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The impact of water regimes on hormesis by glyphosate on common bean

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Abstract

One way to induce the phenomenon of hormesis in plants is to use low herbicide doses. However, because results are not very conclusive, there is the hypothesis that hydric conditions during the crop cycle may influence the results. The present study therefore sought to evaluate the effect of low glyphosate doses on the irrigated common bean subjected to different water regimes. The experimental design consisted of randomized blocks arranged in a 3 x 2 factorial, with the treatments consisting of combinations of three glyphosate doses [0, 10 and 15 g acid equivalent (AE) ha^{-1}] and two water conditions [355 and 391 mm (distributed according to the kc values for each phenological stage of the crop)], with four replications. The study was conducted under field conditions at the experimental farm of the State University of São Paulo-UNESP, Ilha Solteira campus, located in the city of Selvíria-MS, Brazil. The variables measured were: a) plant dry matter; b) nitrogen content in the leaves; c) number of pods $plant^{-1}$; d) number of grains $plant^{-1}$; e) number of grains pod^{-1}; f) mass of 100 grains and g) grain yield. It may be concluded that hydric conditions during the crop cycle of the common bean have a great influence on the results of hormesis by glyphosate. In the presence of low glyphosate doses, the common bean demonstrated greater tolerance to hydric stress.

Keywords: *Phaseolus vulgaris* L.; hormetic effect; water deficit; low herbicide doses.
Abbreviations: AE_acid equivalent; AI_ acid ingredient; EPSPs_5-enolpyruvylshikimate-3-phosphate synthase; DAT_days after treatment; N_nitrogen; IPR-139_common bean cultivar of Agronomic Institute of Paraná; Etc_crop evapotranspiration; SAW_soil available water; CAE_water evaporation; Kp_coefficient class A tank; Kc_crop coefficients; DAE_days after emergence.

Introduction

Stress physiology has been the subject of numerous studies worldwide and occurs for long periods (Calabrese and Baldwin, 2000). Because each organism has its own intrinsic characteristics, physiological responses are specific in relation to the action of stressor agents. This is associated with the accelerated emergence of new plant materials that makes studies on hormesis in plants increasingly important.
The hormesis phenomenon is observed with the use of substances which inhibit the growth of an organism in high doses, but when administered in very low doses stimulates development (Stebbing, 1982; Calabrese and Baldwin, 2002). The relationship of plant research with hormesis originates from a wide range of field and laboratory investigations. However, it is common in all cases that the possibility of enhanced plant growth when using low doses of toxic agents was an unexpected occurrence, which resulted in considerable subsequent comments and in many cases serious follow-up investigations. The main areas where such observations emerged included the following: 1) the estimation of toxicity thresholds similar to what is currently defined within the context of a hazard assessment; 2) the evaluation of how plants respond to physical and chemical stressor agents of a limited nature; 3) the ability to differentiate essential nutrient functions from the capacity of non-nutritive agents to enhance growth and other metabolic functions; and 4) the claims that fungicidal and insecticidal treatments had a direct stimulatory impact on plant growth separate from their pesticidal actions (Calabrese and Baldwin, 2000). Among the chemical stressor agents that produce hormesis in plants, highlighted is glyphosate [(N-phosphonomethyl) glycine]. This is a non-selective herbicide that inhibits synthase of the enzyme 5-enolpyruvylshikimate-3-phosphate (EPSP) involved in the shikimic acid pathway, which is involved in aromatic amino acid synthesis (Silva et al., 2012). Silva et al. (2013a) reported several studies in plants which showed hormesis caused by glyphosate, such as Meschede et al. (2008) which reported that at only 10 days after treatment (DAT) of glyphosate the stimulation of growth in length and leaf area would be observed in *Commelina benghalensis* "Trapoeraba", from the lowest dose of 2 g ha^{-1} to the highest, 24 g ha^{-1}. At 20 DAT the growth rate remained the same, however the growth peaks occurred between glyphosate doses of 6 and 14 g ha^{-1}. In another example, Wagner et al. (2003) reported increases in the green mass of maize as well as Silva et al. (2009) who reported initial growth in sugarcane. As for increases of reproductive structures, Silva et al. (2012) described an increase in productivity of common beans through hormesis caused by glyphosate. Another potential stress agent to plants is the water deficit, especially for the common bean that is classified as a sensitive plant, both to water deficiency and excess of water in the soil (Nobrega et al., 2001; Silveira and Stone, 2004). It is suspected that the hormesis phenomenon in plants can be affected by many factors such as water

availability during the crop cycle. One hypothesis is that a hydrated plant could probably mitigate the effects of partial stress caused by the herbicide. In the case of water deficit, the action of more than one stressing agent with different natures may be applied (physical and chemical), which can be interesting to analyze, considering that without stress, hormesis does not occur. Thus, the objective of this study was to evaluate the use of sublethal glyphosate rates in common bean submitted to two hydric conditions.

Results and discussion

Plant dry matter, leaf nitrogen content and number of pods plant^{-1}

Dry matter was the common bean characteristics most affected by the water regimes and low doses of glyphosate. In general, development of the bean plant was favored in the condition of low hydric availability (355 mm) and 10 g AE ha^{-1} the herbicide applied (Table 1).

Contrarily, the nitrogen content (N) in the leaves was not influenced by the subdoses of glyphosate and the applied water regimes (Table 1). According to Arf et al. (2004), the response to N is dependent on the soil N content available, mineralization of organic matter, temperature, symbiotic N_2 fixing, cultivar, nitrogen fertilization and others.

It was observed that the N values found in all treatments were below those recommended for the culture (30 to 50 g kg^{-1}) to obtain high yields (Ambrosano et al., 1996). Moreover, one should consider the high mass values of the plant dry matter, which may somehow have caused a dilution effect on nitrogen in the leaves. Additionally, the cultivar IPR 139 is not recommended for production in São Paulo state and in the winter season, so the results can serve as a parameter for further research. The influence of each treatment on the plant dry matter and N content in common bean leaves is presented in Fig 1 and 2 by the interaction between the factors water x dose. According to Guimarães et al. (1996), water stress acts in most physiological and morphological processes of plants, as demonstrated in this paper regarding the number of pods plant^{-1}, which was positively influenced by the higher water regime employed, jumping 8.75 pods plant^{-1} in water regime 1 (355 mm) to 11.42 pods on average in the second water regime (391 mm). The number of pods plant^{-1} was also high in treatments without the glyphosate herbicide, as well as in the application of 10 g ha^{-1} (Table 1). Silva et al. (2012) worked for two consecutive years with three common bean cultivars (Carioca Precoce (Type I), Juriti (Type II) and Pérola (Type III)) and five subdoses of glyphosate (0, 10, 20, 30 and 40 g acid ingredient (AI) ha^{-1}) and no significant differences in the number of pods per plant due to the applied doses. However, it is worth mentioning that although the cultivar IPR 139 has the same growth habit of the cultivar Juriti used by Silva et al. (2012), these are distinct cultivars and, as the authors themselves have noted, each cultivar responds differently to hormesis.

Interaction glyphosate × water regimes

In the unfolding of low glyphosate doses within the water regimes (Fig 1), it was observed that in water regime 2 there was an increase in dry matter values for the dose of 10 g ha^{-1}. These results are consistent with those obtained by Rabello et al. (2012) who evaluated growth of the bean plant cv BR1 - Xodó in function of the application of 0, 4.32, 8.64 and 12.96 g ha^{-1} of glyphosate, and concluded the that low dose of 12.96 g ha^{-1} stimulated the common bean growth, providing greater dry matter of branches and leaves. Similarly, Herrera (2011) who worked with black beans, obtained a significant stimulus in bean leaf area on the order of magnitude of 12% compared to the control treatment with application of reduced doses of the herbicide paraquat. Unlike Silva et al. (2014) who when working with eight doses of glyphosate (0, 0.45, 0.90, 1.35, 1.80, 2.25, 2.70 and 3.15 g ha^{-1}) to monitor their effect on the characteristics related to the development of beggarticks (*Bidens pilosa*), reported that there was a decrease in mass accumulation as the herbicide dose was increased, and in this case the doses used were all below the lowest dose of this work. For water regimes within the reduced glyphosate rates (Fig 1), there was no effect for doses of 0 and 15 g ha^{-1}, where water regime 1 generally presented higher dry matters, corroborating with the data obtained by Arf et al. (2004). Also observed were higher dry matter values of bean plants when subjected to lower water levels, which according to these authors, was supposedly due to increased availability of oxygen in soil for root development resulting from less water from irrigation used under such conditions. There was a significant interaction between reduced glyphosate rates and water regimes for N content in common bean leaves (Fig 2). Among doses, only 15 g AE ha^{-1} was not affected by the water regimes, since higher values of N were maintained in leaves of both water regimes. However, other treatments have behaved in different ways. In the water regime 1, the dose of 10 g AE ha^{-1} caused a reduction in N content in the leaves, unlike what happened in conditions of the second regime where the lowest values were observed in the absence of the reduced glyphosate application rates.

These fluctuations may be related to external factors, since it is a field study and facts like these are often observed. However, it is interesting to observe that nutrient absorption in the subdose of 15 g AE ha^{-1}, regardless of the employed water regime, maintained higher values of N in the leaves, presumably due to N accumulation in the vacuoles of cells provided by partial blockage of the shikimic acid route which is a partial precursor of nitrogen absorbed by the plant. Similar results were observed regarding hormesis caused by the herbicide simazine, which provided protein increase in rye plants (Ries et al., 1967), in addition to oat plants and barley (Pulver and Ries, 1973). Therefore, it is believed that these results can be obtained with low application glyphosate rates to act on the shikimate pathway that is one of the glutamine pathways that contains part of the nitrogen available to the plant. As for the deployment of regimes with low glyphosate doses (Fig 2) versus the absence of glyphosate application, the 355 mm condition resulted in higher N levels in bean crop leaves, averaging 24.75 g kg^{-1} versus 22.75 g kg^{-1} in the regime with 391 mm, while in the dose with 10 g AE ha^{-1} the opposite occurred, with average of 23.75 g kg^{-1} of plant material in the water regime with 391 mm and only 20.75 g kg^{-1} in hydric availability of 355 mm.

Number of grains plant^{-1} and grains pod^{-1}

Despite the lower values obtained for the number of pods per plant for the lower hydric availability (Table 1), there was no influence in the number of grains per plant for the common bean, where the values obtained were similar to the average values in both evaluated regimes as shown in Table 2. Consequently, the number of seeds per pod was higher in the lower water regime (355 mm), resulting in an average of 6.00 grains pod^{-1} compared to 5.33 grains pod^{-1} in greater hydric availability (Table 2).

Table 1. Plant dry matter, N content in the leaves and number of pods per plant in winter common bean in function of lower glyphosate doses and water regimes applied by spraying. Selvíria-MS, Brazil, 2013[1].

Treatments		Dry matter (g plant^{-1})	N of the leaves (g kg^{-1})	Pods (nº plant^{-1})
Water regimes (mm)[2]				
355		13.67 a	23.50 a	8.75 b
391		11.75 b	23.83 a	11.42 a
Glyphosate (g ha^{-1})				
0		12.88 a	23.75 a	9.38 ab
10		13.63 a	22.88 a	12.50 a
15		11.63 b	24.38 a	8.38 b
F	W	31.61 **	0.46 n.s	6.83 *
	G	11.71 **	3.10 n.s	5.93 *
	W x G	5.98 *	15.88 **	1.01 n.s
LSD (5%)	W	0.73	1.05	2.17
	G	1.09	1.57	3.25
General Average		12.71	23.67	10.08
CV (%)		6.57	5.12	24.78

Means followed by the same letter in the columns do not differ by Tukey test at 5% probability. n.s. - Not significant; * and ** significant at 5 and 1% probability, respectively. [2] crop coefficient + precipitation. LSD – Least significant difference. CV – Coeficient of variation.

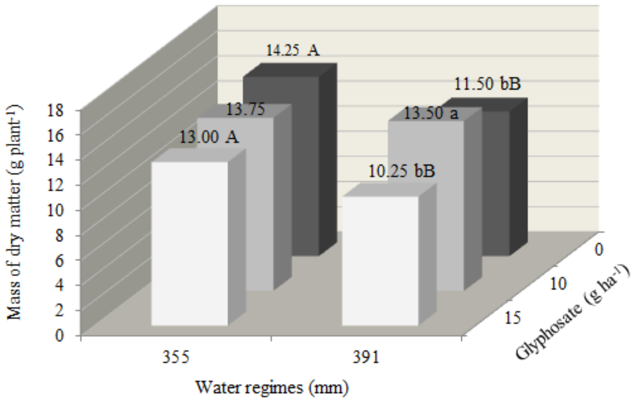

Fig 1. Interaction between water regimes x glyphosate doses about the dry matter of common beans. Selvíria-MS, Brazil, 2013.

This behavior reflect stress in the common bean plant due to a smaller amount of water available for production and reproductive structures, however there was an adaptive stress response that resulted in the highest number of grains pod^{-1}. Just like the number of pods plant^{-1} (Table 1), the number of grains plant^{-1} was also been reduced in the highest herbicide dose (Table 2), falling from the average grain plant^{-1} 62.63 at a dose of 10 g ha^{-1} to 47.88 grains plant^{-1} at the dose of 15 g AE ha^{-1}, which also differed statistically from the control treatment.

Mass of 100 grains and productivity

The mass values of 100 grains, grain yield in different water regimes and low doses of glyphosate resulted in significant interactions at 5% and 1% probability, respectively, according to the data in Table 2. There was a significant interaction between the treatment of water regimes x glyphosate doses (Fig 3) for a mass of 100 grains, where assessment of the interaction revealed that for the regime of 391 mm the dose of 15 g AE ha^{-1} resulted in a reduction of approximately 10% in mass of 100 grains compared to other doses that, in turn, did not statistically differ. Silva et al. (2012) also observed a reduction of 5.63% in mass of 100 grains when they used the dose of 40 g ha^{-1} compared to the treatment without glyphosate application. Therefore, it is evident that the common bean is very sensitive to the effects of this herbicide. Regarding assessment of water regimes within the glyphosate dose (Fig 3), it was observed that in the absence of herbicide application, the 391 mm regime led to an increase of approximately 9% in mass of 100 grains compared to regime 355 mm. This indicates the importance of water for grain filling of the common bean crop. Independently, no significant influence of low glyphosate doses and water regimes in common bean grains was observed (Table 2). However, there was a significant interaction between the treatments, indicating different behavior of glyphosate hormesis in the common bean according to the water regime used during the crop cycle (Fig 4). As was observed for the 355 mm of water regime, application of the herbicide, regardless of the dose, led to higher seed yield values (2227 kg ha^{-1} at a dose of 10 g AE h^{-1} and 2266 kg ha^{-1} at a dose of 15 g AE ha^{-1}) compared to treatment without the application which resulted in 1978 kg ha^{-1}. Therefore, it can be stated that the plant was less sensitive to water deficit in the presence of glyphosate in low doses, probably due to partial blockage of the carbon flux in the shikimate pathway, where glyphosate causes changes in balance of metabolic processes in plants (Meschede et al., 2008). In water regime 2 with 391 mm, absence of the herbicide resulted in the highest yields among all treatments, averaging 2429 kg ha^{-1}. This corroborated with data from Silva et al. (2013b) who registered a decrease in sorghum productivity when subjected to treatments with low doses of glyphosate. When evaluating the interaction of water regimes within the glyphosate doses it can be observed that water regime 2 was favorable for grain yield without glyphosate application, and harmful in the presence of 15 g AE ha^{-1}. On the other hand, the lower dose of 10 g AE ha^{-1} was the most

Table 2. Number of grains plant^{-1}, grains pod^{-1}, mass of 100 grains and grain yeld of winter common bean grain in function of glyphosate doses and water regimes applied by spraying. Selvíria-MS, Brazil, 2013 [(1)].

Treatments		Grains (nº plant^{-1})	Grains (nº pod^{-1})	Mass of 100 grains (g)	Grain yeld (kg ha^{-1})
Water regimes (mm)[(2)]					
355		58.75 a	6.00 a	25.75 b	2157 a
391		58.83 a	5.33 b	26.67 a	2193 a
Glyphosate (g ha^{-1})					
0		58.38 a	5.88 a	26.63 a	2204 a
10		62.63 a	5.75 a	26.63 a	2158 a
15		47.88 b	5.38 a	25.38 a	2163 a
F	W	2.86 $^{n.s}$	7.06 *	4.89 *	0.81 $^{n.s}$
	G	8.50 **	1.43 $^{n.s}$	4.04 $^{n.s}$	0.53 $^{n.s}$
	W x G	0.15 $^{n.s}$	2.10 $^{n.s}$	4.53 *	27.52 **
LSD (5%)	W	6.41	0.53	0.88	84.64
	G	9.57	0.80	1.32	126.40
General Average		56.29	5.67	26.21	2175
CV (%)		13.08	10.85	3.87	4.47

[(1)] Means followed by the same letter in the columns do not differ by Tukey test at 5% probability. $^{n.s.}$ - Not significant; * and ** significant at 5 and 1% probability, respectively. [(2)] crop coefficient + precipitation. LSD – Least significant difference. CV – Coeficient of variation.

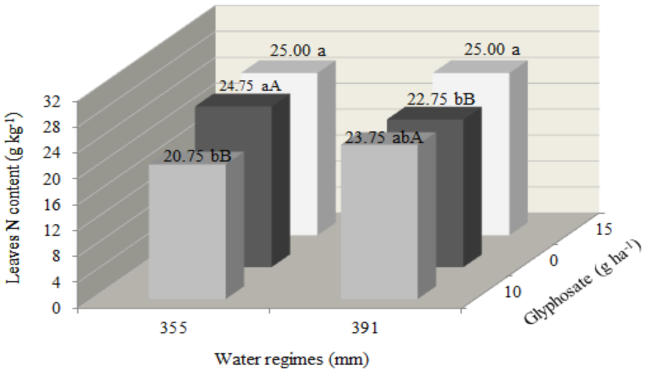

Fig 2. Interaction between water regimes x glyphosate doses on the N content in the leaves of common bean. Selvíria-MS, Brazil, 2013.

stable, while maintaining productivity levels in both water conditions. The high productivity figures in water regime 2 (391 mm) and absence of herbicide application demonstrate the importance of water to ensure high yields in the common bean crop. However, as discussed above, the hormesis method with herbicides may be an alternative for sustainability of the common bean cultivation in water stress conditions, especially those that have affected the southeast and midwest of Brazil.

Materials and Methods

Plant materials

The common bean cultivar utilized was IPR 139 (white Juriti), developed by the Agronomic Institute of Paraná of the Carioca Group, with indeterminate growth habit (Type II), shrubby, erect plant size and little branched stem.

Experimental conditions and soil conditions

The study was conducted in the experimental area belonging to the engineering college of Ilha Solteira - UNESP located in Selvíria-MS, Brazil, from May to August 2013, with geographic coordinates of 51º 24' 1.12" W and 20º 20' 51.27" S, and average elevation of 344 meters.
The soil was classified according to Embrapa (2006), as clayey Red Oxisol. The climate type is Aw, according to Köppen (2004), characterized as tropical humid with rainy summer season and dry in winter. Before the experiment, 20 soil sub-samples from the experimental area were collected at 0-0.10, 0.10-0.20 and 0.20-0.40 m. Chemical analysis of the composite samples were performed according to the methodology proposed by Raij and Quaggio (1983) and the results are presented in Table 3.

Climatic data

Climatic data obtained during the crop cycle is shown in Fig 5.

Experimental design

The experimental was setup in a randomized blocks with 3 x 2 factorial, where the treatments consisting of three glyphosate doses (0, 10 and 15 g AE ha^{-1}) and two water conditions [355 and 391 mm (distributed according to the kc values for each phenological stage of the crop)], with four replications. Plots consisted of 5 lines measuring 4.5 meters long, where the 3 central lines were used as the working area, disregarding 0.5 m at the end of each row.

Pluvial precipitation and water supply

Precipitation during the cultivation period was 266 mm. The water supply was provided by a fixed conventional irrigation sprinkler system with an average irrigation rate of 3.3 mm h^{-1} from the sprinklers. Data related to pluvial precipitation summed with the irrigation depth are shown in Table 4.

Table 3. Chemical analysis of soil in the experimental area. Selvíria-MS, Brazil, 2013.

Depth (m)	pH	P-resin	K	Ca	Mg	Al	H + Al	CTC	V	MO
	$CaCl_2$	--mg dm^{-3}--	--------------mmolc dm^{-3}------------------						%	g dm^{-3}
0.00 – 0.10	5.7	22	3.7	35	26	0	21	85.7	75	23
0.10 – 0.20	5.1	18	2.3	21	17	1	28	68.3	59	18
0.20 – 0.40	4.6	14	1.3	11	8	4	31	51.3	40	14

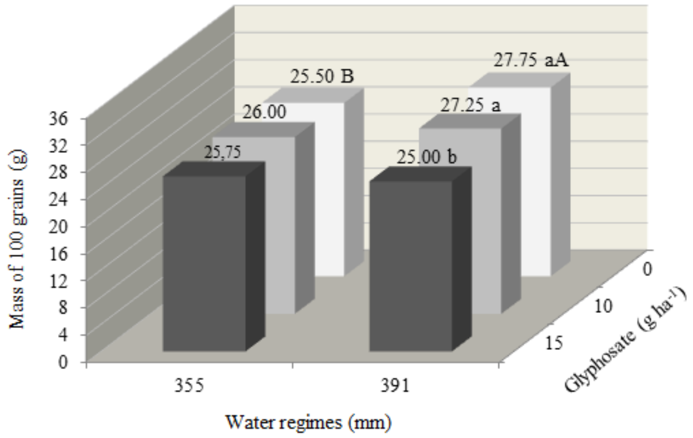

Fig 3. Interaction between water regimes x glyphosate doses in mass of 100 grains of common. Selvíria - MS, Brazil, 2013.

Water replacement was performed when accumulated crop evapotranspiration (ETc) reached values close to the preestablished soil available water (SAW). Water evaporation (CAE) was determined daily from a class A tank installed at the Weather Station located 500 m from the experimental area. The coefficient of the class A tank (Kp) used was proposed by Doorenbos and Pruitt (1976). In crop water management different crop coefficients (Kc) were used for the development phases: germination - primary leaves (V_0 - V_2), first trifoliate leaf - third trifoliate leaf (V_3 - V_4), pre-flowering - pod formation (R_5 - R_7), the pod filling (R_8) and maturation (R_9) (Fernandez et al., 1986). The values of the crop coefficients (K_{C2}) for water regime 2 (391 mm) were proposed by Doorenbos and Kassam (1979). In water regime 1 (355 mm) the crop coefficient values (K_{C1}) were 25% lower than in K_{C2}, as presented in Table 5.

Plant conduction

Basic chemical fertilization in the sowing furrows was performed while taking into account the chemical characteristics of the soil and the recommendations of Ambrosano et al. (1996). For this reason 240 kg ha^{-1} was applied of the formula 4-30-10 + 0.3% Zn. Seeds were sown on 14/05/2013, using the spacing of 0.45 m between rows, and seeds needed to produce 12-13 plants m^{-1} after emergence. Before sowing, the seeds were treated with the insecticide imidacloprid + thiodicarb (45 + 135 g 100 kg^{-1}) and fungicide carboxin + tiran (50 + 50 g 100 kg^{-1}). Emergence of the plants occurred seven days after sowing (DAS) and harvest at 85 days after emergence (DAE). Nitrogen fertilization was carried out in the rows using 80 kg ha^{-1} N as urea (45% N), 30 (DAE), when plants reached the V_{4-6} stadium, or sixth fully formed leaf. Weed control was performed at 16 DAE with the herbicide bentazone (720 g ha^{-1}). The remaining cultural practices were those usually recommended for the common bean crop in the region.

Glyphosate treatments

The application of low glyphosate doses (Roundup Original® - 360 g L^{-1}) was carried out as a foliar spray, with the aid of a CO_2 pressurized backpack sprayer and a spray bar with five spray nozzles, model TXA 8002 VK, maintaining a constant pressure of 3 kgf pol^{-2} and spray volume of 160 L ha^{-1}, with a displacement of 1 ms^{-1} at 0.5 meter in height in relation to the target. This application was performed at 24 days after emergence (DAE) of the V_{4-5} stage plants or with the fifth fully formed leaf. To ensure the quality of the operation, the application of glyphosate was performed in periods of milder temperatures (late afternoon) and low wind interference.

Variables measured

The following evaluations were performed: a) plant dry matter, (at the time of full flowering, after 39 DAE the plants were collected at a predetermined location in the working area of each plot, eight plants were taken to the laboratory, washed, placed in labeled paper bags and then in a forced ventilation oven for drying at an average temperature of 60 - 70 °C until reaching constant weight); b) nitrogen content in the leaves (at 39 DAE leaves were collected from 4 plants per plot), which, once washed and placed for drying in a forced-air oven at 60-70 °C for 72 hours, were ground in a Wiley mill for further sulfuric digestion, according to the methodology proposed by Sarruge and Haag (1974). The following evaluations were performed at 85 DAE during the grain harvest: c) number of pods plant^{-1}; d) number of grains plant^{-1}; e) number of grains pod^{-1}; f) mass of 100 grains and g) grain yield.

Table 4. Water availability from the precipitation and sprinkler irrigation during the common bean cycle. Selvíria-MS, Brazil, 2013.

Water regimes[1]	Precipitation (mm)	Irrigation (mm)	Total (mm)
W_1	266	89	355
W_2	266	125	391

[1] W_1: crop coefficient (Kc_1) + precipitation and W_2: Kc_2 + precipitation.

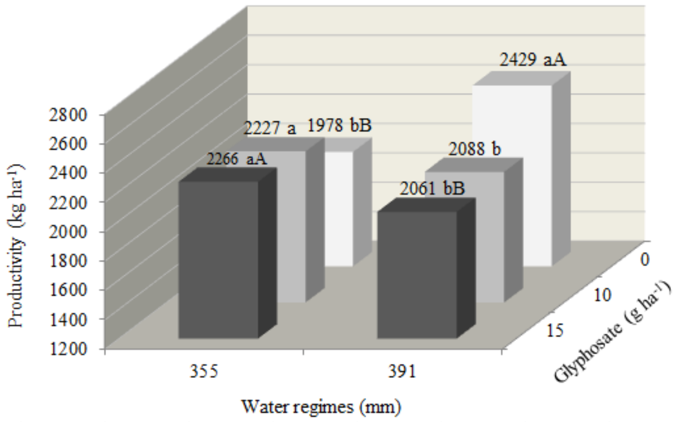

Fig 4. Interaction between water regimes x glyphosate doses on the grain yeld of common bean. Selvíria – MS, Brazil, 2013.

Table 5. Crop coefficient values (Kc) used in the different development stages of the common bean according water regimes applied by spraying.

Water regimes (mm) [1]	Development stages of the common bean[2]				
	V_0–V_2	V_3–V_4	R_5–R_7	R_8	R_9
			Kc		
355	0.23	0.53	0.79	0.56	0.19
391	0.30	0.70	1.05	0.75	0.25

[1] Crop coefficients + precipitation. [2] Development stages (Fernandez et al., 1986): V_0-V_2: germination - primary leaves; V_3-V_4: first trifoliate leaf - third trifoliate leaf; R_5-R_7: pre-flowering - pod formation; R_8: pod filling and R_9: maturation.

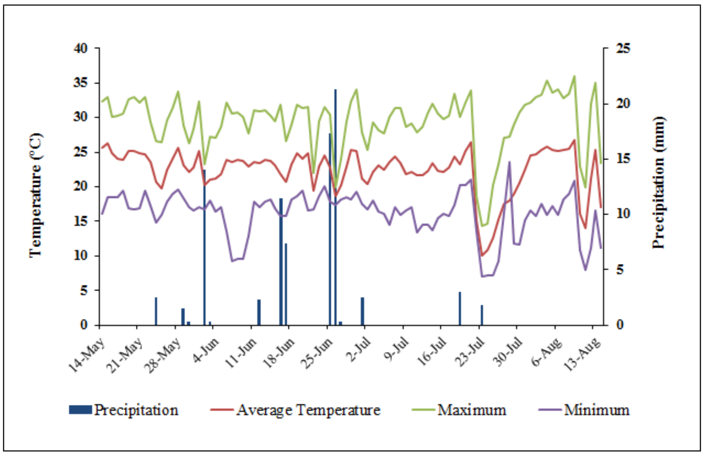

Fig 5. Pluvial precipitation data, minimum temperature, average temperature and maximum temperature during the conduct of research. Selvíria-MS, Brazil, 2013.

Data analysis

Data for the evaluated variables were submitted to analysis of variance by the F-test at 5% error probability. When a significant effect was verified in the analysis of variance, data obtained in the different quantitative treatments was compared via the Tukey's test at a level of 5% error probability. Quantitative tests were performed via the regression study seeking to adjust equations with biological significance. For this the analysis the statistical software Sisvar was used (Ferreira, 2011), and based on this process graphs were made using Office Excel.

Conclusions

Hydric conditions during the crop cycle of the common bean have great influence on the results of hormesis caused by glyphosate. The condition of lower water availability (355 mm) favored plant growth of the common bean when compared to the larger regime used (391 mm), except when applying 10 g AE ha^{-1} in which the dry matter remained the same in both situations. In low water availability conditions, the use of low glyphosate doses (10 g AE ha^{-1} and 15 g AE ha^{-1}) provided higher yields for the common bean cv. IPR-139. In the presence of low glyphosate doses, the common bean showed greater tolerance to hydric stress.

Acknowledgments

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