Relationship between the occurrence of the rice water weevil and water depth in flooded rice crop

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Abstract – The objective of this work was to assess the relationship between the depth of irrigation water and larval infestation by *Oryzophagus oryzae* in flooded rice crop. Water depth and larval infestation were evaluated in the upper levee, in between levees, and in the lower levee. The data were subjected to the descriptive statistical and geostatistical analyses. The highest larval infestation occurs in field areas with greater water depth, which is typical of the lower levee. The spatial distribution of *O. oryzae* larvae is of the aggregate type and depends on the greater irrigation water depth.

Index terms: *Oryza sativa*, *Oryzophagus oryzae*, geostatistics, spatial distribution.

Relação entre ocorrência da bicheira-da-raiz e profundidade da água em arroz irrigado por inundação

Resumo – O objetivo deste trabalho foi determinar a relação entre profundidade da água de irrigação e infestação larval de *Oryzophagus oryzae* em arroz irrigado por inundação. A profundidade da água e a infestação larval foram avaliadas no leiveiro superior, no centro do quadro e no leiveiro inferior. Os dados foram submetidos às análises estatística descritiva e geoestatística. A maior infestação larval ocorre em áreas da lavoura de maior profundidade da água, típica do leiveiro inferior. A distribuição espacial das larvas de *O. oryzae* é do tipo agregada e dependente da maior profundidade da lâmina de irrigação.

Termos para indexação: *Oryza sativa*, *Oryzophagus oryzae*, geoestatística, distribuição espacial.

Oryzophagus oryzae (Costa Lima, 1936) (Coleoptera: Curculionidae) is a pest of high economic importance in flooded rice crops (Martins et al., 2009). The larvae, known as rice water weevils, feed on the plant root system and can reduce grain yield by about 20% (Neves et al., 2011).

The depth of irrigation water affects the population dynamics of rice water weevils (Martins et al., 2009; Tindall et al., 2013). Therefore, spatial distribution and larval density can be altered by soil irregularities and flatness, which includes upper and lower levees and the center of the area limited by both levees in sloped areas. In this context, a greater knowledge of the density, distribution, and spatial dependence of *O. oryzae* in sloped rice crops, irrigated by flooding, can assist in insect management (Dal Prá et al., 2011).

Geostatistics is a key tool in determining the spatial distribution of the pest, because it associates the importance of observation (of larval infestation) and of its location (spatial coordinate and depth of irrigation water) in the estimates of spatial distribution, enabling a better understanding of the spatial behavior of insect pests and, consequently, their integrated management (Pazini et al., 2015).

The objective of this work was to assess the relationship between the depth of irrigation water and larval infestation by *O. oryzae* in flooded rice crop.

The experiment was conducted in the 2012/2013 crop year at the Terras Baixas experimental station of Embrapa Clima Temperado, located in the municipality of Capão do Leão, in the state of Rio Grande do Sul, Brazil (31º49'22"S, 52º27'56"W). The soil of the area was classified as a Planossolo Háplico (Santos et al., 2013), i.e., an Albaqualf, with slopes ranging from 0.2 to 3.0%. The rice (*Oryza sativa* L.) crop covered an area of 2.1 ha in the conventional farming system, and the Puitá Inta-CL cultivar was used.

The study area was divided into eight trays, where the georeferenced sampling points were distributed randomly to assess larval infestation by *O. oryzae* and depth of irrigation water. The monitoring of *O. oryzae* larvae was carried out at 40 days after irrigation, according to Neves et al. (2011). A total of 237 soil and root samples were collected: 79 samples in the upper levee (UL), the highest part of the area in the direction of the slope; 79 samples in the center of the area limited by both levees (CA), the space between levees; and 79 samples in the lower levee (LL), the lowest part of the area. Later, the number of larvae and the depth of irrigation water were recorded.

The data obtained were subjected to the descriptive statistical and geostatistical analyses through the geoR package (Ribeiro Jr. & Diggle, 2001) of the R software, version 3.2.0 (R Core Team, 2015). The descriptive statistical analysis consisted of calculating the mean, standard deviation, maximum and minimum values, coefficient of variation, and variance-to-mean ratio index. The geostatistical analysis was performed using semivariograms and adjustments of theoretical models (Yamamoto & Landim, 2013). The quality of the adjustments was determined by the spatial dependence index (SDI) (Seidel & Oliveira, 2014). Finally, the ordinary kriging was used to interpolate population data and elaborate prediction maps.

The number of *O. oryzae* larvae showed an aggregate distribution, in which the values obtained in the variance-to-mean ratio were greater than a unit (Table 1). This resembles the behavior observed from data on population assessments of other insect pests in the soil (Dal Prá et al., 2011).

The population density of *O. oryzae* was more significant in the LL, where the depth of irrigation water was greater. This result provides subsidies for possible strategies to monitor the insect, by indicating points that are prone to its occurrence, considering the water distribution in the area.

The Gaussian and exponential semivariogram models were adjusted to the count data of *O. oryzae* larvae in the UL, CA, and LL sampling sites. This result corroborates a recent study on insect count (Pazini et al., 2015). The levels of spatial dependence in the LL and UL were greater than the maximum distance of sampling within the georeferenced site. This means that all sampled points are strongly correlated. In the CA, the range was of about 65 m. The quality of adjustments, defined by the SDI, was rated as high in the LL and UL, and as moderate in the CA.

The analysis of the prediction maps showed a similar behavior of larval infestation by *O. oryzae* in the UL and LL regarding the depth of irrigation water, with infestation with up to 16 larvae in crop points with greater irrigation water depth. In the CA, however, the infestation was with six larvae (Table 1 and Figure 1). In addition, in all three sites, the occurrence of small insect groups was observed, showing the aggregated character of larvae distribution (Figure 1).

Table 1. Descriptive statistics for irrigation water depth (cm) and number of *Oryzophagus oryzae* larvae, as well as geostatistical parameters for the semivariogram models on the larval population in the upper levee (UL), center of the area between both levees (CA), and lower levee (LL) in flooded rice (*Oryza sativa*) crop[(1)].

Sampling site	Variable	Minimum value	Maximum value	Mean	Standard deviation	CV (%)	I	Model	Nugget effect	Sill	Range (m)	MD (m)	SDI (%)
UL	Water depth	3.00	19.00	8.87	3.64	41.01	-	Gaussian	4.61	3,090.88	8,951.51	162.67	50.32
	No. of larvae	0.00	11.00	3.49	2.51	71.87	1.81						
CA	Water depth	1.00	15.00	5.96	2.61	43.84	-	Exponential	0.63	1.28	65.17	162.67	12.90
	No. of larvae	0.00	6.00	1.46	1.40	96.40	1.34						
LL	Water depth	6.00	20.00	13.96	3.28	23.49	-	Gaussian	9.65	5,120.05	9,337.13	180.74	50.31
	No. of larvae	1.00	16.00	6.62	3.26	49.29	1.61						

[(1)]CV, coefficient of variation; I, variance/mean ratio; MD, maximum distance between points in the area; and SDI, spatial dependence index, ranging in the interval 0%≤ SDI ≤50.40% in the Gaussian model and 0%≤ SDI ≤31.70% in the exponential one (Seidel & Oliveira, 2014). Number of samples per site was 79.

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The existing relationship between depth of irrigation water and larval population density of *O. oryzae* may also result from the harmful effects of water temperature on insects (Raksarart & Tugwell, 1975). However, this can occur differently, since smaller water depths heat up and cool down in times of greater and lower solar radiation, respectively, while larger water depths heat up less and have a shorter temperature range. Therefore, on the one hand, greater water depth can create favorable conditions for the survival,

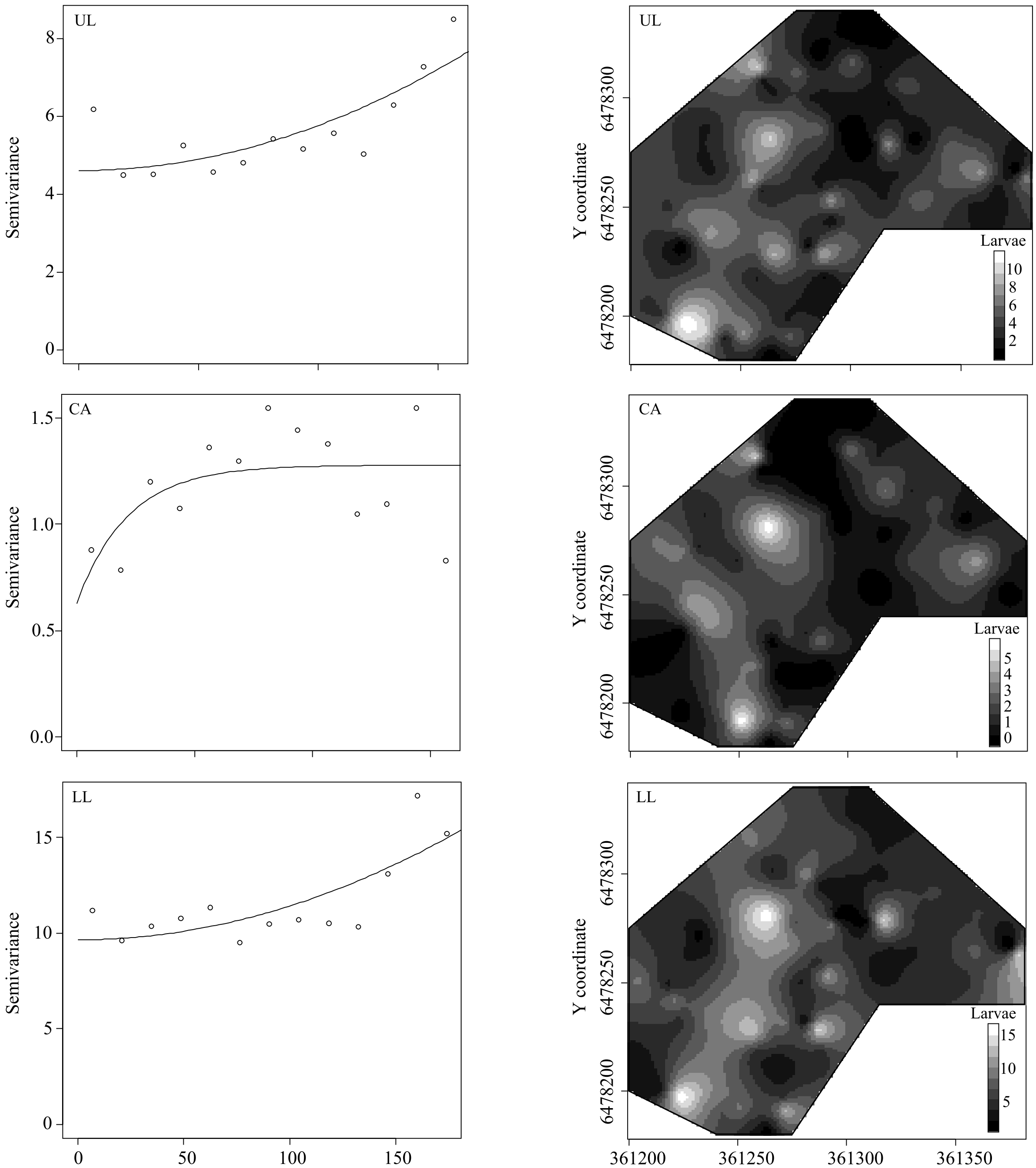

Figure 1. Semivariograms and prediction maps of *Oryzophagus oryzae* larval population in flooded rice (*Oryza sativa*) crop, in the sampling sites: upper levee (UL), by the Gaussian model; center of the area limited by both levees (CA), by the exponential model; and lower levee (LL), by the Gaussian model.

mating, and oviposition of water weevils (Martins et al., 2009). On the other hand, a smaller water depth can reduce oviposition before plants become more tolerant to insect attack, reducing infestation and damages to roots (Stout et al., 2013). Furthermore, the water can reach temperatures that are lethal to eggs and larvae (Raksarart & Tugwell, 1975; Martins et al., 2009; Tindall et al., 2013).

The knowledge of spatial distribution allows predicting the potential damage caused by the insect in different parts of the rice crop and determining the actual need for the adoption of control measures with greater effectiveness, reducing production costs and risks of environmental contamination by agrochemicals.

The infestation of larvae in flooded rice crops in sloped areas is aggregated and higher at greater water depth, typical in the lower levee.

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