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Investigation of Hydrogel Application on the Culture of Beans to Optimie Water Resource and Productivity

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Hydrogels are cross-linked polymers capable to absorb a great amount of water. Due to some of their properties such as hydrophilicity, high swelling capacity, lack of toxicity and controlled release, the applications on agriculture have been suggested for these polymers. Since most of the hydro resources used for human beings are destined for agriculture proposes, studies focused on the development of technologies to optimise the use of water turns out to be essentially important. Based on the subjects above, the goal of this research is to analyse the water absorption capacity of a commercial hydrogel (Stockosorb®) and to investigate if its use can improve the development of the culture of Phaseolus vulgaris beans. Firstly, the capacity of this hydrogel to absorb water was analyzed using gravimetric methods. Moreover, a randomized experimental design was used to investigate the hydrogel efficiency on the bean culture. Besides the control (soil with no amendments), two different concentrations of hydrogel were added to the pots and five levels of irrigation were applied to the experiment. The parameters height, amount of nodes, internodes and bean pods were recorded at weekly intervals to evaluate the growth of the plants. At the end of the experiment, dry weights of leaves, stems and roots and the productivity were also evaluated. In the first experiment it was observed that the hydrogel could absorb a great amount of water (more than 200 times its own initial weight). Also the results of the culture beans shown the addition of hydrogel to the soil was efficient to the growth of the plants and to the productivity. This research presented relevant agronomical and environmental results since it proves the efficiency of the use of the hydrogel Stockosorb® on the culture of Phaseolus vulgaris beans.

1. Introduction

Acrylate hydrogel has received much attention in recent years due to its proprieties and different possibilities of use. Many different applications have been suggested for these materials including their use for extraction of solvents (Freitas and Cussler, 1987), soil conditioners for agriculture (Hüttermann et al., 1999) and the release of agrochemicals and different biomedical uses (Brazel and Peppas, 1999; Saraydin et al., 1998). These hydrogels are cross-linked polymers which can absorb a high amount of water. Acrylates have been used to develop hydrogels capable to absorb more than six hundred times its own weight, although water absorption capacity is a property which can vary according to the medium properties, such as pH and ionic concentration (Mohan et al., 2005; Wu e Wang, 2010). Due to some of their properties such as hydrophilicity, high swelling capacity, response to environmental physical and chemical stimuli, and controlled release, the applications on agriculture have been suggested for these materials.
Due to the fact that water availability is one most important climate factor for growth and productivity of the plants, studies to improve water holding capacity of the soil and to prevent drought stress turns out

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to be essentially important. Many studies focused on the use of the hydrogel in species for forest restoration point out the success of using it to ameliorate the soil moisture, to provide longer survival under water stress and also to provide better development of the species (Hüttermann et al.,1999; Kohls et al., 1999; Arbona et al., 2005; Beniwal et al., 2011).

However, although the effect of the hydrogel on the reforestation was analysed over the years, little attention has been paid to the use of this polymers in agriculture. Brazil uses 70% of its hydro resources in agricultural production and the conservation of water is vital for this country which is dependent of agribusiness. To illustrate the situation, according to Ministério da Agricultura, Pecuária e Abastecimento (MAPA, 2011) Brazil produces about 3.5 Mt. of beans each year and also imports about 130 Mt. necessary to complement the internal consume. This production is considerable important since beans are part of Brazilian basic diet.

Considering that hydro deficit is one of the major limitations for vegetal productivity and seedlings cultivation of beans (Vieira et al., 1998), that new technologies for better use of water should be studied and also the importance of beans production for Brazil, the objectives of this research are to analyse the water absorption capacity of a commercial hydrogel (Stockosorb®) and to investigate if its use can improve the development of the culture of *Phaseolus vulgaris* beans, even at drought conditions.

2. Experimental

2.1 Absorption capacity analyse

Water absorption capacity was analyzed using gravimetric methods. The hydrogels were weighted and then immersed in a solution at room temperature. After 24h they were collected and weighted again (Mohan et al., 2005). The solution in which the hydrogel samples were immerged had pH between 4.5 and 6.5 which are the characteristic values of Brazilian soil.

2.2 Field experiment

The experiment was carried out in a greenhouse at University of Viçosa (UFV), Florestal, Brazil. Different levels of irrigation and hydrogel content was used to investigate the development of the *Phaseolus vulgaris* beans culture. A randomized experimental design, in a 5x3 arrangement, with three replications totalizing 15 treatments, was used to investigate the hydrogel efficiency on the bean culture totalizing 90 plants in 45 pots. Besides the control (soil with no amendments), two different concentrations of hydrogel were added to the pots (4.0 or 8.0 g for each pot of 3 L) and five levels of irrigation, based on filed capacity humidity were applied to the experiment. This filed capacity was considered the highest level of irrigation (100 %) and the others levels were proportional to this one (75 %, 50 %, 25 % e 0 %). The water quantity for the level 0 % should be sufficient to avoid the permanent withering point humidity. Table 1 shows the nomenclature used to identify each treatment. The sowing was done manually, with four seeds in each pot. On the 8-th day of seedling emergence thinning was done, leaving only two plants per pot. All pots contained 3 kg of sub-soil material from a Red-Yellow Latosol, incubated with limestone for three months before sowing. Phosphorus was incorporated 60 days after liming, in the form of superphosphate, at the recommended rate for pots, according to Malavolta and Muraoka (1985).

During experiment condition, the parameters height and the quantity of nodes, internodes and bean pods were recorded at weekly intervals for 13 weeks to evaluate the growth of the plants. It was also recorded the amount of leaves and flowers and the flowering period (data not showed). At the end of the experiment, dry weights of the aerial parts (leaves and stems) and the roots, were measured and analysed. Finally, the productivity indicated by the amount of grains and bean pods and the dry weight of the grains, were also evaluated. For the dry weight analysis, the samples were submitted at 348,15 K (65 ºC) until a constant weight was reached.

2.3 Statistical Analysis

The results were expressed as integrated area under the progress over time curve (AACP) for performing the statistical analyzes. Productivity, indicated by the number of grains and dry weight of grain, was then evaluated. Data were tested for variance and regression analysis. Statistical procedures were carried out using the software “Sisvar” (Ferreira, 2000).

Table 1. Nomenclature used to identify the treatments considering the levels of irrigations and the hydrogel contents in each pot.

Hydrogel Content	Level of irrigation				
	100%	**75%**	**50%**	**25%**	**0%***
0.0 g	A1C1	A2C1	A3C1	A4C1	A5C1
4.0 g	A1C2	A2C2	A3C2	A4C2	A5C2
8.0 g	A1C3	A2C3	A3C3	A4C3	A5C3

* Minimum quantity to avoid withering point humidity

3. Results and Discussion

3.1 Absorption capacity analyse

Data obtained from previous research using different media to analyse water absorption capacity of hydrogels indicates that this behaviour is dependent on the pH of the solution (Mohan et al., 2005; Wu and Wang, 2010). Hence, although the hydrogel had absorbed more than 200 times its own initial weight, decrease in the water absorption was achieved as the solutions became acid as shown in Table 2.The variation was small and the results suggest that the hydrogel analysed may be efficient to store water on Brazilian soil, which has pH between 4.5 and 6.5.

Table 2.Values of Water Absorption according to the medium pH.

Capacity of Water Absorption (g/g)		
pH 6.5	**pH 5.5**	**pH 4.5**
304±45	281±43	242±36

3.2 Field experiment

Results from Field experiment will be divided into three parts as follows: 1) evaluation during the experimental condition; 2) evaluation of dry weight at end of the experiment and 3) evaluation of productivity.

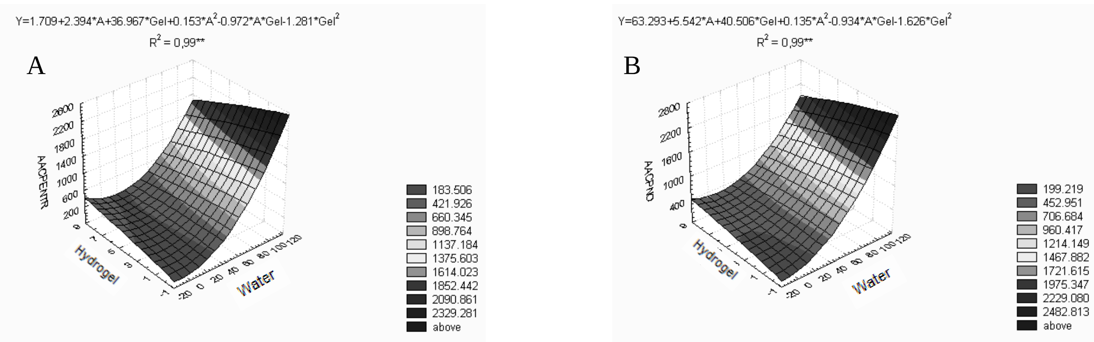

*Figure 1. (A) Area under the progress over time curve from number of nodes (AACPNO) and (B) internodes (AACPENTR), according to the level of water added in each level of hydrogel content. **Significant at 5 % probability by F test.*

Considering all the parameters evaluated during the 13 weeks it was observed an elevation of the integrated area under the progress over time curve as the irrigation and hydrogel content increased. These results suggest that water availability and hydrogel content are intrinsically involved in the growth mechanism. Greater development of beans culture was expected due to the increase of irrigation as hydro deficit is one of the major limitations for vegetal productivity and seedlings cultivation (Vieira et al.,1998). In addition, the results are consistent with other experiments that indicate significant difference between plants cultivated in soil amended with hydrogel compared to the control (Hüttermann et al.,1999; Kohls et al., 1999; Arbona et al., 2004; Beniwal et al., 2011). According to Chirino et al. (2011) using the hydrogel higher the water holding capacity and water distribution of the growing medium which may explain the better development of bean culture even at drought conditions. The results for the number of nodes (AACPNO) and internodes (AACPENTR) can be seen in Figure 1 (A e B).

Moreover, for all level of irrigation, it can be observed from Figure 2 (A), that the plants without hydrogel were nearly 30% shorter than those plants treated with 8 g of this water absorbent. A curve from plant height according to the period of evaluation, from all levels of hydrogel content (C1 = 0, C2 = 4 e C3 = 8 g de hydrogel) and two levels of irrigation (A1 = 100 % e A4 = 25 %) is given in Figure 2 (B). From theses curves it can be confirmed that despite the level of irrigation (A1 or A4), plants treated with hydrogel had developed better during the 13 weeks

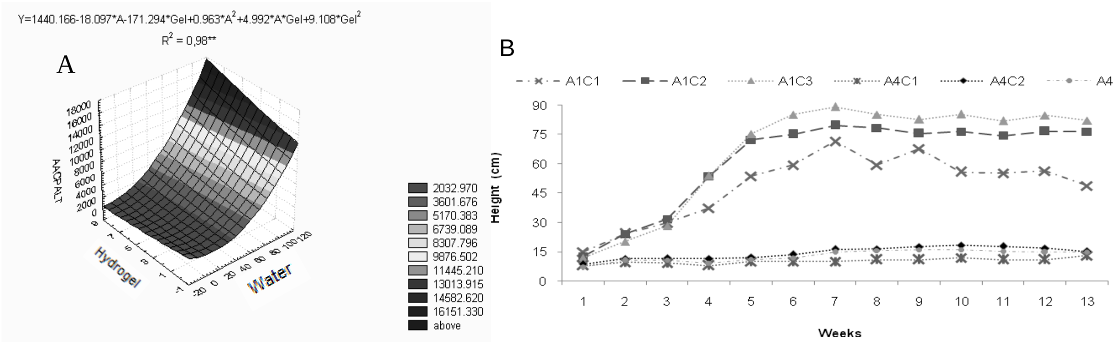

Figure 2. (A) Area under the progress over time curve from plant height (AACPALT) and (B) Height of the plants treated with 100 % and 25 % of water (A1 and A4) combined with 0, 4 and 8 g of hydrogel (C1, C2 e C3) during 13 weeks of evaluation.

Dry weights of aerial parts (leaves and stems), roots and total material (leaves, stems and roots) were measured and analysed after the 13 weeks. Similar to the parameters evaluated during the experimental condition, this result signs that combining the factors water and hydrogel may promote a better development of the bean plants. Furthermore, from Figure 3, it is also possible to observe that the plants treated with the least quantity of water and the highest quantity of hydrogel (8 g) have close results for dry weights compared to the plants treated with 100 % of irrigation and no water absorbent.
At the end of the experiment, beans productivity was analyzed. From Figure 4 it can be seen that the interaction between hydrogel content and irrigation was positive for the productivity, which was indicated by the amount of grains and bean pods and the dry weight of the grains.
Particularly, the quantity of grains had a relevant agronomic result: for any level of irrigation the productivity of the bean plants treated with 8 g of hydrogel were at least 15 % percent greater than those plants without this water absorbent. Although this effect was shorter for the quantity of bean pods and dry weights of grains it is still possible to observe that the hydrogel had contributed to reduce the hydric stress.

All the results showed the efficiency of using the hydrogel to promote a better development of the plants at the same time to optimize the use of water. Although bean culture is not commercially used in pots these plants were chosen because of their response to hydric stress. The results obtained in this work may be extrapolated for the future considering commercial and more economical cultures.

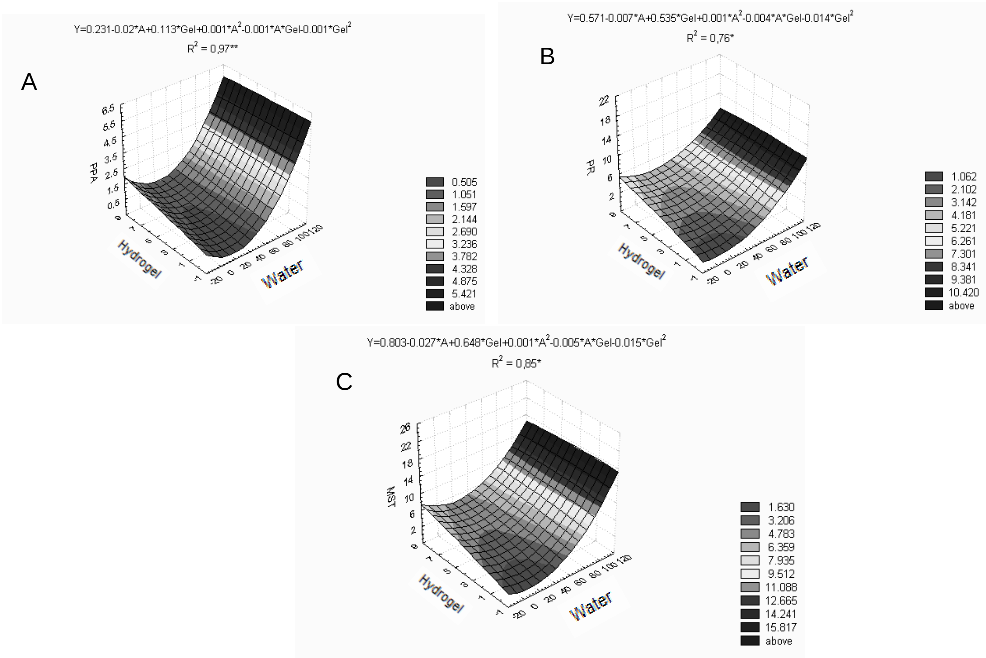

*Figure 3. (A) Dry weights of aerial parts (PPA); (B) Dry weights of roots(PR) and (C) Dry weights of total material (MST) according to the level of water added in each level of hydrogel content. **Significant at 1 % probability by F test*

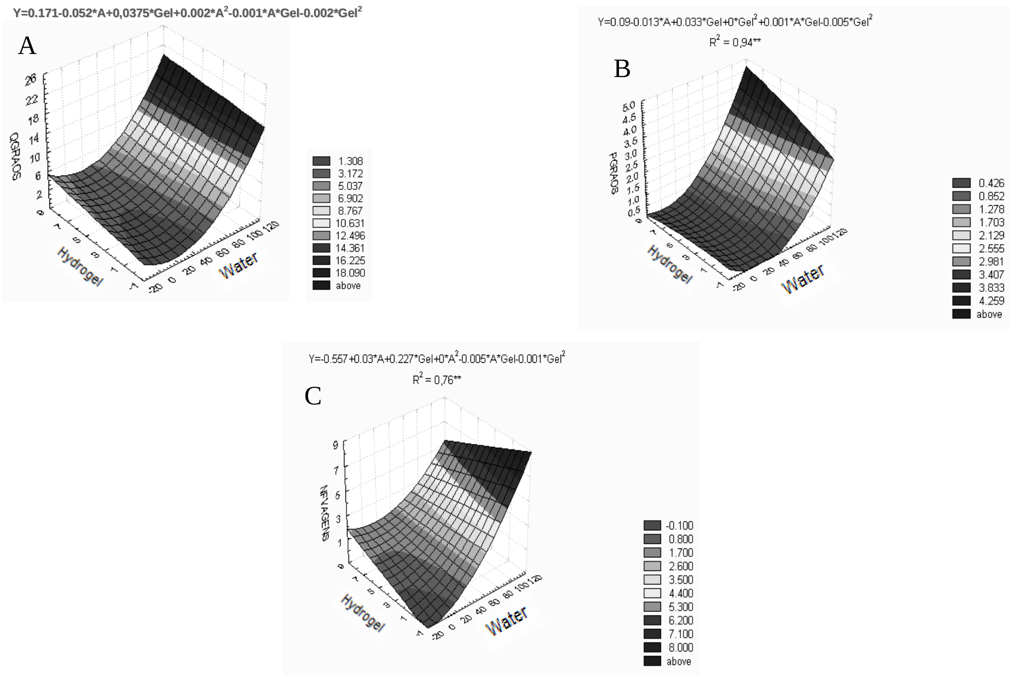

*Figure 4. (A) Quantity of grains (QGRAOS), (B) weight of grains (PGRAOS) e (C) Quantity of bean pods (NFVAGENS) according to the level of water added in each level of hydrogel content. ** Significant at 5 % probability by F test*

4. Conclusion

This research presented relevant agronomical and environmental results. It proves the efficiency of the use of the hydrogel Stockosorb® on the culture of *Phaseolus vulgaris* beans, since satisfactory productivity was achieved with less water quantity for irrigation. Further studies will be carried out so as to evaluate hydrogel application on field experiments, focused on the compatibility of the sustainable use of water along with the improvement of productivity and the economic feasibility.

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