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Phytotoxic Response and Variation in Yield Traits for Post Emergence Herbicides in Chickpea (*Cicer arietinum* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The present investigation was conducted to identify sources of tolerance to the herbicides *viz.*, Topramazone and Quizalofop ethyl in order to potentially employ these sources in the development of herbicide-tolerant chickpea genotypes. Screening of genotypes revealed large variation in tolerance to Topramazone. Three genotypes namely, NBeG 776, RVG 205 and IPC 2010-134 were

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identified as highly tolerant based on herbicide tolerance scores and can be used as source for breeding Topramazone tolerant varieties. Herbicide Quizalofop ethyl showed non phytotoxic effects on chickpea genotypes. Also high yield of genotypes KGD 99-4 and NBeG 776 in presence of Quizalofop ethyl application suggested effective use of this post emergence herbicide to control weeds in chickpea.

Keywords: Post emergence; Topramazone; Quizalofop ethyl; chickpea.

1. INTRODUCTION

Chickpea being a short-day plant and possessing great diversity with respect to growth habit and morphology [1]. lacks consistent production and varies widely due to its varied behaviour to photoperiod, temperature, and extended moisture stress [2]. The average yield of chickpea cultivation in India is low and variable, in spite of its significant nutritional value and economic significance. It has been suggested that one of the main obstacles to increasing chickpea yield is weed infestation. During the initial phases of crop growth and establishment, chickpea grows slowly, making it a poor weed competitor [3]. Besides introducing disease and pest insects, weeds compete with chickpea plants for water, nutrients, sunlight, and space. The yield of chickpeas may be significantly reduced if weeds are not controlled. Mukherjee [4] reported 30-54 % losses in chickpea production caused due to weeds. Many research workers reported the predominance of *Avena ludoviciana, Chenopodium album, Cynodon dactylon, Phalaris minor and Medicago hispida, Anagalis arvensis, Melilotus indica, Melilotus alba, Cyperus rotundus, Argemone maxicana, Solanum nigrum, Vicia hirsute and Vicia sativa* weeds in chickpea field [5]. Controlling weeds in chickpea crop is essential for increasing yields and preserving product quality. Due to rising labor costs, conventional manual and mechanical weed control methods are becoming more and more expensive in developing nations. Due to chickpea's susceptibility to herbicides, pre-emergence herbicides are the most efficient, while post-emergence herbicide alternatives are few [3]. Herbicides applied before crop emergence are successful in halting weed growth during the early stages of seedling development, but weeds that emerge after crop emergence take over the field and significantly reduce yields. In order to give them greater flexibility to use post-emergence herbicides, growers need chickpea cultivars with increased herbicide resistance [6]. Plant resistance is widely acknowledged as the most effective strategy for reducing losses brought on by biotic stressors, such as weeds in chickpea. Identifying the resistance of the crops to make them more selectable rather than changing the characteristics of the herbicide to distinguish between crops and weeds is one strategy to deal with the problem of providing chickpea genotypes with resistance to broad spectrum herbicides. In order to create cultivars resistant to herbicides, it is essential to locate plant resistance sources in germplasm which will help reduce the threat caused by weeds. Therefore, the goal of the current investigation was to find sources of herbicide resistance to prominent herbicides Topramazone and Quizalofop ethyl in chickpea genotypes.

2. METHODOLOGY

The experiment material comprised of a set of 98 chickpea genotypes, procured from Genomic Selection trial, AICRP Chickpea, IIPR, Kanpur and 3 high yielding checks i.e. C.G. Chana-2, RG 2015-08 (CG Lochan Chana) and RG 2016-134 (CG Akshay Chana) from IGKV, Raipur.The experiment was carried out at Research cum Instructional Farm, College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G) during Rabi 2021-22. The genotypes along with 3 high yielding checks were screened for two popular herbicides (most commonly used in Chhattisgarh for controlling weeds in chickpea), Topramazone and Quizalofop ethyl. The experiment was laid in Factorial RBD design with 2 replications and all 101 genotypes inclusive of checks were evaluated under 3 different conditions i.e (T_0) control condition, Topramazone (T_1) treatment and Quizalofop ethyl (T_2) treatments. Each entry was sown in a single row of 2.0 m length; inter and intra-row space was 30 x 10 cm. Agronomical practices were adopted for successful crop. 30 DAS, the seedlings were sprayed with Topramazone 33.6% SC and Quizalofop ethyl 15% EC and the control condition being left untreated. Plant injury ratings of genotypes were recorded at 15 days after herbicide treatment based on visual scoring for both the herbicide conditionsas per score rates followed by Gaur et al., [6].

At harvesting stage, the genotypes were recorded for yield and its attributing traits under all the three conditions. For studying various quantitative traits, observations were taken on 5 randomly selected plants from each genotype. Factorial RBD analysis was performed to evaluate the performance at 3 level factors. Factor A was taken as 101 chickpea genotypes whereas, factor B comprised of two herbicides (Topramazone and Quizalofop ethyl) along with one control condition. The individual effects of genotypes, herbicides and their interaction effects for ten yield and yield attributing traits were estimated.

3. RESULTS AND DISCUSSION

In the present study, several monocot and dicot weeds were observed in the field (Fig. 1). The dominant weed species observed were *Chenopodium album, Medicago spp., Cyperus rotundus, Alternanthra spp., Abotilon indica, Eichinochloa spp. and Physalis minima.* Earlier studies of Kakade et al. [7] Niranjan et al. [8] Gupta et al. [5] Ratnam et al. [9] and Singh et al. [10] also reported similar weed flora in chickpea.

3.1 Crop Phytotoxicity

Screening of 101 chickpea genotypes for tolerance to two herbicides, Topramazone and Quizalofop ethyl, revealed large variation for tolerance to Topramazone, whereas, no variation was observed in levels of tolerance to Quizalofop ethyl. The phytotoxicity symptoms or plant injury rating due to these herbicides on chickpea genotypes was recorded 15 days after herbicide application (DAHA) following 1 to 5 scale suggested by Gaur et al. 2013, where, 1= Highly tolerant (excellent plant appearance, no burning/ chlorosis of leaves), 2= Tolerant (good plant appearance with minor burning), 3= Moderately tolerant (fair plant appearance with moderate burning or chlorosis of leaves), 4 =Sensitive (poor plant appearance with severe burning/chlorosis),5= Highly sensitive (complete burning leading to plant mortality).

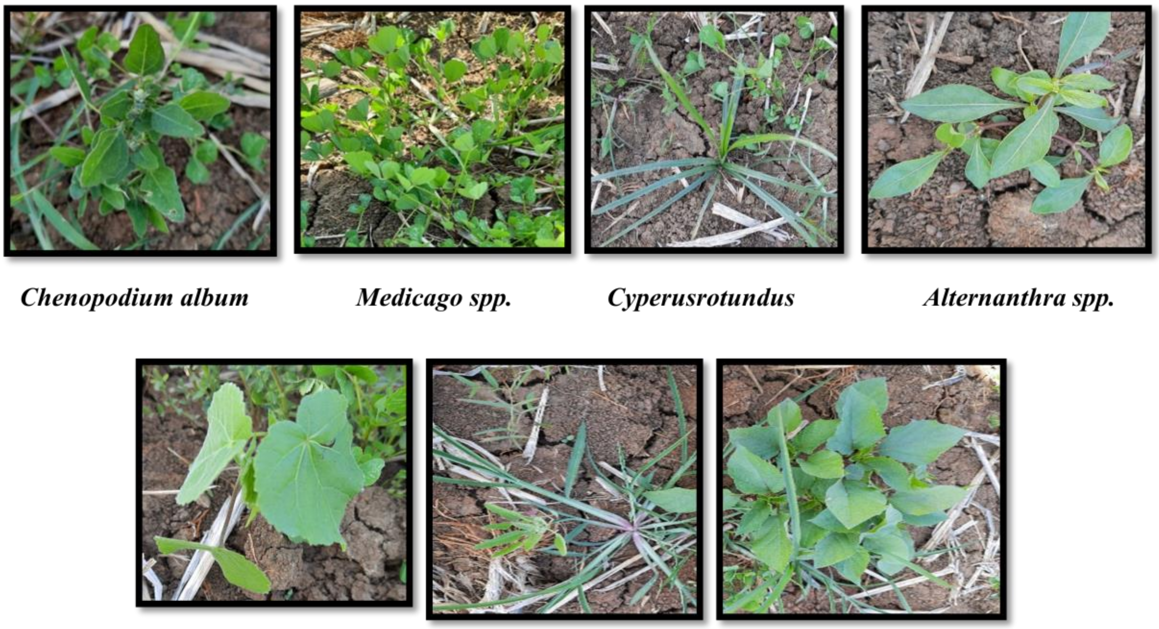
Topramazone 33.6% SC (Elite) which belongs to the phenyl pyrazolyl ketone family of herbicide is used as selective post emergence herbicide to control broad leaf weeds and grasses in chickpea, maize and other crops. Topramazone inhibits an enzyme (4-HPPD) that controls carotenoid biosynthesis in chloroplast of susceptible plants, whereas, Quizalofop ethyl 5% EC (Targa super) is a selective, systemic, post emergence herbicide of Aryloxyphenoxy-propionates group used to control annual and perennial grass weeds in chickpea, potato, soybean, sugar beet, groundnut, vegetables, cotton, linseed and other crops. Quizalofop ethyl inhibits synthesis of fatty acids by inhibiting the acetyl Co A carboxylase synthesis. After foliar application of herbicide, susceptible plants exhibited rapid growth suppression of developing leaves, followed by yellowing and subsequent necrosis at stem base meristematic regions.

On a scale 1 to 5, the level of herbicide tolerance ranged from 1 to 4 for Topramazone whereas, no visual injuries were observed for Quizalofop ethyl and therefore, for all the genotypes the score was 1 indicating high tolerance of genotypes for the herbicide. For Topramazone, three genotypes showed high tolerance with excellent plant appearance, no chlorosis or burning of leaves, 18 genotypes were tolerant having good plant appearance with minor chlorosis/ burning, 53 genotypes showed moderate tolerance having fair plant appearance with moderate burning/ chlorosis of leaves. 27 genotypes showed sensitivity with poor plant appearance whereas, none of the genotype was reported to be highly sensitive for the herbicide (Table 1).

3.2 Effect on Yield and Its Attributing Traits

Factorial RBD analysis was performed to study the effects of 2 different factors i.e genotypes and herbicides, result of which revealed significant effects of genotypes, herbicides as well as genotype x herbicide interaction for all the yield and yield related traits studied. The summarized result of genotype x herbicide interaction and its effects is presented in Table 2.

Studying the performance genotypes for different yield traits revealed the significantly superior performance of genotype GL 1202 for the trait plant height and height of 1^{st} pod. Maximum number of primary branches was recorded by genotype Phule G-96006, whereas, highest number of secondary branches was exhibited by genotype Narsinghpur Bold. GJG 0814 was found significantly at par for the trait pods per plant. For the trait seeds per pod genotype H 16-12and IPC 2005-64 performed best. Significantly superior performance of KGD 99-4 and NBeG 776 was recorded for the trait seed yield per plant, also NBeG 776 was found superior for biological yield. For the trait harvest index and 100 seed weight significantly superior performance was recorded by the genotypes GJG 3 and ICC 4958 respectively.



Chenopodium album *Medicago spp.* *Cyperusrotundus* *Alternanthra spp.*

Abotilonindica *Eichinochloa spp.* *Physalis minima*

Fig. 1. Weed variability observed in the chickpea

Table 1. Rating of genotypes for Topramazone (T1) and Quizalofop ethyl (T2) tolerance

Herbicide	Class	No. of genotypes	Genotypes
Topramazone	Highly tolerant	3	NBeG 776, RVG 205, IPC 2010-134
	Tolerant	18	JSC 35, RVSSG 75, JG 16, PDKV Kanchan, GNG 2285, H 14-01, ICC 5912, IPC 2012-98, IPC 2012-49, GNG 2226, IPC 2007-28, IPC 2006-88 X ILWC 179, IPC 2005-64, IPC 2008-11, KGD 99-4, GNG 2264, RG 2015-08, IPC 2008-69
	Moderately tolerant	53	ICC 4958, RVG 204, JSC 37, RVSSG 74, AKG 70, JAKI 9218, AKG 46, H 12-29, H 08-18, H 12-63, H 13-01, H 13-09, HC-1, H 12-22, H 13-36, H 15-03, H 16-17, H 16-12, Phule G-96006, Mahabaleswar-1, JG 24, ICCV 96854, JG 2018-53, JG2017-48, JG2018-50, JG47315-2, JG 2018-51, Narsinghpur Bold, CSN 8962, GLW 64, GL 13042, GL 1202, PG 211, PG 221, GG 4, GJG 0922, GJG 6, GAG 1107, GAG 111, GJG 0904, ICC 4658, IPC 2005-24, ICC 2277, ICC 11764, Phule G 06102, GL 13001, Rajendra Chana-1, IPC 2013-33, JG 35, MABC 66-266, DKG 964, C.G CHANA 2, RG 2016-134
	Sensitive	27	CSJ 303, CSJ 313, H 15-25, H 15-04, H 15-13, H 14-22, H 12-26, H 16-08, H 15-27, ILC 166, ICCV 92944, JG2018-54, JG 2016-141611, JG74315-14, PG 222, PG 172, PG 170, PG 158, GJK 0921, GJG 0814, GJG 3, ICC 1710, JG 37, IPC 2005-28, JG 3-14-16, CSJ 556, IPC 2008-103
	Highly sensitive	0	None
Quizalofop ethyl	No visual injuries/ phytotoxic symptoms were observed		

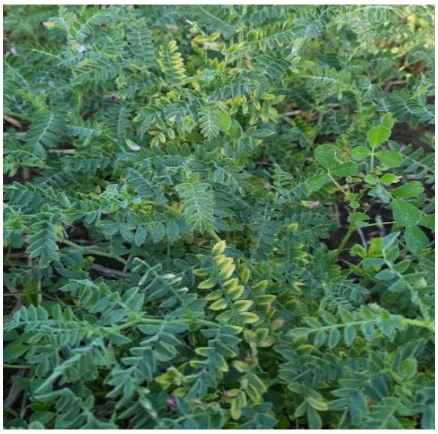



Fig. 2. Plant injuries observed in the field by (T1) Topramazone treatment

Table 2. Summarized result of genotype x herbicide interaction and its effect

Trait	Genotype	Herbicide	Genotype x Herbicide
Plant Height	GL 1202	Control	GL 1202 x control
Height of 1st pod	GL 1202	Quizalofop ethyl	GL 1202 x Quizalofop ethyl
No. of primary branches	Phule G-96006	Control	Phule G-96006 x Control
No. of secondary branches	Narsinghpur Bold	Control	JG2018-54 x Control
Pods per plant	GJG 0814	Quizalofop ethyl	GJG 0814 x control
Seeds per pod	H 16-12and IPC 2005-64	Quizalofop ethyl	CSJ 556 x Quizalofop ethyl
Seed yield per plant	KGD 99-4 and NBeG 776	Quizalofop ethyl	KGD 99-4 x Quizalofop ethyl
Biological yield	NBeG 776	Control	JG 2016-141611 x control
Harvest index	GJG 3	Quizalofop ethyl	Phule G 06102 x Topramazone
100 seed weight	ICC 4958	Control	ICC 4958 x control

Studying the effects of herbicides on different yield traits revealed that the traits *viz.* plant height, no. of primary branches, no. of secondary branches, biological yield and 100 seed weight expressed best in control condition whereas, the traits height of 1st pod, pods per plant, seeds per pod, seed yield per plant and harvest index showed best performance in presence of Quizalofop ethyl treatment.

While studying different genotypes and herbicides for their interaction effects on yield and yield attributing traits it was found that, for the trait plant height, genotype GL 1202 was found significantly at par in control condition; however, same genotype GL 1202 recorded highest height of 1st pod in interaction with Quizalofop ethyl treatment. The significantly superior performance for the traits number of primary branches and number of secondary branches was observed in control condition by the genotype Phule G-96006 and JG2018-54, respectively. In control condition, genotype GJG 0814 was found significantly at par to other interactions for the trait pods per plant whereas, the interaction of CSJ 556 x Quizalofop ethyl exhibited maximum seeds per pod. Seed yield per plant being the most important trait to be considered while considering genotypes having herbicide tolerance was recorded highest in interaction of KGD 99-4 x Quizalofop ethyl. Traits *viz.* biological yield and 100 seed weight was expressed best in control condition by the genotypes JG 2016-141611 and ICC 4958, respectively, whereas for the trait harvest index, genotype Phule G 06102 recorded significantly superior values in interaction withTopramazone treatment.

The reduction in weed population by these herbicides indicated that the weed control was effective by the tested herbicides. The tolerance levels of genotypes to these post emergence application of herbicides suggests their effective use in controlling weed population. The experimental material gave a solid indication of the variation for herbicide tolerance to Topramazone and it would motivate additional screening of a large genotypes collection to look for even more reliable and diverse sources of herbicide tolerance. The development of Topramazone tolerant cultivar could be aided by considering the three highly tolerant genotypes namely NBeG 776, RVG 205 and IPC 2010-134 and 18 tolerant genotypes discovered in this work. It will also be possible to attempt crosses among these genotypes to find molecular markers connected to the genes for herbicide tolerance allowing use of MAS for herbicide tolerance breeding.

Evaluating the effects of genotype x herbicides, it is clear that the best performance of genotypes for different yield and related traits were either recorded in control condition or in presence of Quizalofop ethyl application, since, no phytotoxic effects were exerted on genotypes by Quizalofop ethyl and control condition, whereas, chickpea genotypes did not possessed higher values for any of the traits in presence of Topramazone application, since, it showed phytotoxic effects on genotypes along with controlling weeds. Therefore, the genotypes that are found highly tolerant and tolerant for the herbicide and have performed better than the checks for yield and yield attributing traits can be recommended for further validation and utilization in breeding programs. However, Quizalofop ethyl having no phytotoxic effects on chickpea but effective in controlling weeds can be suggested for post emergence application in chickpea to combat weed menace.

The result of current study was not in agreement with earlier study of Nath et al*.*, [11] who reported no phytotoxicity of Topramazone on chickpea genotypes. Chaturvedi et al*.*, [12] and Gaur et al*.,* [6] evaluated chickpea genotypes for Imazethapyr and Metribuzinphytotoxicity using similar scales (1-5), Dewangan et al. [13] recorded phytotoxic effects of post emergence application of Metribuzin and early post-emergence application of Oxyfluorfen and Taran et al., [14] evaluated chickpea genotypes for different combinations of herbicide of imidazolinone class [15-17].

4. CONCLUSION

The variability revealed in existing set of chickpea genotypes for herbicide tolerance confirms the presence of a sufficient source of herbicide tolerance in the chickpea germplasm which needs to be evaluated by conducting screening trials. Furthermore, using the herbicide-tolerant genotypes identified in current study along with studies for identifying and utilizing genes conferring herbicide tolerance, development of chickpea varieties tolerant to post-emergence herbicides with good agronomical traits is possible. Also popularizing post-emergence herbicides such as Quizalofop-ethyl (with efficient weed control without any phytotoxic effects on chickpea genotypes) and the tolerant chickpea genotypes with good yield performance can assure increased production and profitability.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

SUPPLEMENTARY MATERIALS

Supplementary material is available in the following link:
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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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