

**GENETIC VARIABILITY STUDIES IN CHICKPEA
(*Cicer arietinum* L.) FOR HERBICIDE TOLERANCE**

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**GENETIC VARIABILITY STUDIES IN CHICKPEA
(*Cicer arietinum* L.) FOR HERBICIDE TOLERANCE**

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CERTIFICATE

This is to certify that the thesis entitled “**GENETIC VARIABILITY STUDIES IN CHICKPEA (*Cicer arietinum* L.) FOR HERBICIDE TOLERANCE.**” submitted by **VAISHNAVI HEBSUR** for the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **GENETICS AND PLANT BREEDING**, to the University of Agricultural Sciences, Dharwad is a record of research work done by her during the period of her study in this university under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associate ship, fellowship or other similar titles.

**VIJAYAPUR
JULY, 2017**

**(VIJAYAKUMAR A. G)
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1. _____
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LIST OF ABBREVIATIONS

SN	Abbreviation	Long form
1	**	Significance at 1 % probability level
2	*	Significance at 5 % probability level
3	h^2_{bs}	Broad sense heritability
4	S	Sprayed
5	US	Unsprayed
6	PH	Plant height
7	NPB	Number of primary branches
8	NSB	Number of secondary branches
9	NTB	Number of tertiary branches
10	DFFL	Days to first flowering
11	DFF	Days to fifty percent flowering
12	DFPD	Days to first podding
13	DFP	Days to fifty percent podding
14	DFPM	Days to fifty percent pod maturity
15	DM	Days to maturity
16	PDPL	Pods per plant
17	NSPP	Number of seeds per plant
18	SYPP	Seed yield per plant
19	HSW	Hundred seed weight
20	PY	Plot yield
21	BMPP	Biomass per plant
22	HI	Harvest index

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Introduction

1. INTRODUCTION

Pulses play an important role in Indian agricultural economy because of their high nutritive value and ability to improve soil fertility by fixing atmospheric nitrogen. Pulses produce three times more protein than cereals and contain approximately 18-22 per cent protein and 4-7 per cent fat (Popalghat, 1998). In addition to proteins, it is good source of carbohydrates, minerals and vitamins. Hence, they are primarily important source of dietary requirement, where most of the population is vegetarian and protein malnutrition is of major concern.

Chickpea (*Cicer arietinum* L.), also known as 'Bengalgram', 'Indian pea', 'Chana' and 'Kadale' in Kannada, is an edible legume. It is the only widely cultivated species of the genus *Cicer* and belongs to the sub-family Faboideae of the Fabaceae family. The crop is a cool season self-pollinated, annual, diploid ($2n = 2x = 16$), food legume with a relatively small genome size of 740 Mbp (Arumuganathan and Earle, 1991). Ladizinsky and Adler (1976) regarded *C. reticulatum* as the wild progenitor of chickpea based on cytogenetical and seed protein analysis and consequently nominated South Eastern Turkey as its centre of origin.

Chickpea (*Cicer arietinum* L.) is the third leading grain legume in the world and first in the South Asia. Ninety two percent of the area and eighty nine percent of the grain production concentrated in semi-arid tropical countries. Its range of cultivation extends from the Mediterranean basin to the Indian sub-continent and southward of Ethiopia to the East African highlands. Two types of chickpea viz., Kabuli or macrosperma grown in temperate land mediterranean regions, while the desi type or microsperma are grown in the semi-arid tropics (Muehlbauer and Singh, 1987).

Chickpea is the principal *rabi* pulse crop and important source of calories and protein in India, grown predominantly in the vast rainfed areas of the country. Desi chickpea has a very low 'glycemic index' making it a healthy food source for people with diabetes (Walker and Walker, 1984). It also helps in replenishment of soil fertility by fixing of atmospheric nitrogen through symbiosis coupled with deep root system.

Chickpea contributes 10.9 million tonnes of grains to the global food basket with area coverage of 12.9 million ha (Anonymous, 2014). India ranks first in terms of production and

productivity, followed by Pakistan, Turkey, Iran, Myanmar, Ethiopia, Mexico, Australia, Canada and the United States. India is the leading producer (67 % share in global chickpea production) as well as consumer of chickpea. Chickpea has a major share among pulse crops (40 % of total pulse production) in India. More than two-third (67 %) of the total chickpea area in the country lies in central and southern India (Madhya Pradesh, Maharashtra, Andhra Pradesh and Karnataka). In India, Chickpea covers an area of 7.40 m ha with annual production of 8.25 m tonnes and productivity 889 kg/ha. In Karnataka the crop grown on an area of 9.4 lakh ha and with production of 6.7 lakh tonnes and productivity is 718 kg/ha (Anonymous, 2014).

Majority of chickpea area falls under semi-arid tropic (SAT) region of the world, where the crop is exposed to several biotic and abiotic stresses including weed competition; the crop productivity is seriously challenged. Chickpea is a poor competitor to weeds because of slow growth rate at early stages of crop growth and establishment. Weeds compete with chickpea plants for water, nutrients, sunlight, and space and also harbour insect-pests and diseases. If left uncontrolled, weeds can reduce chickpea yield significantly. Weeds have become a serious problem in both autumn-sown and winter-grown chickpeas and also if the crop is grown under irrigated conditions. Significant yield losses (up to 84 %) due to weeds have been reported in chickpea, more severely (up to 98 %) in autumn-sown chickpea. Thus, weed management is crucial in chickpea to realize maximum yields and also to maintain high quality of produce.

Hand weeding and mechanical weed control methods traditionally followed in the developing countries are becoming expensive due to increased labour wages as well as shortage of agricultural labour. Because of the sensitivity of chickpea to herbicides, most effective are the pre-emergence herbicides, and choices for post-emergence herbicides are limited. The pre-emergence herbicides are effective in controlling weeds at early stage of seedling growth, but weeds germinating after crop emergence become dominant in the field and cause substantial yield losses. Therefore, chickpea cultivars with improved herbicide tolerance, which can offer greater flexibility for use of post-emergence herbicides, are required by the farmers.

Keeping these points in view, an attempt has been made in the present investigation to study the genetic variability in chickpea (*Cicer arietinum* L.) for herbicide tolerance with the following objectives:

1. Screening the chickpea genotypes for herbicide tolerance and yield.
2. Studies on genetic variability, character association and path analysis for phenological and yield traits under herbicide sprayed and unsprayed condition.

Review of Literature

2. REVIEW OF LITERATURE

The research carried out in the past on screening the chickpea genotypes for herbicide tolerance and genetic variability, character association and path analysis and related aspects to the present study have been reviewed briefly and presented under following headlines.

2.1. Screening the chickpea genotypes for herbicide tolerance and yield.

2.2. Studies on genetic variability, character association and path analysis.

2.2.1 Genetic variability and character association

2.2.2 Genetic advance and Heritability

2.2.3 Correlation studies

2.2.4 Path analysis

2.1 Screening the chickpea genotypes for herbicide tolerance and yield

Sullivan *et al.* (1998) reported that in Ontario, Imazamox soil residues were less injurious than imazethapyr soil residues to vegetable crops grown in rotation and resulted in only minor visual injury symptoms and no yield reductions on tomato, potato or cabbage.

Mohammad *et al.* (2007) concluded that in wheat rotational application of bromoxynil plus MCPA at 150 g a.i./ha, 2,4-D plus MCPA, and 2,4-D plus carfentrazone-ethyl at 490 g a.i./ha would be the best option to achieve satisfactory weed control, high grain yield and prevention of evolution of herbicide-resistant weeds.

Grichar *et al.* (2010) revealed that in peanut the high dose of pyraflufen-ethyl, carfentrazone-ethyl and lactofen reduced yield compared with the untreated check.

Taran *et al.* (2010) identified four chickpea accessions with good plant appearance and minor chlorosis at 21 days after application of 35% imazamox and 35% imazethapyr at a rate of 30 g a.i./ha. With further crossing and selection, imidazolinone resistant chickpea cultivars such as CDC Alma and CDC Cory adapted to Western Canadian environments have been developed. However, detailed information on their reaction to imidazolinone application especially under field conditions is lacking. The use of these cultivars may broaden herbicide options for an integrated weed management system in chickpea.

Brandenberger *et al.* (2011) mentioned that halosulfuron did not reduce the emergence of the breeding lines but reduced cowpea emergence. Higher injury (crop stunting, up to 59%)

and reduction in flowering (up to 83%) were observed in Arkansas, but not in Oklahoma. Averaged over herbicide rate, yield was higher and did not differ among cultivars in Arkansas (0.89 to 1.18 Mg/ha²¹) versus Oklahoma (0.36 to 0.82 Mg/ha²¹). Despite observed phytotoxicity symptoms, halosulfuron did not reduce cowpea yield.

Taran *et al.* (2012) results indicated that pre-emergence application of low-rate imazethapyr caused minor levels of injury to the plants and slightly increased ascochyta blight severity, it had only minor effects on plant development and yield compared with sulfentrazone. In contrast, post-emergence applications of imazethapyr, imazamox and metribuzin increased ascochyta blight severity significantly, delayed flowering and maturity and reduced yield. The extent of the effects of pre- and post-emergence herbicide applications varied with cultivars.

Gaur *et al.* (2013) revealed that among 300 genotypes, there was larger genetic variation for tolerance to herbicides imazethapyr & metribuzin, based on average herbicide tolerance scores from 2 experimental locations. Some genotypes were tolerant to imazethapyr, and some were found tolerant to metribuzin. However the sensitivity of genotypes to metribuzin was higher as compared to imazethapyr.

Medeiros *et al.* (2013) concluded that the tolerance of castor bean to trifluralin herbicide is influenced by chemical and physical characteristics of soil. In sandy and sandy loam soils, doses of trifluralin below those commonly used for weed control are sufficient to cause the decrease in the growth of castor bean plants.

Chaturvedi *et al.* (2014) revealed that among 509 chickpea accessions screened during 2011 for the post emergent herbicide Imazethapyr (PursuitTM) tolerance, 31 were most tolerant and 9 were most sensitive. Later these 40 genotypes were re-evaluated during November 2011 to February 2012. Accessions, viz. ICC 1164, IPC 2010-81 and IPC 2008-59 were found to be the most tolerant. Lines such as ICC 8522, ICC 6874 and ICC 5434 were recorded as the most sensitive.

Singh *et al.* (2014) conducted experiment at PAU, Ludhiana on mungbean. The study revealed that application of imazethapyr 100 g/ha at 15 DAS gave the highest gross and net returns followed by imazethapyr at 75 g/ha sprayed at 15 DAS.

Grichar *et al.* (2015) opinioned that castor tolerance to pre-application of acetochlor, clomazone, and pendimethalin was excellent, thus providing the greatest opportunity for future use in castor production.

At Kota., the effect of Imazethapyr 20g/ha post emergent on 10-20 days after sowing was at par with that of Pendimethalin (1.0 kg/ha) PE + one hand weeding at 30 days after sowing in terms of seed yield indicating the role of cost effective herbicide for weed control (Singh, 2014).

Narendrakumar *et al.* (2014) revealed that the increase yield under imazethapyr treated plots in mungbean was mainly due to the increase in plant biomass, nodule number, root weight, number of seed per plant and number of pod per plant. Although, the net return was highest under imazethapyr @ 100 g/ha (Rs. 24, 880/ha) the marginal rate of return was higher in imazethapyr @ 80 g/ha (627 %).

Sajja *et al.* (2015) indicated that time to flowering and maturity was delayed up to 16.5 and 18.5 days, respectively. Herbicide had no effect on primary branches, while the number of secondary branches was increased up to 12. Plant height was severely reduced by 18cm. The reduction in seed yield was observed up to 49 %, whereas 100-seed weight was increased across locations.

Shobha *et al.* (2015) studied residue of imazethapyr in soil and soybean grain and revealed that less residues were found in soils as compared to plant samples. Based on this study a pre-harvest interval of 90–102 days is suggested for soybean crops after imazethapyr application.

Silva *et al.* (2015) studied that in castor two trials were conducted under greenhouse conditions, one with sandy and other with sandy clay loam soil, in a completely randomized design with four replications. The treatments corresponded to five periods between herbicide application and seeding (0, 7, 14, 21 and 28 days) and a control without application. The evaluations made were: plant height at 7, 14, 21 and 28 days after emergence (DAE); stem diameter, leaf area, root volume, dry mass of aerial part and roots at 28 DAE. Halosulfuron-methyl (112.5 g ha^{-1}) is selective to castor bean crop, when applied at pre-emergence modality, before seeding.

Vijayakumar *et al.* (2015) reported that there was increase in number of branches, and took more duration to reach 50 % flowering and maturity in treated plot compared to

unsprayed plot. In treated plot yield reduced significantly in susceptible genotypes, while in resistant genotypes the variation was non-significant indicating that these genotypes could be used as donors in conventional breeding for herbicide tolerance.

Jefferies *et al.* (2016) revealed that susceptibility to IMI herbicides was noted with a delay in flowering and maturity. Results also showed that potential to use IMI herbicides in the resistant chickpea cultivars, expanding the currently limited options for broadleaf weed control in chickpea cultivation.

Antônio *et al.* (2017) studied that weed control prior to crop emergence, the herbicides Diuron, S-metolachlor, Metribuzin, Diquat dibromide and Sulfentrazone gave promising results. In addition to these products, Clethodim and Haloxypop-p-methyl should be noted as potential post-emergent herbicides for cowpea.

2.2. Studies on genetic variability, character association and path analysis.

2.2.1 Genetic variability and character association

In chickpea substantial variability does exist, but much of it cannot be used directly as it is mostly associated either with low yield or poor seed features, making it unacceptable by the consumers. Hence, the information on the magnitude of variability for different quantitative and qualitative traits along with their heritability and relationship with yield in any crop species plays a vital role in formulating efficient breeding programme. Understanding the relationships between yield and yield components is critical for utilizing these relationships effectively and thus developing desirable varieties.

2.2.2 Genetic advance and heritability

In a highly self-pollinated crop like chickpea, the breeding strategy for varietal development generally involves selection of potential genotypes from the existing germplasm, utilizing them in the hybridization programme and isolation of superior recombinants in the segregating population. This necessitates a thorough knowledge of genetic variability, heritability and the genetic advance and gains made there of that can be achieved through selection. The available information on variability, heritability and genetic advance is summarized in Tables 1 and 2 respectively.

Table 1: Summary of review on variability for various traits in chickpea

Sl. No.	Character	Variability	Material studied	Reference
1.	Plant height	High	10 exotic genotypes 16 cultivars 20 genotypes 31 genotypes 32 genotypes 28 genotypes 20 genotypes 20 genotypes	Wahid and Ahmed (1999) Sial <i>et al.</i> (2003) Sharma <i>et al.</i> (2005) Sharaan <i>et al.</i> (2008) Babar <i>et al.</i> (2008) Sharma and Saini (2010) Ali <i>et al.</i> (2011) Akthar <i>et al.</i> (2011)
		Low	17 genotypes 38 genotypes	Hasan <i>et al.</i> (2008) Thakur <i>et al.</i> (2015)
2.	Number of branches per plant	High	2 crosses CP-9623 × T39-1 and RS-11 × T39-1 20 genotypes 360 landraces and lines 31 genotypes 20 genotypes 20 genotypes 28 genotypes	Vijayalakshmi <i>et al.</i> (2000) Sharma <i>et al.</i> (2005) Farshadfar and Farshadfar (2008) Sharaan <i>et al.</i> (2008) Ali <i>et al.</i> (2009) Malik <i>et al.</i> (2009) Sharma and Saini (2010)
		Moderate	17 genotypes 20 genotypes	Hasan <i>et al.</i> (2008) Ali <i>et al.</i> (2011)
		Low	38 genotypes	Thakur <i>et al.</i> (2015)
3.	100 Seed weight	High	50 genotypes 40 cultivar 2 crosses CP -9623 × T39-1 and RS-11 × T39-1 40 genotypes 36 genotypes 33 genotypes 14 genotypes 20 genotypes 15 Kabuli genotypes 18 elite genotypes & 2 vari., 25 genotypes 31 genotypes 32 genotypes 4 varieties 28 genotypes 20 genotypes 106 genotypes 12 genotypes 100 breeding line 144 diverse genotypes	Kumar <i>et al.</i> (2001) Nimbalkar (2000) Vijayalakshmi <i>et al.</i> (2000) Arora and Jeena (2001) Jeena and Arora (2001) Yadav <i>et al.</i> (2003) Burli <i>et al.</i> (2004) Sharma <i>et al.</i> (2005) Yucel <i>et al.</i> (2006) Saleem <i>et al.</i> (2005) Dwevedi <i>et al.</i> (2009) Sharaan <i>et al.</i> (2008) Babar <i>et al.</i> (2008) Bicer (2009) Sharma and Saini (2010) Ali <i>et al.</i> (2011) Jivani <i>et al.</i> (2012) Stuti and Anita (2014) Rajkumar <i>et al.</i> (2014) Kumar <i>et al.</i> (2016)

Table 1: Contd.....

Sl. No.	Character	Variability	Material studied	Reference
4.	Number of pods per plant	High	40 lines derived via intervarietal multiple crosses 100 genotypes 50 genotypes 20 genotypes 31 genotypes 362 accessions 24 kabuli genotypes 18 elite genotypes & 2 vari., 17 genotypes 360 landraces and lines 32 genotypes 25 genotypes 28 genotypes 162 RILs 20 genotypes 106 genotypes 12 genotypes 100 breeding lines 144 diverse genotypes	Rao (1996) Tripathi (1998) Kumar <i>et al.</i> (1999) Sharma <i>et al.</i> (2005) Sharaan <i>et al.</i> (2008) Kumar <i>et al.</i> (2001) Naghavi (2005) Saleem <i>et al.</i> (2005) Hasan <i>et al.</i> (2008) Farshadfar and Farshadfar (2008) Babar <i>et al.</i> (2008) Dwevedi <i>et al.</i> (2009) Sharma and Saini (2010) Sidramappa <i>et al.</i> (2010) Ali <i>et al.</i> (2011) Jivani <i>et al.</i> (2012) Stuti and Anita (2014) Rajkumar <i>et al.</i> (2014) Kumar <i>et al.</i> (2016)
		Low	17 genotypes	Hasan <i>et al.</i> (2008)
		High	40 lines derived via intervarietal multiple crosses 30 F4 progenies 100 genotypes 50 genotypes 10 exotic genotypes 40 genotypes obtained by single, double and multiple crosses 36 diverse genotype 136 genotypes 30 genotypes 33 diverse genotype 14 genotype F3 progenies and biparental population 362 accessions 20 genotypes	Rao (1996) Wanjari <i>et al.</i> (1996) Tripathi (1998) Kumar <i>et al.</i> (1999) Wahid and Ahmed(1999) Rao and Kumar (2000) Jeena and Arora (2001) Hegde <i>et al.</i> (2002) Sable <i>et al.</i> (2002) Yadav <i>et al.</i> (2003) Burli <i>et al.</i> (2004) Singh (2004) Naghavi and Johansour (2005) Sharma <i>et al.</i> (2005) Obaidullah <i>et al.</i> (2006,) Hasan <i>et al.</i> (2008)

Table 1: Contd.....

Sl. No.	Character	Variability	Material studied	Reference
			12 lines 17 genotypes 360 landraces and lines 32 genotypes 18 elite genotypes and 2 varieties 4 varieties 20 genotypes 28 genotypes 20 genotypes 20 genotypes 106 genotypes 12 genotypes 100 breeding lines 38 genotypes 144 genotypes	Farshadfar and Farshadfar (2008) Babar <i>et al.</i> (2008) Saleem <i>et al.</i> (2005) Bicer (2009) Malik <i>et al.</i> (2009) Sharma and Saini (2010) Ali <i>et al.</i> (2011) Akthar <i>et al.</i> (2011) Jivani <i>et al.</i> (2012) Stuti and Anita (2014) Rajkumar <i>et al.</i> (2014) Thakur <i>et al.</i> (2015) Kumar <i>et al.</i> (2016)
5.	Seed yield per plant	Moderate	2 crosses CP -9623 × T39-1 and RS-11 × T39-1	Vijayalakshmi <i>et al.</i> (2000)
6.	Harvest index	high	106 genotypes 12 genotypes 100 breeding lines	Jivani <i>et al.</i> (2012) Stuti and Anita (2014) Rajkumar <i>et al.</i> (2014)

Table 2: Summary of review on heritability and genetic advance for various traits in chickpea

Sl. No.	Character	Heritability	Reference	Genetic advance	Reference
1	Plant height	High	Arshad <i>et al.</i> (2002), Singh <i>et al.</i> (2002), Burli <i>et al.</i> (2004), Saleem <i>et al.</i> (2005), Sharma <i>et al.</i> (2005), Hasan <i>et al.</i> (2008), Babar <i>et al.</i> (2008), Sharma and Saini (2010), Ali <i>et al.</i> (2011) and Akthar <i>et al.</i> (2011). Kumar <i>et al.</i> (2016)	High	Arshad <i>et al.</i> (2002), Sharma <i>et al.</i> (2005), Hasan <i>et al.</i> (2008), Babar <i>et al.</i> (2008), Sharma and Saini (2010) and Ali <i>et al.</i> (2011)
		Moderate	Sharaan <i>et al.</i> (2008)	Moderate	Saleem <i>et al.</i> (2005)
		Low	Thakur <i>et al.</i> (2015)	Low	Singh <i>et al.</i> (2002)
2	No. of branches	High	Wahid and Ahmed (1999), Khorgade <i>et al.</i> (1985), Kampli <i>et al.</i> (2002) and Sial <i>et al.</i> (2003)	High	Arora and Jeena (2001), Kampli <i>et al.</i> (2002), Sharma <i>et al.</i> (2005), Hasan <i>et al.</i> (2008) and Sharma and Saini (2010)
				Moderate	Vijayalakshmi <i>et al.</i> (2000)
			Vijayalakshmi <i>et al.</i> (2000), Babar <i>et al.</i> (2008), Sharma <i>et al.</i> (2005) and Sharma and Saini (2010)	Low	Arshad <i>et al.</i> (2002), Singh <i>et al.</i> (2002) Ali <i>et al.</i> (2011) and Thakur <i>et al.</i> (2015)
		Low	Arshad <i>et al.</i> (2002), Sharaan <i>et al.</i> (2008) and Ali <i>et al.</i> (2011), Thakur, <i>et al.</i> (2015)		
3.	Days to first flowering	High	Stuti and Anita (2014), Puri <i>et al.</i> (2013)	High	Stuti and Anita (2014), Puri <i>et al.</i> (2013)
4.	Daysto 50% flowering	High		High	Khorgade <i>et al.</i> (1985), Govil and Kumar (1989), Jahagirdar <i>et al.</i> (1996), Burli <i>et al.</i> (2004) and Hasan <i>et al.</i> (2008)

Table 2: Contd.....

Sl. No.	Character	Heritability	Reference	Genetic advance	Reference
			Jahagirdar <i>et al.</i> (1996), Kumar and Krishna (1998), Singh <i>et al.</i> (2002), Sial <i>et al.</i> (2003), Arshad <i>et al.</i> (2004), Burli <i>et al.</i> (2004), Bicer and Dogan (2008), Misra (1991), Sharma <i>et al.</i> (2005), Sharaan <i>et al.</i> (2008), Hasan <i>et al.</i> (2008) and Sharma and Saini (2010), and Puri <i>et al.</i> (2013)	Low	Singh <i>et al.</i> (2002), Arshad <i>et al.</i> (2004), Sharma <i>et al.</i> (2005) and Sharma and Saini (2010)
5.	Days to maturity	High	Puri <i>et al.</i> (2013)	High	Puri <i>et al.</i> (2013)
6.	100 seed weight	High	Jahagirdar <i>et al.</i> (1996), Mathur and Mathur (1996), Wanjari <i>et al.</i> (1996), Kumar and Krishna (1998), Kumar <i>et al.</i> (1999), Nimbalkar (2000), Jeena and Arora (2001), Arora and Jeena (2001), Singh <i>et al.</i> (2002), Sable <i>et al.</i> (2002), Arshad <i>et al.</i> (2004), Burli <i>et al.</i> (2004), Kaur <i>et al.</i> (2004), Jeena <i>et al.</i> (2005), Saleem <i>et al.</i> (2005), Sharma <i>et al.</i> (2005), Bicer and Dogan (2008), Hasan <i>et al.</i> (2008), Babar <i>et al.</i> (2008), Sharma and Saini (2010) Varshney <i>et al.</i> (2014b), Jivani <i>et al.</i> (2012), Thakur, <i>et al.</i> (2015), Puri <i>et al.</i> (2013) and Kumar <i>et al.</i> (2016)	High	Jahagirdar <i>et al.</i> (1996), Mathur and Mathur (1996), Kumar <i>et al.</i> (1999) Nimbalkar (2000), Arora and Jeena (2001), Jeena and Arora (2001), Singh <i>et al.</i> (2002), Sable <i>et al.</i> (2002), Sial <i>et al.</i> (2003), Burli <i>et al.</i> (2004), Jeena <i>et al.</i> (2005), Sharma <i>et al.</i> (2005), Hasan <i>et al.</i> (2008), Babar <i>et al.</i> (2008), Sharma and Saini (2010) Ali <i>et al.</i> (2011), Jivani <i>et al.</i> (2012), Thakur <i>et al.</i> (2015), Puri <i>et al.</i> (2013) and Kumar <i>et al.</i> (2016)
				Moderate	Kaur <i>et al.</i> (2004), Jivani <i>et al.</i> (2012)
				Low	Arshad <i>et al.</i> (2004) and Saleem <i>et al.</i> (2005)

Table 2: Contd.....

Sl. No.	Character	Heritability	Reference	Genetic advance	Reference
		Moderate	Vijayalakshmi <i>et al.</i> (2000), Sharaan <i>et al.</i> (2008) and Ali <i>et al.</i> (2011)		
7.	No. of pods	High	Jahagirdar <i>et al.</i> (1996), Kumar <i>et al.</i> (1999), Kumar <i>et al.</i> (2001), Singh <i>et al.</i> (2002), Jeena <i>et al.</i> (2005), Bicer and Dogan (2008), Saleem <i>et al.</i> (2005), Babar <i>et al.</i> (2008), Dwevedi <i>et al.</i> (2009), Sharma <i>et al.</i> (2005), Sharma and Saini (2010) Ali <i>et al.</i> (2011), Jivani <i>et al.</i> (2012), Stuti and Anita (2014), and Kumar <i>et al.</i> (2016)	High	Jahagirdar <i>et al.</i> (1996), Tripathi (1998), Kumar <i>et al.</i> (1999), Kumar <i>et al.</i> (2001), Arshad <i>et al.</i> (2002), Sial <i>et al.</i> (2003), Jeena <i>et al.</i> (2005), Sharma <i>et al.</i> (2005), Babar <i>et al.</i> (2008), Dwevedi <i>et al.</i> (2009), Sharma and Saini (2010) and Ali <i>et al.</i> (2011), Jivani <i>et al.</i> (2012), Stuti and Anita (2014), Puri <i>et al.</i> (2013)
				Moderate	Singh <i>et al.</i> (2002) and Hasan <i>et al.</i> (2008)
				Low	Saleem <i>et al.</i> (2005)
		Moderate	Wahid and Ahmed (1999), Sial <i>et al.</i> (2003), Sharaan <i>et al.</i> (2008) and Hasan <i>et al.</i> (2008)		
		Low	Arshad <i>et al.</i> (2002)		
8.	Seed yield per plant	High	Jahagirdar <i>et al.</i> (1996), Mathur and Mathur (1996), Kumar <i>et al.</i> (1999), Singh <i>et al.</i> (2002), Sable <i>et al.</i> (2002), Deshmukh <i>et al.</i> (2004), Jeena <i>et al.</i> (2005), Saleem <i>et al.</i> (2005), Bicer and Dogan (2008), Sharma <i>et al.</i> (2005), Ali <i>et al.</i> (2011), Sharaan <i>et al.</i> (2008) , Babar <i>et al.</i> (2008), Sharma and Saini (2010)	High	Jahagirdar <i>et al.</i> (1996), Mathur and Mathur (1996), Tripathi (1998), Kumar <i>et al.</i> (1999), Sable <i>et al.</i> (2002), Sial <i>et al.</i> (2003), Jeena <i>et al.</i> (2005), Sharma <i>et al.</i> (2005), Babar <i>et al.</i> (2008), Sharma and Saini (2010), Jivani <i>et al.</i> (2012), Stuti and Anita (2014), Puri <i>et al.</i> (2013)

Table 2: Contd.....

Sl. No.	Character	Heritability	Reference	Genetic advance	Reference
			Akthar <i>et al.</i> (2011) Varshney <i>et al.</i> (2014b), Jivani <i>et al.</i> (2012), Stuti and Anita (2014), and Puri <i>et al.</i> (2013)		
		Moderate	Wanjari <i>et al.</i> (1996), Kumar and Krishna (1998) and Wahid and Ahmed (1999)	Moderate	Vijayalakshmi <i>et al.</i> (2000)
		Low	Arshad <i>et al.</i> (2002) and Sial <i>et al.</i> (2003)	Low	Arshad <i>et al.</i> (2002) and Saleem <i>et al.</i> (2005)
9.	Harvest Index	High	Varshney <i>et al.</i> (2014b), Jivani <i>et al.</i> (2012), Stuti and Anita (2014),	High	Jivani <i>et al.</i> (2012), Stuti Mishra and Anita Babbar (2014)
		Low	Thakur <i>et al.</i> (2015)	Low	Thakur <i>et al.</i> (2015)

2.2.3 Correlation studies

The correlation studies are helpful in formulating efficient breeding programme for multiple trait selection. Correlation coefficient measures the mutual relationship between various plant characters and gives reasonable indication to plant breeders to base his selection on most related characters to improve economic yield. In crop like chickpea, where production of hybrid is impractical and hybridization followed by selection is the main procedure for improvement, the knowledge on correlation is an obligate necessity for achieving genetic improvement. The importance of correlation study in selection programme is appreciable when highly heritable characters are associated with important characters like yield which has low heritability. The previous work on the correlation of characters in chickpea is briefly reviewed as under Table 3.

2.2.4 Path analysis

Selection for yield to improve productivity most often will not be fruitful, since it is a highly complex trait. However, improvement in productivity can be brought about by effecting selection for its closely associated component traits. In order to plan such selection strategy, information on the nature and magnitude of association of the component traits with productivity is a basic pre-requisite. The literature available on the path analysis in chickpea is summarized in Table 4.

Table 3: Summary of correlation among yield and yield related traits with seed yield in chickpea

SI No	Character	Correlation	References
1	Plant height	Positive	Arora <i>et al.</i> (2003), Arshad <i>et al.</i> (2004), Brar <i>et al.</i> (2004), Ciftci <i>et al.</i> (2004), Toker and Cagragan (2004), Jeena <i>et al.</i> (2005), Obaidullah <i>et al.</i> (2006), Yucel <i>et al.</i> (2006), Hasan <i>et al.</i> (2008), Farshadfar and Farshadfar (2008), Sidramappa <i>et al.</i> (2008), Meena <i>et al.</i> (2010), Kobraee <i>et al.</i> (2010) and Akthar <i>et al.</i> (2011), Zali <i>et al.</i> (2011), Anita <i>et al.</i> (2012), Kanouni <i>et al.</i> (2012), Nihal kayan and Sait Adak (2012), Samad (2014), Rajkumar <i>et al.</i> (2014), Parhe <i>et al.</i> (2014)
		Negative	Kumar <i>et al.</i> (1999), Kumar <i>et al.</i> (2002) and Ali <i>et al.</i> (2011)
2	No. of branches	Positive	Vijayalakshmi <i>et al.</i> (2000), Arora <i>et al.</i> (2003), Brar <i>et al.</i> (2004), Ciftci <i>et al.</i> (2004), Qureshi <i>et al.</i> (2004), Toker and Cagragan (2004), Obaidullah <i>et al.</i> (2006), Sharaan <i>et al.</i> (2008), Hasan <i>et al.</i> (2008), Babar <i>et al.</i> (2008), Sidramappa <i>et al.</i> (2008), Malik <i>et al.</i> (2009), Sharma and Saini (2010), Meena <i>et al.</i> (2010) and Ali <i>et al.</i> (2011), Zali <i>et al.</i> (2011), Dar <i>et al.</i> (2012), Rajkumar <i>et al.</i> (2014), Parhe <i>et al.</i> (2014), Sharanappa <i>et al.</i> (2014), Saeed <i>et al.</i> (2016)
		Negative	Yadav and Sharma (1998) and Yadav <i>et al.</i> (2001)
3.	Days to first flowering	Positive	Stuti and Anita (2014),
4	50% flowering	Positive	Saleem <i>et al.</i> (2002), Ali <i>et al.</i> (2011), Babar <i>et al.</i> (2008), Sidramappa <i>et al.</i> (2008) and Sharma and Saini (2010), Samad (2014)
		Negative	Yadav and Sharma (1998), Yadav <i>et al.</i> (2001), Bhaduoria <i>et al.</i> (2003), Sial <i>et al.</i> (2003), Sharma <i>et al.</i> (2005), Jeena and Arora (2007) and Sharma and Saini (2010) and Varshney <i>et al.</i> (2014b), Stuti and Anita (2014),
5.	Days to maturity	Positive	Thakur <i>et al.</i> (2015)
6.	100 seed weight	Positive	Yadav and Sharma (1998), Sial <i>et al.</i> (2003), Toker and Cagragan (2004), Sharma <i>et al.</i> (2005), Jeena and Arora (2007) and Sharma and Saini (2010), Hussain <i>et al.</i> (2016)

Table 3: Contd.....

SI No	Character	Correlation	References
		Negative	Vijayalakshmi <i>et al.</i> (2000), Narayana and Reddy (2002), Saleem <i>et al.</i> (2002), Arora <i>et al.</i> (2003), Sial <i>et al.</i> (2003), Yadav <i>et al.</i> (2003), Arshad <i>et al.</i> (2004), Brar <i>et al.</i> (2004), Ciftci <i>et al.</i> (2004), Qureshi <i>et al.</i> (2004), Toker and Cagragan (2004), Jeena <i>et al.</i> (2005), Rao and Rao (2005), Obaidallah <i>et al.</i> (2006), Yucel <i>et al.</i> (2006), Farshadfar and Farshadfar (2008), Babar <i>et al.</i> (2008), Sidramappa <i>et al.</i> (2008), Ali <i>et al.</i> (2009), Meena <i>et al.</i> (2010), Malik <i>et al.</i> (2009), Yucel and Anlarsal (2010), Kobraee <i>et al.</i> (2010), Sharma and Saini (2010), Ali <i>et al.</i> (2011), Akthar <i>et al.</i> (2011) and Varshney <i>et al.</i> (2014b), Jivani <i>et al.</i> (2013), Stuti and Anita (2014), Zali <i>et al.</i> (2011), Abhishek (2012), Babbar <i>et al.</i> (2012), Kanouni <i>et al.</i> (2012). Nihal kayan and Sait Adak (2012), Samad (2014), Rajkumar <i>et al.</i> (2014), Parhe <i>et al.</i> (2014), Sharanappa <i>et al.</i> (2014), Thakur <i>et al.</i> (2015)
7.	Pods/plant	Positive	Anita <i>et al.</i> (2012), Monpara and Gaikwad (2014), and Samad (2014)
8.	Seeds/Plant	Positive	Jivani <i>et al.</i> (2013), Stuti and Anita (2014), Abhishek (2012), Sharanappa <i>et al.</i> (2014), Singh <i>et al.</i> (2014), and Puri <i>et al.</i> (2013).
9.	Harvest index	Positive	Jivani <i>et al.</i> (2013), Stuti and Anita (2014), Abhishek (2012), Sharanappa <i>et al.</i> (2014), Singh <i>et al.</i> (2014), and Puri <i>et al.</i> (2013).

Table 4: Review of literature on path coefficient analysis for various character combinations in chickpea

Author and Year	No of genotypes	Character	Type of correlation	Correlated with
Singh <i>et al.</i> (1999)	30	Number of pods per pant and 100-seed weight	Direct and Positive	Seed yield
		Primary and secondary branches	Indirect	Seed yield
Kheder and Maloo (1999)	40	Pods per plant, seeds per pod, 100-seed weight and primary branches per plant	Direct and Positive	Seed yield
Singh and Singh (2002)	40	Test weight and secondary branches	Direct and negative	Seed yield
		Pods per plant	Indirect and Positive	Seed yield
Kumar <i>et al.</i> (1999)	50	Number of pods per plant and 100-seed weight	Direct and negative	Seed yield
		Biological yield per plant and harvest index	Indirect	Seed yield
Singh <i>et al.</i> (2001)	34	Total biological yield	Direct and Positive	Seed yield
		Number of pods, days to maturity while, 100-seed weight, number of primary branches, days to flowering	Direct and negative	Seed yield
Pratap <i>et al.</i> (2002)	57	Biological yield, number of pods per plant and harvest index	Direct and Positive	Seed yield
Narayana and Reddy (2002)	31	Number of pods per plant, 100-seed weight, number of seeds per pod and harvest index	Direct and Positive	Seed yield
Ciftci <i>et al.</i> (2004)	14	Biological yield, harvest index and number of seeds per plant	Direct and Positive	Seed yield
Kumar <i>et al.</i> (2003)	26	Harvest index, Direct and Positive	Direct and Positive	Seed yield
Arora <i>et al.</i> (2003)	80	Biological yield per plant, harvest index, pods per plant, 100-seed weight and seeds per pod	Direct and Positive	Seed yield
Yadav <i>et al.</i> (2003)	30	Pods per plant, number of seeds per pod, 100-seed weight and biological yield	Direct and Positive	Seed yield

Table 4: Contd.....

Author and Year	No of genotypes	Character	Type of correlation	Correlated with
Rao and Rao (2005)	30	Total dry matter per plant, harvest index, No of pods per plant	Direct and Positive	Seed yield
Derya <i>et al.</i> (2006)	15	Secondary branches per plant, primary branches per plant and plant height	Indirect	Seed yield
		Days to flowering, first pod height, and total pod number,	Indirect and Negative	Seed yield
Hasan <i>et al.</i> (2008)	21	Number of seeds and full pods	Direct and Positive	Seed yield/plant
		Number of grains per plant, 100 seed weight	Direct and Positive	Seed yield/plant
Yucel <i>et al.</i> (2006)	15	Days to flowering, first pod height and total pod number	Indirect and Negative	Seed yield/plant
Babar <i>et al.</i> (2008)	32	Pods per plant and 100 seed weight	Direct and Positive	Seed yield/plant
Farshadfar <i>et al.</i> (2008)		Number of pods, number of seed and 100 seed weight	Direct and Positive	Seed yield
Sidramappa <i>et al.</i> (2008)		Number of pods per plant, 100 seed weight, plant height and days to 50 per cent flowering	Direct and Positive	Seed yield
Ali <i>et al.</i> (2009)	20	Days to flowering, days to maturity and secondary branches e	Indirect and Negative	Seed yield/plant
Sharma <i>et al.</i> (2010)	28	Biological yield, number of seeds per pod, 100-grain weight	Direct and Positive	Seed yield/plant
		Number of pods per plant and number of branches per plant	Direct and Positive	Seed yield
Kobraee <i>et al.</i> (2010)		Number of seeds per plant and number of pods per plant	Direct and Positive	Seed yield
Biabani <i>et al.</i> (2010)		Filled pod per plant	Direct and Positive	Seed yield
Yucel <i>et al.</i> (2010)	22	Harvest index	Direct and Positive	Seed yield
Akhtar <i>et al.</i> (2011)	20	100 seed weight, plant height and no. of pods per plant	Direct and Positive	Seed yield
Ali and Muhammad (2011)	80	100-seed weight and biomass per plant	Direct and Positive	Seed yield/plant
Zali <i>et al.</i> (2011)	17	Number of seeds per plant and 100-seed weight	Direct and Positive	Seed yield

Table 4: Contd.....

Author and Year	No of genotypes	Character	Type of correlation	Correlated with
Abhishek Kumar (2012)		Plant height, days to 50% flowering and number of pods/plant	Direct and Positive	Seed yield
Jivani <i>et al.</i> (2012)	105	Harvest index, biological yield per plant, number of pods per plant, and 100-seed weight	Direct and Positive	Seed yield
Kanouni <i>et al.</i> (2012)	60	Drought tolerance score, 100-seed weight, plant height and pods per plant, Vigour, days to maturity and 100-seed weight	Direct and Positive	Seed yield/plant
Nihal Kayan and Sait Adak (2012)		Plant height, biological yield per plant and pods per plant	Direct and Positive	Seed yield
Dar <i>et al.</i> (2012)		Number of pods/plant, number of branches/plant, plant height and 100-seed	Direct and Positive	Seed yield
Kumara <i>et al.</i> (2012)	32	Biological yield, harvest index, test weight	Direct and Positive	Seed yield/plant
Puri <i>et al.</i> (2013)	42	Harvest index and biological yield	Direct and Positive	Seed yield
Monpara and Gaikwad (2014)	3 segregating populations	Number of seeds per plant (0.672 to 0.821) and 100-seed weight	Direct and Positive	Seed yield/plant
Samad (2014)	8	Biological yield per plant and harvest index	Indirect and Positive	Seed yield
		Number of seeds per plant	Direct and Positive	Seed yield
Rajkumar <i>et al.</i> (2014)	100 advance breeding lines	Pods per plant and 100- seed weight	Direct and Positive	Seed yield
Parhe <i>et al.</i> (2014)		100 seed weight, number of pods plant and number of secondary branches plant	Direct and Positive	Seed yield
Stuti and Anita (2014)	12	Number of effective pods per plant	Direct and Positive	Seed yield
Chandra <i>et al.</i> (2015)	seven mutagenic populations	Height and number of primary branches	Negative	Seed yield
Thakur <i>et al.</i> (2015)	38	Plant population plot-1	Direct and Positive	Seed yield

Material and Methods

3. MATERIAL AND METHODS

The present investigation was carried out during *Rabi* 2016-2017 to assess herbicide tolerance in Chickpea (*Cicer arietinum* L.). The details of the experimental material and techniques adopted in the present investigation are presented below.

3.1. Experimental site

The experiment was conducted at block number 7 of plant breeding experimental block of AICRP-DA, Regional Agricultural Research Station (RARS), Vijayapur.

3.2. Climate

Vijayapur is situated at 16°49' N latitude, 75°43' E longitude and at 593 m elevation. Vijayapur comes under Northern dry zone of Karnataka with an annual rainfall of 590.7 mm. The soil type and climatic conditions are well suited for chickpea cultivation. The climate during *rabi* 2016-17 is presented in Appendix I.

3.3. Experimental details

The investigation was carried out during *rabi* season 2016. The experimental material consisted of 120 germplasm lines including mutant lines, segregating material and accessions of wild species/lines. The design adopted was randomized block design. Each genotype was planted in a single row of 4 m length with a spacing of 30 x 10 cm in three replication. The recommended cultivation practices were followed to maintain healthy plant population. Observations were recorded on five randomly selected plants in both control and treated plot.

3.4. Recording of observations

3.4.1 Days to first flowering

The number of days taken from the sowing date to the date when first flower appears in any of the plant in each genotype or plot was recorded as days to first flowering.

3.4.2 Days to fifty per cent flowering

The number of days taken from the sowing date to the date when fifty per cent of the plants flower in each genotype or plot was recorded as days to fifty per cent flowering.

3.4.3 Days to first podding

The number of days taken from the sowing date to the date when first pod forms in any of the plant in each genotype or plot was recorded as days to first podding.

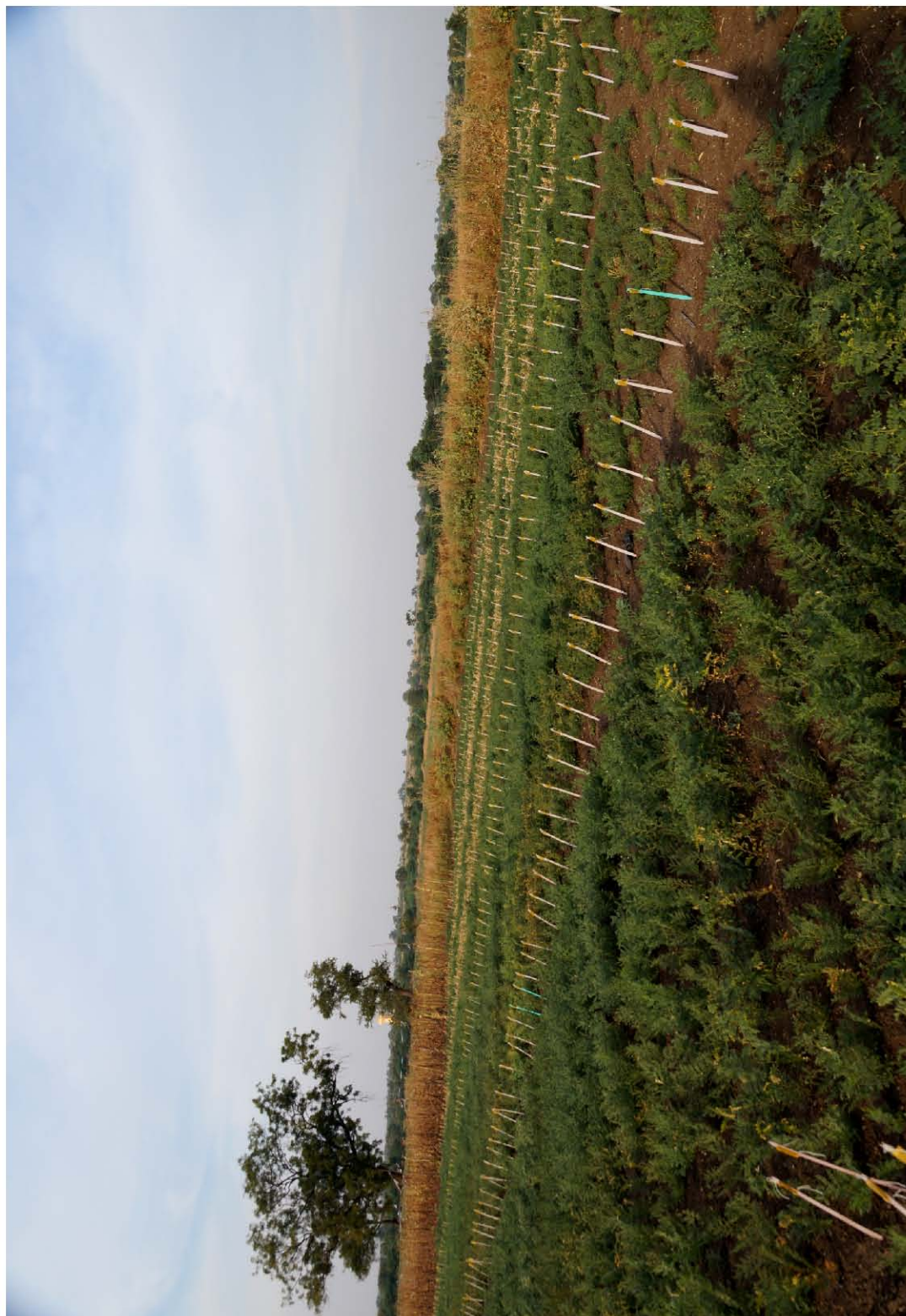


Plate 1: General view of the plot

3.4.4 Days to fifty per cent podding

The number of days taken from the sowing date to the date when fifty per cent of the plants forms pod in each genotype or plot was recorded as days to fifty per cent podding.

3.4.5 Days to fifty per cent pod maturity

The number of days taken from sowing to the date when fifty per cent pod maturity when the pod turns yellow in each genotype or plot was recorded.

3.4.6 Plant height

The height of the plant was measured from the ground level to the tip of the longest branch and was measured in centimeter at physiological maturity.

3.4.7 Primary branches per plant

The number of branches arising directly from the main stem were counted and recorded at the time of harvest.

3.4.8 Number of secondary branches

The number of secondary branches develop at buds located on the primary branches were recorded at the time of harvest.

3.4.9 Number of tertiary branches

The number of tertiary branches arise from the secondary branches were recorded at the time of harvest.

3.4.10 Days to maturity

The number of days taken from the sowing to the date when all the plants in each genotype or plot matures completely was recorded as days to maturity.

3.4.11 Number of pods per plant

Total number of filled pods on from randomly identified five plants were counted at maturity and the average was recorded.

3.4.12 Number of seeds per plant

The total number of seeds per plant on five random plants was counted at the time of harvest and the average was recorded as number seeds per plant.

3.4.13 Seed yield per plant

The weight of seeds in grams (g) from five random plants was recorded, averaged and expressed as seed yield per plant.

3.4.14 Biomass per plant (g)

The dry matter weight after removing seeds was recorded as biomass per plant.

3.4.15 Hundred seed weight (g)

Hundred seeds were counted randomly from each genotype and the weight was recorded in grams.

3.4.16 Seed yield per plot (g)

Seed yield of each genotype was weighed and expressed in gram as seed yield per pot

3.4.17 Harvest Index

Harvest Index was calculated by the following formula given by Fischer and Maurer (1978).

$$HI (\%) = \frac{\text{Economic seed yield}}{\text{Total biomass}} \times 100$$

3.5 Membrane disintegration studies

One gram of leaf sample was taken in a test tube with 25ml of deionized water then the test tubes were kept for four hours at room temperature. The electrical conductivity was measure (EC) with a HI 8633 conductivity meter (Hanna Instruments, Germany). The same procedure is followed for both herbicides sprayed (EC_s) and unsprayed (EC_c) population of chickpea to know the amount of leakage occur due to herbicide injury. (Sullivan and Moss, 1979).

$$\% \text{ leakage} = \frac{EC_s - EC_c}{EC_c} \times 100$$

3.6 Herbicide spray

When the crop was 30 days old seedling herbicide spray of Imazethapyr (@1ml/ltr) and carfentrazone-ethyl (approximately @ 48 g/acre) was done. Scoring for herbicide

tolerance was done after 10, 20, 30 days of spraying based on injury caused to the plants. Herbicide injury score scale is as follows.

Herbicide score (1-5 scale): (Gaur *et al.* 2013)

Sl. No.	Scale	Symptoms
1	1	Highly tolerant (excellent plant appearance, no burning/ chlorosis of leaves)
2	2	Tolerant (good plant appearance with minor burning/ chlorosis of leaves)
3	3	Moderately tolerant (fair plant appearance with moderate burning/ chlorosis of leaves)
4	4	Sensitive (poor plant appearance with severe burning/ chlorosis of leaves) and
5	5	Highly susceptible (complete burning of leaves/ plants)

3.7 Statistical analysis

The mean data of quantitative characters recorded on all the genotypes were subjected to various standard statistical procedures to estimate mean, range, ANOVA, variability parameters, genetic diversity correlation, path and stability analysis. The details are given below.

3.7.1 Mean and Range

On the basis of individual plant observations, the population mean for each character was computed as below.

$$\text{Mean } (\bar{X}) = \frac{\text{Sum of values for a trait of all treatments (genotypes)}}{\text{Total no. of treatments (genotypes)}}$$

The minimum and maximum values on the basis of individual plant observations were used to indicate the range of given character.

3.7.2 Analysis of variance

The data on mean values for all the characters were analyzed for the variance following randomized block analysis as per the outline presented below. The differences among the genotypes were tested by 'F' test as given below.

Where,

r = Number of replication

g = Number of total genotypes

The standard error was calculated as

$$S. EM \pm = \sqrt{EMSS / r}$$

Where,

S. EM = Standard error mean

EMSS= Error mean sum of squares

r = replication

The significance of the differences among the genotypes was tested by table F' value.

3.7.3 Estimation of variance components

Phenotypic and genotypic variance were estimated using the following formula

$$\text{Genotypic variance } (\sigma_g^2) = \frac{\text{MSS (genotype)} - \text{MSS (error)}}{\text{Number of replications}} = \frac{M_2 - M_3}{r}$$

$$\text{Phenotypic variance } (\sigma_p^2) = \text{Genotypic variance } (\sigma_g^2) + \text{Environmental variance } (\sigma_e^2)$$

3.7.4 Coefficients of variability

Both genotypic and phenotypic coefficients of variability were computed as per the method suggested by Burton and Devane (1952).

a. Genotypic coefficient of variability (GCV)

$$GCV = \frac{\sigma_g}{\bar{X}} \times 100$$

b. Phenotypic coefficient of variability (PCV)

$$PCV = \frac{\sigma_p}{\bar{X}} \times 100$$

Where,

σ_g = Genotypic standard deviation

σ_p = Phenotypic standard deviation

X = General mean of the character.

GCV and PCV values were categorized by Shivasubramanian and Menon (1973) as follows,

0-10%: Low

10.1 -20%: Moderate

20.1% and above: High

3.7.5 Heritability (h^2)

Heritability in broad sense was computed as the ratio of the total phenotypic variance to genotypic variance as suggested by Hanson *et al.* (1956) and was expressed as percentage.

$$\text{Heritability } (h^2) = \frac{\sigma_g^2}{\sigma_p^2} \times 100$$

Where,

σ_g^2 = Genotypic variance

σ_p^2 = Phenotypic variance

The heritability percentage was classified by Robinson *et al.* (1949) as follows,

0-30 per cent: Low

30.1-60 per cent: Moderate

60.1 per cent and above: High

3.7.6 Genetic advance (GA)

Genetic advance was estimated by using the formula given by Johnson *et al.* (1955).

$$GA = h^2 k \sigma_p$$

Where,

h^2 = Heritability in broad sense

k = Selection differential which is equal to 2.06 at 5per cent intensity of selection

σ_p = Phenotypic standard deviation

3.7.7 Genetic advance as per cent of mean (GAM)

$$GAM = \frac{GA}{\bar{X}} \times 100$$

Where,

GA = Genetic advance

$\bar{X}$ = General mean of the character

Genetic advance as per cent mean was categorized by Johnson *et al.* (1955) as follows,

0-10 per cent: Low

10.1-20 per cent: Moderate

20.1 per cent and above: High

3.7.8 Character association

The correlation coefficients were worked out to determine the degree of association of a character with yield and also among the yield components. The mean values were used to calculate the phenotypic correlations by using the formula given by Weber and Moorthy (1952).

$$r = \frac{Cov(xy)_p}{\sigma_{px} \times \sigma_{py}} \times 100$$

$$r = \frac{Cov(xy)_g}{\sigma_{gx} \times \sigma_{gy}} \times 100$$

Where,

r = Correlation coefficient

$Cov(xy)$ = Covariance between the characters 'x' and 'y'

σ_{px} and σ_{py} = Phenotypic variance of the character 'x' and 'y' respectively.

Correlation coefficients were compared against 'r' values given in Fisher and Yates (1963) tables at (n-2) degrees of freedom at the probability levels of 0.05 and 0.01 to test for their significance.

3.7.9 Path analysis

Path analysis was carried out by using both phenotypic and genotypic correlation coefficients to know the direct and indirect effects of the components on yield as suggested by Wright (1921) and illustrated by Dewey and Lu (1959). Path coefficients were obtained by solving the simultaneous equations, which express the basic relationship between correlations and path coefficients. The equations are as follows:

$$r_{1y} = a + r_{12} b + r_{13} c + \dots + r_{1I} I$$

$$r_{2y} = r_{21} a + b + r_{23} c + \dots + r_{2I} I$$

$$r_{3y} = r_{31} a + r_{32} b + c + \dots + r_{3I} I$$

$$r_{Iy} = r_{I1} a + r_{I2} b + r_{I3} c + \dots + I$$

Where,

r_{1y} to r_{Iy} = Coefficient of correlation between causal factors 1 to I with dependent characters y.

r_{12} to r_{I1} = Coefficient of correlation among causal factors.

a, b, c...I = Direct effects of characters 'a' to 'I' on the dependent characters 'y'

Residual effect is computed as follows,

$$\text{Residual effect (R)} = 1 - a^2 + b^2 + c^2 + \dots + I^2 + 2abr_{12} + 2acr_{13} + \dots'$$

Experimental Results

4. EXPERIMENTAL RESULTS

Hand weeding and mechanical weed control methods traditionally followed in the developing countries are becoming expensive due to increased labour wages. Further, due to sensitivity of chickpea to herbicides the choices for post-emergence herbicides are limited. The pre-emergence herbicides are effective in controlling weeds at early stage of crop growth, but weeds germinating at later stages become dominant in the field and cause substantial yield losses. Therefore, chickpea cultivars with improved herbicide tolerance, which can offer greater flexibility for use of post-emergence herbicides, are required by the farmers. Hence, the present investigation was carried out to assess the variability for yield related traits and tolerance to post emergent herbicides in chickpea genotypes. Results of the experiments conducted in the present study are given in the following subheadings.

- 4.1 Analysis of variance for yield and yield related traits in unsprayed and herbicide sprayed population of chickpea.
- 4.2 Genetic variability studies in unsprayed and herbicide sprayed population of chickpea genotypes.
- 4.3 Correlation and Path analysis studies in unsprayed and herbicide sprayed population of chickpea genotypes.
- 4.4 Correlation between percent leakage and per cent decrease in yield and yield attributes traits in herbicides Imazethapyr and Carfentrazone-ethyl treated plot

4.1 Analysis of variance for yield and yield related traits in unsprayed and sprayed population of chickpea

4.1.1 Analysis of variance for yield and yield related traits in unsprayed population of chickpea

Assessment of the variability among 120 chickpea genotypes was done in the present investigation. The analysis of variance for yield and yield attributing traits of 120 chickpea genotypes in unsprayed population of chickpea genotypes is presented in Table 5. The differences among the treatments (genotypes) were significant for all the characters studied. Substantial variability was thus available in the germplasm material for yield and yield related traits.

Table 5: Analysis of variance for different characters in chickpea in unsprayed population of chickpea

Characters	Source of variation	PHT	NPB	NSB	NTB	DFFL	DFF	DFPD	DFP	DFPM	DM	PDPL	NSPP	HSW	SYPP	PY	BMPP	HI
Mean Sum of Squares	Replicati -on (d.f=02)	10.62	0.1	0.24	0.54	60.84	68.48	25.2	18.91	54.08	65.62	24.6	6.06	2.85	3.66	1877.9	3	113.95
	Treatme- nts (d.f=119)	26.56 **	0.8**	1.36* *	9.33* *	176.77* *	181.03* *	204.49* *	194.55* *	159.43* *	139.62* *	482.44* *	662**	102.51* *	118.37* *	32655.2 2**	21.09**	295.25* *
	Error (d.f=238)	4.39	0.06	0.31	0.24	53.66	56.68	44.45	46.14	41.51	22.91	21.49	11.54	1.08	1.22	1012.57	1.29	38.25

* and ** indicates significance at 5% and 1% respectively

4.1.2 Analysis of variance for yield and yield related traits in herbicide-Imazethapyr-sprayed population of chickpea

An effort was made to assess the variability among 120 chickpea genotypes yield and yield attributing traits in herbicide Imazethapyr-sprayed population of chickpea genotypes and is presented in Table 6. The mean sum of square due to various sources of variation for quantitative characters indicated significant differences among the genotypes for all the traits under investigation.

4.1.3 Analysis of variance for yield and yield related traits in Carfentrazone-ethyl-sprayed population of chickpea

The analysis of variance for yield and yield attributing traits of 120 chickpea genotypes in herbicide Carfentrazone-ethyl sprayed population of chickpea genotypes is presented in Table 7. The mean sum of squares due to various sources indicated sufficient variability for quantitative characters studied as significant differences among the genotypes were observed for all the traits..

4.2 Genetic variability studies in unsprayed and sprayed population of chickpea genotypes

One hundred and twenty genotypes were assessed for variability and tolerance to herbicides during *rabi* season of 2016-17. The results of experiment are detailed below.

4.2.1 Genetic variability studies in unsprayed population of chickpea

The results pertaining to genetic parameters viz., range, mean, phenotypic coefficient of variation, genotypic coefficient of variation, broad sense heritability (h^2_{bs}), genetic advance and genetic advance over mean (GAM) were computed to know the extent of variability among productivity traits in unsprayed population of chickpea and the same are presented in table.8.

4.2.1.1 Days to first flowering

Mean for days to first flowering was 57.00 days, with a range of 40.66 to 77.33 days. The coefficients of variations in terms of both genotypic (11.22) and phenotypic (17.04) were moderate. The heritability (43 %) estimates was moderate with low value of genetic advance (8.69) and moderate value of genetic advance over mean (15.22) was observed for this trait.

Table 6: Analysis of variance for different characters in chickpea in Imazethapyr-sprayed population of chickpea

Characters	Source of variation	PHT	NPB	NSB	NTB	DFFL	DFF	DFPD	DFP	DFPM	DM	PDPL	NSPP	HSW	SYPP	PY	BMPP	HI
Mean Sum of Squares	Replication (d.f.=02)	19.39	0.03	0.046	2.67	86.89	12.29	10.87	3	9.58	18.01	1.68	40.19	36.46	2.68	96.43	8.65	60.84
	Treatments (d.f.=119)	28.72**	1.12*	12.43*	34.17*	99.82**	19270.53**	141.76*	129.08*	118.69*	101.91**	541.95*	709.9**	91.62*	45.46**	5461.62**	30.87**	323.31**
	Error (d.f.=238)	7.52	0.18	0.71	1.15	33.63	21915.04	4.22	3.92	4.49	22.25	2.14	15.12	12.95	1.82	133.69	3.64	21.85

* and ** indicates significance at 5% and 1% respectively

Table 7: Analysis of variance for different characters in chickpea in Carfentrazone-ethyl-sprayed population of chickpea

Characters	Source of variation	DFFL	DFE	DFPD	DFP	DFPM	PHT	NPB	NSB	NTB	PDPL	NSPP	HSW	DM	SYPP	PY	BMPP	HI
Mean Sum of Squares	Replication (d.f=02)	43.61	55.39	30.47	92.01	203.18	23.73	0.2	1.53	1.88	23.19	52.76	4.74	97.52	0.95	309.35	0.45	177.14
	Treatments (d.f=119)	53.62**	55.81**	53.93**	49.74**	45.11**	35.82**	1.05**	2.99**	6.34**	581.66**	606.69**	79.65**	41.41**	38.57**	2435.79**	14.46**	381.42**
	Error (d.f=238)	14.62	16.3	11.47	34.74	82.96	8.24	0.19	0.72	0.6	25.55	18.11	2.63	28.42	2.18	106.89	0.81	92.74

* and ** indicates significance at 5% and 1% respectively

Table 8: Estimates of genetic variability parameters for seed yield and its component in unsprayed population of chickpea

Characters	DFFL	DFF	DFPD	DFP	DFPM	PHT	NPB	NSB	NTB	PDPL	NSPP	HSW	DM	SYPP	PY	BMPP	HI
Range	40.66- 77.33	44.66- 83	52.00- 89.66	62.67- 104.33	73.00- 111.00	30.00- 45.33	1.00- 4.00	2.00- 6.00	3.00- 18	8.67- 74.67	6.00- 79.00	17.00- 53.67	84.66- 121.33	6.00- 41.33	30.16- 673.00	4.19- 17.25	28.79- 55.92
Mean	57.09	63.19	68.57	78.69	88.73	37.15	3.00	4.00	6.00	33.00	36.90	25.15	99.01	19.33	201.51	9.14	48.00
GCV (%)	11.22	10.19	10.65	8.94	7.06	7.32	20.26	15.65	31.73	37.56	216.82	23.12	6.30	32.34	50.97	28.09	14.53
PCV (%)	17.04	15.68	14.42	12.43	10.13	9.24	22.51	21.47	32.94	40.10	228.36	23.48	7.94	32.84	53.36	30.72	17.47
h^2_{BS} (%)	43.30	42.20	54.50	52.70	48.60	62.70	81	53.20	92.80	87.70	94.90	96.90	62.90	97.00	91.20	83.60	69.10
GA	8.69	8.69	11.11	10.42	9.01	4.44	0.92	0.89	3.46	23.92	29.56	11.79	10.19	12.68	202.09	4.83	15.85
GAM (%)	15.22	13.64	16.21	13.24	10.15	11.94	37.58	23.51	62.95	72.47	80.10	46.88	10.29	65.59	100.29	52.89	24.88

4.2.1.2 Days to fifty percent flowering

The mean for days to fifty percent flowering was 63.19 days, with a range of 45 to 83.00 days. Moderate genotypic (10.18) and phenotypic (15.67) coefficient of variation were recorded with moderate heritability (42.20 %) and low genetic advance (8.69) and moderate genetic advance over mean (13.64) was noticed for this trait.

4.2.1.3 Days to first podding

The overall mean recorded for days to first podding was 68.57 days, with a range of 52.00 to 89.66 days. Moderate estimates of genetic (10.65) and phenotypic (14.42) coefficient of variation were recorded with modest heritability (54.5 %) and high genetic advance (11.11) and genetic advance over mean (16.21) for this trait.

4.2.1.4 Days to fifty percent podding

The average of days to fifty percent podding was 78.69 days with a range of 62.66 to 104.33 days. Low genotypic (8.94) and moderate phenotypic (12.43) coefficient of variation were recorded with moderate heritability (52.70 %) and moderate genetic advance (10.42) and genetic advance over mean (13.24) was noticed for this trait.

4.2.1.5 Days to fifty percent pod maturity

The mean for days to fifty percent pod maturity was 88.73 days with a range of 73.00 to 111.00 days. Low genotypic (7.06) and moderate phenotypic (10.13) coefficient of variation were recorded with a moderate heritability (48.60 %) and low genetic advance (9.01) and moderate genetic advance over mean (10.15) was recorded for this trait.

4.2.1.6 Days to maturity

The overall mean for days to maturity was 99.01 days with a range of 84.66 to 121.33 days. Low genotypic (6.30) and phenotypic (7.94) coefficient of variation were recorded with a high heritability (62 %) and moderate genetic advance (10.19) and genetic advance over mean (10.29) was recorded for this trait.

4.2.1.7 Plant height (cm)

Mean plant height of unsprayed population of chickpea was 37.15 cm with a wider range of 30.00 to 45.33 cm. Low magnitude of genotypic (7.32) and low phenotypic (9.24) coefficient of variation were showed for plant height. Heritability was high 62.70 % with low

amount of genetic advance (4.44) and moderate genetic advance over mean (11.94) was noticed.

4.2.1.8 Number of primary branches

Among 120 genotypes studied, medium range of variation was observed for primary branches per plant. The mean value for the trait was 3.00 with a range of 1.00 to 4.00. High estimate of genotypic (20.26) and phenotypic (22.51) coefficient of variation were recorded, heritability was high 81 % with low genetic advance (0.92) and high genotypic advance over mean (37.58) were observed for this trait.

4.2.1.9 Number of secondary branches

Number of secondary branches varied between 2.00 to 6.00 with an average of 4.00 secondary branches. Moderate genotypic (15.65) and high phenotypic (21.47) coefficient of variation were observed. Moderate heritability (53.20 %) estimates accompanied with low genetic advance (0.89) and high genetic advance over mean (23.51) was observed for this trait.

4.2.1.10 Number of tertiary branches

The range observed for number of tertiary branches was from 3.00 to 18.00 and an overall mean of 6.00. High genotypic (31.73) and high phenotypic (32.94) coefficient of variation were observed. High heritability (92.80 %) with low genetic advance (3.46) and high genetic advance over mean (62.95) was observed for this trait.

4.2.1.11 Number of pods per plant

Wider variability for number of pods per plant was observed with range of 8.67 to 74.67 with a mean value of 33.00 pods per plant. High genotypic (37.56) and phenotypic (40.10) coefficient of variation were observed with high heritability of 87.70 % and high genetic advance (23.92) and high genetic advance over mean (72.47) was recorded for this trait.

4.2.1.12 Number of seeds per plant

Larger variability for number of seeds for plant was noticed with a range of 6.00 to 79.00 and a mean value of 36.90. Very high genotypic (216.82) and phenotypic (228.36)

coefficient of variation with a high heritability of 93.90 % and high genetic advance (26.56) and genetic advance over mean (80.10) was recorded for this trait.

4.2.1.13 Seed yield per plant (g)

In unsprayed population of chickpea genotypes wide range of seed yield per plant (1.33 to 6.00 g) with overall mean of 19.33g was observed. High genotypic (32.34) and phenotypic (32.84) coefficient of variation were recorded with a high heritability (97 %) and moderate genetic advance (12.68) and high genetic advance over mean (65.59) for this trait.

4.2.1.14 Plot yield (g)

In unsprayed population of chickpea genotypes wide range of plot yield (30.16-673.00g) was seen with an overall mean of 201.51 grams. High genotypic (50.97) and phenotypic (53.36) coefficient of variation were recorded with a high heritability (91.20 %) and high genetic advance (202.09) and genetic advance over mean (100.29).

4.2.1.15 Hundred seed weight (g)

Hundred seed weight of genotypes ranged from 17.00 to 53.67g with an overall mean of 25.15 g. High genotypic (23.12) and phenotypic (23.48) coefficient of variation were recorded with a high heritability (96.90 %) and moderate genetic advance (11.79) and higher genetic advance over mean (46.88) for this trait.

4.2.1.16 Biomass per plant (g)

The unsprayed population of chickpea genotypes had wider range of biomass per plant (4.19 to 17.25 g) with overall mean of 9.14 grams. High genotypic (28.09) and phenotypic (30.72) coefficient of variation were recorded with a high heritability (83.60 %) and low genetic advance (4.83) and high genetic advance over mean (52.89).

4.2.1.17 Harvest index (%)

Harvest index varied from 28.79 to 55.92 per cent with mean of 48 per cent. Higher genotypic (14.53) phenotypic (17.47) coefficient of variation with high heritability of 69.10 per cent and very moderate genetic advance (15.85) and high genetic advance over mean (24.88) was recorded for this trait.

4.2.2 Genetic variability studies in herbicide sprayed population of chickpea genotypes

Herbicide tolerant cultivars have been developed in many crops, including some grain legumes, by exploiting available genetic variability in the germplasm or by inducing variability through mutagenesis. Plant resistance has been recognized as most potential way to minimize losses due to biotic stresses including weeds. Application of pre-emergence herbicides is known to reduce weed population in pulse crops at initial stage of crop growth. However, till date no post-emergence herbicide is recommended to control weeds at later stage of the crop growth. Therefore, the need is being felt to identify plant resistance sources from germplasm for their utilization in the development of herbicide resistant cultivars so that menace due to weeds can be minimized.

4.2.2a Genetic variability studies in Imazethapyr-sprayed population of chickpea

The results pertaining to genetic parameters viz., range, mean, phenotypic coefficient of variation, genotypic coefficient of variation, broad sense heritability (h^2_{bs}), genetic advance and genetic advance over mean were computed to know the extent of variability among productivity traits in Imazethapyr-sprayed population of chickpea and the same are presented in Table 9.

4.2.2a.1 Days to first flowering

The overall mean for days to first flowering was 74.00 days, with a range of 62 to 88 days. The coefficient of variations in terms of genotypic (6.32) was low and phenotypic (10.04) was moderate. The heritability (39.60 %) estimates was moderate with low value of genetic advance (6.09) and genetic advance over mean (8.19) was observed for this trait.

4.2.2a.2 Days to fifty per cent flowering

The overall mean for days to fifty percent flowering was 82.00 days, with a range of 63.00 to 92.66 days. Low genotypic (5.90) and moderate phenotypic (13.14) coefficient of variation were recorded with low heritability (20.20 %) and low genetic advance (4.47) and low genetic advance over mean (5.46) was noticed for this trait.

4.2.2a.3 Days to first podding

The overall mean for days to first podding was 89.00 days with a range of 73.00 to 123.00 days. Low genotypic (7.59) and low phenotypic (7.94) coefficient of variation were

Table 9: Estimates of genetic variability parameters for seed yield and its component in Imazethapyr-sprayed population of chickpea

Characters	DFFL	DFF	DFPD	DFP	DFPM	PHT	NPB	NSB	NTB	PDPL	NSPP	HSW	DM	SYPP	PY	BMPP	HI
Range	62-102	63-117	73-123	82-129	91-136	26.68-42.25	1.16-5.00	2.5-15.46	1.00-16.00	4.51-69.00	8.14-100.72	18.50-48.83	98-141	2.31-22.61	17.49-285.94	5.10-19.82	14.13-75.14
Mean	74.00	82.00	89.00	98.00	105.00	34.47	2.35	5.07	5.50	28.52	32.73	24.36	113.00	9.31	98.25	10.79	45.54
GCV (%)	6.32	5.90	7.59	6.60	5.88	7.71	23.82	38.99	60.18	47.03	46.49	21.02	4.58	40.84	42.98	27.90	22.01
PCV (%)	10.04	13.14	7.94	6.91	6.22	11.08	29.73	42.38	63.24	47.31	47.99	25.69	6.21	43.33	44.57	33.02	24.29
h^2_{BS} (%)	39.60	20.20	91.60	91.40	89.40	48.40	64.1	84.70	90.60	98.80	93.90	67.00	54.40	0.89	93.00	71.40	82.10
GA	6.09	4.47	13.35	12.72	12.02	3.81	0.93	3.75	6.51	27.47	30.37	8.63	7.83	7.38	83.72	5.24	18.72
GAM (%)	8.19	5.46	14.98	13.01	11.46	11.06	39.25	73.89	117.99	96.31	92.80	35.44	6.95	79.28	85.38	48.57	41.09

recorded with high heritability (91.60 %) and low genetic advance (13.35) and genetic advance over mean (14.98) was noticed for this trait.

4.2.2a.4 Days to fifty percent podding

The mean observed for days to fifty percent podding was 98.00 days, with a range of 82.00 to 129.00 days. Low genotypic (6.60) and phenotypic (6.91) coefficient of variation were recorded with high heritability (91.40 %) and modest genetic advance (12.72) and genetic advance over mean (13.01) was observed for this trait.

4.2.2a.5 Days to fifty per cent pod maturity

Mean for days to fifty percent pod maturity was 105.00 days with a range of 91.00 to 136.00 days. Low genotypic (5.88) and moderate phenotypic (6.22) coefficient of variation were recorded with a high heritability (89.40 %) and moderate genetic advance (12.02) and moderate genetic advance over mean (11.46) was recorded for this trait.

4.2.2a.6 Days to maturity

Days to maturity had overall mean of 113.00 days with a range of 98.00 to 141.00 days. Low genotypic (4.58) and phenotypic (6.21) coefficient of variation were recorded with a moderate heritability (54.40 %) and low genetic advance (7.83) and genetic advance over mean (6.95) was recorded for this trait.

4.2.2a.7 Plant height (cm)

The variability observed for plant height was high, as reflected by range of variation from 26.68cm to 42.25cm with the mean value of 34.47cm. Low genotypic (7.71) and moderate phenotypic (11.08) coefficient of variation were observed. Magnitude of heritability (48.40 %) was moderate with low genetic advance (3.81) and moderate genetic advance over mean (11.06) was observed for this trait in Imazethapyr sprayed population of chickpea.

4.2.2a.8 Number of primary branches

Among 120 genotypes studied, medium range of variation was observed for primary branches per plant. The mean value for the trait was 2.35 with a range of 1.16 to 5.00. High estimate of genotypic (23.82) and phenotypic (29.73) coefficient of variation were recorded heritability was high 64.1 per cent with low genetic advance (0.93) and high genetic advance over mean (39.25) were observed for this trait.

4.2.2a.9 Number of secondary branches

Number of secondary branches varied from 2.50 to 15.46 with an overall mean of 5.07. High genotypic (38.99) and high phenotypic (42.38) coefficient of variation were observed. High heritability (84.70 %) estimates accompanied with low genetic advance (3.75) and high genetic advance over mean (73.89) was observed for this trait.

4.2.2a.10 Number of tertiary branches

Number of tertiary branches varied from 1.00 to 16.00 with an overall mean of 5.50. High genotypic (60.18) and high phenotypic (63.24) coefficient of variation was observed. High heritability (90.60 %) with low genetic advance (6.51) and high genetic advance over mean (117.99) was observed for this trait.

4.2.2a.11 Number of pods per plant

Wide variability in the number of pods per plant with range of 4.51 to 69.00 and mean value of 28.52. High genotypic (47.03) and phenotypic (47.31) coefficient of variation with high heritability of 98.80 per cent and high genetic advance (27.47) and high genetic advance over mean (96.31) was recorded for this trait.

4.2.2a.12 Number of seeds per plant

Large variability for number of seeds for plant with a range of 8.14 to 100.72 and mean value of 32.73. High genotypic (46.49) and phenotypic (47.31) coefficient of variation were observed with a high heritability of 93.90 per cent and high genetic advance (30.37) and genetic advance over mean (92.80) was recorded for this trait.

4.2.2a.13 Seed yield per plant

In Imazethapyr sprayed population of chickpea genotypes we observed wide range of seed yield per plant (2.31 to 22.61) with overall mean of 9.31 g. High genotypic (40.84) and phenotypic (43.33) coefficient of variation were recorded with a high heritability (89 %) and low genetic advance (7.38) and high genetic advance over mean (79.28) was recorded for this trait.

4.2.2a.14 Plot yield

In this imazethapyr-sprayed population of chickpea genotypes wide range of plot yield (17.49 to 172.66) with overall mean of 98.25 g. High genotypic (42.98) and phenotypic

(44.57) coefficient of variation were recorded with a high heritability (93 %) and high genetic advance (83.72) and genetic advance over mean (85.38) was recorded for this trait.

4.2.2a.15 Hundred seed weight

Hundred seed weight ranged from 18.50 to 48.83 with overall mean of 24.36 g. High genotypic (21.02) and phenotypic (25.69) coefficient of variation were recorded with a high heritability (67 %) and low genetic advance (8.63) and high genetic advance over mean (35.44) was recorded for this trait.

4.2.2a.16 Biomass per plant

In these chickpea genotypes, wide range of biomass per plant (5.10 to 19.82) with overall mean of 10.79 g. High genotypic (27.90) and phenotypic (33.02) coefficient of variation were recorded with a high heritability (71.40 %) and low genetic advance (5.24) and high genetic advance over mean (48.57) was recorded for this trait.

4.2.2a.17 Harvest index (%)

Harvest index varied from 14.13 to 65.14 with mean of 45.54. High genotypic (22.01) phenotypic (24.29) coefficient of variation with high heritability of 82.10 % and moderate genetic advance (18.72) and high genetic advance over mean (41.09) was recorded for this trait.

4.2.2b Genetic variability studies in Carfentrazone–ethyl sprayed population of chickpea

The results pertaining to genetic parameters viz., range, mean, phenotypic coefficient of variation, genotypic coefficient of variation, broad sense heritability (h^2_{bs}), genetic advance and genetic advance over mean were computed to know the extent of variability among productivity traits in Carfentrazone-ethyl-sprayed population of chickpea and the same are presented in table.10.

4.2.2b.1 Days to first flowering

The mean for days to first flowering was 73.00 days, with a range of 63.00 to 86.00 days. The coefficients of variations in terms of both genotypic (5.07) and phenotypic (7.12) coefficient of variation were low. The heritability (51 %) estimates was moderate with low value of genetic advance (5.40) and genetic advance over mean (7.45) was observed for this trait.

Table 10: Estimates of genetic variability parameters for seed yield and its component in Carfentrazone-ethyl-sprayed population of chickpea

Characters	DFFL	DFF	DFFD	DFF	DFPM	PHT	NPB	NSB	NTB	PDPL	NSPP	HSW	DM	SYPP	PY	BMPP	HI
Range	63.00- 86.00	66.00- 93.00	75.00- 102.00	78.00- 111.00	87.00- 114	24.00- 41.67	1.00- 4.00	2.00- 8.00	2.00- 10.00	5.00- 85.72	7.40- 77.76	18.27- 46.50	96.00- 118	2.65- 17.34	17.38- 171.00	2.01- 17.18	31.34- 51.97
Mean	73.00	77.00	84.00	91.00	98.00	32.15	2.00	5	4.00	26.95	29.76	24.38	105.00	8.89	62.84	5.29	41.01
GCV (%)	5.07	4.82	4.48	3.89	3.72	9.44	22.68	19.01	30.92	50.51	46.51	20.79	3.28	37.96	44.20	40.29	16.82
PCV (%)	7.12	6.99	6.03	4.80	4.44	12.98	30.89	27.03	36.51	53.88	50.22	21.80	4.47	44.58	47.60	43.85	21.68
h^2_{BS} (%)	0.51	0.47	0.55	0.66	0.69	0.53	0.54	0.50	0.72	0.88	0.86	0.91	0.54	0.73	0.86	0.84	60.20
GA	5.40	5.27	5.76	5.93	6.25	4.55	0.79	1.26	2.38	26.29	26.39	9.96	5.22	5.92	53.13	4.03	16.41
GAM (%)	7.45	6.83	6.67	6.52	6.41	14.14	34.31	27.81	53.94	97.55	88.72	40.86	4.96	66.57	84.56	76.27	26.89

4.2.2b.2 Days to fifty percent flowering

Mean observed for days to fifty percent flowering was 77.00 days, with a range of 66.00 to 93.00 days. Low genotypic (4.82) and phenotypic (6.99) coefficient of variation were recorded with moderate heritability (47 %) and low genetic advance (5.27) and genetic advance over mean (6.83) noticed for this trait.

4.2.2b.3 Days to first podding

The mean for days to first podding was 84.00 days with a range of 7.00 to 102.00 days. Low genotypic (4.48) and low phenotypic (6.03) coefficient of variation were recorded with moderate heritability (55 %) and low genetic advance (5.76) and genetic advance over mean (6.67) was noticed for this trait.

4.2.2b.4 Days to fifty percent podding

Mean value observed for days to fifty percent podding was 91.00 days, with a range of 78.00 to 111.00 days. Low genotypic (3.89) and phenotypic (4.80) coefficient of variation were recorded with high heritability (66 %) and low genetic advance (5.93) and genetic advance over mean (6.52) was observed for this trait.

4.2.2b.5 Days to fifty percent pod maturity

The mean value for days to fifty percent pod maturity was 98.00 days with a range of 87.00 to 114.00 days. Low genotypic (3.72) and moderate phenotypic (4.44) coefficient of variation were recorded with a high heritability (69 %) and low genetic advance (6.25) and low genetic advance over mean (6.41) was recorded for this trait.

4.2.2b.6 Days to maturity

The overall mean for days to maturity was 105.00 days with a range of 96.00 to 118.00 days. Low genotypic (3.28) and phenotypic (4.47) coefficient of variation were recorded with a moderate heritability (54 %) and low genetic advance (5.22) and genetic advance over mean (4.96) was recorded for this trait.

4.2.2b.7 Plant height (cm)

The variability observed for plant height was high, as reflected by range of variation from 24.00 cm to 41.67 cm with the mean value of 32.15 cm. Low genotypic (9.44) and moderate phenotypic (12.98) coefficient of variation were observed. Magnitude of heritability

(53 %) was moderate with low genetic advance (4.55) and moderate genetic advance over mean (14.14) was observed for this trait under Carfentrazone-ethyl sprayed population of chickpea.

4.2.2b.8 Number of primary branches

Among 120 genotypes studied, medium range of variation was observed for primary branches per plant. The mean value for the trait was 2.00 with a range of 1.00 to 4.00. High estimate of genotypic (22.68) and phenotypic (30.89) coefficient of variation were recorded. Heritability was moderate (54 per cent) with low genetic advance (0.79) and high genetic advance over mean (34.31) were observed for this trait.

4.2.2b.9 Number of secondary branches

Number of secondary branches varied from 2.00 to 8.00 with an overall mean of 5.00. High genotypic (19.01) and high phenotypic (27.03) coefficient of variation was observed. Moderate heritability (50 %) estimates accompanied with low genetic advance (1.26) and high genetic advance over mean (27.81) was observed for this trait.

4.2.2b.10 Number of tertiary branches

Number of tertiary branches varied from 2.00 to 10.00 with an overall mean of 4.00. High genotypic (30.92) and high phenotypic (36.51) coefficient of variation was observed. High heritability (72 %) with low genetic advance (2.38) and high genetic advance over mean (53.94) was observed for this trait.

4.2.2b.11 Number of pods per plant

Wide variability for number of pods per plant with range of 5.00 to 85.72 and mean value of 26.95. High genotypic (50.51) and phenotypic (53.88) coefficient of variation with high heritability of 88 per cent and high genetic advance (26.29) and high genetic advance over mean (97.55) was recorded for this trait.

4.2.2b.12 Number of seeds per plant

Large variability for number of seeds per plant with a range of 7.40 to 77.76 and mean value of 29.76. High genotypic (46.51) and phenotypic (50.22) coefficient of variation with a high heritability of 86 per cent and high genetic advance (26.39) and genetic advance over mean (88.72) was recorded for this trait.

4.2.2b.13 Seed yield per plant (g)

Seed yield per plant showed wide range for seed yield per plant (2.65 to 17.34) with overall mean of 8.89. High genotypic (37.96) and phenotypic (44.58) coefficient of variation were recorded with a high heritability (73 %) and low genetic advance (5.92) and high genetic advance over mean (66.57) was recorded for this trait.

4.2.2b.14 Plot yield (g)

Genotypes showed wide range of plot yield (17.38 to 171.00) with overall mean of 62.84. High genotypic (44.20) and phenotypic (47.60) coefficient of variation were recorded with a high heritability (86 %) and high genetic advance (53.13) and genetic advance over mean (84.56) was recorded for this trait.

4.2.2b.15 Hundred seed weight (g)

Hundred seed weight ranged from 18.27 to 46.50 with overall mean of 24.38. High genotypic (20.79) and phenotypic (21.80) coefficient of variation were recorded with a high heritability (91 %) and low genetic advance (9.96) and high genetic advance over mean (40.86) was recorded for this trait.

4.2.2b.16 Biomass per plant (g)

Wide range of biomass per plant (2.01 to 17.18) was seen with overall mean of 5.29. High genotypic (40.29) and phenotypic (43.85) coefficient of variation were recorded with a high heritability (84 %) and low genetic advance (4.03) and high genetic advance over mean (76.27) was recorded for this trait.

4.2.2b.17 Harvest index (%)

Harvest index varied from 31.34 to 55.97 with mean of 41.01. High genotypic (16.82) phenotypic (21.68) coefficient of variation with high heritability of 60.20 per cent and very moderate genetic advance (16.41) and high genetic advance over mean (26.89) was recorded for this trait.

4.3 Correlation studies in unsprayed and sprayed population of chickpea genotypes

Selection for specific character is known to be result of correlated response in certain other independent characters. Generally, plant breeders make selection for one or two attributes at a time. Hence it becomes important to know the effect of selection on other

related traits. Improvement on seed yield per plant, days to maturity are the most important target characters in most of the crops that can be achieved by direct selection or through other easily observable contributing characters. But, this process necessitates a good understanding of association of different traits with seed yield per plant, days to maturity and their possible associations among themselves.

The results of genotypic and phenotypic correlation for selected traits recorded from 120 genotypes of unsprayed and herbicide treated populations of chickpea during *rabi* 2016 are presented in Table.11, 12 and 13. The values above diagonal and below diagonal represent genotypic and phenotypic level respectively.

4.3.1 Correlation and Path analysis studies in unsprayed population of chickpea genotypes

4.3.1.1 Genotypic and phenotypic correlation coefficient among yield components in unsprayed population of chickpea

The results of this study are presented in Table 11.

4.3.1.1.1 Number of primary branches

Genotypic correlation matrix showed significant positive correlation with number of secondary branches (0.23), number of seeds per plant (0.25), low positive correlation with number of tertiary branches (0.07), number of pods per plant (0.06) and non-significant-negative correlation with hundred seed weight (-0.11). Phenotypic matrix showed positive non-significant correlation for maximum traits considered except for hundred seed weight which showed negative non-significant correlation for hundred seed weight (-0.13).

4.3.1.1.2 Number of secondary branches

Significant positive correlation were observed with number of primary branches (0.23) number of tertiary branches (0.32), while non-significant positive correlation with number of pods per plant, number of seeds per plant and non-significant negative correlation with hundred seed weight (-0.18) in genotypic correlation matrix, where as phenotypic correlation matrix showed non-significant positive correlation for all the traits except hundred seed weight which showed non-significant negative correlation (0.25).

Table 11: Genotypic and phenotypic correlation coefficient among yield components in unsprayed population of chickpea

	NPB	NSB	NTB	PDPL	NSPP	HSW
NPB	1	0.23**	0.07	0.06	0.25**	-0.11.*
NSB	0.33	1	0.32**	0.08	0.08	-0.18**
NTB	0.07	0.46	1	0.17**	0.21**	-0.22**
PDPL	0.07	0.12	0.21	1	0.62**	-0.094*
NSPP	0.29	0.12	0.23	0.68	1	-0.12
HSW	-0.13	-0.25	-0.22	-0.11	-0.13	1

Values above diagonal represent genotypic values and values below diagonal represents phenotypic values, * and ** indicates significance at 5% and 1% respectively

4.3.1.1.3 Number of tertiary branches

Genotypic correlation matrix showed significant correlation with number of secondary branches (0.32), number of pods per plant (0.17), number of seeds per plant (0.21) and non-significant negative correlation with hundred seed weight (-0.22). Phenotypic correlation showed non-significant positive correlation with number of primary branches (0.07), number of secondary branches (0.46), number of pods per plant (0.21), number of seeds per plant (0.23), and negative correlation with hundred seed weight (-0.19).

4.3.1.1.4 Number of pods per plant

Number of pods per plant had positive non-significant association with number of primary branches (0.06), number of secondary branches (0.08), positive significant correlation for number of tertiary branches (0.17), number of seeds per plant (0.21) and negative correlation with hundred seed weight (-0.22). The phenotypic association showed non-significant positive correlation with number of primary branches (0.07), number of secondary branches (0.12), tertiary branches (0.21), number of seeds per plant (0.68) and negative significant correlation with hundred seed weight (-0.11).

4.3.1.1.5 Number of seeds per plant

Genotypic matrix regarding this showed significant positive correlation with number of primary branches (0.25), number of tertiary branches (0.21), number of pods per plant (0.62) and positive non-significant correlation with secondary branches (0.08), and non-significant negative correlation with hundred seed weight (-0.12). Phenotypic correlation showed non-significant negative correlation with hundred seed weight (-0.13) and positive non-significant association with all the traits considered.

4.3.1.1.6 Hundred seed weight (g)

Genotypic results indicated that, there was a significant negative association of all the traits considered except number of pods per plant (-0.09). Whereas phenotypic correlation showed non-significant negative association for all the traits considered.

4.3.2 Correlation studies in herbicide Imazethapyr-sprayed population of chickpea genotypes

4.3.2.1 Genotypic and phenotypic correlation coefficient among yield components in Imazethapyr-sprayed population of chickpea

The results regarding this study are presented in table.12.

Table 12. Genotypic and phenotypic correlation coefficient among yield components in Imazethapyr sprayed population of chickpea

	NPB	NSB	NTB	PDPL	NSPP	HSW
NPB	1	0.31**	0.14**	0.25**	0.26**	-0.09
NSB	0.36	1	0.68**	0.12*	0.15**	0.01
NTB	0.17	0.72	1	-0.01	0.05	0.04
PDPL	0.32	0.14	-0.01	1	0.82**	0.06
NSPP	0.33	0.16	0.06	0.85	1	-0.02
HSW	-0.15	0.02	0.05	0.06	-0.03	1

Values above diagonal represent genotypic values and values below diagonal represents phenotypic values, * and ** indicates significance at 5% and 1% respectively

4.3.2.1.1 Number of primary branches

Genotypic matrix showed significant positive correlation with all traits considered except for hundred seed weight which showed non-significant negative correlation with hundred seed weight (-0.09). Phenotypic matrix of this trait showed positive non-significant correlation among all the traits under consideration and non-significant negative correlation with hundred seed weight (-0.15).

4.3.2.1.2 Number of secondary branches

The results of genotypic matrix indicated that there was a significant positive correlation with all the traits considered except for hundred seed weight which has non-significant positive correlation (0.01) and phenotypic correlations indicated non-significant positive correlation with all traits under consideration.

4.3.2.1.3 Number of tertiary branches

Genotypic matrix exhibited significant positive association with number of primary branches (0.14), number of secondary branches (0.68). Non-significant positive association with number of seeds per plant, hundred seed weight, non-significant negative correlation with number of pods per plant. Phenotypic correlation matrix showed non-significant positive association with all the traits except for number of pods per plant (-0.01).

4.3.2.1.4 Number of pods per plant

Genotypic matrix showed non-significant positive correlation with number of primary branches (0.25), number of secondary branches (0.12), number of seeds per plant (0.82) non-significant positive correlation with hundred seed weight (0.06), non-significant negative correlation with number of pods per plant (-0.01). Phenotypic matrix showed non-significant positive correlation with number of primary branches, secondary branches, seeds per plant, hundred seed weight and non-significant negative correlation with number of tertiary branches(-0.01).

4.3.2.1.5 Number of seeds per plant

Genotypic correlation among the traits showed significant positive correlation with number of primary branches (0.26), secondary branches (0.15), number of pods per plant (0.82) and non-significant positive correlation with number of tertiary branches, hundred seed

weight. Phenotypic correlation showed non-significant positive correlation with all the traits except for hundred seed weight (-0.03).

4.3.2.1.6 Hundred seed weight

Regarding genotypic matrix is concerned hundred seed weight showed significant positive correlation with number of secondary branches, number of tertiary branches, number of pods per plant, number of seeds per plant and negative correlation with number of primary branches (-0.09). Phenotypic correlation showed non-significant negative correlation with number of primary branches (-0.15), number of seeds per plant (-0.03). And non-significant positive correlation for number of secondary branches, number of tertiary branches, number of pods per plant.

4.3.3 Correlation studies in Carfentrazone-ethyl sprayed population of chickpea genotypes

4.3.3.1 Genotypic and phenotypic correlation coefficient among yield components in Imazethapyr-sprayed population of chickpea

The results pertaining to this are presented in Table.13.

4.3.3.1.1 Number of primary branches

The results regarding genotypic correlation indicated that, there was non-significant positive correlation with number of secondary branches(0.03), significant positive correlation with number of pods per plant (0.11), number of seeds per plant (0.12), and negative non-significance for number of tertiary branches (-0.02) and hundred seed weight (-0.13). Phenotypic correlation showed non-significant positive correlation with number of secondary branches (0.07), number of pods per plant (0.16), number of seeds per plant (0.15), and non-significant negative correlation with number of tertiary branches (-0.01) and hundred seed weight (-0.18).

4.3.3.1.2 Number of secondary branches

Genotypic matrix showed significant positive correlation with number of tertiary branches (0.16), number of pods per plant (0.24), and number of seeds per plant (0.19), non-significant positive correlation with number of primary branches (0.03) and negative non-significant correlation with hundred seed weight (0.03). Phenotypic correlation showed non-significant positive correlation with all traits under consideration.

Table 13: Genotypic and phenotypic correlation coefficient among yield components in Carfentra-ethyl-sprayed population of chickpea

	NPB	NSB	NTB	PDPL	NSPP	HSW
NPB	1	0.03	-0.02	0.11*	0.12*	-0.13*
NSB	0.07	1	0.16**	0.24**	0.19**	0.03
NTB	-0.01	0.27	1	0.23**	0.20**	-0.01
PDPL	0.16	0.32	0.32	1	0.81**	-0.02
NSPP	0.15	0.25	0.24	0.90	1	0.03
HSW	-0.18	0.02	-0.01	-0.03	0.03	1

Values above diagonal represent genotypic values and values below diagonal represents phenotypic values, * and ** indicates significance at 5% and 1% respectively

4.3.3.1.3 Number of tertiary branches

Genotypic matrix indicated significant correlation for number of secondary branches, number of pods per plant and number of seeds per plant, non-significant negative correlation with number of primary branches (-0.02), hundred seed weight (-0.01). Phenotypic matrix showed non-significant positive correlation with number of secondary branches, number of pods per plant and number of seeds per plant. Non-significant negative correlation with number of primary branches (-0.01), hundred seed weight (-0.01).

4.3.3.1.4 Number of pods per plant

The results of genotypic matrix showed significant positive correlation with number of primary branches, number of secondary branches, number of tertiary branches and number of seeds per plant. Non-significant negative correlation with hundred seed weight (-0.02). Phenotypic correlation matrix resulted that, non-significant positive correlation with all traits except for hundred seed weight (-0.03) where it got non-significant negative correlation.

4.3.3.1.5 Number of seeds per plant

Genotypic matrix showed significant positive correlation with all traits except for hundred seed weight (0.03) and phenotypic matrix showed non-significant positive correlation with all traits under consideration.

4.3.3.1.6 Hundred seed weight

Genotypic matrix and phenotypic matrix showed both non significant negative and positive correlation *viz.*, non-significant negative correlation with number of primary branches (-0.13, -0.18), number of tertiary branches (-0.01, -0.01) and number of pods per plant (-0.02, -0.03). Non-significant positive correlation with number of secondary branches (0.03, 0.02) and number of seeds per plant (0.03, 0.03) respectively.

4.3.4 Path analysis in unsprayed and herbicide sprayed population of chickpea genotypes

Path coefficient analysis was worked out to partition the correlation coefficient into direct and indirect effects. In the present study direct and indirect effect of six traits *viz.*, number of primary branches, number of secondary branches, number of tertiary branches, number of pods per plant, number of seeds per plant and hundred seed weight were worked

out using all genotypes under unsprayed and sprayed condition separately. Results are presented in Table.14, 15 and 16.

4.3.4.1 Direct (diagonal) and indirect effects of different characters on seed yield per plant in unsprayed population of chickpea

Correlation coefficients were subjected to path analysis for partitioning the correlation values into direct and indirect effect through alternate ways. The results showing the direct and indirect effect of various traits on seed yield per plant in unsprayed population of chickpea genotypes are presented in Table 14.

Number of primary branches has low direct effect (0.076) on seed yield, indirect effect through pods per plant (0.057). Number of secondary branches has direct effect (0.019) on seed yield and indirect effect through pods per plant (0.099). There is no direct effect of tertiary branches on seed yield but has indirect effect through pods per plant (0.17). Pods per plant has high direct effect (0.815) on seed yield, where as seeds per plant has negative indirect effect (-0.03), positive direct effect is through pods per plant (0.55) on seed yield. Hundred seed weight has direct effect (0.023) on seed yield per plant thus resulting in positive correlation with seed yield.

4.3.4.2 Direct (diagonal) and indirect effects of different characters on seed yield per plant in Imazethapyr-sprayed population of chickpea

The results of direct and indirect effects of different traits considered on yield and yield attributes traits pertaining to Imazethapyr sprayed population of chickpea genotypes are presented in Table 15.

Here the primary branches had the negative direct effect (-0.093) on seed yield also has the highest positive indirect effect through pods per plant (0.088). Secondary branches shows low direct effect (0.014) and highest indirect effect through number of tertiary branches (0.139), where as tertiary branches (0.192) has direct effect on seed yield. Number of pods and number of seeds has highest and direct effect (0.279, 0.213) on seed yield per plant hundred seed weight also has direct effect (0.104) thus showing positive correlation among the traits considered.

Table 14: Direct (diagonal) and indirect effects of different characters on seed yield per plant in unsprayed population of chickpea

	NPB	NSB	NTB	PDPL	NSPP	HSW
NPB	0.076	0.025	0.005	0.005	0.022	-0.010
NSB	0.006	0.019	0.009	0.002	0.002	-0.005
NTB	0.000	0.000	0.000	0.000	0.000	0.000
PDPL	0.057	0.099	0.170	0.815	0.553	-0.086
NSPP	-0.009	-0.004	-0.007	-0.021	-0.030	0.004
HSW	-0.003	-0.006	-0.005	-0.003	-0.003	0.023
SYPP	0.127	0.133	0.171	0.799	0.544	-0.074
Partial R²	0.010	0.003	0.000	0.651	-0.016	-0.002

RESIDUAL EFFECT=0.59

Table 15: Direct (diagonal) and indirect effects of different characters on seed yield per plant in Imazethapyr sprayed population of chickpea

	NPB	NSB	NTB	PDPL	NSPP	HSW
NPB	-0.093	-0.034	-0.016	-0.030	-0.031	0.014
NSB	0.005	0.014	0.010	0.002	0.002	0.000
NTB	0.033	0.139	0.192	-0.001	0.012	0.009
PDPL	0.088	0.038	-0.002	0.279	0.237	0.018
NSPP	0.069	0.035	0.013	0.181	0.213	-0.007
HSW	-0.016	0.002	0.005	0.007	-0.003	0.104
SWPP	0.087	0.195	0.202	0.438	0.430	0.138
Partial R ²	-0.008	0.003	0.039	0.122	0.092	0.014

RESIDUAL EFFECT= 0.45

4.3.4.3 Direct (diagonal) and indirect effects of different characters on seed yield per plant in Carfentrazone-ethyl sprayed population of chickpea

The results for direct and indirect effects of many traits considered for yield and yield related components are presented in Table 16.

Number of primary branches and number of tertiary branches has negative direct effect (-0.135, -0.030) and high positive direct effect through number of pods per plant (0.064, 0.123) on seed yield. Number of secondary branches had high positive direct effect (0.114) on seed yield. Even pods per plant, seeds per plant and hundred seed weight have direct positive effect (0.389, 0.170, and 0.058) on seed yield per plant respectively. Showing positive association of traits.

4.4 Correlation between percent leakage and percent decrease in yield and yield attributes traits in herbicides Imazethapyr and Carfentrazone-ethyl treated plot

4.4.1 Correlation between percent leakage and percent decrease in yield and yield attributes traits in herbicides Imazethapyr treated plot

The results regarding this are represented in Table 17 and are explained under.

4.4.1.1 Days to fifty percent flowering

The results pertaining to this study indicates that there non-significant positive correlation between the days to fifty percent flowering and days to fifty percent podding (0.99) and biomass per plant (0.24) and non significant negative correlation between days to fifty percent flowering and remaining all traits under consideration (Number of pods per plant (-0.22), number of seeds per plant (-0.10), hundred seed weight (-0.32), seed yield per plant (-0.21) and harvest index (-0.29).

4.4.1.2 Days to fifty percent podding

Correlation study indicates that days to fifty percent podding is non-significantly and positively associated with days to fifty percent flowering (0.99) and biomass per plant (0.22). There is negative and non-significant relation is seen with days to fifty percent podding and other traits considered (Number of pods per plant (-0.24), number of seeds per plant (-0.20), hundred seed weight (-0.24), seed yield per plant (-0.21), hervest index (-0.29).

Table 16: Direct (diagonal) and indirect effects of different characters on seed yield per plant in Carfentrazone-ethyl-sprayed population of chickpea

	NPB	NSB	NTB	PDPL	NSPP	HSW
NPB	-0.135	-0.010	0.002	-0.022	-0.021	0.024
NSB	0.008	0.114	0.031	0.037	0.028	0.002
NTB	0.000	-0.008	-0.030	-0.010	-0.007	0.000
PDPL	0.064	0.125	0.123	0.389	0.349	-0.012
NSPP	0.026	0.042	0.041	0.152	0.170	0.005
HSW	-0.010	0.001	0.000	-0.002	0.002	0.058
SYPP	-0.047	0.265	0.167	0.545	0.520	0.078
Partial R ²	0.0063	0.0302	-0.005	0.212	0.0884	0.0045

RESIDUAL EFFECT = 0.48

Table 17: Genotypic correlation between percent leakage and percent decrease in yield and yield attributes traits in Imazethapyr treated plot

	DFE	DFP	NPP	NSP	HSW	SYPP	BM	HI
DFE	1	0.99	-0.22	-0.10	-0.32	-0.21	0.24	-0.29
DFP		1	-0.24	-0.20	-0.24	-0.21	0.22	-0.28
NPP			1	0.67	-0.11	0.80	0.12	0.45
NSP				1	-0.12	0.54	0.13	0.35
HSW					1	-0.08	-0.09	-0.01
SYPP						1	0.13	0.67
BM							1	-0.63
HI								1

4.4.1.3 Number of pods per plant

Association study indicated that there is non-significant positive correlation between number of pods per plant and number of seeds per plant (0.67), seed yield per plant (0.80), biomass per plant (0.12) and hundred seed weight (0.45). There is non-significant negative correlation seen between days to fifty percent flowering (-0.22), days to fifty percent podding (-0.24) and hundred seed weight (-0.11).

4.4.1.4 Number of seeds per plant

Association study depicts there is positive non-significant correlation between number of pods per plant (0.67), seed yield per plant (0.54), biomass per plant (0.13) and harvest index (0.35). There is non-significant negative association between days to fifty percent flowering (-0.22), days to fifty percent podding (-0.10), days to fifty percent podding (-0.20) and hundred seed weight (-0.12).

4.4.1.5 Hundred seed weight

This trait is non significantly and negatively correlated with all the traits under consideration (days to fifty percent flowering (-0.32), days to fifty percent podding (-0.24), number of pods per plant (-0.11), number of seeds per plant (-0.12), seed yield per plant (-0.08), biomass per plant (-0.09) and harvest index (-0.01).

4.4.1.6 Seed yield per plant

Seed yield per plant is positively and non-significantly correlated with number of pods per plant (0.80), number of seeds per plant (0.54), biomass per plant (0.13) and harvest index (0.67). We have seen non-significant negative correlation with number of fifty percent flowering (-0.21), days to fifty percent podding (-0.21) and hundred seed weight (-0.08).

4.4.1.7 Biomass per plant

Biomass per plant is non-significantly and positively correlated with all other traits (days to fifty percent flowering (0.24), days to fifty percent podding (0.22), number of pods per plant (0.12), number of seeds per plant (0.13) and seed yield per plant (0.13) except hundred seed weight (-0.09) and harvest index (-0.63).

4.4.1.8 Harvest index

Harvest index is non-significantly and positively associated with number of pods per plant (0.45), number of seeds (0.35) and seed yield per plant (0.67). there is non-significant

and negative correlation with days to fifty percent flowering (-0.29), days to fifty percent podding (-0.28), hundred seed weight (-0.01) and biomass per plant (-0.63).

4.4.1 Correlation between percent leakage and percent decrease in yield and yield attributes traits in herbicides Imazethapyr treated plot

The results pertaining to this are presented in Table 18 and are described below.

4.4.2.1 Days to fifty percent flowering

The results pertaining to this study indicates that there non-significant positive correlation between the days to fifty percent flowering and days to fifty percent podding (0.99) and biomass per plant(0.26) and non significant negative correlation between days to fifty percent flowering and remaining all traits under consideration (Number of pods per plant (-0.22), number of seeds per plant (-0.11), hundred seed weight (-0.32), seed yield per plant (-0.22) and harvest index (-0.29).

4.4.2.2 Days to fifty percent podding

Correlation study indicates that days to fifty percent podding is non-significantly and positively associated with days to fifty percent flowering (0.99) and biomass per plant (0.24). There is negative and non-significant relation is seen with days to fifty percent podding and other traits considered (Number of pods per plant (-0.24), number of seeds per plant (-0.20), hundred seed weight (-0.24), seed yield per plant (-0.21), harvest index (-0.28).

4.4.2.3 Number of pods per plant

Association study indicated that there is non-significant positive correlation between number of pods per plant and number of seeds per plant (0.67), seed yield per plant (0.80), biomass per plant (0.12) and hundred seed weight (0.45). There is non-significant negative correlation seen between days to fifty percent flowering (-0.22), days to fifty percent podding (-0.24) and hundred seed weight (-0.11).

4.4.2.4 Number of seeds per plant

Association study depicts there is positive non-significant correlation between number of pods per plant (0.67), seed yield per plant (0.54), biomass per plant (0.13) and harvest index (0.35). there is non-significant negative association between days to fifty percent flowering (-0.11), days to fifty percent podding (-0.20) and hundred seed weight (-0.12).

Table 18: Genotypic correlation between percent leakage and percent decrease in yield and yield attributes traits in Carfentrazone-ethyl plot

	DFE	DFP	NPP	NSP	HSW	SYPP	BM	HI
DFE	1	1.01	-0.22	-0.11	-0.32	-0.22	0.26	-0.29
DFP		1	-0.24	-0.20	-0.24	-0.21	0.24	-0.28
NPP			1	0.67	-0.11	0.80	0.12	0.45
NSP				1	-0.12	0.54	0.13	0.35
HSW					1	-0.08	-0.10	-0.01
SYPP						1	0.14	0.67
BM							1	-0.62
HI								1

4.4.2.5 Hundred seed weight

This trait is non significantly and negatively correlated with all the traits under consideration (days to fifty percent flowering (-0.32), days to fifty percent podding (-0.24), number of pods per plant (-0.11), number of seeds per plant (-0.12), seed yield per plant (-0.08), biomass per plant (-0.10) and harvest index (-0.01).

4.4.2.6 Seed yield per plant

Seed yield per plant is positively and non-significantly correlated with number of pods per plant (0.80), number of seeds per plant (0.54), biomass per plant (0.14) and harvest index (0.67). We have seen non-significant negative correlation with number of fifty percent flowering (-0.22), days to fifty percent podding (-0.21) and hundred seed weight (-0.08).

4.4.2.7 Biomass per plant

Biomass per plant is non-significantly and positively correlated with all other traits (days to fifty percent flowering (0.26), days to fifty percent podding (0.24), number of pods per plant (0.12), number of seeds per plant (0.13) and seed yield per plant (0.13) except hundred seed weight (-0.10) and harvest index (-0.62).

4.4.2.8 Harvest index

Harvest index is non-significantly and positively associated with number of pods per plant (0.45), number of seeds (0.35) and seed yield per plant (0.67). There is non-significant and negative correlation with days to fifty percent flowering (-0.29), days to fifty percent podding (-0.28), hundred seed weight (-0.01) and biomass per plant (-0.62).

Discussion

5. DISCUSSION

Chickpea (*Cicer arietinum* L.) is commercially grown as a major cool season crop from Mediterranean to sub-tropical. Chickpea is one of the important food legumes in SAT regions. Globally, it is cultivated in more than 57 countries and ranks second in acreage after dry bean. South and Southeast Asian countries account for more than two-third of the total chickpea production. Even though chickpea is cultivated in vast area, the production is low due to poor productivity in the SAT region typically characterized by low-input & poor management practices. There are many constraints like biotic and abiotic stresses which play an important role in lowering productivity of chickpea. Among these, weed management also assumes as a very much important role and acts as major constraints limiting chickpea productivity and yield stability.

Herbicide tolerant chickpea cultivars are very much needed to enhance options for application of post-emergence herbicides. Weed management through herbicides is needed even in the developing countries, such as India, to make chickpea cultivation more profitable. Weed management through herbicides is not only economical but also facilitates zero-tillage or minimum tillage methods, which help in practicing conservation agriculture.

Herbicide tolerance in crops is desirable in agricultural production systems as hand weeding and mechanical weed control methods traditionally followed in the developing countries are becoming expensive due to increased labour wages and migration of labours. Identifying chickpea cultivars with tolerance to herbicides would expand the currently limited broadleaf weed control options. Further, identification of proper growth stages that can tolerate herbicide spray would allow for applications at appropriate timing for maximal weed control. The present study reports the action of two different herbicides and at different growth stages on chickpea germplasm to identify stable sources of resistance to herbicides.

Breeders all over the world have been utilizing the available genetic variability to develop the new cultivar or to modify the existing varieties to meet the ever-changing requirements. The present study aims to identify sources of tolerance by screening available variability for two herbicides with different mode of action (Imazethapyr-amino acid synthesis or meristematic activity inhibitor and carfentrazone-ethyl- photosynthesis inhibitor) for use in developing weed resistant chickpea genotypes. The results of the experiments conducted are discussed below under the following headings.

- 5.1 Analysis of variance for yield and yield related traits in unsprayed and sprayed population of chickpea
- 5.2 Genetic variability studies in unsprayed and herbicide sprayed population of chickpea genotypes
- 5.3 Correlation and path analysis studies in unsprayed and herbicide sprayed population of chickpea genotypes
- 5.4 Potential lines identified as sources of resistance to Imazethapyr and Carfentrazone-ethyl

5.1 Analysis of variance for yield and yield related traits in unsprayed and sprayed population of chickpea

Analysis of variance was performed to test the significance of difference among the genotypes. The mean sum of squares due to various sources of revealed that among the 17 traits studied, all the traits showed significance differences indicating that the sufficient variability existed among the 120 chickpea genotypes in unsprayed and sprayed (Imazethapyr and Carfentrazone-ethyl) population of chickpea genotypes, further it can be used in herbicide tolerant genotype breeding programme. Most of the traits under study, plant height (cm), days to 1st flowering, 50%flowering, days to 1st podding, days to 50% podding, days to 50% pod maturity, days to maturity, number of primary branches, number of secondary branches, number of tertiary branches, number of pods per plant, number of seeds per plant, seed yield per plant (g), plot yield (g), hundred seed weight (g), biomass per plant (g), harvest index (%). Table (5, 6, 7).

5.2 Genetic variability studies in unsprayed and sprayed population of chickpea genotypes.

Success of any breeding programme depends on the extent of variability present in the population so that breeder can effectively operate skill of selection. The information on phenotypic and genotypic coefficient of variation as well as heritability will be handy for prediction of the possible genetic advance by selection for a character. The genetic parameters such as genotypic coefficient of variability and genetic advance help to split the total variability into heritable and non-heritable components. It is worth assessing how diverse the parental material would be based on their evaluation in the present study.

The objective of present investigation was to identify the herbicide tolerant and high yielding genotypes. The material comprising of germplasm lines and advanced breeding lines were subjected for evaluation under herbicide sprayed and unsprayed condition during *rabi* 2016-17. The details of research findings are discussed as follows.

5.2.1. Mean and Range

Screening of 120 genotypes (86 germplasm lines, 25 advanced breeding lines and 9 released varieties) tolerance to two herbicides, Imazethapyr and Carfentrazone-ethyl revealed large genetic variation for tolerance to these herbicides. On a scale from 1 to 5 (1 = highly tolerant and 5 = highly sensitive), the level of herbicide tolerance ranged from 1 to 3 for imazethapyr and 3 for carfentrazone-ethyl. It was observed that many lines showed susceptibility to both the herbicides and none expressed tolerance to either or both the herbicides. In general, the sensitivity for Carfentrazone-ethyl was higher as compared to that for imazethapyr. Based on the average scores, the most tolerant lines to Imazethapyr herbicide were identified (Table 19). The herbicide tolerance scores for these tolerant lines are 1 in Imazethapyr and 2 to 3 in Carfentrazone-ethyl. The five most tolerant genotypes to both the herbicides (scores 1 for Imazethapyr and 2 to 3 for carfentrazone-ethyl) are listed in Table 21.

5.2.1.1. Flowering and maturity duration

The mean and range value for days to flowering and maturity duration in unsprayed population was low as compared to herbicide sprayed (Imazethapyr and Carfentrazone-ethyl) population. Herbicide spray adversely affects these two traits and delays the flowering and pod initiation compared to control or unsprayed plot indicating that maturity of crop is prolonged. This is mainly because herbicide spray affected the crop and prolonged the maturity duration this prolonged duration is mainly because herbicides affected the vegetative growth of the susceptible lines. Imazethapyr mainly killed the growing tips (epical meristem and young leaves) of the branches. Death of the plants was observed in highly sensitive genotypes. In moderately tolerant and tolerant genotypes, the death of epical meristem (Plate 2A) caused by imazethapyr induced branching these effects were similar to that of nipping in chickpea. Other abnormalities included elongation of branches (similar to tendrils) with very small or needle shaped leaves (Plate 2B), delaying of flowering, deformation of flowers, poor pod setting and reduction in pod and seed size. Secondary growth was observed in many lines 20–25 days after herbicidal application leading to flowering and pod set. Carfentrazone-ethyl



A. Death of apical meristamatic



B. Elongation of branches

Plate 2: Effect of Imazethapyr herbicide chickpea viz., death of apical meristem and elongation of branches after recovery from herbicide spray

had very severe crop injury because of its mode of action is inhibition of photosynthesis (Plate 3). Similar results were also reported by, Gaur *et al.* (2013), Taran *et al.* (2012), Delay in days to 50 per cent flowering seems to be due to temporary arrest of the growth of plant after herbicide spray of Imazethapyr in chickpea, Sharma *et al.* (2017), reported reduction in flowering (up to 83 %) Brandenberger *et al.* (2011) took more duration to reach 50 per cent flowering and maturity in treated plot compared to unsprayed plot, Vijayakumar *et al.* (2015). Imazamox treatments caused the most severe delay in days to flowering, Jafferries *et al.* (2016). In growing points, it inhibits the ALS enzyme, causing death of meristematic cells resulting in plant death Chaturvedi *et al.* (2014).

5.2.1.2 Plant height

Spray of both the herbicide (Imazethapyr and carfentrazone-ethyl) did not affect the plant height. Similar results were also obtained by Taran *et al.* (2012). Where as in the study conducted by Sajja *et al.* (2015) plant height was severely reduced.

5.2.1.3 Number branches (Primary, secondary and tertiary)

There was not much differences in the number of primary branches in both the condition *viz.* in unsprayed and herbicide treated plot (imazethapyr and Carfentrazone-ethyl). These results are on par with the results of Jefferies *et al.* (2016) and Sajja *et al.* (2015) also reported that herbicide has no effect on primary branches.

Wide range of variation was observed in number of secondary branches in Imazethapyr treated plot followed by Carfentrazone-ethyl treated plot when compared to unsprayed population. Same results were also reported by one of the researchers like Sajja *et al.* (2015) indicated that number of secondary branches increased up to 12 in Imazethapyr sprayed plot.

No much variation is seen in the case of tertiary branches, when compared to both unsprayed and herbicide sprayed (Imazethapyr and Carfentrazone-ethyl) plot.

Guar *et al.* (2013) reported that Imazethapyr mainly killed the growing tips (epical meristem and young leaves) of the branches. In moderately tolerant and tolerant genotypes, the death of epical meristem caused by imazethapyr induced branching. The effects were similar to that of the removal of shoot tips (called nipping), a general practice for inducing branching in chickpea. Other abnormalities included elongation of branches (similar to tendrils) with very small or needle shaped leaves,



Crop injury

Plate 3: Crop injury due to spray of Carfentrazone-ethyl herbicide

5.2.1.4 Yield and yield attributing traits

Yield and yield attributing traits like number of pods per plant, Number of seeds per plant, seed yield per plant and plot yield indicated that, in herbicide sprayed plot the yields were low compared to unsprayed plot. It is mainly due to action of both herbicides on plants. In susceptible genotypes there is complete death of the plant whereas in tolerant genotypes the yield reduction is seen. For both the herbicides, the most sensitive lines showed 80% to 100% mortality. According to Taran *et al* (2009) post-emergence application of metribuzin herbicide often causes crop injury and tends to reduce stands and yields. Application of imazamox reduced seed yields compared with all other herbicide treatments Taran *et al.* (2012).

The extent of variability as measured by GCV and PCV also give information regarding the relative amount of variation in different characters. A narrow difference between PCV and GCV indicate the negligible influence of extraneous factor on the trait.

Phenotypic coefficient of variation (PCV) were higher than the genotypic variance and genotypic coefficient of variation (GCV) for all the characters in both the levels. This indicates the presence of environmental influence in the expression of these characters. Similar results have been reported by Atta *et al.* (2008) and Khan *et al.* (2006).

In both herbicide sprayed (Imazethapyr and Carfentrazone-ethyl) and unsprayed population of chickpea we have seen similar kind of coefficient of variation for most of the traits. High GCV and PCV are obtained in number of primary branches, number of tertiary branches, number of pods per plant, number of seeds per plant, hundred seed weight, seed yield per plant, plot yield, biomass per plant. It appears that there is wide scope for selection among genotypes for this trait based on its phenotypic appearance

Moderate GCV and high PCV for days to first flowering, fifty percent flowering, days to first podding, days to fifty percent podding, days to fifty percent pod maturity and harvest index were obtained.

Low GCV, PCV for plant height, and low GCV and high PCV is seen for days to maturity. Indicating the difficulty and less chance in improving these traits through selection. These observations are in agreement with those of Atta *et al.* (2008), who reported lowest phenotypic and genotypic coefficient of variation for days to maturity in chickpea.

5.2.2 Heritability, genetic advance, and genetic advance over mean

The coefficient of variation indicates only the extent of variability existing for various traits, but does not give any information about the heritable portion of it, as the estimates of heritability. As such the heritability in a broader prospective is the proportion of genotypic variability to the total variability. Heritability estimates in the broad sense alone is not a true indicator of effectiveness of selection for the trait since is restricted by their interactions with the environment. Hence, heritability values considered along with predicted genetic gain increases the reliability of the parameter as a tool in selection programme. Heritability and genetic advance over mean estimates were given in Table 8, 9 and 10.

In both herbicide sprayed and unsprayed population of chickpea high heritability is seen in days to first podding, days to fifty percent podding, days to maturity, number of primary branches, number of secondary branches, number of tertiary branches, number pods per plant, number of seeds per plant, hundred seed weight, seed yield per plant, plot yield, biomass per plant, harvest index. The results are in agreement with Noor *et al.* (2003), Saleem *et al.* (2002), Hasen *et al.* (2008) and Ali *et al.* (2011). These suggest that direct selection for these traits would be effective for the improvement of yield.

Johnson *et al.* (1955) suggested that high heritability estimates combined with high genetic advance is indicative of additive gene action and selection based on these parameters would be more reliable. In the present investigation, high heritability estimates in conjunction with high genetic advance were observed for number of pods per plant, number of seeds per plant and plot yield. Indicating additive gene effects are more important in determining these characters and the improvement can be done through mass selection based on phenotypic values.

Furthermore, high heritability estimates coupled with low genetic gain were observed for most of the characters plant height, number of primary branches, number of tertiary branches and biomass per plant. Indicating the influence of dominant and epistatic genes for this character. Therefore, there appears to be a limited scope of improvement in this trait.

5.3 Correlation and path analysis studies in unsprayed and sprayed population of chickpea genotypes

Plant breeders judiciously select for yield and component traits, which influence yield directly or indirectly. Breeding for increased grain yield would be most effective if component traits involved were highly heritable and genetically independent or positively

correlated in early generations. Seed yield is a complex character, predominantly governed by large number of genes and is greatly influenced by environmental fluctuations. Therefore, selection based for yield may not be effective. Improvement in chickpea yield can be brought about by effecting indirect selection for yield related traits, whose heritability is high and show a strong association with yield. From the breeder's view point, the type of association of grain yield and its component traits is of paramount importance. Hence correlation coefficients between seed yield and other traits as well as inter se correlation among the yield component traits have been calculated for unsprayed and herbicide sprayed population of chickpea genotypes.

Genotypic and phenotypic correlation coefficients for all the traits in herbicide sprayed and unsprayed population of chickpea are tabulated in Tables 11, 12 and 13. It was found that the estimates of phenotypic correlation coefficients were non-significant for all the traits. The results on genotypic correlation coefficients are discussed below.

Number of primary branches

Genotypic correlation matrix showed significant positive association for yield with number of secondary branches and number of seeds per plant while non-significant positive correlation was noticed with number of tertiary branches and number of pods per plant in unsprayed and herbicide sprayed populations indicating selection for these component traits influences seed yield.

Number of secondary branches

Number of secondary branches per plant was significantly and positively associated with number of tertiary branches, while non-significant positive correlation was seen number of pods per plant and number of seeds per plant. It was negatively influenced by hundred seed weight in both unsprayed and herbicide sprayed populations.

Number of tertiary branches

Unlike other traits tertiary branches per plant exhibited significantly positive correlation with number of primary branches, number of secondary branches and number of pods per plant, while non-significant negative correlation were observed with hundred seed weight in both unsprayed and herbicide population.

Number of pods per plant

Number of pods per plant had positive non-significant association with number of primary branches and number of secondary branches. Positive significant correlation for number of tertiary branches and number of seeds per plant while negative correlation with hundred seed weight in unsprayed population was noticed. However in herbicide (Imazethapyr and Carfentrazone-ethyl) treatments genotypic correlation showed significant and positive influence of number of primary branches, number of secondary branches and number of seeds per plant. The trait hundred seed weight had non-significant positive association influence on number of pods per plant was observed. Whereas, non-significant negative correlation with number of pods per plant was noticed.

Number of seeds per plant

Similar kind of association was seen in both unsprayed and herbicide sprayed population of chickpea viz, significant positive correlation with number of primary branches, number of tertiary branches and number of pods per plant and positive non-significant correlation with secondary branches. This indicates that increase in the branches and number of pods, increases the yield.

Hundred seed weight

Genotypic results indicated that, there was a significant negative association of all the traits considered except number of pods per plant in case of unsprayed population of chickpea. We have seen significant positive correlation with number of secondary branches, number of tertiary branches, number of pods per plant and number of seeds per plant and it had a negative influence on number of primary branches in herbicide Imazethapyr sprayed population were as in Carfentrazone-ethyl sprayed population we have seen non-significant association with all the traits.

The overall results pertaining to correlation studies revealed that seed yield per plant had significant genotypic relationship with pods per plant and seeds per plant. These results suggested that improvement of grain yield in chickpea is linked with these traits and selection of these characters might have good impact on seed yield per plant. Saleem *et al.* (2002), Yucel *et al.* (2006) and Sharma *et al.* (2010) also reported similar results.

5.3.1. Path analysis in unsprayed and sprayed population of chickpea genotypes

The estimation of correlation coefficient reveals only the relationship between yield and yield components but does not provide the direct and indirect effects of different yield components on yield *per se*. The path analysis suggested by Dewey and Lu (1959) provides an effective measure of direct and indirect causes of association and depicts the relative importance of each factor involved in contribution to the final product *i.e.*, yield. Hence, an attempt was made to estimate the cause and relationship between seed yield per plant and its component traits in unsprayed and herbicide sprayed populations through path coefficient analysis. The results are discussed here under.

The path analysis being a more precise method partitions the direct and indirect effects of individual traits (independent) on grain yield per plant (dependent). This analysis would enable chickpea breeders to identify the characters that could be used as selection criteria in chickpea improvement programme. It was observed that in both unsprayed and herbicide sprayed (Imazethapyr and Carfentrazone-ethyl) populations of chickpea genotypes, number of pods per plant had direct and higher influence towards seed yield per plant followed by number of seeds per plant, number of tertiary branches, number of secondary branches and hundred seed weight. Low contribution of number of primary branches towards seed yield per plant. These results are on par with the results of Ali *et al.* (2009), Saleem *et al.* (1999) and Yucel *et al.* (2006).

5.4 Potential lines identified as sources of resistance to Imazethapyr and Carfentrazone-ethyl

Some of the tolerant and susceptible genotypes for both Carfentrazone-ethyl and Imazethapyr herbicides identified based on herbicide tolerance score are furnished in Table 19, 20 and 21 are discussed below.

Imazethapyr compound is used as selective herbicide to control most annual grasses and certain broad leaf weeds of pulses. Imazethapyr inhibits amino acid synthesis and can be applied as pre-emergence as well as post-emergence herbicide in chickpea. These compounds act by inhibiting acetolactate synthase, a key enzyme in the synthesis of branched-chain amino acids like valine, leucine and isoleucine. After being translocated through phloem, it inhibits ALS resulting in the death of meristematic cells and finally the whole plant. Some of the tolerant/highly tolerant lines were identified from this study based on herbicide tolerance

Table 19: Tolerant genotypes for Imazethapyr herbicide

Entry name	10 DAS	20 DAS	30 DAS	DFFL		DFF		DFPD		DFP		DFPM		DM		SWPT		HSW		% decrease in yield
				S	US	S	US	S	US	S	US	S	US	S	US	S	US	S	US	
ICC 8795	1	1	1	76.00	70.67	80.00	76.67	86.67	88.67	93.00	95.67	102.50	103.00	110.50	112.33	7.74	14.78	21.00	22.33	14.25
KAK-2	1	1	1	70.67	41.00	75.50	44.67	81.50	52.67	89.00	63.00	95.00	73.00	102.50	84.67	6.33	17.97	22.50	28.25	17.61
ICCV 11101	1	1	1	68.50	56.33	75.00	61.67	81.00	74.33	88.50	83.33	94.50	93.67	102.50	102.00	3.99	16.16	34.00	19.00	15.91

Table 20: Susceptible genotypes for Carfentrazone-ethyl herbicide

Entry name	10 DAS	20 DAS	30 DAS	DFFL		DFF		DFPD		DFP		DFPM		DM		SWPT		HSW		% decrease in yield
				S	US	S	US	S	US	S	US	S	US	S	US	S	US	S	US	
NBeG 510	5	4	4	64.67	48.00	69.67	54.00	76.00	60.33	83.00	72.00	89.50	83.33	97.00	95.33	14.41	8.81	46.50	52.33	7.17
NBeG 119	5	4	4	66.33	62.00	73.17	68.33	83.50	65.00	90.33	76.33	96.83	87.67	105.50	96.67	5.76	28.33	27.92	29.50	28.13
GL 22014	5	5	5	70.00	61.67	76.00	67.33	83.00	72.00	90.50	82.00	97.00	92.33	106.00	103.67	9.97	8.15	23.08	24.50	6.93
ICCV 05530	5	5	5	66.00	54.67	70.33	59.33	77.33	59.67	86.00	70.67	93.00	81.33	101.67	96.00	8.52	35.83	32.83	33.43	35.60

Table 21: Top five resistant lines for herbicides Imazethapyr and Carfentrazone-ethyl

Imazethapyr	Scoring			D1stF			DM			NPB			NSB			PH			HSW			SWPLOT(g)		
	10 DAS	20 DAS	30 DAS	RI	RII	RIII	RI	RII	RIII	RI	RII	RIII	RI	RII	RIII	RI	RII	RIII	RI	RII	RIII	RI	RII	RIII
ICC 438	1	1	1	76	71	71	101	110	106	1	4	3	4	3	4	34	23	29	19.5	22.8	23.0	60.68	61.60	69.60
PBG-5	1	1	1	87	85	91	119	120	120	3	3	3	3	3	3	34	38	35	23.0	22.3	21.5	34.75	36.25	33.00
KAK-2	1	1	1	66	55	61	97	95	96	2	3	2	3	4	3	31	32	30	39.0	41.5	43.0	80.25	20.63	68.20
NBeG 453	1	1	1	66	65	64	93	102	98	2	2	2	3	2	2	40	39	35	39.0	38.5	38.0	53.00	51.00	55.00
ICCV 11101	1	1	1	77	74	74	100	108	104	1	4	3	5	3	4	34	31	32	23.0	24.5	24.0	49.00	36.25	83.52
Carfentrazone- ethyl	Scoring			D1stF			DM			NPB			NSB			PH			HSW			SWPLOT		
	10 DAS	20 DAS	30 DAS	RI	RII	RIII	RI	RII	RIII	RI	RII	RIII	RI	RII	RIII	RI	RII	RIII	RI	RII	RIII	RI	RII	RIII
ICCV 97034	3	3	2	69	71	70	105	106	106	3	3	3	5	4	4	36	30	36	25.5	20.8	21.0	83.25	58.10	81.32
ICCV 11110	3	3	2	71	73	72	103	108	106	2	2	2	6	4	5	25	27	32	23.0	26.0	27.0	24.75	22.00	23.00
ICCV 97315	3	3	2	68	72	70	100	107	104	2	2	2	3	4	4	33	37	28	28.0	29.5	39.0	14.63	79.09	10.94
ICCV 11118	2	3	3	75	74	75	107	107	107	1	2	2	3	2	3	24	27	27	20.0	21.3	22.0	17.88	39.90	29.25
ICCV 96035	3	3	3	69	70	70	103	102	103	3	3	3	4	4	4	36	32	30	22.0	21.3	22.0	41.82	70.00	81.90

score (1-5). The genotypes ICC 438, PBG-5, KAK-2, NBeG 453, ICCV 11101 showed resistant reaction having the score one at 10, 20 and 30 days after spray indicating high or tolerance to herbicide imazethapyr.

Carfentrazone-ethyl is a contact herbicide used to control broadleaf weeds. The mode of action of carfentrazone-ethyl is the disruption of membranes by inhibiting the action of protoporphyrinogen oxidase, causing cell death. Carfentrazone is non-selective, and can be used for complete vegetation control, as well as, as a desiccant and a defoliant in some crops. As carfentrazone-ethyl is a photosynthetic inhibitor, more injury is caused by this herbicide. Hence only a few genotypes which showed moderate resistance at 10, 20 and 30 days after spray ICCV 97034, ICCV 11110, ICCV 97315, ICCV 11118, ICCV 96035 having score of 2/3 and 3 at 10, 20 and 30 days after spray. Indicating their utilization in further breeding programme for herbicide tolerance.

Among the top five tolerant genotypes identified for each herbicide, no genotype was tolerant to both the herbicides. This may be due to differences in the genes controlling tolerance to these herbicides which have different modes of action—imazethapyr inhibits amino acid synthesis, while metribuzin inhibits photosynthesis. The genotypes (ICC 438, KAK 2) resistant to Imazethapyr are moderately tolerant to Carfentrazone-ethyl can be used as donors in breeding herbicide resistant chickpea cultivars.

Summary and Conclusions

6. SUMMARY AND CONCLUSIONS

Chickpea (*Cicer arietinum* L.) is world's second-most widely grown legume after beans (*Phaseolus vulgaris*). Currently cultivated in over 50 countries and is a rich source of dietary proteins for regular diet; moreover, its ability to fix atmospheric nitrogen via interaction with rhizobia adds to its uniqueness. The production of chickpea is largely constrained by several biotic and abiotic factors. Among many biotic factors weeds possess a major problem. Weeds compete with chickpea plants for water, nutrients, sunlight, and space and also harbour insect-pests and diseases. If left uncontrolled, weeds can reduce chickpea yield significantly. Significant yield losses (up to 84%) due to weeds have been reported in chickpea, more severely (up to 98%) in autumn-sown chickpea. Thus, weed management is crucial in chickpea to realize maximum yields and also to maintain high quality of produce.

Hand weeding and mechanical weed control methods traditionally followed in the developing countries are becoming expensive due to increased labour wages. The pre-emergence herbicides are effective in controlling weeds at early stage of seedling growth, but weeds germinating after crop emergence become dominant in the field and cause substantial yield losses. Therefore, chickpea cultivars with improved herbicide tolerance, which can offer greater flexibility for use of post-emergence herbicides, are required by the farmers. Gaur *et al.* (2013)

The large genetic variability identified in chickpea for herbicide tolerance will stimulate further research efforts towards development of herbicide tolerant cultivars. The present study provided a good indication of the variability present in the germplasm as well as advanced breeding lines for herbicide tolerance and it would encourage further screening of a greater germplasm collection to search robust and diverse sources of herbicide tolerance. The herbicide tolerant genotypes identified in this study would be useful in genetic and physiological studies and in development of herbicide tolerant cultivars.

Herbicide tolerant cultivars have been developed in many crops, including some grain legumes, by exploiting available genetic variability in the germplasm or by inducing variability through induced mutagenesis e.g., a variety “Coromup” in narrow-leaf lupin and a variety “Tracy-M” in soybean with improved tolerance to herbicide metribuzin were developed by screening the advanced breeding lines. In narrow-leaf lupin, two highly tolerant metribuzin mutants, Tanjil-AZ-55 and Tanjil-AZ-33, were identified. Similarly in lentils, a

variety “RH44” with tolerance to imidazolinone was developed by mutagenesis. There are few reports on identification of herbicide tolerance in chickpea. However, these reports indicate presence of genotypic variations for herbicide tolerance in chickpea. The investigation carried out with 120 genotypes (86 germplasm, 25 advanced breeding lines and 9 released varieties) during, *rabi* 2016-17 at RARS, Vijayapur revealed the following aspects:

Salient findings of the investigation

1. Genotypes showed severe visual injury to the herbicide Carfentrazone-ethyl generally the scores are 3, 4 and 5. Imazethapyr had lower injury having injury score of 1, 2, and 3), stunting growth, delayed flowering and maturity under both the herbicides treatment. Unfavourable conditions due to weather or disease can amplify the negative responses from herbicides on the genotypes.
2. Chickpea genotypes were significantly different for evaluated traits under unsprayed and herbicide sprayed conditions, indicating that herbicide spray increased variation for these traits.
3. Correlation among the studied traits with seed yield showed that there was significant and positive correlation between number of pods per plant and seed. Thus, number of pods per plant could be used as selection index for improving seed yield in herbicides (Imazethapyr and carfentrazone-ethyl) sprayed population of chickpea.
4. Path analysis showed pods per plant are directly and highly contributed towards seed yield per plant followed by number of seeds per plant later, followed by number of tertiary branches, number of secondary branches, hundred seed weight and hence emphasis may be laid on these characters for improving yield per plant.
5. Some of the tolerant genotypes identified in Imazethapyr sprayed genotypes *viz.*, ICC 438, PBG-5, KAK-2, NBeG 453, ICCV 11101. In Carfentrazone-ethyl sprayed plot also we have recorded some tolerant genotypes *viz.*, ICCV 97034, ICCV 11110, ICCV 97315, ICCV 11118, ICCV 96035 based on the herbicide tolerance score recorded at 10, 20, 30, days after spraying as well as the yield components. `

Future line work

- Resistant and high yielding genotypes can be released as varieties
- Resistant but may low yielding genotypes are used as a parents in further breeding programme.
- Popularization of post emergence herbicide tolerant chickpea varieties will ensure enhanced productivity in the era of conservation agriculture and increase farm profitability.

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Appendices

Appendix I : List of genotypes and their sources used in present investigation

Sl. No.	Entry name	Sources
1	ICC 5250	ICRISAT, Hyderabad, TS
2	ICC 11532	ICRISAT, Hyderabad, TS
3	ICC 4963	ICRISAT, Hyderabad, TS
4	ICC 8277	ICRISAT, Hyderabad, TS
5	ICC 16141	ICRISAT, Hyderabad, TS
6	ICC 12511	ICRISAT, Hyderabad, TS
7	ICC 8795	ICRISAT, Hyderabad, TS
8	ICC 10090	ICRISAT, Hyderabad, TS
9	ICC 12315	ICRISAT, Hyderabad, TS
10	ICC 16343	ICRISAT, Hyderabad, TS
11	ICC 438	ICRISAT, Hyderabad, TS
12	ICC 9032	ICRISAT, Hyderabad, TS
13	ICC 9567	ICRISAT, Hyderabad, TS
14	ICCIL 01034	ICRISAT, Hyderabad, TS
15	ICCIL 01031	ICRISAT, Hyderabad, TS
16	ICCIL 04004	ICRISAT, Hyderabad, TS
17	ICCIL 04021	ICRISAT, Hyderabad, TS
18	ICCIL 01026	ICRISAT, Hyderabad, TS
19	ICCIL 04016	ICRISAT, Hyderabad, TS
20	ICCIL 86201	ICRISAT, Hyderabad, TS
21	ICCIL 95982	ICRISAT, Hyderabad, TS
22	ICCV 97034	ICRISAT, Hyderabad, TS
23	ICCV 97021	ICRISAT, Hyderabad, TS
24	ICCV 11111	ICRISAT, Hyderabad, TS
25	ICCV 97016	ICRISAT, Hyderabad, TS
26	ICCV 96008	ICRISAT, Hyderabad, TS
27	ICCV 11108	ICRISAT, Hyderabad, TS
28	ICCV 11110	ICRISAT, Hyderabad, TS
29	ICCV97115	ICRISAT, Hyderabad, TS
30	ICCCV 91024	ICRISAT, Hyderabad, TS
31	ICCV 97056	ICRISAT, Hyderabad, TS
32	ICCV 97315	ICRISAT, Hyderabad, TS
33	ICCV 96018	ICRISAT, Hyderabad, TS

Appendix I : Contd.....

Sl. No.	Entry name	Sources
34	ICCV 96325	ICRISAT, Hyderabad, TS
35	ICCV 97308	ICRISAT, Hyderabad, TS
36	ICCV 11118	ICRISAT, Hyderabad, TS
37	ICCV 93005	ICRISAT, Hyderabad, TS
38	ICCV 97119	ICRISAT, Hyderabad, TS
39	ICCV 93055	ICRISAT, Hyderabad, TS
40	ICCV 96007	ICRISAT, Hyderabad, TS
41	ICCV 11115	ICRISAT, Hyderabad, TS
42	ICCV 93054	ICRISAT, Hyderabad, TS
43	ICCV 11303	ICRISAT, Hyderabad, TS
44	ICCV 95138	ICRISAT, Hyderabad, TS
45	ICCV 95008	ICRISAT, Hyderabad, TS
46	ICCV 95005	ICRISAT, Hyderabad, TS
47	ICCV 93122	ICRISAT, Hyderabad, TS
48	ICCV 97018	ICRISAT, Hyderabad, TS
49	ICCV 96003	ICRISAT, Hyderabad, TS
50	ICCV 11101	ICRISAT, Hyderabad, TS
51	ICCV 11109	ICRISAT, Hyderabad, TS
52	ICCV 97025	ICRISAT, Hyderabad, TS
53	ICCV 96035	ICRISAT, Hyderabad, TS
54	ICCV 11116	ICRISAT, Hyderabad, TS
55	ICCV 97019	ICRISAT, Hyderabad, TS
56	ICCV 11102	ICRISAT, Hyderabad, TS
57	ICCCV 97110	ICRISAT, Hyderabad, TS
58	ICCV 96009	ICRISAT, Hyderabad, TS
59	ICCV 97017	ICRISAT, Hyderabad, TS
60	ICCV 97002	ICRISAT, Hyderabad, TS
61	ICCV 97049	ICRISAT, Hyderabad, TS
62	ICCV 97057	ICRISAT, Hyderabad, TS
63	ICCV 96005	ICRISAT, Hyderabad, TS
64	ICCV 95013	ICRISAT, Hyderabad, TS
65	ICCV 97105	ICRISAT, Hyderabad, TS
66	ICCV 96019	ICRISAT, Hyderabad, TS

Appendix I : Contd.....

Sl. No.	Entry name	Sources
67	ICCV 08102	ICRISAT, Hyderabad, TS
68	ICCV 09106	ICRISAT, Hyderabad, TS
69	ICCV 08109	ICRISAT, Hyderabad, TS
70	ICCV95003	ICRISAT, Hyderabad, TS
71	ICCV 97022	ICRISAT, Hyderabad, TS
72	ICCV 94920	ICRISAT, Hyderabad, TS
73	ICCV 96006	ICRISAT, Hyderabad, TS
74	ICCV 96836	ICRISAT, Hyderabad, TS
75	ICCV 96026	ICRISAT, Hyderabad, TS
76	ICCV 10	ICRISAT, Hyderabad, TS
77	ICCV 96011	ICRISAT, Hyderabad, TS
78	ICCV 11117	ICRISAT, Hyderabad, TS
79	ICCV 95012	ICRISAT, Hyderabad, TS
80	ICCV 97007	ICRISAT, Hyderabad, TS
81	ICCV 91902	ICRISAT, Hyderabad, TS
82	ICCV 10114	ICRISAT, Hyderabad, TS
83	ICCV 97020	ICRISAT, Hyderabad, TS
84	ICCV 97033	ICRISAT, Hyderabad, TS
85	ICCRIL11,ICCV 04516	ICRISAT, Hyderabad, TS
86	ICCRIL10,ICCV 05530	ICRISAT, Hyderabad, TS
87	NBeG 453	ARS-Nandyal, AP
88	NBeG 458	ARS-Nandyal, AP
89	NBeG 510	ARS-Nandyal, AP
90	NBeG 119	ARS-Nandyal, AP
91	GL 12003	PAU, Ludhiana, PB
92	GL 10006	PAU, Ludhiana, PB
93	GL 29098	PAU, Ludhiana, PB
94	GL 22014	PAU, Ludhiana, PB
95	GL 12020	PAU, Ludhiana, PB
96	GL 12004	PAU, Ludhiana, PB
97	ST-3-D-16	ARS-Sehore, RVSKVV, Gwalior, MP
98	ST-3-D-2	ARS-Sehore, RVSKVV, Gwalior, MP
99	ST-3-D-5	ARS-Sehore, RVSKVV, Gwalior, MP

Appendix I : Contd.....

Sl. No.	Entry name	Sources
100	ST-3-D-1	ARS-Sehore, RVSKVV, Gwalior, MP
101	ST-3-D-10	ARS-Sehore, RVSKVV, Gwalior, MP
102	RVG-202	ARS-Sehore, RVSKVV, Gwalior, MP
103	RVG-203	ARS-Sehore, RVSKVV, Gwalior, MP
104	RVG-201	ARS-Sehore, RVSKVV, Gwalior, MP
105	RVSSG-22	ARS-Sehore, RVSKVV, Gwalior, MP
106	Pusa 209	IARI, New Delhi
107	Pusa 372	IARI, New Delhi
108	Pusa 1108	IARI, New Delhi
109	Pusa 5028	IARI, New Delhi
110	GLW 12041	PAU, Ludhiana, PB
111	GLW 12042	PAU, Ludhiana, PB
112	JG 6	JNKVV, Jabalpur, MP
113	JG 33	JNKVV, Jabalpur, MP
114	L 556	ARS, Ganganagar, RJ
115	GNG-1958 #	ARS, Ganganagar, RJ
116	BG-2085	IARI, New Delhi
117	BGD128	IARI, New Delhi
118	JSC-37	IIPR, Kanpur, UP
119	PBG-5	PAU, Ludhiana, PB
120	KAK-2	PDKVV, Akola, MH

GENETIC VARIABILITY STUDIES IN CHICKPEA (*Cicer arietinum* L.) FOR HERBICIDE TOLERANCE

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ABSTRACT

Plant resistance mechanism has been widely recognized as the most potential and successful way to minimize losses due to biotic stresses including weeds in chickpea (*Cicer arietinum* L.). Weeds pose great threat to chickpea production through competing for natural resources. Herbicides are the most successful weed controlling agents. The present research work aimed at identification of sources of tolerance to herbicides Imazethapyr and Carfentrazone-ethyl for their possible utilization in development of herbicide tolerant chickpeas. One hundred and twenty genotypes, that included germplasm lines, advanced breeding material, mutants and derivatives of wild species were screened against Imazethapyr and Carfentrazone-ethyl during *rabi* 2016-17 at Regional Agricultural Research Station (RARS), Vijayapur. Herbicide spray of Imazethapyr (@1ml/ltr) and Carfentrazone-ethyl (approximately @ 48 g/acre) was done at 30 DAS. Scoring of herbicide tolerance was done after 10, 20, 30, days of spraying based on injury caused to plants as per Guar *et al.* (2013). Herbicide spray Imazethapyr affected the meristematic cells resulting in increased number of branches, delayed flowering and maturity as compared to unsprayed population. Carfentrazone-ethyl affected the photosynthesis as it is photosynthesis inhibitor, had major crop injury. In general sensitivity for Carfentrazone-ethyl was higher as compared to that for Imazethapyr.

The genotypes ICC 438, PBG-5, KAK-2, NBeG 453, ICCV 11101 showed resistant reaction to herbicide Imazethapyr, while the genotypes ICCV 97034, ICCV 11110, ICCV 97315, ICCV 11118, ICCV 96035 showed moderate resistance to Carfentrazone-ethyl. However none of the genotypes were found to be simultaneously resistant to both post emergent herbicides. Nevertheless, two genotypes ICC 438 and KAK 2 were found resistant to Imazethapyr and moderately tolerant to Carfentrazone-ethyl. These genotypes can be further utilized to study the genetics of herbicide tolerance in chickpea and in breeding programs for developing herbicide tolerant chickpea cultivars.