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IMPLANTATION SYSTEMS AND SURFACE IRRIGATION FOR MAIZE CROP IN LOWLAND AREAS

Abstract - The raised seedbed implantation system and the use of surface irrigation can be important practices to enable rotation with rice and ensure the expression of the productive potential of maize in lowland areas. The purpose of this work was to evaluate the use of implantation systems and surface irrigation on agronomic characteristics and grain yield of maize crop in lowland areas. Two experiments were conducted in the experimental lowland area of the Federal University of Santa Maria – UFSM, during the 2014/15 crop season. The experiments consisted in the use of implantation systems with and without raised seedbeds and surface irrigation. The evaluated characteristics were plant height, shoot dry mass, leaf area index, yield components and grain yield. Plant height, leaf area index and shoot dry mass are higher when maize is grown in raised seedbeds in lowland areas. The raised seedbed system can be considered an efficient way to improve drainage in the cultivation area, resulting in a higher grain yield. The use of irrigation during periods of water deficit, in the critical period of crop growth, increases the grain yield of maize grown in lowland areas.
Keywords: *Zea mays L.,* raised seedbeds, supplemental water supply, crop rotation.

SISTEMAS DE IMPLANTAÇÃO E IRRIGAÇÃO DE SUPERFÍCIE PARA O CULTIVO DE MILHO EM ÁREAS BAIXAS

Resumo - O sistema de implantação com camalhão e a utilização da irrigação por superfície podem ser práticas importantes para viabilizar a rotação com o arroz e assegurar a expressão do potencial produtivo do milho em terras baixas. O objetivo deste trabalho foi avaliar a utilização de sistemas de implantação e irrigação por superfície em características agronômicas e no rendimento de grãos da cultura do milho em terras baixas. Foram conduzidos dois experimentos em área experimental de várzea pertencente à Universidade Federal de Santa Maria – UFSM durante a safra 2014/15, que constituíram-se na utilização dos sistemas de implantação com e sem camalhão e da irrigação por superfície. Foram avaliados: altura de plantas, massa seca de parte aérea, índice de área foliar, componentes de rendimento e rendimento de grãos. A altura de plantas, índice de área foliar e massa seca de parte aérea são maiores quando o milho é cultivado em camalhões em terras baixas. Esse sistema mostra-se como uma forma eficiente de melhorar a drenagem da área de cultivo, resultando em maior rendimento de grãos. A utilização da irrigação em períodos de déficit hídrico no período crítico de desenvolvimento da cultura aumenta o rendimento de grãos de milho cultivado em terras baixas.
Palavras-chave: *Zea mays* L., cultivo em camalhões, suplementação hídrica, rotação de culturas.

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The lowland areas in the Brazilian state of Rio Grande do Sul comprise approximately 4.4 million hectares and are traditionally cultivated with irrigated rice (Pinto et al., 2017). The successive tillage of rice has resulted in reduction of productive capacity in those areas, mainly due to the increase of hard-to-control weeds, especially red rice (Matzenbacher et al., 2013; Sartori et al., 2016). In this context, the crop rotation represents an important practice for control and reduction of soil weed seed bank (Vernetti Junior et al., 2009; Agostinetto et al., 2018). Although the edaphoclimatic conditions in lowlands do not guarantee a stable production of rainfed (non-irrigated) crops, the application of maize crop rotation, with some adjustments, in addition to helping weed control, improves the physical and chemical attributes of the area, providing for a more sustainable use (Vernetti Junior et al., 2009; Giacomeli et al., 2017).

Most of the soils in these areas present limiting properties for rainfed crops. Besides a poor drainage, the soil profile presents a shallow surface layer and an almost impermeable subsurface layer, in addition to high density and low macroporosity, which causes these soils to have low water storage capacity (Pinto et al., 2017). These features, in years of irregular distribution or high rates of precipitation, make the maize more susceptible to stress periods due to water deficit or excess (Ribeiro et al., 2016), with negative impacts on plant growth and grain yield.

For crop rotation with maize in those areas, there must be an efficient surface drainage system (Giacomeli et al., 2017). The application of a raised seedbed system improves drainage in the area, since the furrows formed between raised seedbeds help the excess water from precipitations and irrigations drain out, thus reducing the period of saturation of surface soil layers and the period during which roots are subjected to oxygen-deficiency (Fiorin et al., 2009).

Besides proper drainage, it is important to use an irrigation system in order to enable the maize cultivation, with the purpose to avoid possible periods of water deficit associated with variations in precipitation distribution during growing season. The application of surface irrigation systems is facilitated in those areas due to the terrain that is mostly flat, in addition to the possibility of using the water conveyance system already in place for the rice.

In view of the above, the seed implantation system with raised seedbed and the use of surface irrigation can be important practices to ensure the expression of the productive potential of maize in lowland areas. The purpose of this work was to evaluate the response of the use of implantation systems and surface irrigation on agronomic characteristics and grain yield of maize crop in lowland areas.

Material and Methods

Two experiments were conducted in the experimental lowland area belonging to the Federal University of Santa Maria – UFSM, during the 2014/15 crop season. The area is located in the central region of Rio Grande do Sul (RS), Brazil, at the geographic coordinates 29° 43’ S, 53° 43’ W, with an average altitude of 90 m above sea level. The climate in the region is characterized as humid subtropical (Cfa), according to Köppen climate classification (Alvares et al., 2013), without dry season, with average annual precipitation of 1,616 mm.

The soil in of the area is classified as eutrophic Haplic Planosol in the Brazilian official soil classification system (Santos et al., 2013), with sandy texture and the following physicochemical properties for 0.0-0.20 m layer: pH (H2O 1:1), 5.6 and 5.3; base saturation, 83.2 and 62.7%; Al, 0.0 and 0.3 cmolc dm^3; Ca, 11.3 and 5.0 cmolc dm^3; Mg, 5.9 and 2.3 $cmol_c$ dm^3; K, 48.0 and 60.0 cmolc dm^3; P, extraction by Mehlich, 7.8 and 14.4 cmolc dm 3; S, 14.6 and 9.9 Mg dm 3; MO, 21.0 and 19.0 Mg dm^3; particle density, 2.55 and 2.54 Mg m^3; soil density, 1.44 and 1.37 Mg m^3; field capacity, 0.34 and 0.30 m^3 m^3; and permanent wilting point, 0.13 and 0.12 m^3 m^3; respectively, for experiments I and II. Distribution of particles in the same layer, for experiments I and II, respectively, was: sand, 210, 227 g kg^1; silt, 530, 595 g kg^1; and clay, 245, 185 g kg^1.

Experiment I consisted of a factorial arrangement, conducted on randomized block design with four replications. For the implantation systems factor, the levels were composed of: with raised seedbed; without raised seedbed; and the levels for the irrigation factor were composed of: with irrigation; without irrigation. Dimensions of experimental units were 45 x 3 m. Experiment II was conducted on randomized block design with two treatments: T1, with irrigation; T2, without irrigation, both on raised seedbeds, with four replications. Their experimental units had 45 x 6 m sizes.

Sowings of experiments II and I were made on the 16th of November, 2014 and the 23rd of January, 2015, respectively. For the implantation system with raised seedbed in experiments I and II, the building of raised seedbeds happened at the same time as the sowing, with the use of a planter equipped with moldboard plows responsible for making the raised seedbeds. The raised seedbeds had an average height of 0.12 m and space between furrows of 1 m width, capable of accommodating two rows of maize seeds, with a space of 0.5 m width (Figure 1). As for the sowing in the system with no raised seedbed in experiment I, the same planter was used, but without the moldboard plow mechanism. In both experiments, simple hybrid maize seeds Agroceres 9045 PRO2 were used, from extra-early maturity cycle, with sowing density of 60,000 plants ha^{-1} and 80,000 plants ha^{-1} for experiments I and II, respectively.

For both experiments, the base fertilization

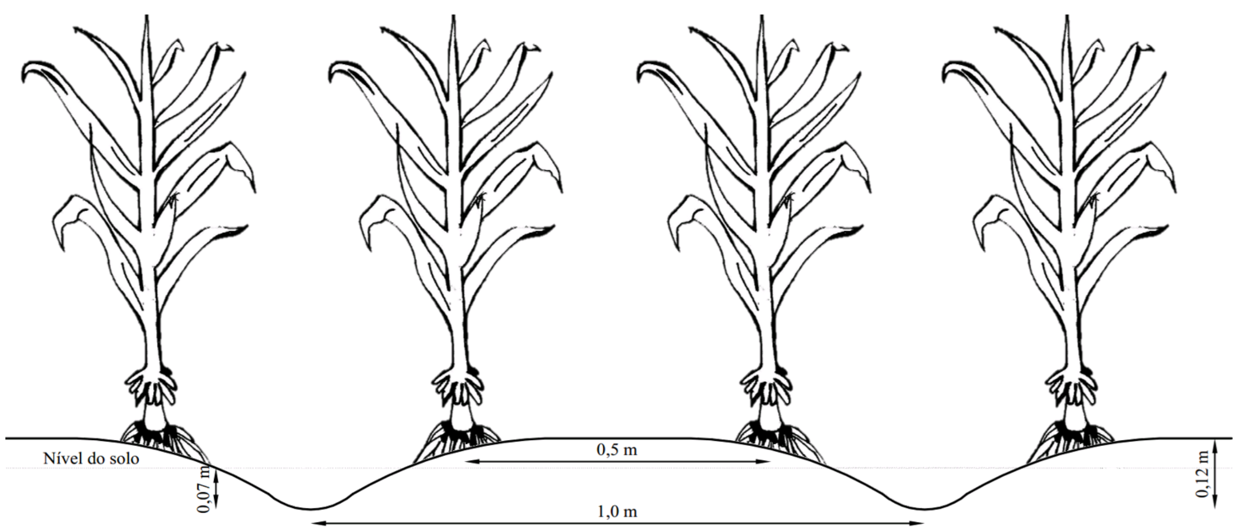

Figure 1. Schematic representation of raised seedbeds in cross section perpendicular to the sowing rows. Source: adapted from Giacomeli et al. (2017)

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(at sowing) and cover fertilization (after sowing), and other culture treatments, were conducted according to technical recommendations for cultivation (Emygdio et al., 2013), for a yield expectation of 10 tons per hectare.

The need of irrigation was determined through monitoring of the volumetric soil water content of the area, by applying the gravimetric method (Donagema et al., 2011), and making 3 to 4 weekly determinations. As a criterion for irrigation, the reference adopted was the average limit of volumetric soil water content of the 0.0 - 0.2 m layer of 60% of field capacity, in other words, when the soil of the area presented average volumetric water content close to 0.21 m^3 m^{-3} for experiment I, and 0.18 m^3 m^{-3} for experiment II, on the day before the event, the irrigation was done.

For the implantation system with raised seedbed in experiments I and II, irrigation was done through the furrows formed at the same time as the raised seedbeds were built. As for the system with no raised seedbed in experiment I, irrigation was done in the form of rows, and building dikes between treatments to prevent the water from moving to the adjacent plots and to facilitate its conveyance until the end of the plot during irrigations.

In both systems, conveyance was carried out until the water could reach the end of plots. Water was then kept within the plots for 30 minutes. After that, plots were drained and the excess water volume was measured, with the use of a cutthroat flume that was installed at the final portion of the plot. During irrigations in both systems, the average flow used was 1 L s^{-1} and the water volume was measured with the use of a water meter.

In the vegetative stage VT of crop growth, according to scale by Ritchie et al. (1993), for experiment I, five maize plants were collected in sequence, at the second row of each plot, and their agronomic features were evaluated: plant height, by measuring the vertical distance between the soil surface and the insertion point of the last leaf; shoot dry mass, where plants were taken to the drying chamber at 65ºC until constant mass was obtained; and leaf area, with the leaf area index (LAI) estimated by applying the method adopted by Sangoi et al. (2007). In the reproductive stage R6, plant height was evaluated for both experiments.

At the end of crop cycle, for experiments I and II, 5 m^2 of each plot were collected and yield components determined: number of spikes per plant; number of grains per spike; 1000-grain weight. After these variables were determined, the threshing of spikes, weighing and determination of grain yield were carried out, with the moisture being corrected to 13%.

Data obtained were submitted to the test of mathematical model assumptions (normality, by Shapiro-Wilk test, and homogeneity of variances, by Bartlett's test). The variance analysis was carried out through F test and the means, when significant, compared through "t" test, with 5% error probability.

Results and Discussion

In the 2014/15 crop season, there was a regular distribution of precipitations during almost the entire maize growing period in experiments I and II (Figure 2). In general, the higher frequency and greater volumes of rainfall occurred during emergence and vegetative growth of crop, thus irrigation was not necessary in those periods. However, for both experiments, during crop reproductive periods, two irrigations were required.

Irrigations for experiment I were done during

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VT and R1 stages of crop growth, period in which there was a 15-day drought (Figures 2A and 2B). The first irrigation was done for the two seed implantation systems when the volumetric soil water content was 0.19 and 0.20 m³ m⁻³ for the systems with and without raised seedbed, respectively (Figure 3A). The second irrigation was done only for the system with raised seedbed, which presented soil water content of 0.19 m³ m⁻³, while the system without raised seedbed presented water content of 0.28 m³ m⁻³ (Figure 3A). The average net irrigation depth applied in each irrigation event, intrinsic to the method used, for the systems with raised seedbed and without raised seedbed, were 31.4 mm and 55.2 mm, respectively, pointing out that the system with raised seedbed received a total of 62.8 mm.

Irrigations in experiment II were done during VT and R1 stages, when the soil water content was 0.18 m³ m⁻³ (Figure 3C). In each irrigation event, an average net irrigation depth of 24.5 mm was applied, totalizing 49 mm of water used in the irrigated treatment.

As observed in Figures 3A and 3B, the system with raised seedbed provided lower volumetric

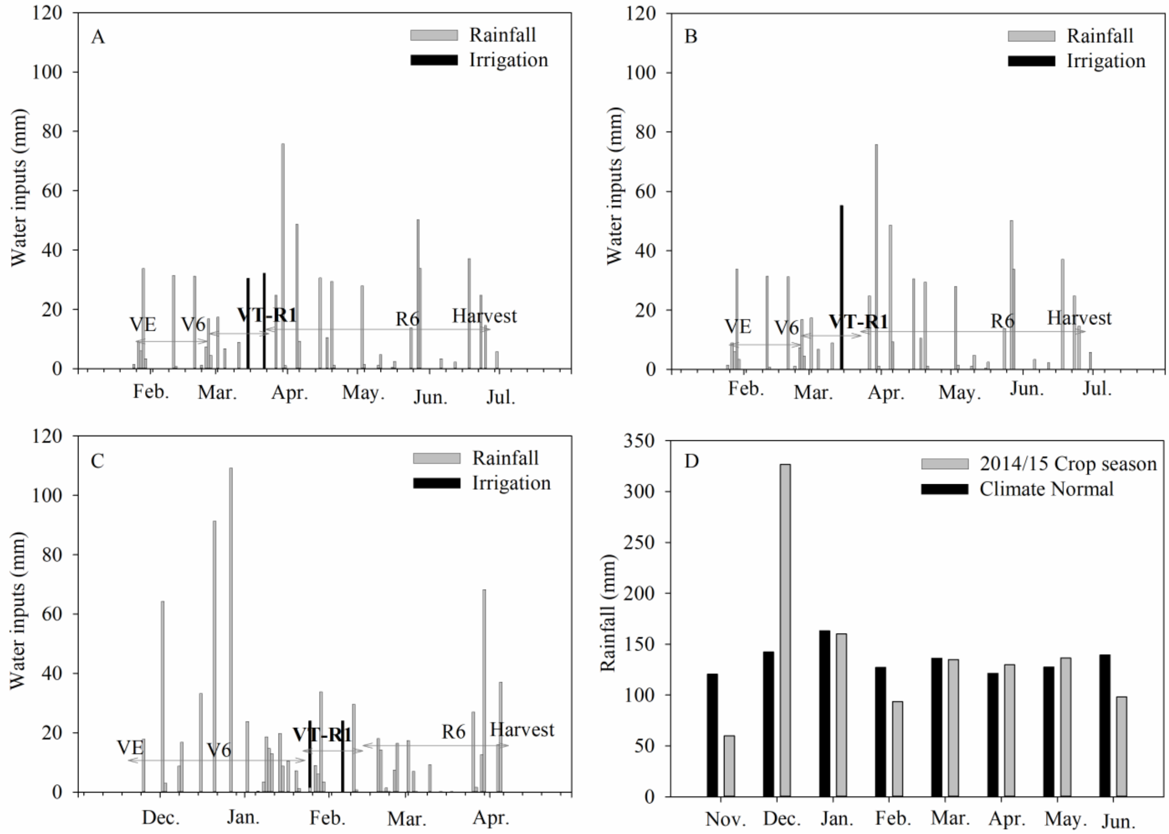

Figure 2. Distribution of rainfall and irrigation events for treatments with raised seedbads (A) and without raised seedbads (B) in experiment I, with irrigation (C) in experiment II, and monthly and climate normal rainfall (D) for Santa Maria, RS, during the months of cultivation of maize in lowland área in the 2014/15 crop season. *The horizontal lines indicate the duration of the phenological stages of maize: VE: seedling emergence; V6: six fully formed leaves; VT-R1: tesseling and flowering. R6: physiological maturity.

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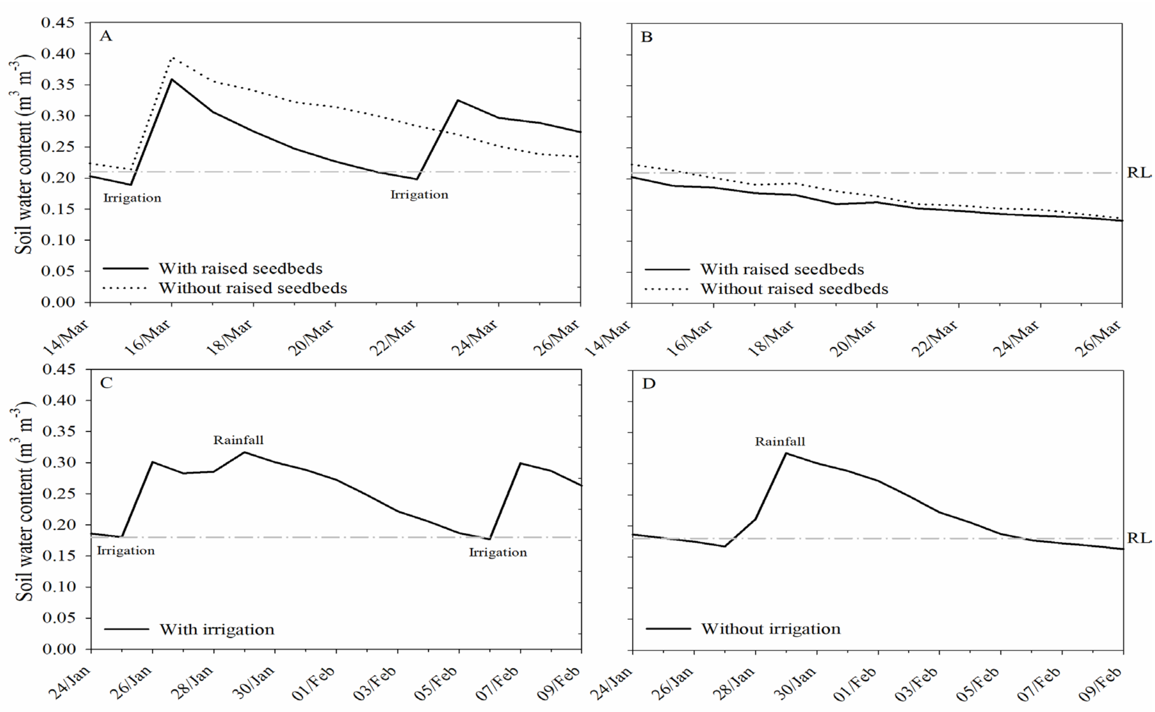

Figure 3. Variation of volumetric soil water content in the 0.0-0.2 m layer for treatments with raised bed and without raised bed with irrigation (A), and with raised bed and without raised bed with no irrigation (B) in experiment I; and with irrigation (C) and without irrigation (D), in experiment II, during maize irrigation events in the 2014/15 crop.

soil water content when compared to the system without raised seedbed for the period assessed, which occurred during the entire crop cycle. This result can be attributed to the drainage improvement in the area due to the facilitated runoff of the water excess from precipitations through furrows formed between raised seedbeds. Since the excess of moisture in the soil is an environmental stress condition for maize growth (Ferreira et al., 2008), the more efficient drainage of the system with raised seedbed may have been the decisive factor for the better results obtained for that system, according to the parameters assessed in this work, which will be presented and discussed hereinafter.

There was no interaction between factors studied. In experiment I, plant height, leaf area index (LAI) and shoot dry mass were higher with the application of the seed implantation system with raised seedbed compared to the system without raised seedbed (Table 1). Those results corroborate the ones found by Fiorin et al. (2009) and Giacomeli et al. (2017), in which LAI and shoot dry mass of maize plants, plant height and leaf area, respectively, for maize cultivated in rice planosol areas, were higher when in raised seedbeds. The authors also attribute the results, among other factors, to the drainage improvement in the cultivation area due to the use of raised seedbeds.

The lower numbers of spikes per plant and grains per spike observed for the system without

Table 1. Plant height in VT and R6 stages of plant growth, leaf area index (LAI), shoot dry mass in VT stage, number of spikes per plant, number of grains per spike, 1000-grain weight, grain yield and water use efficiency (WUE) of maize as a result of seed implantation systems and irrigation for experiment I and irrigation for experiment II. Santa Maria, RS, 2014/15 crop season.

Seed Implantation Systems	Plant height		LAI	Shoot dry mass	Spikes	Grains per spike	1000-grain weight	Grain Yield
	VT	R6	VT	VT				
	m			g pl^{-1}	No. pl^{-1}	No.	g	Mg ha^{-1}
				Experiment I				
With raised seedbeds	1.71a	1.79a	3.92a	110.12a	1.30a	339.15a	347.12^{ns}	8.9a
Without raised seedbeds	1.43b	1.60b	3.17b	82.52b	1.06b	302.85b	344.47	6.5b
Irrigated	-	1.67^{ns}	-	-	1.18^{ns}	327.20a	350.13^{ns}	7.8a
Non-irrigated	-	1.70	-	-	1.18	314.80b	341.46	7.6b
Mean	-	-	-	-	1.18	321	345.79	7.7
CV$^{(1)}$ (%)	6.47	3.61	12.35	17.58	4.49	2.31	2.31	7.2
				Experiment II				
Irrigated	-	2.17^{ns}	-	-	1.1^{ns}	398.9a	317.67^{ns}	9.6a
Non-irrigated	-	2.16	-	-	1.1	334.8b	316.17	8.0b
CV$^{(1)}$ (%)	-	4.49	-	-	7.04	2.64	4.10	6.38

*Means followed by small letters in the column statistically differ from each other by “t” test at 5% error probability. ns Not significant, in the columns. (1) Coefficient of Variation determined by variance analysis.

raised seedbed in comparison to the system with raised seedbed (Table 1) can be also associated to the less efficient drainage in that system. According to Shah et al. (2012), the water excess that occurred during the crop vegetative period influences the reduction of maize yield components.

Besides, there was an increase of 27% in grain yield as a result of applying the system with raised seedbed, which is equivalent to 40 sacks of maize. The higher volumetric soil water content in

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the system without raised seedbed, associated with the high frequency of precipitations, may have been decisive factors for yield reduction in that system. Vernetti Junior et al. (2009) observed grain yield reduction in maize cultivated in lowland areas in year with frequent rainfall distribution. Giacomeli et al. (2017) also found higher maize grain yield when the sowing was carried out in raised seedbeds in planosol areas. The referred authors report that this system is responsible for increasing the macroporosity of the soil, characterized by Ribeiro et al. (2016) as a limiting factor to the growth of rainfed (non-irrigated) crops in lowland areas. According to Giacomeli et al. (2017), the increased macroporosity helps maximize drainage and intensify the oxygenation of maize plant roots in lowland areas.

With regard to irrigation, there was an increase in the number of grains per spike, resulting in a higher grain yield for irrigated systems in experiments I and II (Table 1), regardless of the cultivation system adopted for experiment I. As mentioned before, irrigations were done in maize tasseling and blossoming stages and coincided with the critical water deficit period for maize (Bergamaschi et al. 2006). Therefore, the treatments with no irrigation were subjected to water deficit in that period and that caused the reduction in the number of grains per spike, which, according to Bergamaschi et al. (2004), is one of the components more impacted by this stress due to the loss of tassel-spike synchronism and possible desiccation of pollen grains, with negative consequence in grain yield. Results obtained are in line with the referred authors, who realized that there may be yield reduction, even in years when climate conditions are favorable, if the water deficit occurs during the critical period of crop.

In general, the potential occurrence of water stresses during the growth cycle of maize was observed, either due to excess or deficit. Those stresses are associated with the adverse features of lowland soils, mainly the low water storage capacity (Rocha et al., 2017), which causes deficits and, together with the almost impermeable subsurface layer, also soil saturation. The cultivation in raised seedbeds was capable of improving the drainage in the area and reducing the occurrence of water excess, being considered an important strategy to ensure the productive potential of maize in those areas. The results found demonstrate the increment in the agronomic components and grain yield in this system

The irrigation in periods of insufficient precipitations was capable of mitigating the harmful effects of water deficit on maize plants, which occurred in the critical period of the crop to this stress, resulting in increment in maize grain yield in lowland areas.

Conclusions

Raised seedbeds implantation system performance can be identified by the variables: plant height, leaf area index and shoot dry mass; which are significantly superior in this system in lowland areas.

The raised seedbeds demonstrated to be an efficient way to improve the drainage in the crop area, resulting in higher grain yield.

The use of irrigation in water deficit periods during the critical period of crop growth increases the grain yield of maize cultivated in lowland areas.

References

ALVARES, C.A.; STAPE, J. L.; SENTELHAS, P. C.; GOLÇALVES, J. L. M.; SPAROVEK, G. Köppen's climate classification map for Brazil. **Meteorologische**

DOI: https://doi.org/10.18512/1980-6477/rbms 2020.v19.e1110

Zeitschrift, v.22, n. 6, p.711-728, 2013. DOI: 10.1127/0941-2948/2013/0507.

AGOSTINETTO, D.; FRAGA, D. S.; VARGAS, L.; OLIVEIRA, A. C. B.; ANDRES, A.; VILLELA, F. A. Response of soybean cultivars in rotation with irrigated rice crops cultivated in clearfield® system. **Planta Daninha**, Viçosa, v. 36, e018110991, 2018. DOI: 10.1590/s0100-83582018360100048.

BERGAMASCHI, H.; DALMAGO, G. A.; COMIRAN, F.; BERGONCI, J. I.; MÜLLER, A. G.; FRANÇA, S.; SANTOS, A. O.; RADIN, B.; BIANCHI, C. A. M.; PEREIRA, P. G. Deficit hídrico e produtividade na cultura do milho. **Pesquisa Agropecuária Brasileira**, Brasília, v. 41, n. 2, p. 243-249, 2006. DOI: 10.1590/S0100-204X2006000200008.

BERGAMASCHI, H.; DALMAGO, G. A.; BERGONCI, J. I.; BIANCHI, C. A. M.; MÜLLER, A. G.; COMIRAN, F.; HECKLER, B. M. M. Distribuição hídrica no período crítico do milho e produção de grãos. **Pesquisa Agropecuária Brasileira**, Brasília, v. 39, n. 9, p. 831-839, 2004. DOI: 10.1590/S0100-204X2004000900001.

DONAGEMA, G.K.; CAMPOS, D. V. B.; CALDERANO, S. B.; TEIXEIRA, W. G.; VIANA, J. H. M. (Org.). **Manual de métodos de análise de solo**. 2.ed. rev. Rio de Janeiro: Embrapa Solos, 2011. 230p.

FERREIRA, J. L.; MAGALHÃES, P. C.; BORÉM, A. Avaliação de três características fisiológicas em 4 ciclos de seleção no cultivar de milho BRS-4154 sob solo encharcado. **Ciência e Agrotecnologia**, Lavras, v. 32, n. 6, p. 1719-1723, 2008. DOI: 10.1590/S1413-70542008000600006.

FIORIN, T. T.; SPOHR, R. B.; CARLESSO, R.; MICHELON, C. J.; DALLA SANTA, C.; DE DAVID, G. Produção de silagem de milho sobre camalhões em solos de várzea. **Pesquisa Aplicada e Agrotecnologia**, v. 2, n. 1, p. 147-153, 2009.

GIACOMELI, R.; MARCHESAN, E.; OLIVEIRA, M. L.; MARTIN, T. N.; TELÓ, G. M.; DONATO, G.; SILVA, M. F. Physical Properties and Crop Management for Corn in an Albaqualf. **Revista Brasileira de Ciência do Solo**, Viçosa, v. 41, e0160237, 2017. DOI: 10.1590/18069657rbcs20160237.

MATZENBACHER, F. O.; KALSING, A.; MENEZES, V. G.; BARCELOS, J. A. N.; MEROTTO JUNIOR, A. Rapid diagnosis of resistance to imidazolinone herbicides in barnyardgrass (*Echinochloa crus-galli*) and control of resistant biotypes with alternative herbicides. **Planta Daninha**, Viçosa, v. 31, n. 3, p. 645-656, 2013. DOI: 10.1590/S0100-83582013000300016.

PINTO, L. F. S.; MIGUEL, P.; PAULETTO, E. A. Solos de várzea e terras baixas. *In*: EMYDGIO, B. M.; ROSA, A. P. S. A.; OLIVEIRA, A. C. B. (Ed.). **Cultivo de soja e milho em terras baixas do Rio Grande do Sul**. Brasília, DF: Embrapa, 2017. cap. 2, p. 23-43.

EMYGDIO, B. M.; ROSA, A. P. S. A.; TEIXEIRA, M. C. C. (Ed.). **Indicações técnicas para o cultivo de milho e de sorgo no Rio Grande do Sul**: safras 2013/14 e 2014/2015. Brasília, DF: Embrapa, 2013.

124p.

RIBEIRO, P. L.; BAMBERG, A. L.; REIS, D. A.; OLIVEIRA, A. C. B. Condições físico-hídricas de Planossolo cultivado com soja em plantio direto e preparo convencional. **Pesquisa agropecuária brasileira**, Brasília, v. 51, n. 9, p. 1484–1491, 2016. DOI: 10.1590/s0100-204x2016000900047.

RITCHIE, S. W.; HANWAY, J. J.; BENSON, G. O. **How a corn plant develops**. Ames: Iowa State University of Science and Technology, 1993. (Special Report,48)

ROCHA, T. S. M.; STRECK, N. A.; ZANON, A. J.; MARCOLIN, E.; PETRY, M. T.; TAGLIAPIETRA, E. L.; BARLEST, D.; BEXAIRA, K. P. Performance of soybean in hydromorphic and nonhydromorphic soil under irrigated or rainfed conditions. **Pesquisa agropecuária brasileira**, Brasília, v. 52, n. 5, p. 293-302, 2017. DOI: 10.1590/s0100-204x2017000500002.

SANGOI, L.; SCHMITT, A.; ZANIN, C. G. Área foliar e rendimento de grãos de híbridos de milho em diferentes populações de planta. **Revista Brasileira de Milho e Sorgo**, v. 6, n. 3, p. 263-271, 2007. DOI: 10.18512/1980-6477/rbms.v6n3p263-271.

SANTOS, H. G.; JACOMINE, P. K. T.; ANJOS, L. H. C.; OLIVEIRA, V. A.; LUMBRERAS, J. F.; COELHO, M. R.; ALMEIDA, J. A.; CUNHA, T. J. F.; OLIVEIRA, J. B. de. **Sistema brasileiro de classificação de solos.** 3. ed. rev. e ampl. Brasília, DF: Embrapa, 2013. 353 p.

SARTORI, G. M. S.; MARCHESAN, E.; DE DAVID, R.; CARLESSO, R.; PETRY, M. T.; AIRES, N. P.; GIACOMELI, R.; ARAMBURU, B. B.; SILVA, A. L. Soybean Tillage Systems and Physical Changes in Surface Layers of Two Albaqualf Soils. **Revista Brasileira de Ciência do Solo**, v. 40, e0160019, 2016. DOI: 10.1590/18069657rbcs20160019.

SHAH, N. A.; SRIVASTAVA, J. P.; SILVA, J. A. T.; SHAHI, J. P. Morphological and Yield Responses of Maize (Zea mays L.) Genotypes Subjected to Root Zone Excess Soil Moisture Stress. **Plant Stress**, v. 6, n. 1, p. 59-72, 2012.

VERNETTI JUNIOR, F. J.; GOMES, A. S.; SCHUCH, L. O. B. Sucessão de culturas em solos de várzea implantadas nos sistemas plantio direto e convencional. **Revista Brasileira Agrociência**, Pelotas, v. 15, n. 4, p. 37-42, 2009.