The aim of this study was to evaluate the growth and production components of cowpea ‘BRS Nova Era’ under different planting densities in two growing conditions. The experiment followed an experimental design of randomised blocks, which comprised two environments (Pesqueira and Lajedos cities, Brazil) and five planting densities (6, 8, 10, 12 and 14 plants m⁻¹). In Pesqueira, all production components were influenced by planting density except for plant height. In Lajedo, all production components were influenced by planting density. Productivity per total area was 74.25 and 58.33% higher at a density of six plants m⁻¹ compared to the highest density for both Pesqueira and Lajedos, respectively. The growth of cowpea under edapho-climatic conditions of Lajedos resulted in better development and productivity than in Pesqueira. Therefore, under the conditions of our study, different planting densities of the cowpea promote changes in production components and productivity, with better results obtained at a density of 6 plants m⁻¹.

Key words: Vigna unguiculata (L.) Walp, spatial arrangements, growth, production components, productivity.

INTRODUCTION

Cowpea [Vigna unguiculata (L.) Walp.] is widely cultivated in tropical and subtropical regions, being characterised as a hot-season crop due to its adaptation to high temperatures (Naim and Jabereldar, 2010). In Brazil, the cowpea is widely grown in northern and northeastern regions, especially in the semi-arid areas of the Northeast, where it is well adapted to climate and soil conditions. However, the crop has been expanding into the cerrado regions of the Midwest; this has helped to foster research into the crop, which has been intensively

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researched in recent decades (Brilhante et al., 2014; Souza et al., 2016; Costa et al., 2017a, 2017b).

Even with the increasing expansion of cowpea to other regions of the country coupled with the physiological quality of the materials being released, there has been no substantial increase in the productivity of this legume. Among the agronomic practices that have a direct relationship with grain production in the cowpea, plant density is one of the most important, especially influencing morphophysiology, production components and productivity (Bezerra et al., 2012). In this respect, Klehm et al. (2013) developed research towards the interaction between plant density and changes in the productive behaviour of the plant, and found that every dense plants undergo modifications to their physiological components, triggering significant changes in production components, and consequently altering productivity.

The choice of spacing used is closely linked to density and cultivar to be introduced; and thinnings allows for better crop establishment in the field, optimising plant development and reducing competitiveness, which consequently results in more significant grain production (Klehm et al., 2013).

According to Cardoso and Ribeiro (2006), productivity and grain production per plant in the cowpea are modified by row spacing and plant density. The effects of spacing decrease linearly for the two aforementioned characteristics. As spacing increases over 50 cm, both grain production per plant and productivity per hectare are negatively affected; and with an increase in plant density, there is a decrease in the number of pods per plant, as well as in grain production per plant. For Bezerra et al. (2012), a lack of attention to the plant population when planting cowpea, whether mechanised or not, promotes significant changes in plant morphology, with reductions in the production components.

According to Bezerra et al. (2012), the trend has been to develop cultivars with a high potential for grain production and good plant architecture, thereby adapting denser crops. Further, with the aim of facilitating mechanised harvesting to meet the requirements of technified cultivation, and make large areas in the Midwest, North and Northeast, which have been increasing every year, viable for planting, plant architecture is being worked on and studied in research experiments in an effort to adjust the cowpea to new trends in the marketplace.

With this in mind, the aim of this work was to evaluate the morpho-agronomic characteristics of the cowpea under different planting densities.

### MATERIALS AND METHODS

This experiment was conducted in the towns of Pesqueira and Lajedos in the State of Pernambuco, Brazil. The experimental area in Pesqueira is located at latitude 8°34'17" S and longitude 37°12'0" W, in soil classified as Neosol. In Lajedos, the experimental area was located at latitude 8°39'29" S and longitude 36°19'46" W, in soil classified as Regosol (Embrapa, 2006).

The experimental design was of randomised blocks, comprising five treatments: planting densities of 6, 8, 10, 12 and 14 plants m⁻¹ and four replications, using the ‘BRS Nova Era’ cultivar. Each plot was composed of four rows, five metres in length, spaced 0.5 m apart; the working area was taken to be the complete middle four rows. The experiment was kept free of weeds through manual weeding, while other cropping treatments were those normally applied to the crop.

Soil samples were taken at a depth of 20 cm for chemical analysis (Table 1), in order to check soil fertility and nutrient availability to the plants, and for the possible correction of nutrient levels. The soil was prepared mechanically, which consist of ploughing and harrowing to level the ground. Seeding was carried out on May 7, 2014, following the recommendations for climatic risk zoning of the Ministry of Agriculture, Livestock and Supply. Planting was done manually, at four seeds per hole. Thinning was carried out 15 days after planting, leaving one plant per hole to achieve the desired populations.

Fertilisation was manual, distributing the equivalent of 5 t ha⁻¹ of cattle manure in the planting furrows (Table 1); chemical fertilisation was unnecessary due to the concentration of the soil nutrients. Evaluations were made of growth (plant height) and production, such as productivity and its primary components (number of pods per plant, number of grains per pod and mean 100-grain weight). When 90% of the pods were physiologically mature and ready for harvest, and the grain displayed 13 to 15% humidity, the following characteristics were evaluated: pod weight, pod length, number of pods, shell weight, mean 100-grain weight and productivity per hectare.

All the characteristics were submitted to analysis of variance, to observe the effect of the different locations on the genotypes. The mean values for the variables were compared by Tukey’s test at 5% probability. The data on sowing density were submitted to regression analysis.

#### Table 1. Analysis of soil fertility in the experimental areas and chemical analysis of the cattle manure used in the experiment.

<table>
<thead>
<tr>
<th>Location</th>
<th>pH</th>
<th>MO</th>
<th>P</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
<th>Al</th>
<th>H+Al</th>
<th>BS</th>
<th>CEC</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CaCl₂ (g Kg⁻¹)</td>
<td>(mg dm⁻³)</td>
<td>cmolc/dm³</td>
<td>(pH 7)</td>
<td>(%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pesqueira</td>
<td>6.2</td>
<td>34.4</td>
<td>100</td>
<td>0.25</td>
<td>28</td>
<td>1.23</td>
<td>0.0</td>
<td>3.31</td>
<td>29.48</td>
<td>32.79</td>
<td>89.90</td>
</tr>
<tr>
<td>Lajedo</td>
<td>6.2</td>
<td>16.7</td>
<td>47</td>
<td>0.30</td>
<td>3.75</td>
<td>0.75</td>
<td>0.0</td>
<td>4.26</td>
<td>4.80</td>
<td>9.06</td>
<td>52.98</td>
</tr>
<tr>
<td>Manure cattle</td>
<td>N</td>
<td>P</td>
<td>P₂O₅</td>
<td>K</td>
<td>K₂O</td>
<td>Ca</td>
<td>CaO</td>
<td>Mg</td>
<td>MgO</td>
<td>S</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>1.97</td>
<td>0.07</td>
<td>0.17</td>
<td>1.97</td>
<td>2.36</td>
<td>0.47</td>
<td>0.66</td>
<td>0.45</td>
<td>0.78</td>
<td>0.29</td>
<td>-</td>
</tr>
</tbody>
</table>
RESULTS AND DISCUSSION

In Table 2, it can be seen that, in the region of Pesqueira, with the exception of plant height, there was a significant effect, ranging from 1 to 5% probability, for all the variables under study, as a function of planting density. It can further be seen that, except for plant height, the linear model fitted the mean values of the variables, also as a function of planting density.

Plant height, stem diameter, shoot dry weight, height of pod insertion, number of pods per plant and productivity displayed maximum values of approximately 78 cm, 8 mm, 213 g, 64 cm, 12.5 and 951 kg ha⁻¹, respectively, under a planting density of 6 to 8 plants m⁻², with exception of plant height, which showed inverse behaviour (Figure 1). These responses observed for the variable plant height are usually related to the development of undesirable processes, such as etiolation, due to the competition for light and another production factors (Larcher, 2003; Taiz et al., 2015).

The lower values for the morphoagronomic components seen with the increase in planting density, occurred due to the stress imposed by the competition between plants, which results in a decrease in light intensity that directly affects the photosynthetic activity of the plants (Larcher, 2003). In the region of Pesqueira, the increase in cowpea planting density had a negative effect on productivity (Figure 1). Based on the linear behaviour ($R^2=0.94$), the total productivity per area was 74.25% greater at a density of 6 plants m⁻¹ in relation to the density of 14 plants m⁻¹.

With the aim of evaluating different population densities ($10^5$, $3 \times 10^5$ and $5 \times 10^5$ plants ha⁻¹) on the morphological and production characteristics of cowpea genotypes, Bezerra et al. (2012) reported a higher productivity (1,836 kg ha⁻¹) at a planting density of 300,000 plants ha⁻¹.

Under such conditions, there was a cooperative interaction when competition occurred at favourable times and levels, which promoted greater grain productivity. According to the same authors, a reduction in productivity with the increase in plant density is a response to the reduction in the number of lateral branches, which is a consequence of the increased competition, and directly affects the productive capacity of the plants.

Photosynthesis is limited by low levels of incident light, causing a decrease in carbon gain, plant growth and consequently, grain productivity (Larcher, 2003). However, the reduction in the number of lateral branches with the increase in population density, favours mechanised harvesting of the cowpea crop. Table 3 shows a significant effect from planting density in the Lajedo region (1 to 5% probability) for all the variables under study. It can also be seen that the linear model fitted the mean values for stem diameter, height of pod insertion and shoot dry weight. The mean values for height, number of pods per plant and productivity were fitted to the quadratic model.

In Lajedo conditions we observed that both growth and production components showed similar behaviour as observed in Pesqueira, with better results under the lowest planting densities (6 to 8 plants m⁻¹), except for plant height values. In this environment, plant height, stem diameter, shoot dry weight, height of pod insertion, number of pods per plant and productivity presented maximum values of approximately 106 cm, 7 mm, 202 g, 61 cm, 14 and 1,240 kg ha⁻¹ respectively (Figure 1). The enhanced productivity obtained in this region occurred as a result of better values in production components under this condition, such as height of pod insertion and number of pods per plant. Therefore, under Lajedo environmental conditions, cowpea seems to enhance carbon allocation driven to sink organs, such as pods and grain, improving the source-sink interactions of this crop (Taiz et al., 2015).

The data for plant height differ from Horn et al. (2000), who found an increase in plant height (12%) for an increase in spacing. Taller plants tend to display greater lodging. However, this did not occur, due to the uniformity seen in the field, that is, the plants supported each other, reducing the instances of lodging.

As also seen in the region of Pesqueiro, in Lajedo, the
Figure 1. Plant height, cm (A) stem diameter, mm (B), shoot dry weight, g (C), height of pod insertion, cm (D), number of pods per plant (E) and productivity, kg ha\(^{-1}\) (F) of cowpea grown in Pesqueira, Brazil, due to different planting densities.

Table 3. Summary of the analysis of variance (mean squares) of the data for plant height, stem diameter (SD), shoot dry weight (SDW), height of pod insertion (HPI), number of pods per plant (NPP) and productivity (P) of cowpea grown in Lajedo, Brazil, due to different planting densities.

<table>
<thead>
<tr>
<th>S.V.</th>
<th>DF</th>
<th>Height</th>
<th>SD</th>
<th>HPI</th>
<th>NPP</th>
<th>SDW</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>4</td>
<td>1783.67**</td>
<td>0.072**</td>
<td>546.93**</td>
<td>51.825**</td>
<td>3710.69**</td>
<td>216235.18**</td>
</tr>
<tr>
<td>Linear</td>
<td>1</td>
<td>3515.63**</td>
<td>0.256**</td>
<td>1428.03**</td>
<td>189.23**</td>
<td>9063.11**</td>
<td>786541.60**</td>
</tr>
<tr>
<td>Quadratic</td>
<td>1</td>
<td>3165.02**</td>
<td>0.0257ns</td>
<td>161.16ns</td>
<td>17.16*</td>
<td>0.0016ns</td>
<td>75925.79**</td>
</tr>
<tr>
<td>Regr. Dev.</td>
<td>2</td>
<td>454.06ns</td>
<td>0.00623ns</td>
<td>598.51ns</td>
<td>0.914ns</td>
<td>5779.66ns</td>
<td>2773.31ns</td>
</tr>
<tr>
<td>Block</td>
<td>3</td>
<td>22.80ns</td>
<td>0.0193ns</td>
<td>75.00ns</td>
<td>3.325ns</td>
<td>738.14ns</td>
<td>2542.45ns</td>
</tr>
<tr>
<td>Residual</td>
<td>12</td>
<td>76.67</td>
<td>0.0077</td>
<td>83.13</td>
<td>1.20</td>
<td>638.60</td>
<td>7374.08</td>
</tr>
<tr>
<td>C.V. (%)</td>
<td>-</td>
<td>11.64</td>
<td>14.84</td>
<td>18.49</td>
<td>21.20</td>
<td>15.50</td>
<td>9.70</td>
</tr>
</tbody>
</table>

**Significant at 1% probability, *Significant at 5% probability, ns Not significant.

An increase in cowpea planting density reduced productivity (Figure 2). Following a linear behaviour \((R^2=0.91)\), the total productivity per area was 58.33% higher for a density of 6 plants m\(^{-1}\) compared to the density of 14 plants m\(^{-1}\).

As seen in Pesqueiro, there was an inverse relationship...
between the increase in plant height and productivity, probably due to a reduction in the number of lateral branches. This inverse relationship also suggests a smaller leaf area per plant, which, according to Saidi et al. (2007), affects production and biomass partitioning, as well as grain production per plant and area. According to Taiz et al. (2015), the ability to produce dry matter from a crop under satisfactory conditions of water and nutrients will ultimately depend on solar radiation use efficiency, considering that only 5% of incident radiation is converted into carbohydrates by the leaf.

In our study, the reduction in productivity was due to a reduction in the number of pods per plant. Similarly, a reduction in the mean value for NPP in response to the increase in plant population per hectare was also reported by Cardoso and Ribeiro (2006), Lemma et al. (2009) and Naim and Jabereldar (2010).

**Conclusions**

Different cowpea planting densities and edapho-climatic conditions promote changes in production components and productivity, in a way that most parameters evaluated are reduced in both regions due to increases in cowpea planting density. Therefore, the density of 6 plants per linear meter is the most adequate for both regions, being environmental conditions of Lajedo more appropriated to achieve better productivity.

**CONFLICT OF INTERESTS**

The authors have not declared any conflict of interests.
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