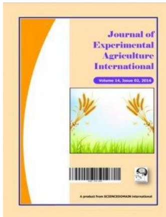

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Influence of Water Availability and Wood Ash Doses on the Productive Characteristics and Water Usage of Potted Gerbera

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Authors' contributions

This work was carried out in collaboration between all authors. Authors MK, EMBS and TJAS designed the study, performed the statistical analysis and wrote the protocol. Authors CSLLB and MK were responsible for conducting the experiment and scientific writing. All authors read and approved the final manuscript.

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ABSTRACT

The use of irrigation and wood ash are technologies that have been interfering positively in the experimental conduction of some crops in Brazil. The objective of this study was to evaluate the production characteristics and water use in cultivated potted gerbera plants under water availability and wood ash doses. The experiment was conducted in a greenhouse, belonging to the Agricultural and Environmental Engineering course of the Federal University of Mato Grosso, in the city of Rondonopolis, Brazil (16°28' S, 50° 34' W, and altitude of 284 m). The statistical design adopted was randomized blocks, in a 5x5 factorial scheme, with five percentages of water availability (40, 60, 80, 100 and 120% of pot capacity) and five doses of wood ash (0, 8, 16, 24 and 32 g dm^{-3}) with four replicates, totaling 100 experimental units. The variables evaluated were: number of total and open

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chapters, fresh leaf mass, floral stems and chapters, and water consumption and efficiency. The data of the evaluations were submitted to analysis of variance and when significant to the regression test, up to 5% probability. For water availability close to 80.6%, gerbera plants have higher production characteristics. The highest water consumption is obtained with a value lower than the pot capacity. The use of wood ash in gerbera plants promotes increased production and maximum retention capacity and water use efficiency.

Keywords: Irrigation management; greenhouse; flower; vegetable residue.

1. INTRODUCTION

Floriculture with commercial intentions in Brazil has only recently been practised. Kick-started in the 1940s, floriculture has had modest growth and is directed towards the "big centers'. However, over the last decade, this sector has exploded, achieving an average growth of 7.7 % per year. Two factors have basically been responsible for this difference, viz., the surge in the purchasing power of the interior parts of the country and the innovative and advanced technologies in this sector that have reached the producer's consumer market [1].

Flowers cultivated in protected surroundings and the production and introduction of new varieties of cultivars due to the technological advancements, propelled the expansion in the producing areas, traditionally restricted to south and southeast of Brazil. From among the cultivars in the market gerbera is an excellent choice for this rapidly growing market.

The gerbera (*Gerbera jamesonii* Bolus ex Hook), of the family Asteraceae, is a herbaceous plant, standing erect bearing the inflorescence in chapters found at the apical points of long stems without leaves. It bears/displays lígulas of varied and vibrant colouring. However, it is intolerant to excessive direct sunshine [2,3].

Traditionally, gerbera was cultivated for the commercial market as cut flowers; however, as consumer market research has indicated there is a growing demand for potted flowers [1,4]. As potting is a recent development, much research is needed in terms of plant behaviour related to the water, chemical and physical aspects supplied via this cultivation system [5].

In light of these facts, it is significant to note that potting imposes limitations on root development besides the nutrients and water available to the plants. Therefore, adequate irrigation and fertilization management becomes crucial for a good harvest [6].

Water availability is vital for plant growth, as it is a universal solvent and essential for plant metabolism; therefore, adopting a high standard of irrigation management will result in more efficient water usage, minimal use of financial resources, as well as a rise in the productivity [7]. Besides precise irrigation management, fertilization and maintenance of correct soil acidity are important. One of the low-cost substitutes for such corrective measures is the utilization of residues like vegetable ash [8]. From various studies, wood ash has been found to be efficient in the macro and micronutrient production (barring nitrogen), apart from correction of the soil pH, boosting it to suitable levels [9].

From the facts mentioned, the aim of this study was to determine the productive characteristics and water use in potted gerbera plants, under different conditions of water availability and wood ash dosages.

2. MATERIALS AND METHODS

The experiment was conducted in a greenhouse situated at the coordinates 16°28' S and 50° 34' W, at an altitude of 284 m. According to the Köppen classification, the Aw climate type prevails here, which is tropical and characterized by winters with drought and summers with rainfall [10]. During the experiment, average temperatures between 24.1 and 30.6°C and relative air humidity between 56 and 69% were recorded. The floor area of the greenhouse was 216 m² and 6 m on the right-hand side, with an arched overhead structure, covered with a 200-micron transparent plastic canvas. While the floor was paved with concrete, evaporative panels were present as a cooling system.

To facilitate improved developmental conditions for the plants, a shade screen (50% protection against solar radiation) was installed to cover the experimental area.

The statistical randomized complete block design was adopted following a 5x5 factorial scheme, with five different levels of water availability in percentages (40, 60, 80, 100 and 120% of pot capacity) and five doses of wood ash (0, 8,16, 24 and 32 g dm^{-3}) involving four replicates, to make a total of 100 experimental units.

Dystrophic Red Latosol [11] was collected from a site supporting cerrado vegetation at the Federal University of Mato Grosso, Campus Universitário de Rondonópolis, from a layer 0 to 0.20 m in depth. The soil was sifted through a 2-mm mesh sieve with and after the chemical and granulometric characterization was performed, the following composition was noted: pH in $CaCl_2$ = 4.1; M.O. = 19.7 g dm^{-3}; P = 1.1 mg dm^{-3}; K = 47 mg dm^{-3}; Ca = 0.2 $Cmol_c$ dm^{-3}; Mg = 0.1 $Cmol_c dm^{-3}$; H = 4.7 $Cmol_c$ dm^{-3}; Al = 1.0 $Cmol_c$ dm^{-3}; CTC = 6.1%; V = 6.9%; m = 70.4% and sand, silt and clay = 575, 50 and 375, respectively. Soil used to fill the pots was passed through a 4-mm mesh sieve.

Fertilization was performed by adding wood ash alone (barring nitrogen). This was drawn from the ceramic sector residues and analyzed as a fertilizer, based on the method of Darolt et al. [12]. The vegetal dose was composed of pH in $CaCl_2$ = 6.6; M.O. = 38.26%; CO = 19.62%; PN = 7.8%; N = 3.6 mg dm^{-3}; P_2O_5 = 3.0 mg dm^{-3}; K_2O = 4.0 mg dm^{-3}; Ca = 1.7 mg dm^{-3}; Mg = 1.2 mg dm^{-3}; S = 0.4 mg dm^{-3}; Zn = 10.8 mg dm^{-3}; Cu = 6.0 mg dm^{-3}; Mn = 3.8 mg dm^{-3}; B = 5.88 $mgdm^{-3}$ and Fe = 1441.2 mg dm^{-3}.

The experimental unit was a vessel, 2 dm³ in volume, and the selected cultivar was the Red F1 generation of the Festival Light Eye series of gerbera, from Sakata Seeds Sudamérica®.

The seedlings were raised on a commercial substrate mixture and vermiculite in 2:1 ratio. Next, 30 days post sowing, one seedling was transplanted into each pot. Relative to the developmental time of the seedlings, the soil was incubated using the wood ash in the respective doses.

The recommended dose of 120 mg dm^3 of nitrogen fertilization was performed in three divided applications of 40 mg dm^{-3} each [13], spaced over seven days from the tenth day post transplantation, using urea as the source.

Irrigation management was performed after the initial estimation of the pot capacity for each plant ash dose through the gravimetric method [14]. The wood ash doses revealed a pertinent difference in the maximum soil water retention capacity. Thus, for the same soil moisture percentage the corresponding mass value varied, depending on the ash doses applied.

Surface irrigation was manually done to maintain the soil moisture water replenishment. At each irrigation, the experimental units were weighed and the water added was annotated. The water consumption and efficiency of its usage were then analyzed.

The variables were analyzed at the marketing point, characterized by the stamen opening stage with the flowers showing at least two open circles and pollen release [15]. This stage was normally 90 days post transplantation, and the estimations were done for all the plants growing in the plots and the variables listed below were noted:

The maximum soil water retention capacity was determined by testing the pot capacity for each dose of vegetable ash. To accomplish this the water volume retained in each treatment (in dm^3) was noted.

The variable number of total chapters was recorded by counting all the chapters fully formed and / or in the process of formation.

For the variable number of open chapters, only the chapters that had reached the point of commercialization at the time of cutting were counted.

The fresh leaf mass was established by weighing all the leaves in the experimental unit in a semi-analytical balance.

To determine the fresh mass of the floral stems all the chapters and stems were cut at the soil level and weighed in a semi-analytical balance.

The fresh mass of the chapters was estimated by cutting the lower chapters at the floral stem base and weighing them in a semi-analytical balance.

Water consumption is related to the quantity of water added for each treatment during irrigation, throughout the crop cycle.

The efficiency of water use corresponded to the ratio between the dry mass quantity of the total aerial parts produced for every unit of water volume absorbed by the plants.

The data from these calculations were submitted to the analysis of variance and when found significant (up to 5% probability) they were subjected to the regression test, through the statistical program SISVAR [16].

3. RESULTS AND DISCUSSION

The variables analyzed showed no interaction between the water availability factors and plant ash doses. Pot capacity, and water use efficiency exhibited significant differences for the wood ash doses alone. The variables total number of chapters and water consumption revealed statistical difference solely for water availability. The number of open chapters, fresh masses of floral stems and chapters showed an isolated effect for the factors of water availability and wood ash doses.

The pot capacity exhibited significant difference for the factor wood ash doses, in which a quadratic adjustment was noted (Fig. 1). This variable registered the highest water volume of 0.79 dm^3 stored in the soil in response to the addition of the plant ash dose of 17.75 g dm^{-3}. Knowing the maximum water retention capacity of the soil is essential for the planning and executing of an irrigation project, because it enables the irrigation to be done accurately, thus minimizing the nutrient leaching, as well as the surface of the flow and the transportation of the particles.

Wood ash can strongly influence the water-retention capacity of a soil as it contributes to the organic matter. Once it enters in the system, the wood ash contributes to the water adsorption by the colloids, thus increasing the water-retention capacity of the soil. By way of verification, [17] in their utilization of plant ash in the gladiolus cultivation in the soil collected from the same site as that of the present study, reported an increase in the water-retention capacity of the soil as the doses of this residue increased, although it did not reach a ceiling. Such differentiation in the behavior of the regressions is ascribed to the difference in the origin of the wood ash sources used in the studies.

The total number of chapters showed statistical difference only for the water availability factor (Fig. 2). An adjustment was made to the quadratic regression model, where the highest value was 5.81 chapters, in response to the water availability equivalent to 81.43% of pot capacity. [6] for the variable number of chapters, the water availability factor exerted more effect than the nutritional factor, although not significant for the variable, similar to the findings of the current study.

For the number of open chapters, a single statistical difference was noted between the factors of water availability and plant ash doses. Water availability exhibited quadratic behavior in which the most number of pots per pot in the order of 3.25 was recorded at 75.07% of the pot capacity (Fig. 3A). However, the plant ash revealed a linear regression behavior, facilitating an increase of 42.92% in the crop in the number of open chapters when compared with the absence of application of the residue (Fig. 3B).

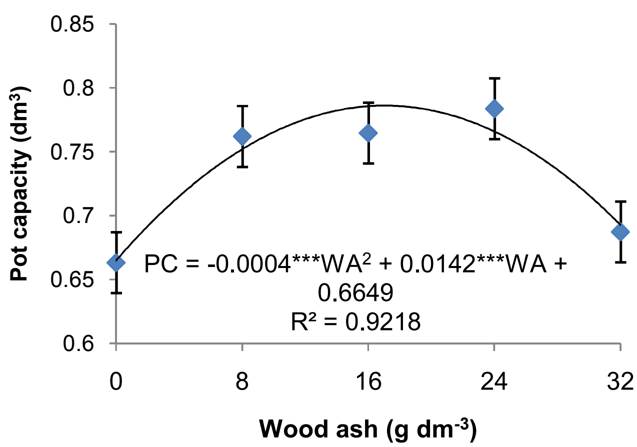

Fig. 1. Available water for the gerbera subjected to wood ash doses
*PC = Pot Capacity. WA = Wood Ash. *** significant at 0.1% probability*

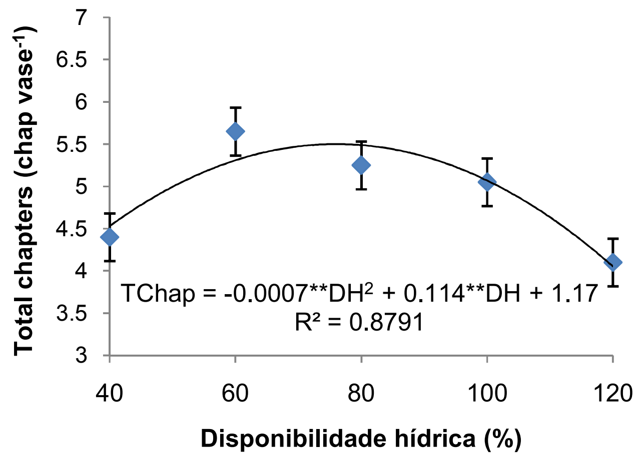

Fig. 2. Total number of chapters of gerbera under water availability
*TChap = Total Chapters, DH = Water Availability, ** significant at 1% probability*

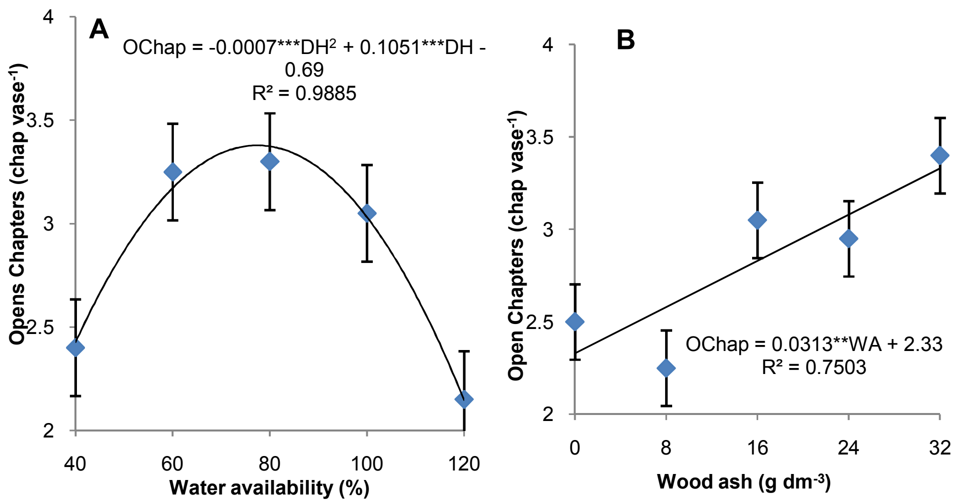

Fig. 3. Number of open chapters of gerbera under water availability (A) and wood ash (B)
*OChap = Open Chapters. DH = Water Availability. WA = Wood Ash. ** and *** significant at 1 and 0.1% probability, respectively*

The number of chapters produced at the commercialization time ranks among the most relevant criteria for the consumers, with the minimum requirement of two chapters per vessel [5,18], and thus, the present study has met this value.

The behavior expressed by the factor number of open chapters in the treatments shows the degree of influence exerted by the water availability factor on the crop, because even in the treatments lacking the wood ash application, the gerbera continued to produce chapters. However, on considering the response of the gerbera plants to water, it was clearly noted that the highest results in chapter production were achieved in the percentages of water less than the maximum water retention capacity of the soil. Similar to other flowers belonging to the same family, like sunflower and chrysanthemum, the gerbera has revealed itself to be more sensitive to the variations in the availability of water than to nutrients [19,20].

The fresh mass of floral stems exhibited an isolated statistical difference between the water availability and plant ash doses factors. The water availability was adjusted to the quadratic regression model, showing the greatest fresh mass production of floral stems (29.80 g pot^{-1}) at 81.35% of the pot capacity (Fig. 4A), while the wood ash doses conformed to the linear regression model revealing a 39.97% increase in the fresh mass of floral stem production when

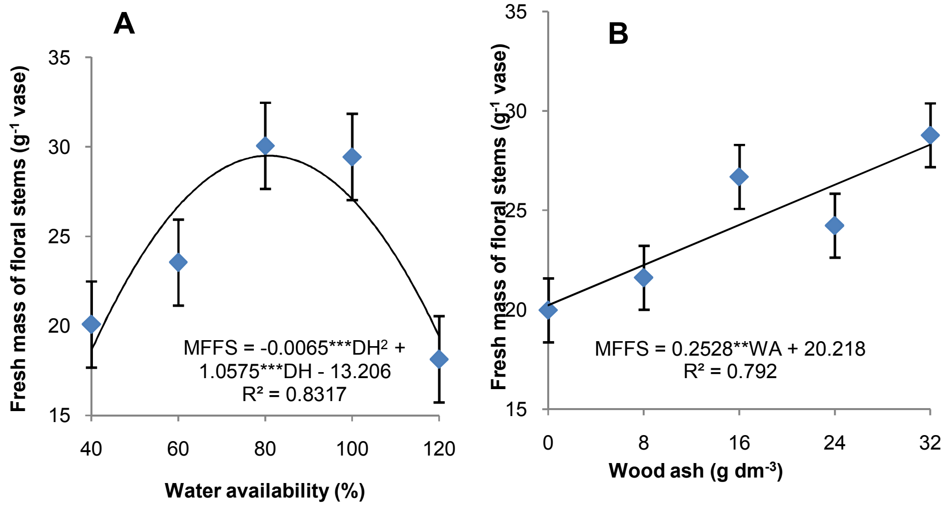

Fig. 4. Fresh mass of floral gerbera stems under factors of water availability (A) and wood ash (B)

*MFFS = Fresh Mass of Floral Stems. DH = Water Availability. WA = Wood Ash. ** and *** significant at 1 and 0.1% probability, respectively*

compared to the higher dose applied with the treatment lacking the application of the wood ash (Fig. 4 B).

Nutrients like phosphorus and potassium supplied by the wood ash can be linked to the increased output of the fresh mass of the floral stems [21]. Besides its other roles, phosphorus supplies energy to the plants, enabling them to perform their vital functions; on the contrary, their absence hinders the plants from completing their life cycle. Potassium too plays a part in the control, regulation and stomatal conductance, directly interrupting the CO_2 input into the system and thus, in the build-up of the photoassimilates and thus in the escalation of the vegetal output [22,23,24].

Partly confirming these results [17] observed in their cultivation of gladiolus subject to soil moisture levels and plant ash doses in the Dystrophic Red Latosol, an adjustment to the quadratic model of regression in the fresh mass of the floral stems for the factors of water treatment and wood ash supplied, and that the greatest mass value was noted under more conducive soil water conditions. The difference between the two studies in terms of the wood ash added, can be due to the nutritional singularities of the crops and the nutrient boost by the wood ash, the present study revealing the lowest amount of nutrients in its composition. Such a nutritional distinction arises from the difference in the origin and collection of this residue, in the two works.

The fresh mass of the chapters displayed the same behaviour as the factor fresh mass of the floral stems in the regression model. Water availability induced the greatest mass of chapters, equivalent to 16.58 g pot^{-1} to 80.54% of the pot capacity (Fig. 5A). The vegetable ash added induced a rise of 43.21% in the fresh mass of the chapters produced when the higher wood ash dose was compared with no wood ash supplied (Fig. 5B).

Potassium and phosphorus, among the nutrients supplied by the plant ash, were seen to directly and/or indirectly influence the plant production, and positively affect the production of the fresh mass of chapters; however, the doses used did not enable them to achieve the maximum production limit. Thus, it can be highlighted that actually reach maximum production the wood ash doses need to be increased. [20] in their assessment of sunflower development under irrigation and fertilization using residues, also reported the linear behaviour of its variables.

As reported for the production of chapters, the gerbera culture exhibited a higher response to water than to the nutritional supplements for the fresh mass of flower stems and chapters. This expression in the flowers of the Asteraceae family was reported by [19] who in their work on raising chrysanthemum under irrigation slides, observed that the greater and lower tensions of water in the soil resulted in a production decline. This reduction can be ascribed to the water stress experienced by the plants (both through excess and deficit), similar to the findings of the current study.

Water consumption revealed a statistical difference for the water availability factor alone, which was adjusted to the quadratic regression model. The highest water consumption, equivalent to 6.99 dm^3, was found at 96.2% of the pot capacity (Fig. 6).

Despite the greatest consumption being confirmed in percentages approaching the maximum water retention capacity of the soil, the gerbera plants revealed the higher output in percentages of around 82% of the pot capacity. Thus, a higher water consumption by the plants does not inevitably imply higher production.

By way of verification, [19] in their study on chrysanthemum noted that although the higher water consumption was observed during times of lower water stresses in the soil, these plants failed to exhibit the highest development. This result is probably due to the relative growth rate (TCR), in which the plants experiencing conditions of less favourable water levels in the soil show more intense adaptive capacity when compared with those that grew under more satisfactory conditions of water availability.

The variable efficiency of water usage showed statistical differences only for the factor wood ash doses, with adjustment to the linear regression model. Vegetable ash-induced a 25.2% increase in the efficiency of water use for the highest dose when compared with the lack of plant ash in the system (Fig. 7).

The performance of the variable efficiency in the use of water in response to the wood ash doses can be related to the productive traits, which exhibited similar behaviour (linear regression), because this variable reveals the ratio between the amount of dry matter of the aerial parts produced to every dm^3 of water consumed. The escalation in the linear adjustment of the water use efficiency may be linked to the nutrient supplements, like potassium and phosphorus, supplied through the wood ash, which due to the doses administered were inadequate to achieve the upper limit of the nutritional needs of the gerbera plants.

In terms of the effect of the nutrients, potassium in particular, on the variable water use efficiency, [25] in their assessment of the production of arugula with supplemental doses of potassium fertilization recorded the maximum value of the water use efficiency, very different from the findings of the current study. This antagonism is interpreted as being caused by the origin of the fertilization sources, the work mentioned above having utilized mineral fertilizer as the potassium source as its nutritional contribution is superior in comparison to that supplied by the wood ash doses utilized in the present study.

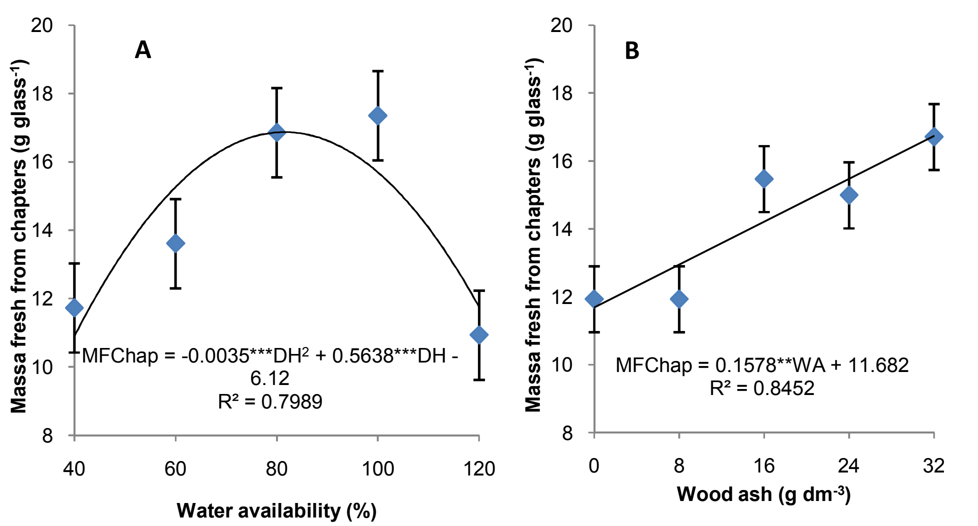

Fig. 5. Fresh mass of gerbera chapters under conditions of water (A) and wood ash (B) availability

*MFChap = Fresh Mass of Chapters, DH = Water Availability, WA = Wood Ash, ** and *** significant at 1 and 0.1% probability, respectively*

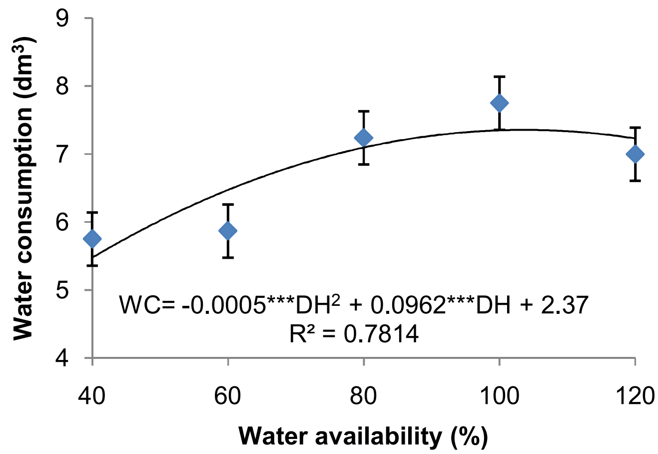

Fig. 6. Water consumption of gerbera under water availability
*WC = Water Consumption; DH = Water Availability; *** significant at 0.1% probability, respectively*

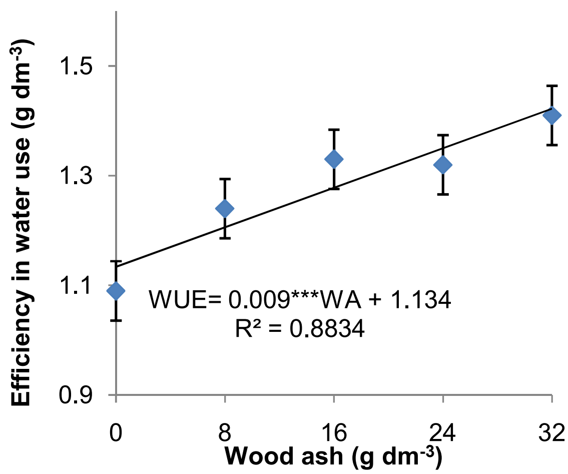

Fig. 7. The efficiency of water use by the gerbera underwood ash doses
*WUE = Water Use Efficiency, WA = Wood Ash, *** significant at 0.1% probability, respectively*

4. CONCLUSION

Gerbera plants exhibit the greatest productive features when cultivated under conditions of water availability (up to 80.6%). Already the greater consumption of water and obtained with value inferior to the capacity of the pot.

The addition of wood ash into the system as a fertilizer source and soil corrective induced a production spike, with maximum water retention capacity of the soil and the efficient use of the water by the gerbera plants.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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