Autocorrelation of Production Components of Irrigated Garlic Crop

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Abstract. The study aimed to analyze the distribution and spatial autocorrelation of irrigation concerning the other productive components of the garlic crop. The productive components were distributed in thematic maps, and the spatial autocorrelation was estimated by the Moran index, which quantifies the autocorrelation degree. Results show that irrigation contributes to higher yield, with bulbs of larger diameter and heavier cloves. Plants under drought stress conditions tend to develop wider and longer leaves with a higher shoot dry matter. The bivariate analysis revealed that irrigation in garlic is closely related to all explanatory variables.

Garlic (*Allium sativum* L.) is an essential vegetable in human food, and its production chain is a source of job and income generation for the producer. Garlic plant variables, such as total plant mass, floral tassel length, leaf length, leaf width, number of leaves, dry mass, pseudostem diameter, number of cloves, mass of clove, and root mass, were studied by Oliveira et al. (2020a). These authors point out that these surveys can provide crop status and essential information about the activities developed, mainly in the context of attention to crop management.

The positive spatial autocorrelation of the studied attributes can be understood when the higher or lower values are grouped in a point or location. However, when the spatial autocorrelation is negative, there is a dissimilarity

between the attributes in space (Anselin et al., 2006; Neves et al., 2015).

The spatial distribution analysis of indicators is an instrument that can contribute to the understanding of the processes involved in a given phenomenon that is to be studied, allowing the analysis of characteristics and differences of each territorial space, beyond the simple geographical view, covering the production space (Oliveira et al., 2020b).

Given the importance of knowing the reality of each point of the field concerning the performance of the crop, especially about the productivity of the garlic crop, exploratory studies that use data from production components must be carried out. Therefore, this study aimed to analyze the spatial autocorrelation of irrigation concerning the other productive components of the garlic crop.

Material and Methods

The soil was classified as Latossolo Vermelho Amarelo (Embrapa, 2018) or Oxisol, and a sandy clay textural class. The soil in the 0–20-cm layer was composed of 460, 150, and 390 g·kg⁻¹ of sand, silt, and clay, respectively. The soil had the following chemical traits pH (H₂O): 6.0; organic matter content: 2.18 dag/kg; and 21.2 and 135.0 mg/dm³ of phosphorus and potassium, respectively. The values of cation exchange capacity (CEC) and the sum of bases were 6.1 and 3.7 cmol/dm³, respectively.

The experimental area was conducted under a conventional tillage system and had

an irrigation system. The soil was plowed and harrowed, and then seedbeds were made with the aid of a rotary tiller for the planting of garlic.

The *x* and *y* directions of the cartesian coordinate system were defined; and, at the end of the garlic phenological cycle (15 Sept. 2018), the experimental grid was staked in plots spaced at 1.6 m between them. Each experimental grid was constituted of three transects of 48 × 1.6 m. Therefore, the transects were spaced 1.6 m, with sample points squared in 1.6 × 1.6 m, containing 90 of them.

The productive components determined were individually collected in the useful area of the sampling point, which was composed of a double row, one meter long, totaling 20 plants. The laboratory stage of the analyzes was carried out between Oct. and Nov. 2018. The analysis of all attributes followed the methodology described by Oliveira et al. (2020a, 2020b).

For each phenological index studied, a classic descriptive analysis was performed, with the aid of the statistical program Rbio (biometry in R) version 17, in which the mean, median, minimum and maximum values, standard deviation, and cv were calculated.

For the spatial autocorrelation, the global Moran and local Moran (LISA) indices were used as a statistical tool. Spatial autocorrelation measures the relationship between observations with spatial proximity, considering that spatially close observations have similar values. Global spatial autocorrelation indicators (Moran I and II) provide measurements for the set of all points of the geostatistical grid, characterizing the entire study region.

The global spatial autocorrelation is shown in the Moran dispersion diagram with associations: high-high (AA), low-low (BB), low-high (BA), and high-low (AB). In positive spatial association, the regression line is increasing and the values of the attributes of the garlic plant tend to group in the first and third quadrants—because when the relationship is negative, the line is decreasing (Almeida, 2012).

The distribution patterns of the indicators were examined on a smaller scale through the local Moran (LISA), producing a specific value for each production component, allowing the visualization of groupings of each component with similar values for the selected indicators (Anselin et al., 2006).

The analysis considered a significance level of $P < 0.05$, and the cartographic products were prepared using the software QGIS 3.6.0. The level of pseudo-significance of the bivariate Moran index was tested by the GeoDa software, using randomization (999 permutations). Permutations are performed to execute a statistical pseudo-test based on the Monte Carlo method (Anselin et al., 2006).

Results and Discussion

The use of a bivariate Moran's index becomes an appropriate tool for determining

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Fig. 1. Cluster maps of the bivariate Moran indexes between irrigation (IRR) and (A) leaf length (LL), (B) leaf width (LW), (C) shoot dry mass (SDM), (D) yield (GY), (E) number of leaves (NL), (F) clove mass (CM), (G) bulb diameter (BD), and (H) lateral shoot growing (LSG).

spatial correlation. The irrigation significance maps (IRR) and other production components that present the best global Moran indexes verified in Supplemental Fig. 1 are shown in Supplemental Fig. 2.

After adjusting the dispersion diagrams (Supplemental Fig. 2A–H) of irrigation concerning the other components of the garlic crop, values were estimated using the cluster maps. Therefore, it was possible to build maps with the concentration patterns for the variables of this study (Fig. 1A–H), which allowed us to visualize and show where the significant spatial groupings were formed.

The maps of bivariate clusters presented in Fig. 1 show in which regions the spatial groupings were statistically significant at least 5% of the relationship between the irrigation indicator and the other variables. These mappings of bivariate regimes allow adequate geographical visualization of the concentration degree of the studied variables, referring to the local bivariate Moran indexes or local indicators of spatial association (Moran LISA).

In this way, a farmer can take advantage of the historical information of the area from

mapping to make the necessary decisions that guide the correct management of the crop, identifying regions where there is a greater or lesser need for intervention, whether in the soil or the plant (Oliveira et al., 2018). This study can serve as a basis for irrigation management or soil management (fertility) at varying rates, and would also be useful when thinking about plant breeding or the use of drones in agriculture, aiming at higher yield and increased income for the producer.

Conclusions

The bivariate analysis revealed that irrigation in garlic is closely related to all explanatory variables, thus reinforcing that the areas with the largest number of leaves, clove mass, and larger diameter of bulbs, tend to have higher yields with more noble garlic.

Literature Cited

- Almeida, E. 2012. Econometria espacial aplicada. 1ª edição. Alínea, Campinas, Brazil.
 Anselin, L., I. Syabri, and Y. Kho. 2006. Geoda: An introduction to spatial data analysis. Geogr.

Anal. 38(1):5–22, doi: 10.1111/j.0016-7363.2005.00671.x.

- Embrapa (Empresa Brasileira de Pesquisa Agropecuária). 2018. Sistema brasileiro de classificação de solos. 5. ed. rev. e ampl. Brasília, DF.
 Neves, C., M.R.G. da Camara, U.A.S. Filho, E.G.Z. Esteves, and M. Marconato. 2015. Análise do índice de Gini nos municípios de Santa Catarina em 2000 e 2010: Uma abordagem exploratória de dados espaciais. Revista Brasileira de Estudos Regionais e Urbanos 9(2):209–227. <https://revistaaber.org.br/rberu/article/view/145>.
 Oliveira, J.T., M. de Passos, C.G. Roque, F.H.R. Baio, K.M. Kamimura, I.S. Ribeiro, and P.E. Teodoro. 2018. Space variability of phenological indicators of common bean crop. Biosci. J. 34(2), doi: 10.14393/BJ-v34n2a2018-39659.
 Oliveira, J.T., R.A. Oliveira, L.A.A. Oliveira, P.E. Teodoro, and R. Montanari. 2020a. Spatial variability of irrigated garlic (*Allium sativum* L.) production components. HortScience 55(3):300–303, doi: 10.21273/HORTSCI14409-19.
 Oliveira, J.T., R.A. Oliveira, M. Puiatti, P.E. Teodoro, and R. Montanari. 2020b. Spatial analysis and mapping of the effect of irrigation and nitrogen application on lateral shoot growing of garlic. HortScience 55(5):664–665, doi: 10.21273/HORTSCI14881-20.

Supplemental Fig. 1. Correlation network of bivariate Moran's analysis of the production components of the garlic plant: Garlic yield (GY), total plant mass (TPM), floral tassel length (FTL), leaf length (LL), leaf width (LW), number of leaves (NL), shoot dry mass (SDM), pseudostem diameter (PD), number of cloves per bulb (NCB), clove mass (CM), root dry mass (RDM), bulb diameter (BD), bulb height (BH), lateral shoot growing (LSG), and irrigation (IRR).

Supplemental Fig. 2. Moran Dispersion Diagram between irrigation (IRR) and (A) leaf length (LL), (B) leaf width (LW), (C) shoot dry mass (SDM), (D) yield (GY), (E) number of leaves (NL), (F) clove mass (CM), (G) bulb diameter (BD), and (H) lateral shoot growing (LSG).