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GLYPHOSATE HORMESIS INCREASES GROWTH AND YIELD OF CHICKPEA (*Cicer arietinum* L.)

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ABSTRACT

Herbicides have been shown to increase crop growth and yield when applied at low doses, observable fact is known as herbicide hormesis.A pot study was conducted to access the effect of ten different doses of glyphosate (0, 1.8, 3.6, 7.2, 18, 36, 72, 180, 360 and 720 g a.e. ha^{-1}) on growth and yield of chick pea in wire house, ofAgronomic Research Area,University of Agriculture,Faisalabad, during winter 2013-14. Four weeks after chick pea emergence treatments were applied to assess their effect on plant growth and yield atcrop maturity. Data for chickpea growth were collected 21 days after glyphosate application and then at plant maturityfor growth and seed yield. Results of data collected 21 days after glyphosate application showed that low doses of glyphosate caused up to 35, 22, 34, 74, 39 and 24 % stimulation in shoot length, root length, number of secondary branches, root volume and dry weight of shoot androot, respectively. Results of date collected at physiological maturity showed that increase in plant height, root length; number of secondary branches, biological yield and grain yield was up to 32, 24, 35, 35 and 34%, respectively.Glyphosate doses ranging from 18 to 72 g a.e. ha^{-1} caused maximum stimulation in different growth and yield parameters. Hormetic response of low dose of glyphosate against weeds and weed crop competition is still unknown which should be studied for practical application of glyphosate in crop production.

Key words: herbicide hormesis, weeds, herbicide drift, resistance evolution, food security.

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INTRODUCTION

World population is increasingat very high rate which is predicted to be 9 billion in 2050 but our land resources are limited to

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feed increasing population. This upcoming gap between availability and demand of food is creating a massive challenge for human beings (Martindale and Trewavas, 2008; Murchie*et al*., 2009). Therefore effective techniques which can increase crop yield per unit land areaare needed to achieve food security. Low dosesof toxic chemicals stimulate the growth of target organisms, this phenomenon exist in different living organism including crop plants. Most of the studies have conducted on the direct benefits of this phenomenon on human, while the role of this stimulating factor in increasing food production has got very less consideration (Calabrese and Baldwin, 2003).

Low dose of herbicides stimulate the growth and yield of target plant, this growth stimulating phenomenon ofherbicides is known as herbicide hormesis (Calabrese *et al*., 2007). It is one of the emerging windows to improve crop production, which can change the focus of herbicide use towards crop production from crop protection. Different studies regarding herbicide's low dose effect against crops species have been conducted both under laboratory and field conditions, which revealed that some herbicides at low doses stimulate crop growth (Cedergreen *et al*., 2007; Velini *et al*., 2008). Hormetic effect of herbicides strongly depends upon the type of herbicide, herbicide dose, time of application, crop or weeds species and other management practices (Belz *et al*., 2008, 2011; Cedergeen and Olesen, 2010).

Glyphoste which is one of the most widely used herbicide in the world showed biphasic dose response phenomenon (Cedergreen, 2008). Higher doses of glyphosate show its phytotoxic impact and kills plants but when glyphosate is applied to plants at 10 % of rate recommended in field conditions, it promotes crop growth (Asman *et al*., 2003). Application of glyphosate at low doses stimulates photosynthesis by increasing the CO_2 efficiency (Cedergreen*et al*., 2010). By stimulating photosynthesis, glyphosate increases the growth of different crop species. Consistent hormetic effects of glyphoste have been reported against growth and yield of different crop species both under controlled and field conditions (Duke *et al*., 2006; Belz *et al*., 2008; Cedergreen, 2008; Velini *et al*., 2008). However, most of the studies about glyphosate hormesis have reported its hormetic effect on the early seedling growth of target plants. Only a few studies are available that showed the hormetic effect of glyphoste applied at terminal growth stages of crop plants on the crop growth and grain yield (Cedergreen *et al*., 2009).

Studies highlighting the effect of low dose of glyphosate applied at seedling stage of cropson growth and grain yield are not available. Therefore this study was conducted with hypothesis that low dose of glyphosate will tend to increase the growth of chick pea that will

sustain up to the maturity leading to higher yield. The objective of the study was to know the effect of glyphosate lower doses applied at early seedling stage on growth and yield of chick pea (*Cicer arietinum* L.).

MATERIALS AND METHODS

A pot study was conducted to evaluate the effect of different doses of glyphosate on *Cicer arietinum*in wire house at Agronomy Research Area, University of Agriculture, Faisalabad, during winter 2013-14. Sandy clay loam soil having pH 7.6-8.0 and 0.95% organic matter was collected from non-cropped area which was free from any vegetation. Soil EC andcation exchange capacity were 0.85 dSm^{-1} and 3.9$cmol_c$ kg^{-1}, respectively. The mean minimum and maximum temperatures in the wire house were 20°C and 28°C during the experimental period. Pots were filled with soil and 7 seeds of *C. arietinum* seeds were sownin each potand then after a week thinning was done to keep 5 plantsin each pot. After irrigating the pots they were arranged in randomized complete block design. Each treatment was replicated four times. All pots were irrigated regularly till maturity. Glyphosate at ten different doses (0, 1.8, 3.6, 7.2, 18, 36, 72, 180, 360 and 720 g a.e. ha^{-1}) were sprayed four weeks after seedling emergence.Data regarding different growth parameters was recorded about 21 days after glyphosate application. For biomass, two plants form each pot were used and 3 plants were remained in each pot for further growth and yield evaluation. At maturity these remaining plants were used to record plant height, root length, number of secondary branches, biological yield and grain yield.

Fisher's analysis of variance technique was carried out to analyze the data and comparison of treatments means was done using least significant difference test at 5% probability level (Steel *et al.,* 1997). However, before carrying out analysis of variance the data were transformed using square root transformation to make the data normal by reducing the deviation of individualsfrom their population means to minimize the error.

RESULTS AND DISCUSSIONS

Growth of *C. arietinum* plants 21 days after application

Results of different growth parameters including shoot length, root length, number of secondary branches, root volume and dry weight of shoot and root revealed that low doses of glyphosate stimulate the growth of *C. arietinum*. But the stimulatory effect was highly dose-dependent; glyphosate doses above 72 g a.e. ha^{-1} inhibit the *C. arietinum* growth. There was significant increase in shoot lengthof *C. arietinum* at different doses of glyphosate ranging from1.8

to 72 g a.e. ha^{-1}. Maximum shoot length (3.7cm) was observed at glyphosate dose of18 g a.e. ha^{-1} (Fig. 1a). Root length (3.4 cm) was also significantly increased at lower doses of glyphosateranging from 1.8 to 72 g a.e. ha^{-1}. Glyphosate doses above 72 g a.e. ha^{-1} significantly reduced the root growth (Fig. 1b). Results about number of secondary branches revealed that lower dose between 1.8 to 180 g a.e. ha^{-1} increase the number of secondary branches but trend was unique in case of this parameter. Because maximum number of secondary branches (2.3) were observed at glyphosate dose 180 g a.e. ha^{-1} followed by 72 g a.e. ha^{-1}. This change in trend may be due to suppressive effect of glyphosate at 180 g a.e. ha^{-1} which may cause reduction in epical dominance (Fig.1c). Root volume was significantly improved than control at lower doses of glyphosate ranging from 1.8 to 180 g a.e. ha^{-1}. Maximum root volume (2.6 cm^3) was measured at 72 g a.e. ha^{-1} dose of glyphosate (Fig. 1d). Root and shoot dry weight also showed hormetic trend, dry biomass was increased at lower doses between 1.8 to 72 g a.e. ha^{-1}but it showed reduction at increasing doses of glyphosate above 72 g a.e. ha^{-1} (Fig. 1e-f). Different parameters showed their unique response to glyphosate doses, but it was very important that all growth parameters showed positive response to glyphosate dosesbetween 1.8 to 72 g a.e. ha^{-1}which showed that growth stimulation was not due to trade-off mechanism between different plant parts.Glyphosate doses caused up to 35, 22, 34, 74, 39 and 24 % stimulation in shoot length, root length, no. of secondary branches, root volume and dry weight of shoot and root respectively (Fig. 1).

This increase in different growth parameters was due to increase in photosynthetic rate of plants treated with low doses of glyphosate. As literature showed that application of glyphosate at low doses increased the photosynthesis which may due to increase in rubisco activity (Cedergeen and Olesen, 2010). Results are consistent with previous findings which showed that low doses of glyphosate caused stimulation in different growth parameters (Cedergreen, 2008; Velini *et al*., 2008).

Growth and grain yield of *Cicer arietinum* at maturity

Results of different growth and yield parameters recorded at plant maturity showed that stimulation in early seedling growth caused due to low doses of glyphosate, applied at seedling stage sustained over time and it contribute in biological yield and economical yield of *C. arietinum* (Fig. 2-3). There was significant difference in height of plants which was treated with lower doses of glyphosate ranging from 1.8 to 72 g a.e. ha^{-1}then control. Maximum plant height (5 cm) was recorded at glyphosate dose 7.2 g a.e. ha^{-1} which was followed by 18 g a.e. ha^{-1} (Fig. 2a). Highest root length (2.7 cm) than control was

observed in plants which were treated with glyphoste below 72 g a.e. ha^{-1}. But higher doses caused inhibition in root growth (Fig. 2b). Number of secondary branches was also increased at glyphosate doses between 1.8 to ranging from 1.8 to 72 g a.e. ha^{-1} (Fig.2c). Total dry biomass also showed hormetic trend to increasing doses of glyphosate, with increasing the doses of glyphosate from 0 to 72 g a.e. ha^{-1} increases in total dry biomass was observed but doses above 72 g a.e. ha^{-1} caused reductionsin biological yield (Fig. 2d). Grain yield of *C. arietinum* was significantly increased in pots which were treated with 3.6 to 18 g a.e. ha^{-1} doses of glyphosate. Maximum grain yield (1.1) was achieved in pots which were sprayed with glyphosate dose 7.2 g a.e. ha^{-1} followed by the yield of pots where 18 g a.e. ha^{-1} glyphosate was sprayed (Fig. 3). The increase in plant height, root length, number of secondary branches, biological yield and economic yield was up to 32, 24, 35, 35 and 34 percent respectively (Figure 2-3). These findings are supported by previous researches which revealed glyphosate doses below 72 g a.e. ha^{-1} elevated crop growth, increase in yield is supported by researches which showed that low dose contribute to increase the photosynthesis and photosynthates allocation pattern (Duke *et al*., 2006; Cedergreen *et al*., 2007; Cedergreen, 2008). Cedergreen *et al*., (2009) reported that low dose application of glyphosate increased the grain yield of barley. It might be possible that spray of glyphosate induced some kind of defense mechanism in chick pea plants that make these plants more tolerant to other type of stresses. Because early exposer of plant to one stress makes it more tolerant to other type of stresses (Calabrese *et al*., 2007). Use of low doses of glyphosate may help us to improve the food production without increasing the agriculture land area and also help us in reducing the environmental load by changing use of chemical fertilizers.

In our field conditions weeds plants grown at field boundaries exposed to low doses of herbicidesdue to herbicides drift, possibly get the low doses which caused hormetic effects and increase weed growth. Even in conditions weeds which grown under shade of crop plants or cover crops may exposed to lower doses of herbicides which may increase weed growth. Dew drops and rain after herbicides application may also dilute the herbicides dose which can cause hormesis. Possible hormetic response of weeds may influence the weed crop competition. It is also very important that if the field dose of herbicides equates the hormetic dose for herbicide resistant weeds, it will increase the evolution of herbicide resistance weeds by stimulating their growth and seed production ability of resistant plants. Because the lethal doses of herbicides for resistant weeds are normally more than the recommended field rates use to control of susceptible

weeds. So recommended field rate may cause hormesis in high level resistance weeds. Research is needed to evaluate the effect of low doses of different herbicides on weed growth and their seed producing potential.

CONCLUSION

It is concluded that application of low doses of glyphosate ranging from 18to 72 g a.e. ha^{-1}three weeks after emergence of chick pea stimulate the growth and yield of chick pea. Early growth stimulation sustained till the chick pea maturity caused up to 34% increase grain in production of chikapea. Further studies are needed to confirm the hormetic effects of glyphosate on chick pea under field conditions. Before the practical application of glyphosate as a growth stimulator, studies are needed to check the effects of low doses of glyphosate on grain quality, environment and associated weeds of chick pea.

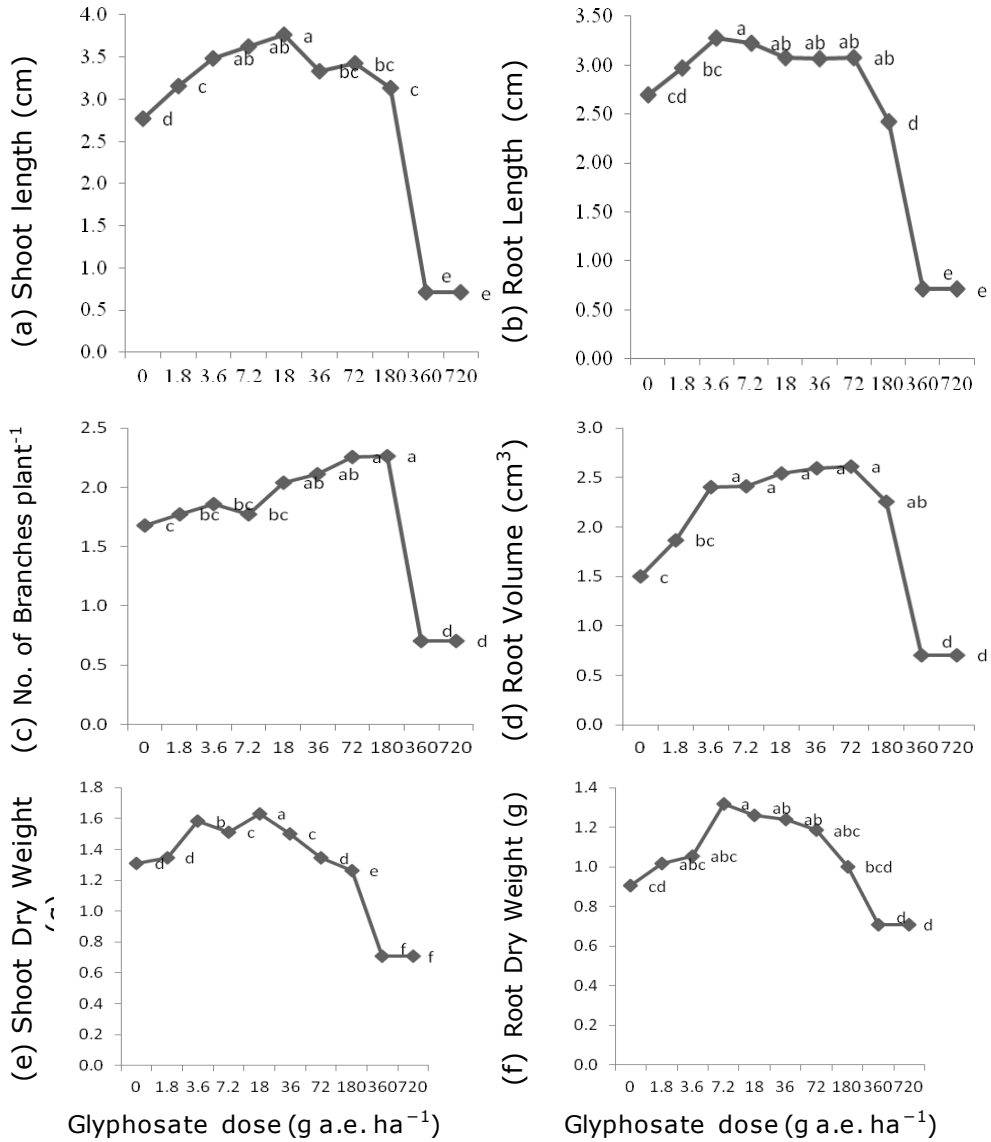

Figure 1. Stimulatory effect of glyphosate on chick pea growth 21 days after spray

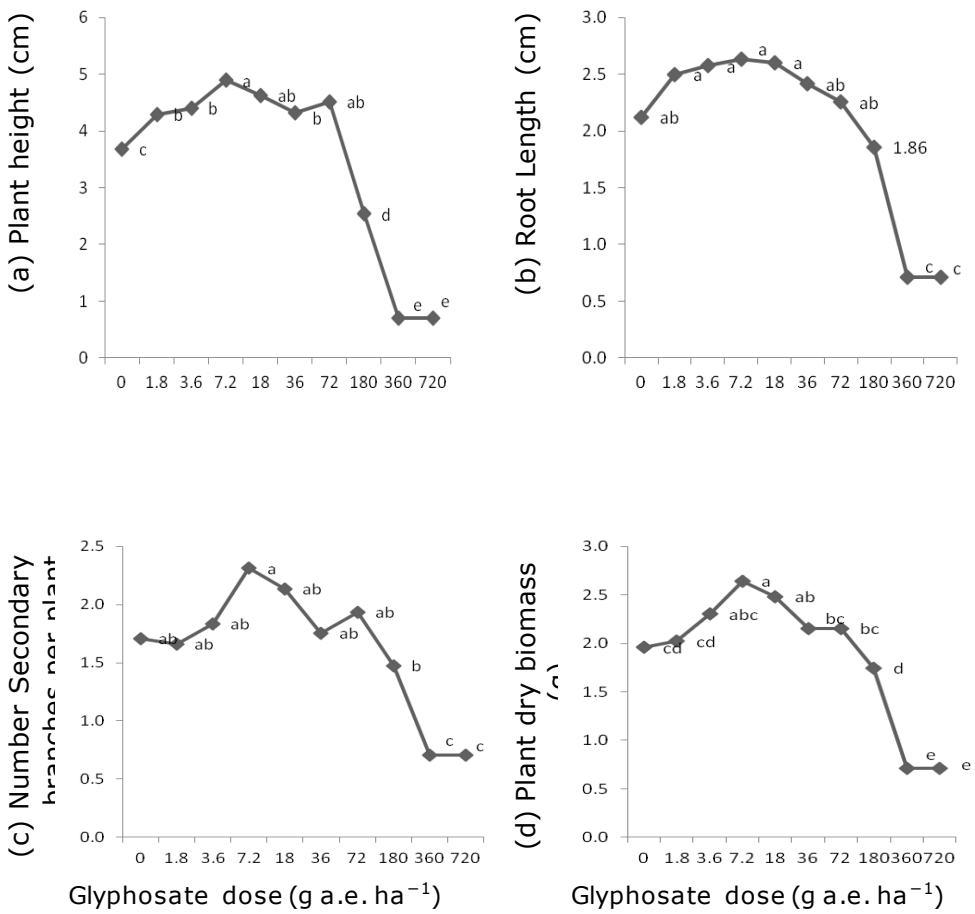

Figure 2. Stimulatory effect of glyphosate on chick pea growth at maturity

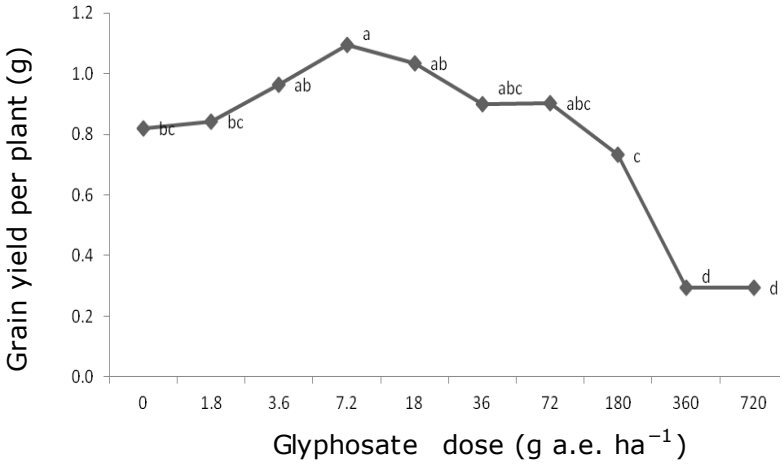

Figure 3. Stimulatory effect of glyphosate on chick pea grain yield

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