Hormesis Influence of Glyphosate in Between Increasing Growth, Yield and Controlling Weeds in Faba Bean

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Abstract: This study investigates the response of faba bean and associated weeds to the low rates of glyphosate (1.4, 2.8, 5.6, 11.2, 22.4, 44.8, and 89.6 g a.i./feddan) corresponding to 0.3, 0.6, 1.2, 2.4, 4.8, 9.6, and 19.2% of the usage rate (0.467 kg/feddan), respectively. Two field experiments were conducted in this regard during two successive seasons (2008/2009-2009/2010). The plants were sprayed once and twice, 5 and 15 weeks after sowing. Generally, the one foliar application treatments were more effective in increasing faba bean growth than the two foliar application treatments. The best results obtained were for the concentration 11.2 g/feddan, especially sprayed as once. Plant height, fresh and dry weight as well as yield and its components were significantly increased in response. Total protein and carbohydrate contents were unaffected by the treatments. Weeds in converse were negatively affected recording the highest inhibition rate at the concentration 11.2 g sprayed also as once. It has been suggested that the low doses of glyphosate can induce faba bean growth, and this could indirectly affect weeds growth. [El-Shahawy, T.A. and Faida A.A. Sharara. Hormesis Influence of Glyphosate in Between Increasing Growth, Yield and Controlling Weeds in Faba Bean. Journal of American Science 2011;7(2):139-144]. (ISSN: 1545-1003).

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Introduction

Searching for new uses of herbicides started very long time ago with discovering hormesis, the beneficial effect of low doses of toxicants against living organisms. The story is quite different than that, started earlier with using medicines in curing diseases. The chemist and surgeon scientist Aureolus Philippus Theophrastus who is known also as Paracelsus (1493-1541) is the one who set the broad lines of such science (Duke *et al*. 2006). Paracelsus who is regarded also as the father of toxicology is often paraphrased to have mentioned that the poison is in the dose ["Alle Ding sind Gifft nichts ohn Gifft. Allein die Dosis macht das ein Ding kein Gifft ist." (All things are poison and are not poison; only the dose makes a thing not a poison"]. On that basis, we can find many compounds toxic at higher doses and stimulatory or even beneficial at low doses as pharmaceuticals that are used for their beneficial effects and pesticides that are normally used as toxicants. The separating line is then the dose and every thing is turning around it. Although of this old historical background, discovering hormesis is even too older. According to Duke *et al*. (2006), the term hormesis was first used by Southam and Ehrliech (1943) to describe the effect of an oak park compound that promoted fungal growth at low doses but strongly inhibited it at higher doses. It is originated from the Latin word "Hormo" (to excite), the same used in hormone expression. Experimental data, which can be qualified as hormesis phenomenon should fulfill a number of requirements (Szarek 2005). Of which the most important is that the substances causing hormesis response should be potentially toxic or even very toxic. It is also important if researched materials are subjected to operation in at least 6 various doses.

Hormesis has been found within all groups of organisms from bacteria to fungi to even higher plants and animals (Calabrese 2005). Great concern has been forward in this phenomenon to animals and mammals (Cook and Calabrese 2006 and Sanders and Scott 2008). Slight concern, however, has been given to plants (Mushak 2007 and Calabrese 2009). Less documentation is found and approximately no information concerning the mechanisms of action is presented (Cedergreen *et al*. 2007).

Most researches on plants and herbicides have been done with the purpose of weed control (focus has been on the adverse effects) and hormesis is normally commented on as a non-target objective (Streibig 1980). Hormesis in the plants has therefore received little attention until recently (Calabrese 2005 and Calabrese and Blain 2005).

A survey of hormesis caused by herbicides in crops and aquatic plants demonstrated that hormesis can range from a few percentages up to 100% increase in the measured parameters, but with an average of 20-30% stimulation compared to the control (Cedergreen *et al*. 2005). Allender *et al*. (1997) found 2,4-D and metrbuzine as effective hormetization factors for increasing growth of cotton and corn plants when used at sublethal doses. On the other hand, the authors revealed that such increasing in growth can be stopped with using lithium and lanthanum chlorides. In an

experiment involved 8 different herbicides and 10-15 doses of their effects on barely, the results showed that glyphosate together with the sulfonylurea metsufuron had caused aerial parts to increase by up to 25% more than the control only if used at 5 to 10% of the usual field rate. In contrast, the other 6 left herbicides failed to show a similar response on target plant (Cedergreen 2008a). With focusing research on glyphosate, the globally most widely used herbicide (Bradberry *et al.* 2004*)*, the results showed a unique effect on increasing plant growth at rates less than toxic dose (Ellis and Griffin 2002, Ellis *et al*. 2003 and Velini *et al*. 2008). Similar action was noticed with gluphosinate. The authors revealed that the hormetic effect in glyphosate is related to the molecular target of action, since the effect was not seen in glyphosate- resistant crops e.g. soybean.

The present study evaluates the hormetic effect of glyphosate on faba bean growth as well as its associated weeds.

Materials and Methods

A field experiment was conducted during two successive seasons (2008/2009-2009/2010) to study the potential hormetic effect of glyphosate [(Roundup® 48%, *N*-(phosphonomethyl)glycine), Monsanto Co.] on the growth and development of faba bean (*Vicia faba* L., var. Aquadulce) plant as well as the effect on the associated weeds. The study was carried out at the experimental station of National Research Centre, El-Behera Governorate, Egypt. The soil texture was sandy soil with pH= 7.3, EC= 0.3%, OM= 0.3%, $CaCl_3$= 1.3%, N= 8.1 ppm, P= 3.2 ppm, and K (exchangeable)= 20 ppm (Chapman and Pratt 1978). Faba bean seeds were obtained from Agricultural Research Centre, Ministry of Agriculture and Land Reclamation, Egypt. The seeds were sown in the 1st week of November in the two seasons. After 5 and 15 weeks from sowing, the plants were sprayed once or twice with 0.3, 0.6, 1.2, 2.4, 4.8, 9.6, and 19.2% of the usage rate of 0.467 kg a.i./feddan glyphosate (1.4, 2.8, 5.6, 11.2, 22.4, 44.8, and 89.6 g/feddan, respectively). Three replicates were used for each treatment in a completely randomize block design. A preliminary trail was conducted under greenhouse conditions on faba bean without weeds infection to determine the appropriate time/concentrations to be used under field conditions, and to avoid confounding hormesis effect with weed control influence.

After two weeks of the treatment, a sample of one square meter of faba bean plants of those applied as once was taken. Plant height, number of branches per plant as well as fresh and dry weights were estimated. At the same time, weed samples were taken, and the fresh and dry weights were estimated for both broad and narrow-leaved weeds. *Brassica nigra* L., *Melilotus indica* L., *Amaranthus cruentus* L., *Chenopodium ambrosioides* L., *Chenopodium murale* L., *Sisymbrium irio* L., *Eragrostis cilianensis* All., *Phalaris minor* Retz. and *Poa annua* L. dominated the area.

At harvest, plant height, seed yield/feddan (feddan=4200m^2) and yield components e.g. number of pods/plant, pods weight/plant, pod length, seeds number/pod, and 100- seeds weight were estimated. Total nitrogen and carbohydrates (%) were determined in the seeds (A.O.A.C., 1980). Nitrogen values were multiplied by 6.25 to determine total crude protein.

Results and Discussion

1-Growth

a-Faba bean plants:

Spraying faba bean with glyphosate at different concentrations varied between positive and negative effect to even no effect on increasing faba bean growth. No clear toxicity was observed at any of the examined concentrations (Table1). Applying the herbicide once was generally more effective than applying it twice (Data not estimated) at all traits had estimated (visual observation). Spraying glyphosate once at 11.2 g/feddan was the most effective treatment over all. Plant height, fresh and dry weights were all increased in response. Insignificant effect was noticed on no. of branches per plant. These results coincide with the results obtained by Cedergreen (2008b) who confirmed that glyphosate is able to increase plant growth if used at sub-toxic level (5-60 g a.i./ha). Velini *et al*. (2008) found that subinhibitory dosages of glyphosate (1.8-36 g a.i./ha) can induce hormesis growth in crops and plant species as different as sorghum, maize, convential soybean, *Eucalyptus grandis*, *Pinus caribea*, and *Commelia benghalensis*. The theories which explain hormetic growth are various based on the chemical being used and/or the plant species exposed to these chemicals. However, they all agree in one main point that is the plant escape to this phenomenon to overcome unfavorable growth conditions or chemical stresses (Cedergreen *et al*. 2007). Kovalchuk *et al*. (2003) reported that the induction in defense mechanisms induced by free radicals of oxygen can lead to increase growth in the presence of low doses of phytotoxic chemicals. On the other hand, some of the hormetic responses could stem from induction of plant hormonal systems as it was established with synthetic auxins (Morre 2000). The auxinic herbicides are a good example of these chemicals where they can induce growth at non-toxic concentrations through mimicking the growth hormone auxin, in the same time they are lethal at higher doses (Allender *et al*. 1997). Weyers and Paterson (2001) in this regard stated that if low doses of chemicals stimulated the production or activity of natural auxins or other plant hormone

systems, hormetic responses could then be expected.

Table (1): Effect of low doses of glyphosate applied once on the vegetative growth of faba bean plants at two weeks after treatment during the two successive seasons.

Glyphosate rates (g a.i./feddan)	Season 2008/2009				Season 2009/2010			
	Plant height (cm)	Branches number /plant	Fresh weight (g/plant)	Dry weight (g/plant)	Plant height (cm)	Branches number /plant	Fresh weight (g/plant)	Dry weight (g/plant)
1.4	30.0	3.3	8.0	5.8	29.0	3.0	8.4	6.8
2.8	30.0	3.3	9.3	7.0	30.3	3.7	9.8	7.7
5.6	32.7	3.7	9.2	6.7	32.0	3.0	9.3	7.7
11.2	36.3	3.7	13.3	9.6	35.3	3.7	14.6	10.7
22.4	29.7	3.3	9.0	6.3	30.7	3.7	9.4	7.2
44.8	29.7	3.7	8.3	6.0	27.3	3.7	9.1	7.3
89.6	29.7	3.3	8.0	6.3	26.7	3.3	9.1	6.7
Control	32.0	3.7	9.0	6.0	31.3	3..0	9.5	8.0
LSD $_{0.05}$	2.5	N.S.	2.7	2.0	2.2	N.S.	2.3	1.9

b- Weeds:

Weeds were negatively affected in response of the different treatments (Table 2). Various activities were recorded in this regard. The three lowest concentrations (1.4, 2.8, and 5.6 g) had approximately no inhibitory effect on the associated weeds including broad and narrow-leaved weeds. The greatest inhibition of weed growth was found with the concentration 11.2 g/feddan sprayed as once. This effect could be due to the greatest induction in faba bean growth which indirectly affected the growth of associated weeds (increasing competition upon weed plants). This result might be boosted by the results obtained by Cedergreen (2008b) who confirmed that glyphosate causes an actual biomass growth in plants and this growth can keep treated plants larger than untreated plants for up to six weeks which give them more opportunity to be more competitive than any others in the area including weeds. Moderate reductions were estimated at the concentrations 22.4, 44.8, and 89.6 g a.i./feddan, regardless if they applied once or twice (notes from visual seeing).

Table (2): Effect of low doses of glyphosate applied once on the growth of associated weeds at two weeks after treatment. (Combined analysis of two seasons)

Glyphosate rates (g a.i./feddan)	Broad-leaved		Grasses	
	Fresh weight (g/m^2)	Dry weight (g/m^2)	Fresh weight (g/m^2)	Dry weight (g/m^2)
1.4	13.4	9.7	6.5	3.9
2.8	13.6	9.5	6.1	3.4
5.6	10.8	8.3	4.3	3.1
11.2	5.1	4.8	3.3	1.5
22.4	7.2	7.7	4.2	2.2
44.8	7.5	6.6	4.7	2.4
89.6	6.7	6.1	4.6	2.4
Control	14.0	11.7	7.3	4.4
LSD $_{0.05}$	2.1	1.8	0.9	1.0

2- Faba bean yield and its components:

Application of glyphosate (either once or twice) at the different non-toxicant rates resulted in increasing faba bean yield and its components. Applying the herbicide once was generally more effective than applying it twice at all traits investigated (Tables 3 and 4). This included the number of pods/plant, pods weight /plant, pod length, number of seeds/pod, 100- seeds weight, seed yield/plant and per feddan. Spraying faba bean plants with glyphosate at 11.2 g a.i./feddan after 5 weeks from sowing surpass all other treatments and cause an enhancement in seed yield per feddan by 58.93 and 65.23% over control in the first and second season, respectively (Tables 3 and 4). These increments may be due to the increasing occurred in number of pods per plant together with the weight of pods per plant not any of the other

estimated characteristics. The decrement in enhancement of the subletheal dose of glyphosate at higher doses (more than 11.2 g a.i./feddan) could be explained by Wagner *et al*. (2003) who reported that total plant fresh weight presented a logistic response to glyphosate amounts, including a growth stimulant effect (hormesis), when corn plants absorbed less than 0.6 µg, but when corn plants absorbed more than 0.6 µg they showed a decrease in growth.

Table (3): Effect of low doses of glyphosate on faba bean yield and its components in the first season (2008/2009).

Glyphosate rates (g a.i./feddan)		Plant height (cm)	Pods No. /plant	Pods weight /plant (g)	Pod length (cm)	Seeds No. /pod	100- seeds weight (g)	Seed yield/ plant (g)	Seed yield/ feddan (Kg)
One spray	1.4	57.0	5.7	60.0	18.1	4.6	136.3	48.3	1158
	2.8	61.3	6.7	64.9	17.6	4.5	137.6	52.7	1266
	5.6	65.7	9.7	78.2	18.9	4.5	143.5	55.8	1338
	11.2	77.0	13.0	117.2	18.5	4.8	150.6	77.4	1858
	22.4	62.0	11.0	72.3	18.2	4.5	133.8	56.5	1355
	44.8	53.3	7.3	59.2	18.4	4.7	126.2	43.6	1046
	89.6	49.7	5.3	48.2	16.3	3.8	126.3	40.3	968
Two spray	1.4	57.3	6.0	41.5	17.5	4.4	136.3	44.8	1074
	2.8	53.7	6.3	45.6	18.0	3.6	135.7	46.5	1117
	5.6	52.0	5.3	44.7	18.6	3.7	142.8	53.4	1282
	11.2	60.0	8.7	68.9	18.1	4.0	149.4	58.0	1392
	22.4	58.3	6.3	55.3	17.0	4.4	128.8	40.4	969
	44.8	51.7	5.3	35.1	17.0	3.5	124.3	29.2	702
	89.6	50.3	5.0	32.9	16.6	3.9	122.6	26.2	629
Control		59.0	6.3	62.1	16.7	4.0	137.2	48.7	1169
LSD 0.05		6.0	2.0	12.3	N.S	N.S	N.S	12.0	289

Table (4): Effect of low doses of glyphosate on faba bean yield and its components in the second season (2009/2010).

(Glyphosate rates (g a.i./feddan)		Plant height (cm)	Pods No. /plant	Pods weight /plant (g)	Pod length (cm)	Seeds No. /pod	100- seeds weight (g)	Seed yield /plant (g)	Seed yield /feddan (Kg)
One spray	1.4	58.0	6.7	53.9	16.9	4.4	134.7	41.2	990
	2.8	59.3	7.0	57.4	17.3	4.2	136.1	43.4	1042
	5.6	62.0	8.7	72.6	16.5	3.9	138.2	51.1	1226
	11.2	79.3	11.7	101.4	16.3	4.1	148.6	70.5	1692
	22.4	63.0	10.3	71.8	17.0	3.8	141.0	53.2	1276
	44.8	59.7	9.3	67.7	17.5	4.1	128.9	45.4	1089
	89.6	49.7	5.3	41.1	16.9	4.2	125.6	27.1	650
Two spray	1.4	60.7	6.3	49.1	17.0	3.8	131.8	39.2	941
	2.8	56.0	7.3	53.0	17.0	3.3	132.3	40.6	974
	5.6	56.7	8.0	54.2	17.0	3.9	139.1	42.1	1010
	11.2	64.3	8.7	66.8	18.0	4.4	145.0	49.8	1195
	22.4	58.3	7.3	48.5	16.8	3.9	132.2	33.8	811
	44.8	56.7	5.3	35.5	16.1	4.1	129.8	26.4	634
	89.6	47.3	5.0	33.1	15.7	4.8	124.8	25.7	618
Control		61.0	7.0	55.8	17.9	4.1	134.5	42.7	1024
LSD 0.05		6.9	2.2	11.8	N.S.	N.S.	N.S.	11.8	283

More or less total carbohydrates and total protein slightly affected by the subletheal doses of glyphosate treatments (Table 5).

Table (5): Effect of low doses of glyphosate on the protein and carbohydrate contents in faba bean seeds.

Glyphosate rates (g a.i./feddan)		Total Carbohydrates (%)	Total Protein (%)
One spray	1.4	62.26	26.58
	2.8	62.35	26.65
	5.6	62.43	26.44
	11.2	63.10	28.36
	22.4	62.73	27.93
	44.8	61.71	26.20
	89.6	61.63	25.95
Two spray	1.4	61.10	26.06
	2.8	61.40	26.28
	5.6	61.80	26.59
	11.2	61.60	26.73
	22.4	61.50	25.85
	44.8	59.66	25.64
	89.6	58.53	25.02
Control		62.30	26.66

It could be suggested that the subinhibitory dosages of glyphosate can induce faba bean growth and gave more seed yield. It's worthy to mention that glyphosate is break down rapidly to amino acid glycine and it could be considered as safe herbicide (Cerdeira and Duke 2006).

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