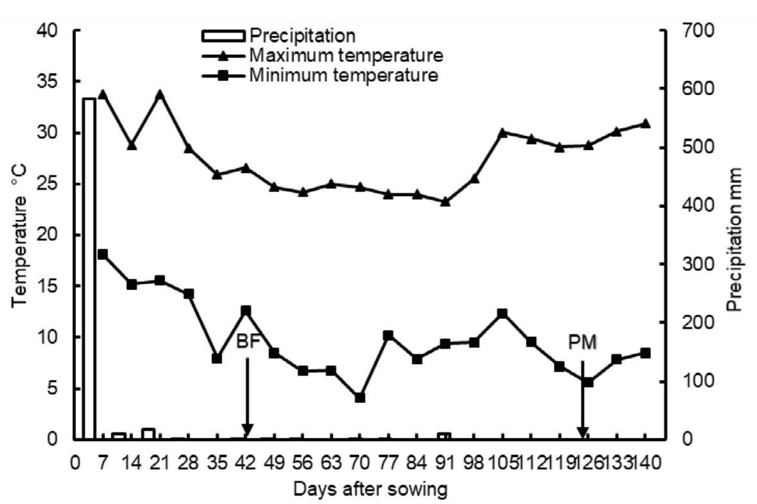

Figure 1. Weekly average maximum and minimum air temperature and cumulative rainfall per week during the 2020-2021 fall-winter cycle. Juan José Ríos, Guasave, Sinaloa. BF=beginning of flowering; PM=physiological maturity.

Table 1. Yield and its components in bean (Azufrado Higuera variety) under the effect of different biostimulants. Autumn-winter cycle (2020-2021). Juan José Ríos, Guasave, Sinaloa, Mexico.

Treatments	SY (g m^{-2})	AB (g m^{-2})	HI (%)	NP m^2	NSP	100SW (g)	PH (cm)
Fia Kelp (AM)	343.0 a	744.9 a	47.3 a	873.7 a	4.4 a	49.5 a	41.2 a
Agrimin 200 (AA)	251.1 ab	574.5 a	43.7 a	790.0 a	4.3 a	48.0 ab	39.1 ab
BioBravo (MB)	285.6 ab	575.4 a	50.3 a	822.7 a	4.2 ab	48.4 a	40.1 a
Humiphy (AHF)	221.4ab	601.4 a	37.0 a	762.7 a	4.2 ab	48.7 a	40.2 a
Control (C)	171.8 b	616.5 a	28.7 a	707.0 a	3.8 b	46.5 b	36.4 b
General average	254.6	622.5	41.4	791.2	4.2	48.2	39.42
F	5.04*	1.33 ns	2.27 ns	3.45 ns	6.11*	11.7**	11.02**

SY (RS)=Seed yield; AB (BMA)=Aerial biomass at physiological maturity; HI (IC)=Harvest index; NP m^2 (VN m^2)=Normal pods per m^2; NSP (NSV)=Number of seeds per pod; 100SW=100-seed weight; PH (AP)=Plant height; F=F values and their significance; *=Significance at 0.05; **=Significance at 0.01; ns=Not significant.

control. However, an increase in seed yield and 100-seed weight was reported by Zewail (2014) who applied seaweed extracts and amino acids to common beans in two different agricultural cycles. Similarly, Kocira *et al.* (2020) reported a 32.08% increase in bean yield compared to the control when using seaweed extracts.

In other experiments performed on common beans, an increase in seed yield was also observed when applying beneficial microorganisms (Quintero-Rodríguez *et al.*, 2018) and humic and fulvic acids (El-Sawy *et al.*, 2020). For their part, Petropoulos *et al.* (2020) reported a higher number of seeds per pod when applying seaweed. Finally, higher seed weight was reported with the application of seaweed (Kocira *et al.*, 2020), beneficial microorganisms (Petropoulos *et al.*, 2020), and amino acids (Zewail, 2014).

In this study, the aerial biomass, the harvest index, and the number of pods per m^2 were similar in the bean variety Azufrado Higuera with type I growth habit for all the treatments assessed. Contrary to these results, statistically significant differences in these variables were obtained by Quintero-Rodríguez *et al.* (2018), who reported higher values as a result of the foliar application of different biostimulants than the control, in the common bean variety Bat 304 with type III growth habit under field conditions.

The application of seaweed (S), beneficial microorganisms (BM), and humic and fulvic acids (HFA) increased plant height by 19.7, 16.5, and 16.8%, respectively. In other research works on beans, an increase in AP was also observed with respect to the control when products based on amino acids, beneficial microorganisms, and humic and fulvic acids were applied. An increase from 13 to 46% in the PH of common bean was reported by Zewail (2014) in two field experiments, when seaweed and amino acids were applied in different individual doses and when both biostimulants were combined. An increase in AP with the application of different doses of fulvic acids in three varieties of green beans was determined by El-Sawy *et al.* (2020). Similarly, Quintero-Rodríguez *et al.* (2018) pointed out that PH increased compared to the control, when three consortia of beneficial microorganisms were applied in beans. The correlation analysis established a positive and significant relationship between SY and its components and PH, except for AB. NP m^2 had the greatest influence on yield, followed by HI, NSP, seed weight, and PH (Table 2).

Table 2. Correlation coefficients between plant height, yield, and its components.

Treatments	SY (g m^{-2})	AB (g m^{-2})	HI (%)	NP m^2	NSP	100SW (g)	PH (cm)
SY (g m^{-2})	1	0.59 ns	0.89**	0.99**	0.87*	0.85*	0.85*
BA (g m^{-2})		1	0.15 ns	0.55 ns	0.41 ns	0.48 ns	0.39 ns
HI (%)			1	0.90**	0.80*	0.75*	0.80*
NP m^2				1	0.89**	0.87**	0.87**
NSP					1	0.93**	0.92**
100SW (g)						1	0.99**
PH (cm)							1

SY (RS) = Seed yield; AB (BMA) = Aerial biomass at physiological maturity; HI (IC) = Harvest index; NP m2 (VN m2) = Normal pods per m2; NSP (NSV) = Number of seeds per pod; 100SW = 100-seed weight; PH (AP) = Plant height; F= F values and their significance; *= Significance at 0.05; **= Significance at 0.01; ns = Not significant.

Szparaga *et al.* (2018) also observed a positive and significant correlation between yield and plant height, number of pods, and number of seeds per pod, when applying synthetic biostimulants during three agricultural cycles of soybean (*Glycine max* L.). In addition, Quintero-Rodríguez *et al.* (2018) mentioned that the number of pods is an important yield indicator, since the increase of this variable is a strong stimulus for an increased plant productivity.

CONCLUSIONS

Biostimulants had a positive effect on seed yield and some of its components with respect to the control. The seaweed-based (*Ascophyllum nodosum* and *Macrocystis pyrifera*) Fia Kelp® biostimulant had an outstanding performance resulting in an increase in plant height, seed yield, number of seeds per pod, and 100-seed weight. The number of normal pods per m^2 was the yield component that showed the highest correlation percentage with seed yield.

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