ECOLOGICAL ASPECTS, INTERFERENCE AND MANAGEMENT OF *Euphorbia dracunculoides* AND *Astragalus* spp.: WEEDS OF CHICKPEA

BY

Rao Muhammad Ikram
M.Sc. (Hons.) Agronomy
Redg. # 2003-ag-1928

A thesis submitted in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY
IN
AGRONOMY

DEPARTMENT OF AGRONOMY,
FACULTY OF AGRICULTURE,
UNIVERSITY OF AGRICULTURE,
FAISALABAD, PAKISTAN.

2014

DECLARATION

I hereby declare that contents of the thesis, "Ecological aspects, interference and management of *Euphorbia dracunculoides* and *Astragalus*

spp.: Weeds of chickpea" are product of my own research and no part has been copied from any published source (except the references, standard mathematical or genetic models/equations/formulate/protocols etc.). I further declare that this work has not been submitted for award of any other diploma/degree. The university may take action if the information provided is found inaccurate at any stage. (In case of any default, the scholar will be proceeded against as per HEC plagiarism policy).

Rao Muhammad Ikram

2003-ag-1928

The Controller of Examinations,
University of Agriculture,
Faisalabad.

We, the supervisory committee, certify that the contents and the form of thesis submitted by **Mr. Rao Muhammad Ikram**, Regd. No. 2003-ag-1928 have been found satisfactory and recommend that it be processed for evaluation by the External Examiner (s) for award of Degree.

SUPERVISORY COMMITTEE:

CHAIRMAN : _____
(**Dr. Asif Tanveer)**

MEMBER : _____
(Dr. Zahid Ata)

MEMBER : _____
(**Dr. Muhammad Saqib)**

DEDICATED

TO

MY BELOVED FATHER
(Rao Muhammad Luqman)
and
AFFECTIONATE SUPERVISOR
Dr. Asif Tanveer

ACKNOWLEDGEMENTS

Saying of Prophet Muhammad (PBUH) `A person who is not thankful to his benefactor is not thankful to ALLAH'. All and every kind of praises is upon ALLAH ALMIGHTY, the strength of universe, whoever helps in darkness & difficulties. All and every kind of respect to His Holy Prophet Muhammad (PBUH) for unique comprehensive and everlasting source of guidance and knowledge for humanity.

I would like to extend my heartiest gratitude to **Dr. Asif Tanveer**, Professor, Department of Agronomy, University of Agriculture, Faisalabad, under whose supervision, scholastic guidance, consulting behavior, this work was planned, executed and completed. I appreciate and thank to members of my supervisory committee, **Dr. Zahid Ata**, Professor, Department of Agronomy, University of Agriculture, Faisalabad for his helping attitude and **Dr. Muhammad Saqib,** Assistant Professor, Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad, for their valuable and continuous guidelines during the preparation of this manuscript and kind hearted behavior throughout my doctoral studies. I am also highly indebted to **Higher Education Commission (HEC), Government of Pakistan** for granting me Indigenous fellowship throughout my doctoral study.

I shall be missing something if I don't extend my admiration and appreciation to my sincere friends **Dr. M. Sibtain, Dr. Attaullah Mohsin, Dr. Rana Nadeem Abbas, Usman Akram, Dr. M. Mansoor Javaid, Ihsan Safdar, Irfan Rasool, Dr. Saqib Saleem Akhtar, Dr. Haseeb ur Rehman, M. Farooq, A. Majeed Sethar, M. Atif Majeed, Naeem Qadir Khan** and all my lab fellows who supported me morally throughout my study. In addition, deepest appreciations are due to my wife and little angels (Aden Fatima, Aqsa and Aleeza). Last but not the least gratitude is to be expressed to my affectionate and loving mother, and my beloved brothers, sisters and all family members for their love, inspiration, good wishes and unceasing prayers for me to achieve higher goals in life.

Rao Muhammad Ikram

TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

Page

ABBREVIATIONS

Abbreviation	Full
%	percent
a.i.	active ingredient
@	at
ºC	centigrade
Corp.	corporation
cm	centimeter (s)
cm^2	centimeter square
d	day (s)
DAE	days after emergence
EC	Emulsifiable concentrates
E_{50}	time to 50% emergence
EI	emergence index
g	gram (s)
g m^{-2}	gram per square meter
GI	germination index
h	hour (s)
ha	hectare
ha^{-1}	per hectare
DAS	Days after sowing
HI	Harvest index
K	Potassium
kg	kilogram

kg ha^{-1}	kilogram per hectare
L	Litter
LSD	Least significant difference
m	meter
m^{-2}	per square meter
MET	mean emergence time
mg g^{-1}	milli gram per gram
MGT	mean germination time
ml	millilitter
mm	millimeter
mM	milli Molar
MPa	Mega Pascal
nm	nano-meter
N	Nitrogen
NS	non-significant
P	Phosphorus
CRD	completely randomized design
RCBD	randomized complete block design
RCI	relative competitive index
Rs.	Rupees
PKR	Pakistani Rupees
USD	United states dollar
T_{50}	time to 50% germination

ABSTRACT

Ecological aspects, interference and management of *Euphorbia dracunculoides* L. and *Astragalus* spp. was studied in the laboratory, department of Agronomy, University of Agriculture, Faisalabad, Pakistan and under farmer's field conditions. Results of our laboratory experiments suggested that GA_3 (50, 100, 150, 200, 250 and 300 ppm) and KNO_3 (5000, 10000, 15000, 20000, 25000 and 30000 ppm) were more effective in breaking dormancy of *E. dracunculoides and Astragalus* spp. than thiourea (50, 100, 150, 200, 250 and 300 ppm). *Euphorbia dracunculoides and Astragalus* spp. can tolerate a wide range of environmental factors. Germination of *E. dracunculoides and Astragalus* spp. was maximum at 15ºC under light condition. Increase in water stress from 2.5 to 15% significantly decreased *E. dracunculoides and Astragalus* spp. germination. A considerable germination of *E. dracunculoides and Astragalus* spp. was occurred at pH levels from 6.00 to 9.00. *Euphorbia dracunculoides and Astragalus* spp. were very sensitive to salinity; however a few seeds of *Astragalus* spp. even germinated at 150 mM salt stress. Seeds of *E. dracunculoides and Astragalus* spp. showed maximum emergence at soil surface, however considerable number of seeds emerged at 1, 2 and 3 cm burial depth. Chickpea yield parameters e.g. number of pods per plant, number of seeds per pod and 100-seed weight were significantly decreased with an increase in *E. dracunculoides and Astragalus* spp. competition duration from 45 DAS to full season. Chickpea seed yield losses were in the range of 13-54% under different *E. dracunculoides and Astragalus* spp. competition durations. Critical weed crop competition period was 45 days after sowing. Weed control with pre-emergence application of pendimethalin+prometryn @ 450 + 600 g a.i. ha^{-1} and metribuzin @ 187.5 g a.i. ha^{-1} was maximum but chickpea grew well with pendimethalin+prometryn @ 375 + 500 g a.i. ha^{-1} which resulted in highest chickpea seed yield. There were some suppressive effects on crop at higher doses of both herbicides which resulted a decrease in chickpea growth. Highest chickpea seed yield (2376.30 kg ha^{-1}) was recorded with hand weeding which was statistically similar with that of yield obtained when pendimethalin+prometryn was sprayed @ 375 + 500 g a.i. ha^{-1}. Hand weeding plots resulted 61-66% more yield over weedy check followed by that of pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1} (56-61%) during both years of study. Macro and micro nutrients losses by weeds increased with increase in competition duration. Macro and micro nutrient losses by weeds ranged from 5-53 kg ha^{-1} and 12-177

g ha^{-1}, respectively. Maximum marginal rate of return (2803%) was achieved with metribuzin @ 150 g a.i. ha^{-1} in first year and 5416% with pendimethalin+prometryn @ 375 + 500 g a.i. ha^{-1} in second year.

CHAPTER 1 INTRODUCTION

Chickpea (*Cicer arietinum* L.) is an important grain legume used as a source of human and animal nutrition. It is the third most important pulse crop of the world and is mainly grown in dry and semi-dry areas relatively high in India, Pakistan and Iran (Mohammadi *et al.,* 2005; Paolini *et al.,* 2006). Pakistan is the second largest producer of chickpea (9.5%) after India (65%), followed by Turkey (6.7%) in the world (Shah *et al.,* 2006). There are two types of chickpea based on seed color in the world named 'Kabuli' or white and 'desi' or brown (Kaya *et al*., 2008). Desi chickpea accounts for about 90% of the world's current commercial production. Chickpea is grown on 0.99 million hectares in Punjab, Sindh and Khyber Pakhtoonkhawa provinces of Pakistan with total production of 0.67 million tons. Punjab constitutes 80% of total area grown, 92% of which is rainfed "Thal" contributing about 77% to the total chickpea production of Pakistan. In rainfed areas chickpea is sown in October-November on soil moisture conserved from summer moon soon (July-September). At farmer's field there is a big gap (2.63 t ha^{-1}) between the potential yield (3.3 t ha^{-1}) and the average yield (0.67 t ha^{-1}) (Govt. of Pak., 2013). The main factors that contribute to lower yield include, environmental factors (moisture shortage due to inadequate and erratic rains, low temperature stress (frost) during early crop growth), sowing on marginal land, low or no use of fertilizers and presence of weeds. Weed invasion is one of the most important factors responsible for low yield and economic returns of chickpea (Mohammadi *et al.,* 2005). Weeds compete crop plants for resources like nutrients, moisture, light, air and space and act as a barrier for control (Ahmad and Sheikh, 2003). Weeds deteriorate the crop quality and reduce its market value (Marwat *et al*., 2005). Chickpea plant develops slowly and has an open design on the surface and short stature which limit its ability to compete with weeds. Yield losses up to 97% due to weeds in chickpea have been reported (Paolini *et al.,* 2006; Patel *et al.,* 2006). Losses due to weeds depend on factors like weed type, weed density, weed germination time, weed infestation duration, space for growth, environmental and management factors. In chickpea yield losses are more as density of weeds increased (Whish *et al*., 2002).

Understanding the biology of weeds is mandatory for the success of weed in field condition and for its effective management (Koger *et al*., 2004; Fenner and Thompson, 2005). It is permissible for a comprehensive review of the factors in dealing with the germination of weed seeds to facilitate the development of cultural weed management through active suppression or enhancement of germination and seedlings at a time when it

can be easily controlled (Chauhan and Johnson, 2010). Understanding of dormancy is of ecological importance. This information can be used for management programs and species reintroduction (Koyuncu, 2005; Ortega-Base and Rojas-Arechiga, 2007). Dormancy behavior of weed seeds also helps to dodge the weeding practices like herbicides and make them successful to persist in an agro-ecosystem (Tang *et al*., 2008; Khan and Shah, 2011). Efficient crop production can be achieved by assisting the new methods of dormancy release (Gu *et al*., 2004). Germination of weed seeds is affected by number of ecological factors such as pH, light, temperature, moisture, salinity and seeding depth which varies from weed to weed (Benvenuti *et al*., 2001; Chauhan *et al*., 2006; Rizzardi *et al*., 2009).

Biochemical interaction in the environment which affects the growth of other plants (stimulatory or inhibitory) through the release of secondary substances is termed as allelopathy (Rice, 1984). It plays an important role in agro-ecosystems, affecting growth and product quality (Singh *et al.,* 2001; Batish *et al*., 2002). Weeds affect crops by the release of allelochemicals from seeds, decomposition of waste, leachate, and volatile secretions (Narwal, 2004). Studies reported that several weed species stuck the growth and development of crops (Dongre and Singh, 2007) and some have stimulatory effects (Mandal, 2001). Aerial parts of the plant are more effective than the sub-aerial portion in reduction of germination and effects are concentration dependent (Khan *et al*., 2007; Li and Jin, 2010; Hussain *et al*., 2011).

Strategies to manage weeds mean attempt to limit the harmful effects of weeds growing in a crop. Such effects may be very different, but the most common is the competition for the available growth factors which reduce crop yield considerably (Deen *et al*., 2003). If weeds are able to take advantage of a sufficient quantity of growth factors, the result may be and often, a negative impact on the crop. Knowledge of weed competition in crops is effective in taking right decisions for suitable weed management and to reduce the cost of weed management (Evans *et al*., 2003). In a growing season when crop plants are more sensitive to weeds presence, it is said to be critical period. For determining the start of critical period of weed-crop competition, weeds density is very important (Martin *et al.*, 2001; Mohammadi *et al.*, 2005).

Methods used to control weeds include manual, mechanical and cultural, biological and chemical tactics. The first two methods are common in less developed agricultural systems. Beside with environmental and some crop quality concerns, the most common method currently used to manage weeds is the use of herbicides. Herbicides do not generally control a single species but more than one, each with a

different level of efficacy. Like most legumes, chickpea is more tolerant of pre-emergence herbicides than post-emergence. The selectivity and efficacy of soil acting herbicides is usually limited to specific agro-ecological conditions because of differences in soil type, moisture availability, temperature, and weed flora (Vangessel *et al.*, 2000). It is prerequisite to use proper herbicide for proper weed which may be effective in harming the weed only. Pre-emergence herbicides are good to use because they kill the target plants before emergence by inhibiting cell division and cell elongation depending upon the nature and mode of action. Mixture of two or more herbicides is a very common and useful practice in an exhaustive agriculture. Herbicides mixture aims to broaden spectrum of weeds control by improving efficacy of combined herbicides at reduce rate and to delay herbicide resistance development in weed. Application of two or more herbicides simultaneously, either using prepackage mixture or by mixing herbicides at the time of application can also reduce the cost and time of weed control. Contrary to this, single herbicide has a narrow spectrum, inadequate for satisfactory and cost effective weed control (Damalas, 2004). There are numerous reports on the use of pendimethalin for control of weeds in chickpea. However, no reports are available on testing of other herbicides with different mode of action to control weeds in chickpea. Reports also lack on influence of a low rate of pendimethalin in combination with prometryn on weeds. Therefore, closer examination of weed species responses to different herbicides is necessary to determine the most effective rate, stage of plant growth at time of application. Combining other herbicides with pendimethalin for controlling weeds of chickpea would require that they match the soil residual activity of pendimethalin and enhance its phytotoxic activity against weeds at germination. Pre-emergence soil applied herbicides can successfully decrease early competition from weeds. Therefore evaluation of newly developed and currently recommended herbicides is necessary to refine management strategies for control of weeds.

Euphorbia dracunculoides is an annual herb. It belongs to family Euphorbiaece, usually 15-40 cm tall, often much branched from the base and is one of the major weeds in chickpea and wheat in rainfed areas of Pakistan. Several species of *Euphorbia* have been demonstrated to be allelopathic i.e. *Euphorbia granulata* Forssk., *Euphorbia pilulifera, Euphorbia esula, Euphorbia helioscopia, Euphorbia maculate and Eupatorium odoratum* (Steenhagen and Zimdahl, 1979; Hussain, 1980; Hussain *et al.*, 1985; Bararpour *et al.*, 1994; Kumar *et al.*, 2007). On the other hand *Astragalus* spp. is an annual shrub belongs to

Fabaceae family normally achieves the 40 cm height. *Astragalus* is also a troublesome weed of chickpea as well as of wheat.

Allelopathic effects and control of Euhporbia species have been reported under controlled conditions. However, these investigations did not address the germination ecology, competitive effects and control of *E. dracunculoides*. On the other hand, there is no work on *Astraglus* spp. especially in Pakistan and a little more in the world. So a lot of consideration through ecological understanding is necessary. As there is no information for the control of *E. dracunculoides* and *Astragalus* spp. in chickpea, there is a dire need to evaluate the effectiveness of some herbicides especially for controlling *E. dracunculoides* and *Astragalus* spp. Once this basic foundation is established, it will be possible to explore the relationships and interactions that exist among environment, weeds and crops to provide chickpea growers, a technology which should be effective for the control of weeds particularly *E. dracunculoides* and *Astragalus* spp. These weeds are particularly chosen because these are ubiquitous in 'Thal' typical chickpea zone of Punjab, Pakistan and known to occur in chickpea-chickpea mono cropping system. In view of the aforesaid importance of *E. dracunculoides* and *Astragalus* spp., the present project, therefore, was planned with the objectives:

- To understand the germination response of *E. dracunculoides* and *Astragalus* spp. to various environmental factors.
- To explore the allelopathic effects of *E. dracunculoides* and *Astragalus* spp. on the germination and seedling growth of chickpea.
- To find out critical period of *E. dracunculoides* and *Astragalus* spp. competition in chickpea.
- To study the growth and reproductive parameters of chickpea in response to *E. dracunculoides, Astragalus* spp. infestation.
- To study effect of different pre-emergence herbicides on *E. dracunculoides, Astragalus* spp. and chickpea in rainfed conditions.

CHAPTER 2 REVIEW OF LITERATURE

2.1 Dormancy

Dormancy is a property of many weed seeds that enables them to survive under hazardous conditions and to germinate at some latter time or in some other place (Roberto *et al*., 2000; Finch-Savage and Leubner-Metzger, 2006). Dormancy cycles observed in some species are known to be regulated mainly by soil temperature in temperate environments where water is not seasonally restricted. (Batlla and Benech-Arnold, 2007). Dormancy is of different kinds and its understanding is of ecological importance. This information can be used for management programs and species reintroduction (Koyuncu, 2005; Ortega-Base and Rojas-Arechiga, 2007). Dormancy behavior of weed seeds helps to dodge the weeding practices like herbicides and make them successful to persist in an agro-ecosystem (Tang *et al*., 2008; Khan and Shah, 2011).

For enhancement of seed dormancy breaking, in many studies hormones have been applied. GA_3 is one of the hormones suggested to control dormancy by persuading germination (Iglesias and Babiano, 1997; Keshtkar *et al.,* 2008b). Germination of weed seeds has been under great influence of growth hormones like GA_3, KNO_3, thiourea and sodium azide to break seed dormancy (Vieira *et al*., 2002; Cetinbas and Koyuncu, 2006; Khan and Shah, 2011). Fatma (2005) reported that GA_3 (250 mg L^{-1}) combine with stratification (100 days) gave high germination percentage (96%) of black mulberry (*Morus nigra* L.) seed than stratification (86%) and GA_3 (up to 67%) alone and GA_3 at 1000 mg L^{-1} proved more effective than 0, 250. 500 and 2000 mg L^{-1}. Primary dormancy of *Solanum rostratum* was significantly broken by KNO_3 or GA_3. The optimum concentration for KNO_3 ranged from 20-40 mM which resulted in over 70% seed germination. When pre-soaked with GA_3 at 30 ^oC in dark for 24 h, maximum germination (over 98%) was obtained at 2.4 mM, (Ming and Qin, 2003; Wei *et al.,* 2010). *Astragalus cyclophylon* seeds were soaked in GA_3 (100, 200, 300, 400 and 500 ppm) for 72 h, H_2SO_4 (50 and 98%) and hot water (60, 80 and 100 ^oC) for 5 and 10 minutes to enhance germination. H_2SO_4 and GA_3 had significant effect on seed germination. While the maximum germination percentage (81%) was obtained when the seeds were treated with 500 ppm GA_3 (Keshtkar *et al.,* 2008a).

Priming seed of eastern gamagrass (*Tripsacum dactyloides* L.) with GA_3 increased germination to 18% compared with 13% without GA_3 (Rogis *et al.,* 2004).

Application of KNO_3, thiourea, pre chilling, acetylsalicylic acid and distilled water showed significant effect on germination percentage of two medicinal species of *Descurainia sophia* and *Plantago ovata* (Ali *et al.*, 2010). But in another study Sadeghi *et al.* (2009) suggested that mechanical scarification is highly recommended than chemical scarification (H_2SO_4), pre chilling, GA_3, hot water and light to overcome dormancy. Effective (GA_3) and ineffective (thiourea and KNO_3) behavior at different concentrations on different plant seeds has been reported by Vieira *et al.* (2002) and Ali *et al.* (2011).

2.2 Germination Ecology

Major objective of the seed germination ecology is to know how germination occurred in nature and research on germination ecology helps to know and clarify plant evaluation and adaptation (Baskin *et al*., 2004). Information based on ecological studies of economic importance species provides essential knowledge to get them under cultivation (Suthar *et al.,* 2009). Critical stage of plant life depends upon seed germination because of that research based on seed germination knowledge helps to clarify plant development, seed dormancy patterns, ecological adaptation traits, distribution and management strategies. Various studies on germination ecology stated that many factors such as salinity, temperature, seed age, sowing depth, pH, light and moisture influence the germination and emergence of species (Chauhan and Johnson, 2008; Chauhan and Johnson, 2009; Nakamura and Hossain, 2009; Zaman *et al.,* 2009). In regeneration process germination offers many possible and unrecognized sources of variation i.e. taxasweed (*Caperonia palustris*) seed may survive in different climatic and edaphic conditions (Koger *et al.,* 2004).

2.2.1 Temperature

In regulating the germination, optimum temperature is probably the most important factor. Temperature determines the ecological limitation and adaptation for the geographical distribution of species and also determines when seeds will grow under field conditions (Turkoglu *et al.,* 2009). Temperature was found to be germination inhibitor of *Rumex obtusifolius* L. (Benvenuti *et al.,* 2001). Some weeds like *Triglochin maaritima* are highly sensitive to temperature regime. Germination parameters of *Urochondra seulosa* were significantly higher at 20-30 ^oC than at 10-20 ^oC (Gulzar *et al.,* 2001). Different temperature treatments significantly affected the mean germination of *Capparis ovata* and *Fraxinus angustifolia* seeds (Tulku and Ek, 2005; Basbag *et al*., 2009). Maximum

germination of mulberry weed (*F. villosa*) was observed at 25 ºC and with increase in temperature; there was a decrease in germination or even no germination at lower than 15 ºC and higher than 42 ºC (Gina and Joseph, 2003). *Caragana microphylla* and *Hedysarum laeve* two leguminous shrubs of sandy areas of China, both species optimal temperature was 10 to 15 ºC in a study (Zhu *et al*., 2004). Zhou *et al.* (2005) reported that temperature range from 19℃ to 39℃ was required for germination of hairy nightshade (*S. sarrachoides* L.) seeds and maximum germination occurred from 27 to 33 ℃. Germination at these temperatures was more than 90%. Germination decreased at temperatures greater than and less than this range. With increasing temperatures within the range of 20 to 34 ℃ germination speed of hairy nightshade (*S. sarrachoides* L.) seeds increased.

Temperature plays a decisive role in many biological and physiological processes like germination of plants (Berti and Johnson, 2008). Trasoff *et al*. (2007) reported that a temperature range of 10-50 °C has been recorded as an optimum temperature for different weed species like weeping alkaligrass (*Puccinellia distans*), Nuttall's alkaligrass (*Puccinellia nuttalliana*) and Kentucky bluegrass (*Poa pratensis*). Tlig *et al*. (2008) reported that the temperature changes have major impact on a number of processes which regulate seed germination, including membrane permeability and the activity of membrane-bound as well as cytosolic enzymes.

Chejara *et al.* (2008) stated that in coolatai grass (*Hyparrhenia hirta*) germination was occurred over a wide range of diurnally alternating temperatures from 5 to 45 ℃ and for given temperature combinations, there were no differences between the day and night responses. An experiment was conducted by Guma *et al*. (2008) to determine the effect of temperature on seed germination of *Salsola vermiculata* L. (Chenopodiaceae), they reported that germination rate and germination percentage decreased with an increase in temperature. Al-Taisan (2010) reported that in *Pennisetum divisum* at 15/25°C temperature optimum germination was attained. Amri (2010) exposed the seeds of Buch ex Dc. *(Terminalia sericea)* in different temperature regime (10, 15, 20, 25, 30, 35 and 40°C) and reported that optimum temperature regime was found at 25℃ with germination 35%. Alatar (2011) investigated the effect of alternating and constant temperatures on germination of *Achillea fragrantissima* and *Moringa peregrine*. He reported that at constant temperature of 25℃, germination percentage of *A. fragrantissima* and *M. peregrina* was maximum (67.7 and 83.0%, respectively), while at alternating temperatures,

the optimal germination (81.0%) of *A. fragrantissima* occurred at 15/25°C, and for *M. peregrine*, it (95.3%) was at 25/35°C.

2.2.2 Light

Light is the one of the environmental factors that can influence dormancy. There are some seeds which require light due to photo dormant but they are very little in numbers. There are many weed species which respond to environment stimulus to light for growth and development (Maloof *et al*., 2000). Light exposures of less than a minute and for some species less than a second is enough to induce germination in seeds of some species (Milberg *et al.*, 1996). Khan and Ungar (1999) reported that absence of light almost inhibited the germination completely of *Triglochin maritime* and partially inhibited germination of *Apium graveolens* (Gracia *et al.*, 2005). Daily exposure of seed to natural light resulted in lower germination than in darkness, whereas germination was not influenced by brief exposure of red or far-red light in case of pitted morningglory (*Ipomoea lacunosa*) under laboratory and green house conditions (Oliveira and Norsworthy, 2006).

Zhou *et al.* (2005) stated that the seeds of hairy nightshade (*Solanum sarrachoides* L.) germinated equally well (93%) under both a 14-h photoperiod and continuous darkness, indicating that hairy nightshade seeds are not photoblastic. Soil disturbance in darkness reduced and delayed the weed seed emergence than soil disturbed in daylight due to penetration of light in soil depth (Jensen, 2008). Similarly, mulberry weed (*Fatoua villosa*) seed germination (48-60%) was stimulated by light as compared with dark (less than 5%) (Gina and Joseph 2003). Lu *et al*. (2006) observed that crofton weed (*Eupatorium adenophorumI* L.) was moderately photoblastic, with 17% germination occurring in the dark. But here is another study which showed that light absence had no effect on seed germination of *Urochondra setulosa* and *Halopyrum mucronatum* but in case of *Aeluropus lagopoides* darkness markably influenced the germination (Khan and Gulzar, 2003). Likewise, Chauhan and Johnson (2008) stated that light was not required by nalta jute (*Corchorus olitorius*) and redweed (*Melochia concatenata*) and Wilson *et al*. (2006) also observed that light did not enhance germination of doveweed (*Murdannia nudiflora*). But Chauhan *et al*. (2006b) revealed that light enhanced the seed germination of sowthistle (*Sonchus oleraceus* L.) but some seed germinated well in the dark.

2.2.3 pH

The pH of neighboring area is one of the important environmental factors that can severely restrict the germination, plant growth and development. Germination is a process

of enzyme reaction and pH has its effects on enzyme such as α-amylase activity of red clover (*Trifolium pratense*) was significantly affected. There are plants which are specie specific to their pH for their growth like neutrophilic, basophilic and acidophilic. Seeds of Fabaceae family are sensitive to acidity (Brkic *et al*., 2004). *Ipomoea lacunosa* and *C. arenarius* showed optimal pH from 6 to 9 while germination occurred on wide range of 3-10 pH in taxasweed (Koger *et al.*, 2004; Oliveira and Norsworthy, 2006; Ebrahimi and Eslami, 2012). Similarly, germination of threehorn bedstraw was found over a range of pH from 4 to 10 (Chauhan *et al*., 2006).

Zhou *et al.* (2005) concluded that in hairy nightshade (*Solanum sarrachoides* L.) the optimum pH range for germination was between 6 and 8. When pH was outside this range a distinct decrease in germination occurred. At pH levels 4 and 9 about 31 and 48% of hairy nightshade seeds germinated, respectively. Nandula *et al*. (2006) observed that the germination of horseweed (*Conyza canadensis*) was the highest (36%) under 24/20 ℃ day/night temperature at pH level 7 and minimum (19%) germination was recorded at pH level 4. Lu *et al.* (2006) reported that crofton weed (*Eupatorium adenophorum*) germinated in a narrow range of pH (5–7). Maximum germination (94%) was observed in distilled water at pH 5.7. No germination occurred at pH less than 5 and more than 7. Oliveira and Norsworthy (2006) examined that in laboratory the germination of pitted morningglory (*Ipomoea lacunose*) occurs at solution pH range of 3 to 10 and was optimal from pH 6 to 8. Chejara *ea al.* (2008) reported in coolatai grass (*Hyparrhenia hirta*) seed germination was decreased as the solution pH decreased or increased compared with the control (pH 6.45) and neutral (pH 7). At control (pH 6.45) greatest germination (93%) was recorded and germination at neutral pH 7 was 92%. At pH levels 5 and 9 (moderately acidic or alkaline conditions, respectively) germination was reduced by about 10%, whereas pH levels 4 and 10 (strongly acidic or alkaline conditions, respectively) gave an even larger reduction (about 38%). Rao *et al.* (2008) reported that in American sloughgrass (*Bechmannia syzigachne*) buffered pH had no influence on seed germination of American sloughgrass. Over the pH range 4 to 10, seed germination was above 82% in all treatments. The maximum germination percentage was observed at pH 5 in red clover over pH 4 to 7 (Agic *et al.*, 2009). Studying on different environmental factors Suthar *et al.* (2009) stated that *S. nigrum* germinated maximum on neutral pH. Similarly, a considerable seed germination rate of *M. pudica* was observed over a wide range of pH. These results showed that the pH of the soil could not be a preventive feature for the germination and emergence of this weed species under field conditions (Chauhan and Johnson, 2009b). Sangli *et al.* (2011)

reported that in common ragweed (*Ambrosia artemisiifolia* L) germination success exceeded 48% in solutions with pH values between 4 and 12, with maximum rates occurring in distilled water at pH 5.57.

2.2.4 Salt stress

Plants are threatened by many abiotic stresses such as salts (Achuo *et al.*, 2006). Salts make deficit of water along with nutritional imbalance and become another reason for unfavorable environment for germination and plant growth. Gulzar *et al.* (2001) reported that maximum germination of *Urochondra setulosa* seeds was obtained under non saline environments. Seed germination of *Limonium stocksii, Ceratoides lanata* and *Chenopodium glaucum* decreased with increase in salinity and when un-germinated seeds were transferred to distilled water, readily germinated (Zia and Khan, 2002; Duan *et al.*, 2004; Khan *et al.*, 2004). In another study Khan *et al.* (2000) reported that in high salt treatments final germination percentage was considerably higher showing that high salt treatments did not permanently inhibit germination of *Salicornia rubra* Nels. Germination of *Lotus creticus* L. significantly decreased by salt concentrations at increased levels more than 300 mM (Rejili *et al.*, 2009). In pot experiment of three treatments viz., 5, 10 and 15 dSm^{-1}, the germination and seedling growth of *Vicia sativa* declined at 10 and 15 dSm^{-1} applied salt (Akhatr and Hussain, 2009). Whereas Hassan *et al.* (2010) revealed that *Striga hermonthica* and *Parthenium hysterophorus* L. seed germination decreased by 79 and 81%, respectively at maximum salt concentration. Similarly, threehorn bedstraw (*Galium tricornutum*) was found to be sensitive to salt stress by Chauhan *et al*. (2006). But some weeds are moderately tolerant like nalta jute (*Corchorus olitorius*) and redweed (*Melochia concatenata*) to salt but nalta jute was more successful than redweed (Chauhan and Johnson, 2008). Sodium chloride (NaCl) concentrations (4.5, 8.6, 12.7 and 16.3 dSm^{-1}) did not effect on frequency of germination of chickpea; however higher NaCl concentration decreased early seedling growth (Kaya *et al.*, 2008).

2.2.5 Drought Stress

Water stress (due to drought and salinity) is probably the most noteworthy abiotic feature limiting the germination, plant growth and development (Berg and Zeng, 2006). Seeds are sensitive to drought conditions and the imbibition process remains incomplete. So embryo of the seeds could not germinate into radical and plumule. In case of severe drought, germination process stops. That is why moisture availability has very dynamic

role in seed germination and plant development. Almansouri *et al.* (2001) reported that water and temperature are critical factors for germination of seeds. Polyethylene glycol (PEG) is extensively used to induce artificial drought which is expected not to penetrate into plant easily or rapidly and when transferred to water from PEG solution recovery or complete germination was noted (Nepomuceno *et al.*, 1998; Duan *et al.*, 2004). Taisan (2010) revealed that water availability determine the germination of dispersed seed because seed must imbibe water to germinate. In dry environment water deficit is often a critical reason for seedling mortality (Schutz *et al*., 2002). Misra and Dwivedi (2004) reported that drought cause reduction in percentage and rate of germination and seedling growth. In Petri dish (*in vitro*) sodium chloride and PEG compounds have been used to simulate osmotic stress for seed germination and seedling growth and to maintain uniform water potential throughout the experimental period. Zhou *et al.* (2005) reported that in hairy nightshade (*S. sarrachoides* L.) optimum germination (more than 90%) occurred at osmotic potentials between 0 and -0.2 MPa and at osmotic potential of 0, -0.3, and -1.0 MPa germination was 90, 84 and 17%, respectively. In a study of Chauhan and Johnson (2008), nalta jute (*C. olitorius*) and redweed (*M. concatenata*) were moderately tolerant to osmotic stress. Similarly threehorn bedstraw (*Galium tricornutum*) was tolerant to osmotic pressure little bit (Chauhan *et al*., 2006).

Al-Taisan (2010) observed that with no osmotic potential (0 MPa) under 15/25°C the highest values of germination parameters were obtained. As the osmotic potential increased the rate of germination and final germination percentage in the *Pennisetum divisum* seeds were decreased. At treatment by PEG where osmotic potential was -0.6 MPa, the germination was severely decreased. Mut *et al.* (2010) conducted an experiment on fifty-five oat genotypes to check the effect of osmotic stress and seed size on germination and seedling growth of these genotypes. Germination was checked in polyethylene glycol (PEG-6000) solutions with initial osmotic potentials ranging from 0 to -0.75 MPa at 8°C. With decreasing seed size and osmotic potential, high mean germination time and low final germination percentage was observed in all genotypes. Yucel *et al.* (2010) evaluated the effect of drought stress on nine genotypes of Chickpea (*Cicer arietinum* L.) with five levels (0, -0.2, -0.4, -0.6 and -0.8 MPa) of drought stress using PEG-6000 and reported that in all genotypes germination stop completely at 0.8MPa. Sangli *et al.* (2011) studied that in common ragweed (*Ambrosia artemisiifolia* L) germination was greatly reduced in solutions with osmotic potentials below −0.8 MPa.

2.2.6 Seeding Depth

Seeding depth is one of the important environmental factors concerning seed germination because of seed present in soil at different depths. Behavior of seed germination changes with an increase or decrease in soil depth environment. The ideal soil depth varies with species. Superficially seeded *Fimbristylis miliacea, Myriophyllum spicatum* and *Potamogeton malaianus* showed maximum seed germination from a range of 0-5 cm soil depths (Begum *et al.,* 2006; Xiao *et al.,* 2010). Seeding depth affected negatively on *Leymus chinensis* seedling emergence. Out of all seeding depths (1, 2, 4, and 6 cm) the maximum germination percentage (60) was at 1 cm and lowest (13%) at 6 cm (Liu and Han, 2008). Whereas in another study one cm deep sown seeds of *Solanum nigrum* showed maximum seed germination followed by surface sown and 2.0 cm deep in soil (Suthar *et al.,* 2009). When ivyleaf speedwell (*Veronica hederifolia* L.) seeds were buried at 0, 5, 10, 20 cm in a field and seed retrieved from soil surface and at 5 cm germinated well but germination and seedling emergence decreased with burial depth increased (Mennan and Zandstra, 2006). With increase in depth, there was decrease in seedling emergence. Maximum seedling emergence of nalta jute and redweed was at depth of 0-2 cm with no emergence at 8 cm (Chauhan and Johnson 2008). The seedling emergence of threehorn bedstraw (*G. tricornutum*) was maximum at depths of 1 to 2 cm (89 to 91%, respectively) and emergence decreased with increase in depths. At 0 cm depth there was not found any seedling emergence (Chauhan *et al*., 2006). Similarly, *Pistacia atlantica* seeds were sown at three different depths (0, 4 and 8 cm) but at 0 cm sowing depth, no seedlings emerged. Survival was greater at 4 cm than at 8 cm sowing depth (Hosseini *et al*., 2007). *Phalaris paradoxa* seedling emergence was most from 2.5 and 5 cm and least from soil surface (Taylor *et al*., 2005). Ebrahimi and Eslami (2012) conducted an experiment with 8 different treatments, among these 7 treatments (0-8 cm) were without filter paper covering and 8th treatment was at 0 cm (surface soil) covered with three filter papers. The maximum seedling emergence (94%) of *Ceratocarpus arenarius* was observed in seeds covered with three layers of filter paper on soil surface. Another field and laboratory experiment resulted as *Lithospermum arvense* seed germinated from 55-65% at 2 cm and 5-30% greater than 20 cm depth whereas in laboratory experiment germination of buried seed was unaffected. Among deeper seed, enforced dormancy was higher (Chantre *et al*., 2009).

2.3 Allelopathic effect of weeds

Allelopathy is an important mechanism involved in any place for the release of bioactive chemicals in the environment which affect the growth of other plants (Rice, 1984). To explore the nature and mechanism of allelopathy against chickpea, an experiment was conducted by Sing *et al.* (2004) which showed the presence of phenolic in *Ageratum conyzoides*. Hoque *et al.* (2003) and Kadioglu *et al.* (2005) reported that the maximum inhibitory effects (10-90%) on seed germination of chickpea were noted from weed extract of *Acacia auriculiformis, Solanum nigrum, Chenopodium album and Matricaria chamomilla*. Chickpea germination and seedling growth was reduced when high plant residue (4 tons/ ha^{-1}) of horse purslane (*Trianthema portulacastrum*) was used (Mishra *et al*., 2004). Hoque *et al*. (2003) observed that at aqueous leaf extracts (0, 10, 25, 50, 75 and 100%) of *Acacia auriculiformis*, the maximum inhibitory effect (90.39%) was observed on chickpea seed germination with 100% leaf aqueous extract. Extracts of *S. nigrum*, *C. album* and *M. chamomilla* (10, 20 and 22.5%, respectively) inhibited the seed germination of chickpea. On the other hand, *Glycyrrhiza glabra*, *Sorghum halepense* and *Reseda lutea* extracts stimulated chickpea seed germination at 95, 94, and 93%, respectively, compared to the control (Kadioglu *et al*., 2005). Similarly three crops chickpea (*Cicer arietinum*), mustard (*Brassica campestris*) and rice (*Oryza sativa*) were tested against allelopathic effect of a weed (*Ageratum conyzoides*). A significant reduction of seedling growth and dry weight were detected in all crops (Sing *et al*., 2004). The *E. odoratum* and *A. conyzoides* completely inhibited the germination of *B. campestris* and significantly of chickpea (Batish *et al.*, 2006; Kumar *et al.*, 2007). Javaid *et al.* (2006) reported that *Alstonia scholaris, Azadirachta. indica* and *Eucalyptus citodora* significantly reduced the final germination (43-100%) of the target weed species and usually the higher concentrations reduced significantly shoot and root growth of target weed species.

Leaf and flower aqueous extract of *Parthenium hysterophorus* extremely inhibited seed germination and seedling growth of lettuce whereas aqueous extracts of root and stem did not harm the germination seriously (Wakjira *et al*., 2006). Leaf aqueous extracts (2, 4 and 8%) of *Alstonia scholaris, Azadirachta indica* and *Eucalyptus citriodora* reduced final germination (43-100%) of *Phalaris minor*. Generally higher concentration of leaf extract showed significant negative impact on germination of *P. minor* (Javaid *et al*., 2006). In another study with increase in *Chenopodium murale* residue in soil (5, 10, 20 and 40 g kg^{-1}), growth associated with *C. arietinum* and *Pisum sativum* was gradually declined. With this residue increase, chlorophyll contents also decreased (Batish *et al.*, 2007).

Among water extracts of roots, shoots and fruits of wild onion (*Asphodelus tenuifolius*), fruits extracts proved to be more inhibitory than roots and shoots extracts for germination, root and shoot length and biomass of the chickpea seedlings (Babar *et al*., 2009). The leaf leachates (*Xanthium strumarium, Asphodelus tenuifolius*) caused the highest reduction in germination percentage and germination index of chickpea (Tanveer *et al.,* 2008; Babar *et al.,* 2009). Extract of *Hemistepta lyrata* strongly inhibited the germination and seedling growth of wheat (*Triticum* aestivum), rape (*B. campestris*), and radish (*Raphanus sativus*) at higher concentration. At lower concentration the extract stimulated the growth of roots and hypocotyls (Gao *et al*., 2009). In different growth media (germination paper, sand, and soil), the aqueous extracts and dried leaf powder/granule of *Suregada multiflorum* was applied on weed species, barnyardgrass (*Echinochloa crus-galli*) and slender amaranth (*Amaranthus viridis*). Plant parts varied in their prospective and extent of effects such as the leaves and branches followed by the bark had a strongest inhibitory effects. The leaves aqueous extract of *S. multiflorum* completely inhibited the germination and seedling growth of slender amaranth when applied at concentration of 100 g L^{-1} as compared with barnyardgrass. Dried leaf granules had stronger inhibitory effect than the aqueous extract and dried leaf powder of *S. multiflorum* (Laosinwattana *et al*., 2010). Aqueous extracts of plants parts (leaf, stem and root) of *Mikania micranthai* differed in their effects and effect of *C. lacryma-jobi* was concentration dependent. Leaf extract had a stronger inhibitory effect on seed germination and seedling growth of *C. lacryma-jobi* than any other (Li and Jin, 2010).

2.4 Weed competition

Weeds are considered to be unwanted guests. They compete for nutrients, water and space. This competition may be among weeds or crops themselves or may between weeds and crop. Basically chickpea is a sensitive crop to weed-crop competition. If weeds are able to take advantage of a sufficient quantity of growth factors, the result may be and often, a negative impact on the crop. Knowledge of weed competition in crops is effective in taking right decisions for suitable weed management and to reduce the cost of weed management (Evans *et al*., 2003). In a growing season when crop plants are more sensitive to presence of weeds, it is said to be critical period. For determining the start of critical period of weed-crop competition, weeds density is very important (Martin *et al.,* 2001; Mohammadi *et al.,* 2005).

Study of weed competition in a crop is an important factor that determines the yield losses. Yield and parameters of yield reduced with increase in density of weeds such as *Euphorbia heterophylla* in soybean and cowpea and *Euphorbia geniculata* in chickpea (Olorunmaiye and Ogunfolaji, 2002; Whish *et al*., 2002; Mishra and Singh, 2003; Adelusi *et al*, 2006; Mishra *et al.*, 2006). Yield losses up to 97% due to weeds in chickpea have been reported (Paolini *et al.*, 2006; Patel *et al.*, 2006). Whish *et al.* (2002) studied the effect of different densities of weeds in chickpea and reported that with increasing weed density chickpea yield losses were also increased. Yield reduction was high (50%) even with lower densities of weeds (< 10 weed plants m^{-2}) and yield losses were increased as row spacing become wider. Ozhan (2005) studied the effect of different densities (1, 2, 4, 8 and 16 plants m^{-2}) of wild reddish (*Raphanus raphanistrum*) on wheat yield. He concluded that economic threshold density level of wild reddish is from 1.8-2 plants m^{-2} in wheat. Collins *et al.* (2008) checked the densities of three leguminous crops to suppress different densities of smooth pig weed (*Amaranthus hybridis*). They found that biomass of 5 plants of smooth pig weed per m^{-2} was suppressed by 15, 38 and 44 plants per m^{-2} of velvet bean (*Mucuna pruriens*), cowpea (*Vigna unguiculata*) and sunhemp (*Crotalaria juncea*), respectively. In the 2nd year of their study, they reported that 15 plants of cowpea m^{-2} did not suppress the biomass of smooth pig weed; however smooth pig weed biomass decreased up to 51% as sunhemp and velvet beans densities increased up to 100 and 50 plants m^{-2}, respectively.

2.5 Weed Control

Weeds deteriorate the quality of the crop produce and also are a major cause of low yield especially in rainfed areas where already scarcity of resources prevails. Chickpea is a sensitive crop to weed competition and losses due to weeds ranges 40-87%. Almost 60 weeds species have been reported to infest chickpea fields in the world (Anonymous, 2012). There are many methods to control weeds but chemical weed control is dominant because of saving time and weeding labor (Zhang, 2003). The selectivity and efficacy of soil acting herbicides is usually limited to specific agro-ecological conditions because of differences in soil type, moisture availability, temperature, and weed flora (Vangessel *et al.*, 2000). It is prerequisite to use proper herbicide for proper weed which may be effective in harming the weed only. Research on chemical weed control in chickpea is less than required by the farmers. Presently, pendimethalin is the only pre-emergence herbicide recommended for weed control in chickpea in irrigated areas. Not a single pre/post-

emergence herbicide is available to cope with the problem of weeds in chickpea in rainfed areas of Pakistan.

Under rainfed conditions an experiment was conducted by Budhar and Tamilselvan (2003) on chemical weed control in sorghum + intercropping of pulses. They reported that weeds were effectively controlled with atrazine applied @ 0.25 and metolachlor applied @ 1.00 kg a.i ha^{-1} in sorghum alone and intercropping, respectively as compared with controlled plots (no herbicide). Marwat *et al.* (2004) also reported minimum number of weeds in chickpea plots treated with Stomp 330-EC (pendimethalin) and minimum grain yield was recorded in control (weedy check) plots. Studies of Yadav *et al.* (2006) revealed that chickpea germination percentage was not affected by the use of metolachlor, pendimethalin and fluchloralin applied @ 2.0, 1.5 and 1.0 kg a.i. ha^{-1}, respectively. A research trial was conducted by Datta *et al.* (2008) in green house to observe chickpea tolerance to pre-emergence spray of isoxaflutole @ 300 g a.i. ha^{-1}, 75 g a.i. ha^{-1} (recommended dose) and 0.00 (no herbicide) at different soil pH levels. It was observed that with increasing herbicide dose and soil pH, phytotoxicity and activity of isoxaflutole was also increased. Rashid *et al.* (2009) reported that weed control enhanced the yield of chickpea and also improved the inputs efficiency under rainfed condition. Datta *et al.* (2009) reported that isoxaflutole at 75 g ha^{-1} gave satisfactory control of problematic weeds of chickpea in Australia. Application of oxadiargyl at 0.075 kg ha^{-1} carried out 76.5% weed control (Patel *et al.*, 2006).

Tanveer *et al.* (2010) reported higher chickpea seed yield from plots treated with Dual Gold-960EC (S-metolachlor), Stomp-455CS (pendimethalin), Buctril Super-60EC (bromoxynil+MCPA), Aim-40DF (carfentrazone-ethyl) and Topgrow-90WDG (terbutryn) (pre-emergence spray). This was possibly achieved due to better weed control and highest plant population in these plots as compared with the plots treated with Basagran-48SL (bentazon), Starane-M60EC (fluroxypyr+MCPA) and Sencor-70WDG (metribuzin) which caused crop mortality. Similar results were observed by Gosheh and Shatnawi (2005). They checked the efficacy of various herbicides to control *A. tenuifolius* in chickpea and recorded highest grain yield (1164 and 1150 kg ha^{-1}) of chickpea with pendimethalin and S-metolachlor each @ 3 L ha^{-1}, respectively. Ansar *et al.* (2010) reported effective weed control and higher chickpea yield (353 kg ha^{-1}) with Puma Super-75 EW (phenoxaprop-p-ethyl) @ 1.2 L ha^{-1} under semi rainfed conditions of Pothohar (Pakistan). Mohammad *et al.* (2011) recorded maximum pods per plant in hand weeding and as a result higher chickpea

yield was achieved in hand weeding. In herbicide treated plots more pods (per plant) were observed with pendimethalin and lowest was observed in weedy check plot.

To sum up, Chickpea (*Cicer arietinum* L.) is one of the major pulse crops in the dry areas of Pakistan. *Euphorbia dracunculoides* and *Astragalus* spp. has become a major problem in these areas. In order to maximize the success of weed management approaches, an understanding of weed seed dormancy mechanisms is of ecological and economic importance. From an ecological perspective, germination can be viewed as being dependent on seed dormancy. Understanding weed germination ecology is pre requisite for effective weed management. Most weeds have characteristics of tolerance to a wide range of environmental conditions. Weed management is to make the environment unfavorable for weeds. Comprehensive understanding of the factors influencing the germination of weed seeds could facilitate the development of more effective weed management practices. Allelopathy is one of numerous characteristics which enable a plant to ascertain itself in new environmental conditions. Allelopathy is a mechanism for the impressive success of invasive plants and may contribute to the ability of particular species to become dominant in invaded plant communities. The timing of weed emergence in the field and weed competition duration had an important effect on the yield of crops. Study of weed competition is an important factor that determines the crop yield losses. The major challenge for farmers is effective weed management. Amongst a wide range of weed control methods, chemical weed control is most trustworthy, easy, effective, economical, time saving and less affected by unfavorable environmental conditions like wind, humidity, temperature and rainfall. For successful crop production, use of an appropriate herbicide is prerequisite.

CHAPTER 3 MATERIALS AND METHODS

3.1 Seed collection

Mature seeds of *E. dracunculoides* and *Astragalus* spp. were collected using random sampling technique from southern arid area of Punjab (Khushab), Pakistan. Immediately after collection, seeds were isolated from fruits of *E. dracunculoides* and pods of *Astragalus* spp. and then these were separated from the undesired plant materials and unripe seeds on arrival at the laboratory. The seeds were stored in sealed paper bags under normal laboratory condition (Mean maximum and minimum summer temperature 37/25 ^{o}C and winter 21/6 ^{o}C) after drying for a weak under shade. Only mature and uniform sized seeds were used in the experiments.

The proposed study was comprised of the two types of experiments:-

1: Laboratory experiments

2: Field experiments

3.2 Experimental site

Germination ecology and allelopathic effect of *E. dracunculoides* and *Astragalus* spp. on chickpea was studied under laboratory conditions, Department of Agronomy, University of Agriculture, Faisalabad (31º N, latitude and 73º E, longitude), Pakistan. Competition and control of *E. dracunculoides* and *Astragalus* spp. in chickpea was studied under farmer's field conditions in Thal area of district Khushab (32º N, latitude and 71º E, longitude), Punjab, Pakistan.

3.3 Meteorological data

During the growing season of chickpea, meteorological data regarding temperature (means on monthly basis), relative humidity and rainfall for the years 2010-11, 2011-12 and 2012-13 were obtained from Agricultural Meteorological Centre, Noorpur Thal, district Khushab, Punjab, Pakistan (Table 3.2).

Table 3.1: Physico-chemical soil analysis of experimental area

Characteristic	Soil sample depth															
	Site I								Site II							
	2010				2011				2012				2013			
	15 cm	30 cm	45 cm	Mean	15 cm	30 cm	45 cm	Mean	15 cm	30 cm	45 cm	Mean	15 cm	30 cm	45 cm	Mean
Soil pH	8.3	8.2	8.3	8.27	8.2	8.4	8.1	8.23	8.1	8.2	8.2	8.17	8.3	8.2	8.1	8.2
EC (dSm^{-1})	1.32	1.23	1.10	1.22	1.12	1.20	1.09	1.14	1.10	1.08	1.01	1.06	1.18	1.04	1.13	1.15
Organic Matter (%)	0.54	0.43	0.49	0.48	0.54	0.49	0.53	0.52	0.59	0.56	0.49	0.55	0.60	0.47	0.48	0.52
Total Nitrogen (%)	0.04	0.031	0.032	0.034	0.036	0.029	0.031	0.032	0.037	0.033	0.030	0.033	0.04	0.036	0.029	0.035
Available P (mg kg^{-1})	6.6	5.8	6.0	6.13	6.3	5.7	5.4	5.80	5.8	6.0	5.40	5.73	6.0	5.5	5.6	5.70
Available K (mg kg^{-1})	256	240	227	241	251	221	230	234	231	209	217	219	252	230	234	238
Texture	Sandy loam				Sandy loam				Sandy loam				Sandy loam			

Table 3.2 Meteorological data during the crop growing season 2010-11, 2011-12 and 2012-13

	Mean Temperature (°C)			Relative Humidity (%)			Rain Fall (mm)		
Month	**2010/11**	**2011/12**	**2012/13**	**2010/11**	**2011/12**	**2012/13**	**2010/11**	**2011/12**	**2012/13**
OCT	27.9	27.5	25.5	50.8	48.3	51.1	0.0	0.5	0.6
NOV	20.2	22.1	19.7	50.7	59.4	58.7	0.0	0.1	0.0
DEC	13.8	14.8	14.1	53.2	52.7	66.1	0.0	0.0	0.8
JAN	11.6	11.8	11.8	57.1	55.2	62.2	0.0	0.1	0.0
FEB	15.2	13.2	15.2	61.4	51.2	69.4	1.10	0.4	2.3
MAR	22.4	21.3	21.5	51.2	41.4	57.7	0.2	0.1	1.3
APR	26.0	26.7	26.9	44.6	50.0	45.6	0.3	2.4	1.4

Source: Pakistan Meteorological Department, Islamabad, Pakistan.

3.4 Laboratory experiments:

Experiment 3.4.1: Effect of hot water treatment on breaking seed dormancy of *Euphorbia dracunculoides* and *Astragalus* spp.

Two hundred seeds each of *E. dracunculoides* and *Astragalus* spp. were soaked for 15, 30, 45, 60, 75, 90, 105 and 120 minutes in water, when it started boiling. Seeds were removed after prescribed period and allowed to cool on room temperature.

Experiment No 3.4.2: Comparative performance of chemicals for breaking seed dormancy of *Euphorbia dracunculoides* and *Astragalus* spp.

Twenty five seeds per Petri dish were soaked in different concentrations of GA_3, KNO_3 and thiourea [$(NH_2)_2CS$] separately for each specie and chemical 24 hours at 16/14 °C.

Treatments

GA_3/Thiourea

G_1: Control (Distilled Water)

G_2: No Soaking

G_3: 50 ppm

G_4: 100 ppm

G_5: 150 ppm

G_6: 200 ppm

G_7: 250 ppm

G_8: 300 ppm

KNO_3

K_1: Control (Distilled Water)

K_2: No Soaking

K_3: 5000 ppm

K_4: 10,000 ppm

K_5: 15,000 ppm

K_6: 20,000 ppm

K_7: 25,000 ppm

K_8: 30,000 ppm

Experiment: No 3.4.3: Effect of environmental factors on seed germination of *Euphorbia dracunculoides* and *Astragalus* spp.

3.4.3.1 Temperature

To know whether seeds of *E. dracunculoides* and *Astragalus* spp. have capacity to germinate under variable temperature, Petri dishes containing seeds were placed in germinators at different temperature levels.

Treatments

T_1: 10 ^{0}C

T_2: 15 ^{0}C

T_3: 20 ^{0}C

T_4: 25 ^{0}C

3.4.3.2 Light

In order to check whether the seeds have ability to germinate in darkness, Petri dishes were wrapped with the single layer of aluminium foil to ensure no light penetration, or left uncovered to allow continuous light exposure at room temperature (16/14 ^{o}C).

Treatments

L_1: Dark (complete dark)

L_2: Light (10 hours light)

3.4.3.3 pH

The effect of pH on seed germination of *E. dracunculoides* and *Astragalus* spp. was studied using buffer solutions of pH 6 to 9 prepared as described by Reddy and Singh (1992). A 2-mM solution of MES [2-(*N*morpholino) ethanesulfonic acid], HEPES [*N*-(2-hydroxymethyl) piperazine-*N*-(2-ethanesulfonic acid)] and tricine [*N*-tris(hydroxymethyl) methylglycine] were adjusted to pH 6, 7-8 and 9 with 1 N NaOH. Unbuffered deionized water was used as a control. Petri dishes with seeds were placed at room temperature (17-15 ^{o}C).

Treatments

P_2: 6.0

P_3: 7.0

P_4: 8.0

P_5: 9.0

3.4.3.4 Salt stress

Seed germination capacity of *E. dracunculoides* and *Astragalus* spp. were assessed under different levels of salt (Sodium Chloride) stress.

Treatments

S_1: Control

S_2: 25 mM

S_3: 50 mM

S_4: 75 mM

S_5: 100 mM

S_6: 125 mM

S_7: 150 mM

3.4.3.5 Drought stress

Seed germination response of *E dracunculoides* and *Astragalus* spp. under different levels of drought stress was evaluated under laboratory conditions. Polyethylene glycol with a molecular weight of 8000 (PEG-8000) was used as a drought stimulator in Petri dish experiment with eight water stress levels. In pot experiment emergence of *E dracunculoides* and *Astragalus* spp. was measured at four (4) field capacity levels. Four soil samples of 100 g weight each were taken at the time of filling the plastic pot. These samples were incubated at 105 ^oC for 24 hours. The oven dried samples were weighed and averaged to determine total moisture contents. After that the saturation percentage of oven dried samples was approximated by measuring and then averaging the distilled water used to make completely saturated paste samples. Field capacity was determined by means of the following formula:

Field Capacity = Saturation percentage/2

Since the weight of each plastic pot plus filled soil and the moisture contents therein at the time of sowing were already known, the weight of each filled plastic pot containing

moisture contents equal to 100%, 75%, 50% and 25% field capacity. Pots were placed in a laboratory at room temperature (17-15 ^{o}C).

Treatments

D_1: Control

D_2: 2.5 % (-0.17 MPa)

D_3: 5.0 % (-0.47 MPa)

D_4: 7.5 % (-0.91 MPa)

D_5: 10.0 % (-1.48 MPa)

D_6: 12.5 % (-2.18 MPa)

D_7: 15.0 % (-3.02 MPa)

FC_1: 25%

FC_2: 50%

FC_3: 75%

FC_4: 100%

3.4.3.6 Seeding depth

Ten seeds each of *E. dracunculoides* and *Astragalus* spp. were placed in 10 cm diameter plastic pots separately at different sowing depths. Sand was used as a media for germination in pots. Initially 100 ml distilled water was given to each pot and then water was applied whenever needed.

Treatments

SD_1: 0 cm

SD_2: 1 cm

SD_3: 2 cm

SD_4: 3 cm

SD_5: 4 cm

SD_6: 5 cm

SD_7: 6 cm

3.4.4 Germination test

For all laboratory experiments the seeds were rinsed thoroughly with sterilized water four times and placed on double layered Watt man No.10 filter paper in sterilized Petri dishes each with 9 cm diameter. After rinsing, the seeds were allowed to sun dry on the blotter paper at temperature (19 ℃) before placing in Petri dishes. Initially 5 ml of distilled water/respective solution of each treatment were given to each Petri dish separately and after this solution was

applied whenever needed. All dishes were sealed with a strip of paraffin to reduce water loss (Nadjafi *et al.*, 2006) and placed at room temperature (17/15 ^{o}C). A completely randomized design for each experiment with four replications was used. Twenty five seeds (except pot experiment) were assigned per Petri dish. Germination counts were made every day for 2 weeks. A seed were considered germinated when the tip of the radical had grown 2 mm free of the seed coat (Auld *et al.*, 1988).

Experiment 3.4.5: Allelopathic potential of *Euphorbia dracunculoides* and *Astragalus* spp. against chickpea.

Treatments:

Field grown plants of *E. dracunculoides* and *Astragalus* spp. were uprooted at maturity using random sampling technique from chickpea field and were dried at room temperature for seven days. The chopped leaves of both species were dried in an oven at 70°C for 48 h. The dried leaves were immersed in distilled water for 24 hours at room temperature in the ratio of 1 g herbage: 20 ml water (Hussain and Gadoon, 1981). The aqueous extract was obtained by passing through a sieve and then filtering the mixture. Extracts were made in different concentrations (1, 2, 3 and 4%) from stock solution (5%). The above mentioned procedure was repeated for whole plant extracts of *E. dracunculoides* and *Astragalus* spp. and fruit stem and root of *Astragalus* spp. only.

The experiments with leaf extract of *E. dracunculoides* and *Astragalus* spp. were carried out in two phases in a laboratory. In phase-I, twenty five chickpea seeds were placed evenly on Watt man No. 10 filter paper in 9 cm diameter Petri dishes. During the course of experiment aqueous extract was added to each Petri dish according to the treatment and distilled water was used as a control. The treatments were arranged in a completely randomized design with four replications for *Astragalus* spp. and completely randomized design (factorial) for *E. dracunculoides*. The experiment was repeated twice.

In phase-II of the experiment, pots measuring 10 cm depth and 10 cm diameter were filled with sand. Ten seeds of chickpea were sown in each pot. Extracts were added to respective pot according to the requirement. The treatments were arranged in a completely randomized design with four replications for *Astragalus* spp. and completely randomized design (factorial) for *E. dracunculoides*. Root and shoot lengths of seedlings were measured

after 15 days. Seedlings were separated into roots and shoots and were weighed after oven drying at 65ºC for 24 hours.

3.4.6 Determination of total water soluble phenolics in *E. dracunculoides and Astragalus* spp.

Total water soluble phenolics were determined as described by Randhir and Shetty (2005) and were expressed as gallic acid equivalents.

3.4.7 Detection of Phytotoxins in aqueous *Euphorbia dracunculoides and Astragalus* spp. extracts.

Due to their greater suppression potential, leaf aqueous extracts of *E. dracunculoides and Astragalus* spp. were chemically analyzed on Shimadzu HPLC system (Model SCL-10A, Tokyo, Japan) for identification and quantification of their suspected phytotoxins. The conditions of separation are listed in Table.

The peaks were detected by UV detector. Standards of suspected phytotoxins (Aldrich, St Louis, USA) were run similarly for identification and quantification. Standards of phenolics were prepared in different concentrations. Vanillic acid and 4-(hydroxymethyl) benzoic acid were identified by their retention time with authentic standards. Concentration of each isolated compound was determined by the following equation:

$$Concentration\,(ppm) = \frac{Area\ of\ the\ sample}{Area\ of\ the\ standard} \times Concentration\ of\ the\ standard \times Dilution\ \ factor$$

Table 3.3 HPLC conditions for determination of phytotoxins in aqueous *Euphorbia dracunculoides and Astragalus* spp. leaf extract.

Parameter	Characteristic
Column dimensions	25 cm length ×4.6 mm diameter, particle size of 5 µm
Diatomite	Supleco wax 10
Attenuation	0.01ppm
Rate of recorder	10 mm min^{-1}
Detector	SPD-10A vp-detector
Detection	UV,280 nm
Flow rate	0.25 ml min^{-1}
Volume injection sample	50 µl
Type of Column	Shim-pack CLC-Octadecyl Silicate (ODS) (C-18)
Mobile phase	Isocrartic;100% methanol
Temperature	25 ◦C

Field experiments:

Experiment 3.5 Study on competition of *Euphorbia dracunculoides* and *Astragalus* spp. with chickpea.

Treatments

W_1: Weed free (Zero competition)

W_2: Weed competition for 45 days after sowing (DAS)

W_3: Weed competition for 60 DAS

W_4: Weed competition for 75 DAS

W_5: Weed competition for 90 DAS

W_6: Weed competition for 105 DAS

W_7: Weed competition till harvest

After each prescribed competition period the plots were kept clean from all types of weeds till harvest.

Experiment 3.6: Control of *Euphorbia dracunculoides* and *Astragalus* spp. in chickpea by using herbicides.

Treatments

W_1: Control

W_2: Manual Hoeing (2)

W_3: Pendimethalin + Prometryn @ 450 + 600 g a.i. ha^{-1}

W_4: Pendimethalin + Prometryn @ 375 + 500 g a.i. ha^{-1}

W_5: Pendimethalin + Prometryn @ 300 + 400 g a.i. ha^{-1}

W_6: Metribuzn @ 187.5 g a.i. ha^{-1}

W_7: Metribuzn @ 150 g a.i. ha^{-1}

The herbicides were sprayed just after sowing with knapsack hand sprayer fitted with flat fan nozzle. The volume of spray (310 L ha^{-1}) was determined by calibration before spraying the herbicides. The net plot size was 5.0 m × 1.8 m.

In both experiments crop was planted in the field where heavy infestation of *E. dracunculoides* and *Astragalus* spp. has been reported in previous year. The chickpea variety "Pb-2008" was sown in October 2010, October 2011 and October 2012 in 30 cm apart rows by tractor mounted drill, using a recommended seed rate of 60 kg ha^{-1}. No land preparation was done before sowing of chickpea during both the years of experimentation and crop was sown on residual moisture of July-August rainfall. Crop rotation of chickpea-chickpea is common in the area under our study. No irrigation and NPK fertilizer was applied to the crop. All weeds other than *E. dracunculoides* and *Astragalus* spp. (e.g *Asphodelus tenuifolius* Cav., *Chenopodium* album L. and *Convolvolus arvensis* L.) were pulled out manualy when they emerged/seen (competition experiment). Weeds were removed manually after every three days to maintain weed free plots during both the years. Thinning was done to maintain plant to plant distance of 15 cm at early growth stages of chickpea. Hand weeding and weedy check were included in the last field experiment for comparison.

3.7 Observations

Data on the following parameters were recorded during the course of these studies:

Lab experiment:

Seed germination

- Germination percentage (AOSA, 1990)
- Time to 50% germination (T_{50}) (Coolbear *et al*., 1984)
- Mean germination time (MGT) (Ellis and Roberts, 1981)
- Germination index (GI) (AOSA, 1990)
- Germination Energy (GE)

Seedling growth

- Shoot length per plant (cm)
- Root length per plant (cm)
- Seedling fresh weight (g)
- Seedling dry weight per plant (g)

3.8 Procedure for recording observations

Data on various germination/emergence parameters of *E. dracunculoides and Astragalus* spp. were recorded by the following procedures.

3.8.1 Germination/emergence (%)

A seed was considered germinated when the tip of the radicle (2 mm) had grown free of the seed. Germination counts were made every day for 3 weeks. However, in seed burial depth experiment, seedling emergence was considered when *E. dracunculoides and Astragalus* spp. cotyledon became visible on surface. Seedling emergence data was recorded up to 30 days. Total germinated/emerged seeds were counted and their germination/emergence percentage was calculated by using the following formula.

$$\text{Germination or emergence percentage} = \frac{\text{Germinated or emerged seeds}}{\text{Total seeds}} \times 100$$

3.8.2 Germination/emergence index (GI/EI)

The germination/emergence index (GI/EI) was calculated as described by the Association of Official Seed Analysts (1990) by using the following formula:

$$\text{GI/EI} = \frac{\text{No. of germinated/emerged seeds}}{\text{Days of first count}} + \cdots + \frac{\text{No. of germinated/emerged seeds}}{\text{Days of final count}}$$

3.8.3 Time to 50% germination/emergence (days)

Time taken to 50% germination/emergence of seedlings (T_{50}) was calculated according to the following formula (Coolbear *et al.*, 1984).

$$T_{50} = t_i + \frac{(N/2 - n_i)(t_j - t_i)}{n_j - n_i}$$

Where N is the final number of germinated/emerged seeds, and n_i and n_j are the cumulative number of seeds germinated/emerged by adjacent counts at times t_i and t_j, respectively, when $n_i < N/2 < n_j$.

3.8.4 Mean germination/emergence time (MGT/MET)

Mean germination/emergence time was calculated according to the equation of Ellis and Roberts (1981).

$$MGT = \sum (D_n) / \sum n$$

Where n is the number of germinated seeds or emerged seedlings on day D and D is the total number of days counted from the beginning of germination/emergence.

3.8.5 Germination energy (%)

Germination/emergence Energy (GE,EE) was determined on fourth day of seed sowing (Farooq *et al.*, 2006). It is the percentage of germinated seeds 4 days after planting relative to the total number of seeds tested (Ruan *et al.*, 2002).

$$\text{Germination energy} = \frac{\text{Total Germinated seeds at } 4^{th} \text{ day}}{\text{Total seeds}} \times 100$$

3.8.6 Shoot length per plant (cm)

Separated shoots of chickpea were taken and their length was measured in cm from the point where root and shoot joins to the end of the shoot. Then the average shoot length was worked out.

3.8.7 Root length per plant (cm)

The survived plants (if any) of chickpea were uprooted from each pot under wet condition. Root length was measured in cm from the point where root and shoot joins to the end of the root. Then the average root length was calculated.

3.8.8 Seedling fresh weight (g)

Fresh biomass of chickpea seedlings from each pot was weighed on an electric balance.

3.8.9 Seedling dry weight (g)

Fresh biomass of chickpea seedlings from each pot was oven dried at 70 ℃ for 48 hours and weighed for seedlings dry weight per palnt.

Field Experiments:

Weed

- Number of weeds (m^{-2}) at different intervals
- Fresh weight of weeds (g) at harvest
- Dry weight of weeds (g) at harvest
- Number of fruits per plant
- Number of seeds per fruit/pod
- Seed weight per plant (g)
- NPK concentration (%)
- Micro nutrient concentration (%)
- NPK uptake (kg ha^{-1})
- Micro nutrient uptake (g ha^{-1})
- Relative competitive index (RCI)

3.10 Procedure for recording data

Standard procedures were adopted for recording the data on various growth and yield parameters of *E. dracunculoides and Astragalus* spp.

3.10.1 Number of weeds at different intervals (m^{-2})

Number of *E. dracunculoides and Astragalus* spp. plants per unit area (m^{-2}) was counted randomly at three different places and then an average was calculated in each plot after prescribed competition periods (Experiment 3.5) and four times (i.e. at 40, 60, 80 days after emergence) and at maturity (Experiment 3.6) in each growing season.

3.10.2 Fresh weight of weeds per unit area (g m^{-2})

Euphorbia dracunculoides and Astragalus spp. plants per unit area were uprooted randomly at three different places in each plot at maturity (Experiment 3.5 and 3.6). These plants were weighted by using an electrical balance, then average fresh weight of weeds per unit area was calculated.

3.10.3 Dry weight of weeds per unit area (g m^{-2})

The dry weight of *E. dracunculoides and Astragalus* spp. plants was determined after oven-drying at 70^{o}C until constant weight was achieved.

3.10.4 Number of fruits/pods per plant of *E. dracunculoides and Astragalus* spp.

Number of fruits/pods per plant was counted by selecting 5 plants at random from each plot and then average was taken (Experiment 3.6).

3.10.5 Number of seeds per pod

Number of seeds per triloculate/pod of *E. dracunculoides and Astragalus* spp. plant was counted by selecting 10 pods from each plant at random from each plot and then average was taken.

3.10.6 NPK contents of *Euphorbia dracunculoides and Astragalus* spp.

Oven dried samples of *E. dracunculoides and Astragalus* spp. were ground with grinder and NPK contents (%) were determined as suggested by AOAC (1984).

3.10.7 NPK uptake by *Euphorbia dracunculoides and Astragalus* spp.

NPK concentrations in *E. dracunculoides and Astragalus* spp. were multiplied with dry weight of respective weed to calculate N, P and K uptake by *E. dracunculoides and Astragalus* spp.

3.10.8 Micro nutrient contents of *Euphorbia dracunculoides and Astragalus* spp.

Oven dried samples of *E. dracunculoides and Astragalus* spp. were ground with grinder and micro nutrient contents were determined as suggested by Jan *et al.* (2011).

3.10.9 Micro nutrient uptake by *Euphorbia dracunculoides and Astragalus* spp.

Micro nutrient concentrations in *E. dracunculoides and Astragalus* spp. were multiplied with dry weight of respective weed to calculate micro nutrient uptake by *E. dracunculoides and Astragalus* spp.

3.10.10 Relative Competitive Index (RCI)

Jolliffe *et al.* (1984) formula was used to describe relative competitive index (RCI) of *E. dracunculoides and Astragalus* spp.

$$RCI = \frac{Y_{Weed\,free} - Y_{Weed}}{Y_{Weed\,free}} \times 100$$

Where $Y_{weed\ free}$ was chickpea seed yield of weed free plot and Y_{weed} was yield in the presence of weed.

3.11 Chickpea

- Plant height (cm)
- Number of primary branches per plant
- Number of secondary branches per plant
- Number of Pods per plant
- Number of seeds per pod

- 100- seed weight (g)
- Biological yield (kg ha^{-1})
- Seed yield (kg ha^{-1})
- Harvest index (%)
- NPK concentration (%)
- Crude protein
- Chlorophyll contents (mg g^{-1})
- Estimation of yield loss
- Percent yield increase over weedy check

3.11.1 Plant height (cm)

Height of ten chickpea plants selected at random from each plot was taken from ground to the top of plant with the help of a meter rod. Then average height was calculated.

3.11.2 Number of primary branches per plant at maturity

Number of primary branches of ten randomly selected plants from each plot was calculated at maturity by counting the number of branches emerging from crown or base of the stem and then average was computed.

3.11.3 Number of secondary branches per plant at maturity

Number of secondary branches emerging from primary branches of ten randomly selected chickpea plants from each plot was calculated at maturity by counting the number and then average was computed.

3.11.4 No. of pods per plant

Number of pods per plant was counted by selecting 5 chickpea plants at random from each plot and then average was taken.

3.11.5 No. of seeds per pod

Number of seeds per pod of chickpea plant was counted by selecting 10 pods from each plant at random from each plot and then average was taken.

3.11.6 100-seeds weight (g)

Five samples per plot of 100-seed of chickpea were weighed on an electrical balance and then average was taken to calculate 100-seed weight in grams.

3.11.7 Biological yield (kg ha^{-1})

All the chickpea plants of each net plot was harvested with a sickle at maturity and tied into a bundle. After five days sun drying, it was weighed with an electrical balance and biological yield was calculated.

3.11.8 Seed yield (kg ha^{-1})

Dried samples of each plot were threshed manually. Grain yield of each plot was recorded and converted into kilograms per hectare.

3.11.9 Harvest index (%)

Harvest index of chickpea was calculated by using the following formula

$$HI = \frac{Economic\ yield}{Biological\ yield} \times 100$$

3.11.10 NPK contents (%)

Oven dried samples of *E. dracunculoides and Astragalus* spp. were ground with grinder and NPK contents (%) were determined as suggested by AOAC (1984).

3.11.11 Crude protein (%)

Crude protein in chickpea grains was calculated by multiplying a factor (6.25) with nitrogen contents.

3.11.12 Chlorophyll contents of chickpea leaves (mg g^{-1})

Chlorophyll contents (Experiment 3.6) of chickpea leaves (mg g^{-1}) were determined at 40, 60 and 80 days after crop emergence by using Arnon (1949) and Mochizuki *et al.* (2001) protocols. 25 mg of fresh leaves was taken, then ground it in a mortar with 10 ml of 80% acetone solution (80 ml acetone+ 20 ml water), filtered the extract and made the volume up to

25 ml with 80 % acetone in a bottle. Reading was noted on spectrophotometer at 645 and 663 nm for each sample (PERKIN-ELMER JUNIOR Model-35, Perkins Elmer Corp. U.S.A.). Following equation was used to calculate chlorophyll contents.

Chlorophyll contents = [20.2 (D 645nm) + 8.02 (D 663 nm)] × V/1000 × W.

D = Optical density readings of chlorophyll extract at 645 or 663 nm wavelength of spectrophotometer

V = Final volume of extract (ml)

W = Weight of Leaves (g)

3.11.13 Estimation of yield loss

The percentage of yield loss (YL) of each infested plot was calculated by following equation:

YL (%): $Y_{wf} - Y / Y_{wf} \times 100$

Where, Ywf is the seed yield of chickpea in weed free plots and Y is the seed yield from each infested plot.

3.11.14 Percent yield increase over weedy check

It was calculated with the formula given by Frans *et al.* (1986).

% Yield increase over weedy check = $Y_{\text{weedy check}} - Y_{\text{treatment}} / Y_{\text{weedy check}} \times 100$

Where chickpea seed yield in weedy check plot is denoted by $Y_{\text{weedy check}}$ and yield of respective plot is denoted by $Y_{\text{treatment}}$.

3.11.15 Economic analyses

Economic analyses was carried out in Experiment 3.6 to look into comparative benefits of different weed management practices used in these studies. Marginal analysis was carried out according to procedures devised by Byerlee (1988).

3.11.16 Marginal analysis

In economic analyses, the costs that vary are not compared with net benefits. For such a comparison, marginal analysis is required. The marginal analysis involves the dominance analysis and marginal rate of return that are detailed below.

3.11.17 Dominance analysis

For dominance analysis, treatments were arranged in order of increasing variable costs. A treatment was considered dominated (D) if the variable costs were higher than the preceding treatment, but its net benefits were equal or lower (CIMMYT, 1988).

3.11.18 Marginal rate of return

Marginal rate of return is the marginal net benefit i.e., the change in net benefit divided by the marginal cost i.e., change in costs expressed as a percentage. MRR was determined by using the formula given by CIMMYT (1988).

$$\text{MRR (\%)} = \frac{\text{Marginal benefit}}{\text{Marginal cost}} \times 100$$

3.11.19 Statistical analysis

The data collected were analysed by using the Fisher's analysis of variance function of MSTAT statistical computer package and LSD at 5% probability were used to compare the treatment's means (Steel *et al,*. 1997).

In field experiments, data was pooled where the year effect was non-significant. If year effect was significant, it was presented separately.

CHAPTER 4 RESULTS AND DISCUSSION

4.1 Laboratory Experiments

4.1.1 Comparative performance of different methods for breaking dormancy of *Euphorbia dracunculoides* and *Astragalus* spp.

In this experiment different methods were used to break the seed dormancy of *E. dracunculoides* and *Astragalus* spp.

4.1.2 Hot water seed treatment on breaking seed dormancy of *Euphorbia dracunculoides* and *Astragalus* spp.

Seed treatments with hot water had been described to improve germination of hard seed coat species by uplifting water and O_2 permeability of the testa of seed coat (Teketay, 1998; Aydın and Uzun, 2001) but in our study hot water treatments failed to boost the germination of *E. dracunculoides* and *Astragalus* spp. (Table 4.1.1). These results are supported by those of Ghahfarokhi and Afshari (2007) who stated that *Ferula gummosa* showed no significant effects on seed germination in soaking of different hot water treatments.

Table 4.1.1 Effect of hot water seed treatment on breaking seed dormancy of *Euphorbia dracunculoides* and *Astragalus* spp.

Treatment	Time (minutes)	Result
Boiling water	15	No germination
Boiling water	30	No germination
Boiling water	45	No germination
Boiling water	60	No germination
Boiling water	75	No germination
Boiling water	90	No germination
Boiling water	105	No germination
Boiling water	120	No germination

4.1.3 Effect of GA_3 on germination traits of *Euphorbia dracunculoides* and *Astragalus* spp.

Gibberalic acid (24 hours soaking) proved to be effective in breaking seed dormancy of *E. dracunculoides* and the significantly higher G percentage and GI (89, 3.91, respectively) was recorded at 250 ppm (Table 4.2). The maximum GE (22) was recorded at 250 ppm which was statistically at par with that of 300 ppm GA_3. Similarly time to 50% germination was also

minimum (5.64) at 250 ppm but was not significantly different from those of distilled water, 100, 150, 200 and 300 ppm. Maximum (6.54) T_{50} was recorded in non-soaked seeds.

Gibberalic acid (GA_3) did not affect seed germination significantly of *Astragalus* spp. (Table 4.1.2). The maximum G percentage (28) was recorded at 50 ppm which was statistically at par with those of 100 ppm of GA_3 and distilled water treatment. With increase in concentration of GA_3, G percentage decreased and at highest GA_3 concentration (300 ppm) the G percentage was very less than that of non-soaked seeds of *Astragalus* spp. The maximum GE (19) and GI (3.74) were detected at 50 ppm which was statistically alike with those of distilled water. The minimum MGT (4.47) and time to 50% germination (2.59) was noted at 50 ppm of GA_3 which was statistically similar to those of all other treatments except non-soaked seeds of *Astragalus* spp.

Euphorbia dracunculoides germination results in our study are similar to those of Karam and Al-Salem (2001) and Rahman *et al*. (2006) who reported that 250 ppm concentration of GA_3 gave maximum G (31.67 and 86%) in *Allium sativum* and *Arbuts andrachne* L, respectively. In contrast, Koyuncu (2005) and Ghahfarokhi and Afshari (2007) noted that 1000 ppm GA_3 application proved more effective against black mulberry (*Morus nigra* L.) than any of other GA_3 concentration (0, 250, 500, 1000 and 2000 ppm) but increase in concentration linearly increased the G percentage. Germination of *Astragalus* spp. is in contradiction with the results reported by Keshtkar *et al*. (2008) whose study revealed that maximum G (81%) of *Astragalus cyclophyllon* was achieved when seeds were treated with 500 ppm concentration of GA_3. But results of Khan *et al*. (2002) showed no significant effect of GA_3 concentrations (50, 300 and 500 ppm) on final G percentage of non-legume. Controversial results may be due to specie difference.

4.1.4 Effect of KNO_3 on germination traits of *Euphorbia dracunculoides* and *Astragalus* spp.

Soaking of *E. dracunculoides* seeds in potassium nitrate (KNO_3) induced higher germination at all concentrations. The significantly higher G percentage (81.50), GI (7.51) and GE (11.50) was recorded at 15000 ppm of KNO_3 while significantly minimum G

Table 4.1.2 Effect of GA_3 on germination traits of *Euphorbia dracunculoides* and *Astragalus* spp.

GA_3	G (%)	GE	GI	MGT (d)	T_{50} (d)
E. dracunculoides					
Not soaked	12.00 g	0.00 c	0.86 e	7.37	6.54 a
Distilled Water	25.00 e	0.00 c	1.99 d	6.66	5.89 ab
50 ppm	18.00 f	3.00 c	0.67 e	7.41	6.50 a
100 ppm	20.00 ef	3.00 c	0.81 e	6.68	5.68 b
150 ppm	68.00 d	16.00 b	2.75 c	7.15	6.27 ab
200 ppm	75.00 c	17.00 b	3.05 c	7.22	6.26 ab
250 ppm	89.00 a	22.00 a	3.91 a	6.65	5.64 b
300 ppm	82.00 b	20.00 ab	3.52 b	6.71	5.81 ab
LSD	5.868	4.949	0.32 6	NS	0.698
Astragalus spp.					
Non Soaked	4.75 a	5.57 a	1.42 e	14.00 c	4.50 f
Distilled Water	2.88 b	4.65 b	3.51 ab	27.00 a	18.00 ab
50 ppm	2.59 b	4.47 b	3.74 a	28.00 a	19.00 a
100 ppm	3.23 b	5.05 ab	3.18 b	26.00 a	16.00 bc
150 ppm	2.96 b	4.73 b	2.71 c	21.00 b	14.00 c
200 ppm	3.43 b	4.94 ab	1.87 d	15.00 c	10.00 d
250 ppm	3.14 b	4.74 b	1.32e	10.50 d	7.00 e
300 ppm	2.75 b	5.08 ab	0.93f	6.00 e	4.00 f
LSD	0.994	0.662	0.338	2.364	2.438

Means followed by the same letter in a column did not differ significantly according to LSD test ($p < 0.05$). T_{50} = Time taken to 50% germination, MGT = Mean Germination time, GI = Germination Index, LSD = Least Significance Difference, NS= non-significant,
d: days

percentage, GI and GE was recorded in non-soaked treatment (Table 4.1.3). Minimum MGT (5.74) was recorded at 15000 ppm which was statistically not different from those of all others except non-soaked and distilled water treatment. Minimum time to 50% germination (4.79) was taken by the seeds which were subjected to soaking in 15000 ppm of KNO_3 but was not statistically different with those of all other treatments except non-soaked, distilled water and 2000 ppm KNO_3.

Potassium nitrate was not so much effective in breaking seed dormancy of *Astragalus* spp. The maximum G percentage (27) was achieved by distilled water which was statistically at par with that of 5000 ppm of KNO_3 (Table 4.1.3). With increase in concentration up to 25000 ppm, G percentage decreased and at highest concentration (30000 ppm) it increased a little bit. The minimum G percentage was noted at 25000 ppm. The significantly maximum GI was attained at 5000 ppm and minimum at 25000 ppm which was statistically similar to that of 20000 ppm. The maximum GE (19.50) was observed at 5000 ppm which was statistically at par with that of distilled water. The minimum GE (2) was resulted at 20000 ppm which was statistically at par with those of 25000 and 30000 ppm of KNO_3. The significantly minimum MGT was observed at 5000 ppm and the maximum at higher concentrations (20000, 25000 and 30000 ppm) of KNO_3. The minimum time to take 50% germination (2.37) was noted at 5000 ppm which was statistically similar to that of distilled water. Higher concentrations (20000, 25000 and 30000 ppm) along with non-soaked treatment showed maximum T_{50} germination. It might be due to gentleness of *Astragalus* spp. seeds and higher salt ratio of KNO_3 which prohibited the seed germination.

Similar to our results were observed by Ramzan *et al*. (2010) who stated that among KNO_3 concentrations (10000, 20000, 30000, 40000 and 50000 ppm) lower concentrations (10000 and 20000 ppm) and distilled water was more effective in increasing germination than higher concentrations of KNO_3 when tested against *Allium sativum* seeds. Nitrogen containing compounds like KNO_3, $NaNO_3$, $NHNO_3$ and NH4Cl enhanced seed germination of *Centaurea tomentella* hand.-mazz, *Chenopodium album* and other plants (Uysal *et al*., 2006; Tang *et al*., 2008 and Khan and Shah, 2011). Contrary to that Ghahfarokhi and Afshari (2007) reported that KNO_3 failed to stimulate the germination of *F. gummosa*. Contradictory results were observed by Ramzan *et al*. (2010) who stated that among KNO_3 concentrations

Table 4.1.3 Effect of KNO_3 on germination traits of *Euphorbia dracunculoides* and *Astragalus* spp.

KNO_3	G (%)	GE	GI	MGT (d)	T_{50} (d)
E. dracunculoides					
Non soaked	12.00 d	0.00 d	0.86 d	7.37 a	6.54 a
Distilled Water	25.00 c	0.00 d	1.99 c	6.66 b	5.89 c
10000 ppm	75.50 b	7.00 c	6.52 b	6.25 bc	5.00 cd
15000 ppm	81.50 a	11.50 a	7.51 a	5.74 c	4.79 d
20000 ppm	75.00 b	7.00 c	6.32 b	6.37 bc	5.45 bc
25000 ppm	75.50 b	7.00 c	6.59 b	6.17 bc	4.79 d
30000 ppm	74.00 b	9.00 b	6.68 b	5.83 c	4.93 cd
LSD	4.549	1.667	0.4395	0.642	0.589
Astragalus spp.					
Non-soaked	14.00 bc	4.50 c	1.42 d	5.57 b	5.70 ab
Distilled Water	27.00 a	18.00 a	3.51 b	4.65 c	2.88 d
5000 ppm	26.50 a	19.50 a	4.63 a	3.75 d	2.37 d
10000 ppm	15.50 b	7.00 b	1.73 c	5.43 bc	4.25 c
15000 ppm	15.00 b	4.50 c	1.34 d	6.65 a	4.75 bc
20000 ppm	12.00 cd	2.00 d	0.95 ef	7.14 a	6.25 a
25000 ppm	7.500 e	2.00 d	0.69 f	6.64 a	6.37 a
30000 ppm	11.00 d	3.50 cd	1.02 e	6.64 a	5.25 abc
LSD	2.474	2.383	0.304	0.893	1.296

Means followed by the same letter in a column did not differ significantly according to LSD test ($p < 0.05$). T_{50} = Time taken to 50% germination, MGT = Mean Germination time, GI = Germination Index, LSD = Least Significance Difference, d: days

(10000, 20000, 30000, 40000, 50000 ppm and distilled water) ditilled water (92%) was more effective than that of any KNO_3 concentrations followed by that of 10000 ppm (80%) when tested against *Allium sativum* seeds. Nitrogen containing compounds like KNO_3, $NaNO_3$, $NHNO_3$ and NH_4Cl enhanced seed germination of *Centaurea tomentella* hand.-mazz, *Chenopodium album* and other plants (Uysal *et al*., 2006; Tang *et al*., 2008 and Khan and Shah, 2011).

4.1.5 Effect of thiourea on germination traits of *Euphorbia dracunculoides* and *Astragalus* spp.

Thiourea succeeded to a small scale to motivate the germination of *E. dracunculoides* (Table 4.4). The maximum G percentage was resulted at 250 ppm which was statistically at par with that of 300 ppm of thiourea. *Euphorbia dracunculoides* showed maximum GE (25.50) at 300 ppm which was statistically at par with those of 250, 150, 100 ppm followed by 200 and 50 ppm. Similarly the significantly maximum GI was recorded at 300 ppm. Minimum MGT and time to 50% germination was achieved at 50 ppm and 150 ppm of thiourea, respectively. Overall in all treatments non-soaked and distilled water treated seeds showed less germination.

Efficiency of thiourea against *Astagalus* spp. in breaking dormancy was not impressive as maximum G percentage (28) was resulted from 150 ppm which was statistically at with that of distilled water (Table 4.1.4). Similarly the maximum GE (18) and GI (3.51) were observed from distilled water which was not statistically different from those of 150 ppm thiourea. The significantly minimum G percentage (6), GE (3) and GI (0.84) was recorded at highest concentration (300 ppm) applied against *Astragalus* spp. The minimum MGT (4.40) was noticed at 50 ppm of thiourea which was alike statistically with those of all other treatments except non-soaked and 300 ppm of thiourea. The minimum time to 50% germination (2.74) was noticed at 50 ppm of thiourea which was similar statistically with those of all except non-soaked seeds. Maximum MGT (5.57) was detected at non-soaked treatment which was statistically similar to those of all others treatments except 50 ppm. The significantly maximum time to 50% germination (4.75) was noted in non-soaked treatment.

Khan *et al*. (2003) reported that G of *A. prostrata* was stimulated by thiourea. In another study Erez (2005) stated that thiourea promoted growth in soybean, tobacco, and

Table 4.1.4 Effect of thiourea on germination traits of *Euphorbia dracunculoides* and *Astragalus* spp.

Thiourea	G (%)	GE	GI	MGT (d)	T_{50} (d)
E. dracunculoides					
Non Soaked	12.00 e	0.00 c	0.86 f	7.37 a	6.54 a
Distilled Water	25.00 d	0.00 c	1.99 e	6.66 b	6.51 a
50 ppm	33.50 c	18.50 b	3.96 d	4.73 d	3.85 b
100 ppm	44.00 b	22.00 ab	4.92 bc	5.19 cd	3.96 b
150 ppm	40.50 b	21.50 ab	4.61 c	5.29 cd	3.93 b
200 ppm	42.50 b	20.00 b	4.59 c	5.47 c	4.16 b
250 ppm	51.00 a	23.00 ab	5.40 b	5.75 c	4.27 b
300 ppm	49.00 a	25.50 a	5.59 a	5.14 cd	3.96 b
LSD	4.958	4.508	0.631	0.696	0.811
Astragalus spp.					
Non-soaked	14.00 d	4.50 de	1.42 d	5.57 a	4.75 a
Distilled Water	27.00 a	18.00 a	3.51 a	4.65 bc	2.88 b
50 ppm	20.00 b	14.50 b	2.76 b	4.40 c	2.74 b
100 ppm	20.50 b	14.00 b	2.60 b	4.59 bc	3.10 b
150 ppm	28.00 a	17.00 a	3.48 a	5.03 abc	3.17 b
200 ppm	17.00 c	10.50 c	2.13 c	5.00 abc	3.05 b
250 ppm	10.00 e	6.00 d	1.28 d	4.66 bc	3.46 b
300 ppm	6.00 f	3.00 e	0.84 e	5.39 ab	3.25 b
LSD	2.579	2.249	0.311	0.892	0.833

Means followed by the same letter in a column did not differ significantly according to LSD test ($p < 0.05$). T_{50} = Time taken to 50% germination, MGT = Mean Germination time, GI = Germination Index, LSD = Least Significance Difference, d: days

apple. Whereas Ali *et al*. (2011) revealed contradictory results as thiourea was ineffective to break seed dormancy of *Rhynochosia capitata*.

4.1.6 Effect of GA_3 for short soaking time on germination traits of *Astragalus* spp.

Best concentration (50 ppm) of GA_3, KNO_3 (5000 ppm) and thiourea (150 ppm) at 24 hours was made to assess and improve the G percentage at less soaking time but failed to enhance the germination significantly than that of 24 hours soaking. Germination percentage, GE and GI increased significantly with increase in soaking time from 4 to 12 hours (Table 4.1.5). Mean germination time and T_{50} was non-significant in all the treatments.

Results of Khan *et al*. (2002) showed no significant effect of GA_3 concentrations (50, 300 and 500 ppm) on final G percentage of grape fruit (*C. paradisi* Macf.) and kinnow mandarin (*C. reticulate* Blanco).

Table 4.1.5 Effect of GA_3 for short soaking time on germination traits of *Astragalus* spp.

Treatments	G (%)	GE	GI	MGT (d)	T_{50} (d)
4 hours	7.00 c	9.00 c	1.10 c	3.91	2.62
8 hours	11.50 b	14.00 b	2.26 b	3.72	2.62
12 hours	16.50 a	19.00 a	3.18 a	4.36	2.75
LSD	2.262	4.524	0.584	NS	NS

Means followed by the same letter in a column did not differ significantly according to LSD test ($p < 0.05$).

T_{50} = Time taken to 50% germination, MGT = Mean Germination time, GI = Germination Index, LSD = Least Significance Difference, NS= non-significant

d: days

4.1.7 Effect of KNO_3 for short soaking time on germination traits of *Astragalus* spp.

The concentration of KNO_3 (5000 ppm) which resulted in maximum G percentage was selected for further study of short soaking times (4, 8 and 12 hours). Germination increased from 4 hours to 8 hours soaking then declined at 12 hours soaking time. The significantly maximum G percentage (22), GE (21) and GI (3.59) was detected at 8 hours soaking time (Table 4.1.6). The significantly minimum G percentage and GE was observed at 12 hours

soaking treatment while minimum GI was also noticed in 12 hours treatment which was similar to that of 4 hours treatment statistically. The significantly minimum time to take 50% germination (2.75) was observed at 12 hours treatment and the maximum time to take 50% germination (4.18) was resulted at 8 hours which was statistically at par with that of 4 hours.

Nitrogen containing compounds like KNO_3, $NaNO_3$, $NHNO_3$ and NH_4Cl enhanced seed germination of *Centaurea tomentella* hand.-mazz, *Chenopodium album* and other plants (Uysal *et al*., 2006; Tang *et al*., 2008 and Khan and Shah, 2011) which support our results.

Table 4.1.6 Effect of KNO_3 for short soaking time on germination traits of *Astragalus* spp.

Treatments	G (%)	GE	GI	MGT (d)	T_{50} (d)
4 hours	18.50 b	17.00 b	2.30 b	5.16	4.06 a
8 hours	22.00 a	21.00 a	3.59 a	4.96	4.18 a
12 hours	10.00 c	13.00 c	2.05 b	4.41	2.75 b
LSD	2.770	3.199	0.601	NS	0.699

Means followed by the same letter in a column did not differ significantly according to LSD test ($p < 0.05$).

T_{50} = Time taken to 50% germination, MGT = Mean Germination time, GI = Germination Index, LSD = Least Significance Difference, NS= non-significant

d: days

4.1.8 Effect of thiourea for short soaking time germination traits of *Astragalus* spp.

The significantly maximum G percentage (22), GE (16) and GI (3.11) was recorded in 8 hours soaking treatment (Table 4.1.7). The significantly minimum G percentage was noted in 12 hours soaking treatment. The minimum GE (5) and GI (0.58) were attained in 12 hours soaking treatment which was alike statistically with those of 4 hours. The significantly minimum MGT (3.05) and time to take 50% germination (1.73) was gained in 8 hours soaking treatment. The maximum MGT (5.78) and T_{50} (4.62) was observed in 4 hours soaking time which was statistically at par with those of 12 hours soaking time.

Khan *et al*. (2003) reported that G of *A. prostrata* was stimulated by thiourea and nitrate compounds. In another study Erez (2005) stated that thiourea promoted growth in

soybean, tobacco, and apple. Whereas Ali *et al*. (2011) revealed contradictory results as thiourea was ineffective to break seed dormancy of *Rhynochosia capitata*.

Table 4.1.7 Effect of thiourea for short soaking time on germination traits of *Astragalus* spp.

Treatments	G (%)	GE	GI	MGT (d)	T_{50} (d)
4 hours	16.00 b	6.00 b	0.90 b	5.78 a	4.62 a
8 hours	22.00 a	16.00 a	3.11 a	3.05 b	1.73 b
12 hours	10.00 c	5.00 b	0.58 b	5.00 a	4.00 ab
LSD	4.265	4.130	0.693	1.906	2.271

Means followed by the same letter in a column did not differ significantly according to LSD test ($p < 0.05$).

T_{50} = Time taken to 50% germination, MGT = Mean Germination time, GI = Germination Index, LSD = Least Significance Difference, d: days

Experiment 4.2: Effect of different ecological factors on seed germination of *Euphorbia dracunculoides* and *Astragalus* spp.

4.2.1 Temperature

Germination of *E. dracunculoides* and *Astragalus* spp. was tested at constant temperature of 10, 15, 20 and 25°C. Germination of *E. dracunculoides* was influenced significantly by different temperature levels (Fig. 4.2.1). Significantly maximum G percentage (50), GE (13) and GI (2.12) was recorded at 15 °C and it decreased to 44, 9 and 1.65 at 20 °C. Later was followed by 24, 3 and 0.83 at 25 °C (Fig. 4.2.1 and Table 4.2.1). Significantly minimum G percentage (4), GE (0) and GI (0.08) was observed at 10 °C. Mean germination time and time taken to 50% germination was non-significant at all temperatures.

Significantly maximum G percentage (40) of *Astragalus* spp. was observed at 15°C followed by that of 20°C. Minimum G percentage (20) was recorded at 25 °C (Fig. 4.2.1) which was not different statistically from that of 10°C. Maximum GE (18) was observed at 15°C (Table 4.2.1) which was statistically alike with that of 20°C followed by that of 10°C. Germination index was significantly maximum (2.44) at 15°C which decreased to 1.93, 1.25 at 20 and 10 °C, respectively. Significantly minimum GI (0.73) was noticed at 25°C. Significantly minimum MGT (4.69) was recorded at 10°C which increased with increase in temperature with significantly maximum MGT (8.33) at 25°C. Minimum T_{50} (4.31) was observed at 20 °C which was statistically at par with those of 10 and 15°C and maximum T_{50} (7.25) was observed at 25°C.

Number of studies depicted that germination of many weed species have been affected by temperature as Benvenuti *et al*. (2001) reported that low temperature <15 °C induced maximum germination inhibition in *Rumex obtusifolius* L.. In another study maximum germination was observed at 25°C and with increase in temperature; there was a decrease in germination or even no germination of mulberry weed (*Fatoua villosa*) at lower than 15°C and higher than 42°C (Gina and Joseph, 2003).

4.2.2 Light

When seeds of *E. dracunculoides* were exposed to 10 h photoperiod, they showed significantly maximum G percentage (66), GE (23) and GI (2.87) as compared to those seeds which were under complete darkness (10, 0 and 0.31, respectively) (Fig. 4.2.2 and Table

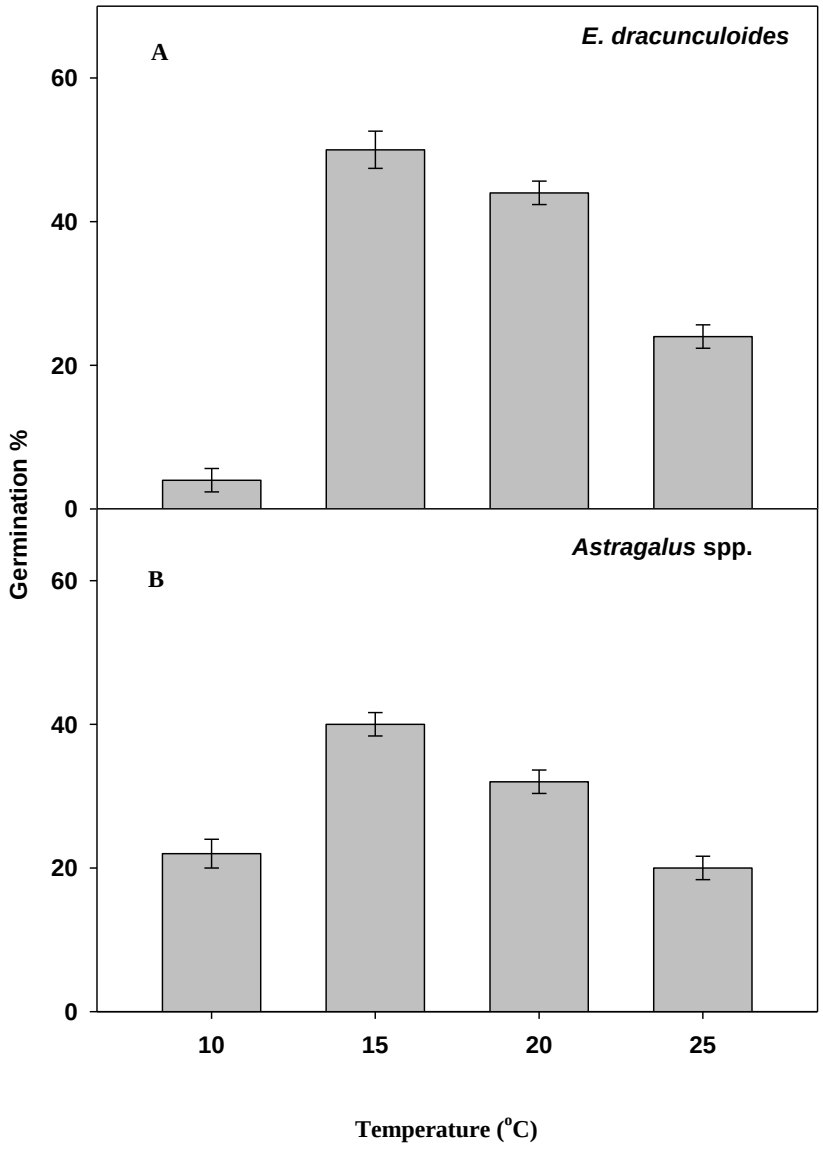

Fig. 4.2.1: Effect of temperature on seed germination of *Euphorbia dracunculoides* (A) and *Astragalus* spp. (B)

Table 4.2.1 Effect of temperature on germination traits of *Euphorbia dracunculoides* and *Astragalus* spp.

Temperature (^{o}C)	GE	GI	MGT (d)	T_{50} (d)
E. dracunculoides				
10	0.00 c	0.08 d	15.62	8.50
15	13.00 a	2.12 a	7.44	6.06
20	9.00 b	1.65 b	8.30	7.43
25	3.00 c	0.83 c	8.44	7.50
LSD	3.667	0.341	NS	NS
Astragalus spp.				
10	10.00 b	1.25 c	4.69 c	4.62 b
15	18.00 a	2.44 a	5.88 b	4.50 b
20	16.00 a	1.93 b	6.07 b	4.31 b
25	4.00 c	0.73 d	8.33 a	7.25 a
LSD	5.031	0.359	1.001	1.798

Means followed by the same letter in a column did not differ significantly according to LSD test ($p < 0.05$). GE: Germination Energy, T_{50} = Time taken to 50% germination, MGT = Mean Germination time, GI = Germination Index, LSD = Least Significance Difference, NS= non-significant,

d: days

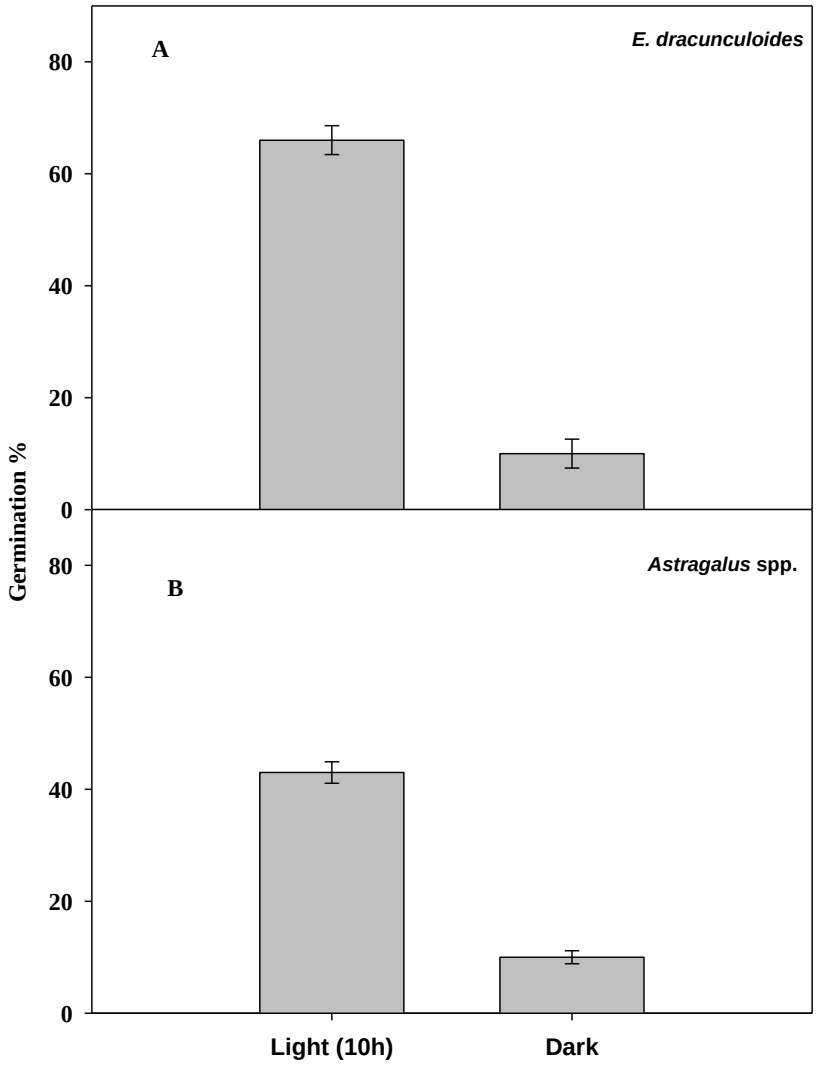

Fig. 4.2.2 Effect of light on seed germination of *Euphorbia dracunculoides* and *Astragalus* spp.

Table 4.2.2 Effect of light on germination traits of *Euphorbia dracunculoides* and *Astragalus* spp.

Light	GE	GI	MGT (d)	T_{50} (d)
E. dracunculoides				
Light (10h)	23.00 a	2.87 a	7.45 b	6.37 b
Dark	0.00 b	0.31 b	8.52 a	8.12 a
LSD	4.685	0.274	1.002	1.637
Astragalus spp.				
Light	17.00 a	2.23 a	6.23	5.66
Dark	4.00 b	0.47 b	5.70	4.43
LSD	4.685	0.539	NS	NS

Means followed by the same letter in a column did not differ significantly according to LSD test ($p < 0.05$). GE: Germination Energy, T_{50} = Time taken to 50% germination, MGT = Mean Germination time, GI = Germination Index, LSD = Least Significance Difference, NS= non-significant,

d: days

4.2.2). Significantly minimum MGT (7.45) and time to 50% germination (6.37) was recorded in seeds which were under light exposure.

Astragalus spp. seeds also showed significant response towards light and significantly maximum G percentage (43), GE (17) and GI (2.23) were observed under light treatment. Mean germination time and T_{50} was observed to be non-significant at both treatments.

These results suggested that both weeds are light sensitive and problem of light sensitive weeds can be overcome by dominating dense crop plantation. Very little germination of both weeds in dark condition leads towards a knowledge that they can not germinate well under shade. But in contrast research revealed that light was not required by nalta jute (*Corchorus olitorius*) and redweed (*Melochia concatenata*) (Chauhan and Johnson, 2008). It could be due to specie difference.

4.2.3 pH

Significantly maximum G percentage (52) of *E. dracunculoides* was observed at pH 7 which was statistically similar with that of pH 6 (Fig. 4.2.3). Germination (39%) further decreased at pH 8. Significantly minimum germination (25%) was recorded at pH 9. Significantly maximum GE (18) was indicated by pH 7 followed by 6 (12) (Table 4.2.3). Germination index was significantly maximum (3.18) at distilled water followed by 2.52 at 7 buffer solution. Significantly maximum GI (2.52) was recorded at pH 7 which was followed by that of pH 6 and 8. Significantly minimum GI (0.96) was noted at pH 9. Minimum MGT (6.33) and T_{50} (4.91) were recorded at pH 7 which was statistically similar with those of pH 6. Maximum MGT (9.28) and T_{50} (8.39) was observed at pH 9 which were statistically alike with those of pH 8.

In *Astragalus* spp. maximum germination (38%) was observed at pH 7 which was statistically similar with that of pH 8 and followed by that of pH 6. Significantly minimum germination (16%) was recorded at pH 9. Maximum GE (16) was recorded at pH 7 which was statistically similar with those of pH 6 and 8. Germination energy significantly reduced to 5 at pH 9. Germination index was maximum (2.04) at pH 7 which was statistically similar with that of pH 8. Latter in turn, was not different statistically with that of pH 6. Significantly minimum GI (0.79) was recorded at pH 9. Mean germination time and T_{50} was non-significant.

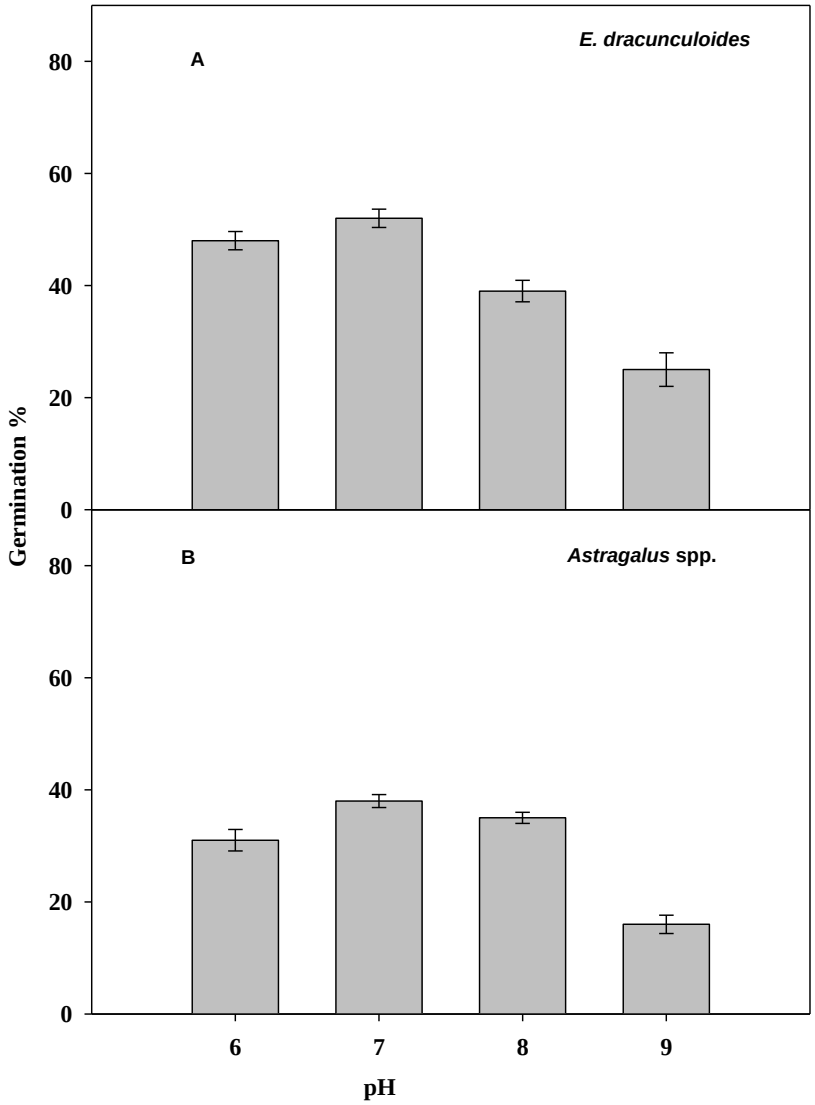

Fig. 4.2.3 Effect of pH on seed germination of *Euphorbia dracunculoides* (A) and *Astragalus* spp. (B)

Table 4.2.3 Effect of pH on germination traits of *Euphorbia dracunculoides* and *Astragalus* spp.

pH	GE	GI	MGT (d)	T50 (d)
E. dracunculoides				
6	12.00 b	1.51 b	7.14 b	6.43 b
7	18.00 a	2.52 a	6.33 b	4.91 b
8	2.00 c	1.23 bc	8.92 a	8.00 a
9	4.00 c	0.96 c	9.28 a	8.39 a
LSD	5.335	0.326	1.051	1.560
Astragalus spp.				
6	12.00 a	1.68 b	6.04	4.68
7	16.00 a	2.04 a	6.20	5.00
8	13.00 a	1.74 ab	6.56	5.12
9	5.00 b	0.79 c	6.68	5.68
LSD	4.472	0.394	NS	NS

Means followed by the same letter in a column did not differ significantly according to LSD test ($p < 0.05$). GE: Germination Energy, T_{50} = Time taken to 50% germination, MGT = Mean Germination time, GI = Germination Index, LSD = Least Significance Difference, NS= non-significant,

d: days

It is indicated from the results that both species were sensitive to pH 9 while both germinated well at other pH levels. This kind of weed behavior suggested that they can adapt a wide range of soil conditions. Having this kind of character is admissible to become an invasive weed (Watanabe *et al*., 2002). Germination of threehorn bedstraw (*Galium tricornutum*) was found over a range of pH from 4 to 10 (Chauhan *et al*., 2006) and *Solanum nigrum* showed high percentage of germination at neutral pH (Suthar *et al*., 2009).

4.2.4 Salt stress

Sodium chloride at different concentrations affected germination of *E. dracunculoides* significantly. Significantly maximum germination 68% (Fig. 4.2.4), GE (22) and GI (3.18) were achieved with distilled water (Table 4.2.4). Germination decreased significantly with increase in salt concentrations and there was no germination at 125 and 150 mM of NaCl. Leaving un-germinated treatments, minimum mean germination time (4.62) and time taken to 50% germination (4) was recorded at 100 mM concentration which was statistically similar with those of control and 25 mM treatments which further were not different statistically from 50 and 75 mM concentrations.

In case of *Astragalus* spp. maximum germination (41%) was observed at 25 mM concentration which was statistically alike with that of control followed by 50 mM. Here also a trend of decreased germination with increased concentration of NaCl was observed and significantly minimum germination (11%) was detected at highest salt concentration. Maximum germination energy (15) and GI (2.19) was observed from control which was statistically alike with that of 25 mM concentration. With increase in concentration of salt there was a significant reduction in germination energy and germination index and minimum GE (1) and GI (0.34) was recorded at 150 mM concentration, respectively. Minimum MGT (6.04) and T_{50} (4.56) was recorded at control (distilled water) which was statistically similar to those of 25 and 50 mM NaCl concentrations. There was an increase in MGT and T_{50} with increase in salt concentration.

Results showed that *Astragalus* spp. is fairly tolerant to salt as compared to *E. dracunculoides*. *Astragalus* spp. germinated somewhat at 150 mM concentration but *E. dracunculoides* did not germinate at 125 and 150 mM. Ability of *Astragalus* spp. to germinate at high salt concentrations may lead to spread to plain areas of Pakistan. This is

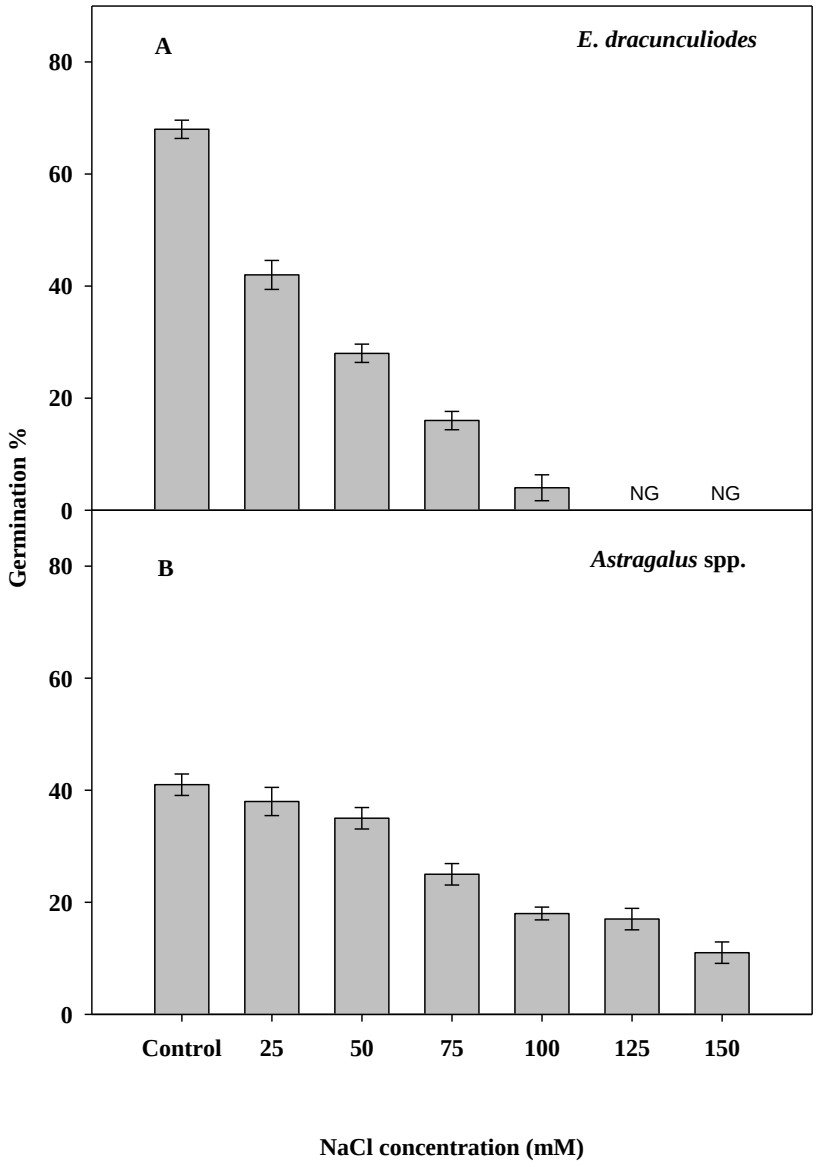

Fig. 4.2.4 Effect of salt stress on seed germination of *Euphorbia dracunculoides* (A) and *Astragalus* spp. (B)

NG: Not germinated

Table 4.2.4 Effect of salt stress on germination traits of *Euphorbia dracunculoides* and *Astragalus* spp.

Salt stress (mM)	GE	GI	MGT (d)	T_{50} (d)
E. dracunculoides				
0	22.00 a	3.18 a	6.37 ab	5.45
25	8.00 b	1.68 b	7.49 ab	6.56
50	6.00 b	1.07 c	7.91 ab	6.68
75	0.00 c	0.50 d	8.64 a	7.31
100	0.00 c	0.11 e	4.62 b	4.00
125	NG	NG	NG	NG
150	NG	NG	NG	NG
LSD	3.113	0.291	3828	NS
Astragalus spp.				
0	15.00 a	2.19 a	6.04 e	4.56 c
25	15.00 a	2.19 a	6.36 de	5.77 bc
50	5.00 b	1.36 b	7.23 cde	6.25 bc
75	3.00 bc	0.95 c	7.32 cd	6.31 b
100	2.00 bc	0.63 cd	8.00 bc	7.37 ab
125	2.00 bc	0.55 d	8.69 b	8.37 a
150	1.00 c	0.34 d	10.27 a	8.37 a
LSD	3.573	0.328	1.268	1.743

Means followed by the same letter in a column did not differ significantly according to LSD test ($p < 0.05$). GE: Germination Energy, T_{50} = Time taken to 50% germination, MGT = Mean Germination time, GI = Germination Index, LSD = Least Significance Difference, NS= non-significant, NG= non-germinated, d: days

also a reason to colonize weed to saline areas. These results are in line with those of Chauhan and Johnson (2008) who reported that nalta jute (*Corchorus olitorius*) and redweed (*Melochia concatenata*) were moderately tolerant to salt stress and in another study NaCl concentrations (4.5, 8.6, 12.7 and 16.3 dS/m) did not effect on frequency of germination.

4.2.5 Drought stress

Germination percentage, germination energy and germination index of *E. dracunculoides* decreased as drought stress increased (Fig. 4.2.5 and Table 4.2.5). Significantly maximum G percentage 68 (Fig. 4.2.5), GE (22) and GI (3.18) of *E. dracunculoides* was recorded with distilled water. Minimum MGT (2) and T_{50} (1.87) was observed at 12.5% drought stress which was statistically similar with that of 10%.

Astragalus spp. seeds showed decreased germination, germination energy and germination index with increased in drought stress and significantly maximum G percentage (39) and GI (2.19) was observed at control treatment. Maximum GE (15) was recorded at control which was statistically similar with that of 2.5% drought stress. Significantly minimum MGT (2.25) and T_{50} (2.12) was recorded at 12.5% PEG solution. All the other treatments except 15% PEG remained statistically non-significant with one another. Minimum mean germination time and T_{50} at drought stress (12.5%) might due to very little germination occurred at early stage and then there was no germination at all ahead. This water stress study revealed the association between rain or water availability and germination of *E. dracunculoides* and *Astragalus* spp. Both weeds germinated to wide range of water stress but overall performance of *Astragalus* spp. was higher than *E. dracunculiodes*. Results of this experiment indicated the potential of these species to tolerate water stress and spread to low moisture conditions. Some weeds such as crafton (*E. adenophoum*) and taxsasweed (*Caperonia palustris*) are sensitive to drought stress (Koger *et al*., 2004; Lu *et al*., 2006) and in contrast, other weed species like venice mallow (*Hebiscus trionum*) and hairy nightshade (*Solanum sarrachoides*) showed tolerance to drought stress (Zhou *et al.*, 2005; Chachalis *et al*., 2008).

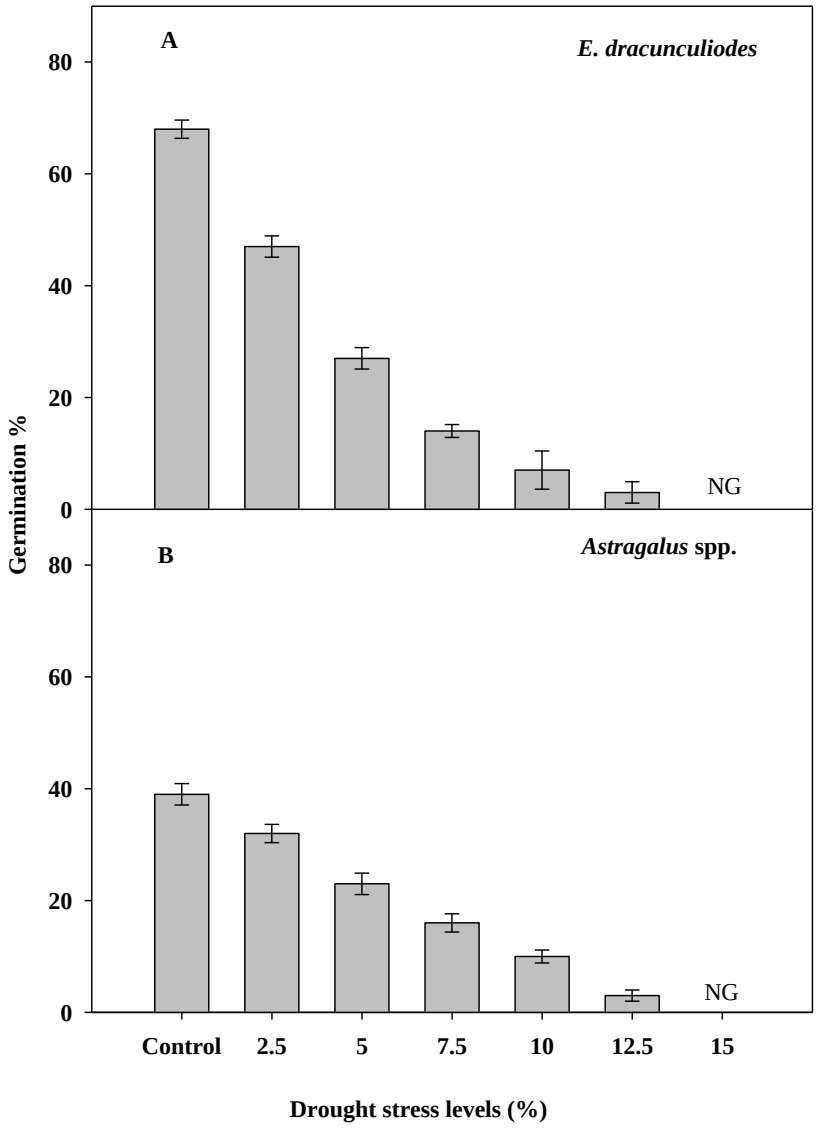

Fig. 4.2.5 Effect of drought stress on seed germination of *Euphorbia dracunculoides* (A) and *Astragalus* spp. (B)

NG= Not germianted

Table 4.2.5 Effect of drought stress on germination traits of *Euphorbia dracunculoides* and *Astragalus* spp.

Drought stress (%)	GE	GI	MGT (d)	T_{50} (d)
E. dracunculoides				
0	22.00 a	3.18 a	6.37 a	5.45 a
2.5	6.00 b	1.93 b	6.60 a	5.81 a
5	1.00 c	1.09 c	6.46 a	5.93 a
7.5	0.00 c	0.57 d	6.39 a	5.70 a
10	0.00 c	0.26 e	5.18 ab	4.62 ab
12.5	0.00 c	0.09 e	2.00 b	1.87 b
15	NG	NG	NG	NG
LSD	2.322	0.285	3.307	3.049
Astragalus spp.				
0	15.00 a	2.19 a	6.04 a	4.56 ab
2.5	11.00 ab	1.58 b	6.63 a	5.62 a
5	7.00 bc	1.07 c	6.66 a	5.81 a
7.5	4.00 cd	0.67 d	6.82 a	6.00 a
10	0.00 d	0.35 de	7.37 a	6.00 a
12.5	0.00 d	0.03 e	2.25 b	2.12 b
15	NG	NG	NG	NG
LSD	4.484	0.347	3.001	2.897

Means followed by the same letter in a column did not differ significantly according to LSD test ($p < 0.05$). GE: Germination Energy, T_{50} = Time taken to 50% germination, MGT = Mean Germination time, GI = Germination Index, LSD = Least Significance Difference, NG = Not-germinated,

d: days,

4.2.6 Field capacity

Euphorbia dracunculoides emergence (60%) (Fig. 4.2.6), EE (5) and EI (0.78) were significantly maximum at 100% field capacity (Table 4.2.6). Emegence and EI decreased with decrease in field capacity level and were significantly minimum at 25% field capacity. Emergence energy was recorded 0 at all the remaining levels of field capacity. Significantly minimum MET (8.91) and T_{50} (7.31) was recorded at 100% field capacity and it increased with decrease in field capacity level. Significantly maximum MET (15.45) and T_{50} (15) was observed at lowest field capacity level (25%).

In *Astragalus* spp. seeds, emergence increased with increase in field capacity level (Fig. 4.2.6). Maximum emrgence (47.50%) occurred at 100% field capacity which was not different statistically from that of 75% and followed by that of 50% field capacity. Significantly minimum (5%) emrgence was observed at 25%. Significantly maximum EI (0.69) was recorded at 100% filed capacity which decreased with decrease in field capacity level and minimum EI (0.05) was recorded at 25% which was statistically similar to that of 50% field capacity. Minimum MET (4.75) was recorded at minimum (25%) filed capacity level which was statistically similar with that of 100% which in turns was statistically not different from those of 50% and 75%. Minimum T_{50} (4.50) occurred at 25% which was statistically similar with those of 100 and 75%, which were not different statistically from that of 50% field capacity level.

Minimum mean emergence time and time taken to 50% emrgence might due to very little germination occurred at lowest field capacity level at early stage in case of *Astragalus* spp. Both weeds emerged little or more at all field capacity levels. Results indicated potential of weeds to tolerate water stress and spread to low moisture conditions. Some weeds such as crafton (*E. adenophoum*) and taxsasweed (*Caperonia palustris*) are sensitive to drought stress (Koger *et al*., 2004; Lu *et al*., 2006) and in contrast, other weed species like venice mallow (*Hebiscus trionum*) and hairy nightshade (*Solanum sarrachoides*) showed tolerance to drought stress (Zhou *et al*., 2005; Chachalis *et al*., 2008).

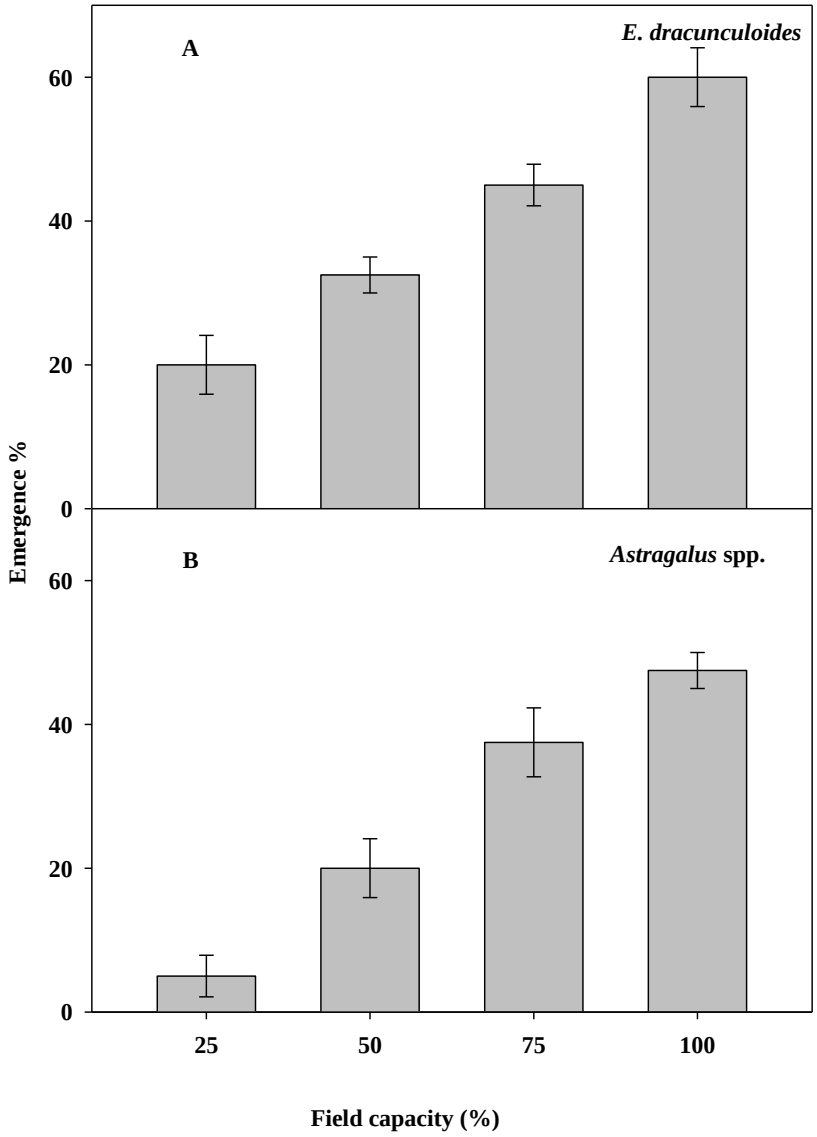

Fig. 4.2.6 Effect of field capacity on seed emergnce of *Euphorbia dracunculoides* (A) and *Astragalus* spp. (B)

Table 4.2.6 Effect of filed capacity on emergence traits of *Euphorbia dracunculoides* and *Astragalus* spp.

Field capacity (%)	EE	EI	MET (d)	T_{50} (d)
		E. dracunculoides		
25	0.00 b	0.13 d	15.45 a	15.00 a
50	0.00 b	0.26 c	12.56 b	11.62 b
75	0.00 b	0.44 b	11.38 b	9.56 bc
100	5.00 a	0.78 a	8.91 c	7.31 c
LSD	4.447	0.123	1.950	2.502
		Astragalus spp.		
25	0.00	0.05 c	4.75 b	4.50 b
50	0.00	0.18 c	10.58 a	9.18 a
75	0.00	0.42 b	9.50 a	7.87 ab
100	0.00	0.69 a	7.41 ab	6.18 ab
LSD	NS	0.136	4.395	4.260

Means followed by the same letter in a column did not differ significantly according to LSD test ($p < 0.05$). EE: Emergence Energy, T_{50} = Time taken to 50% germination, MET = Mean Emergence time, EI = Emergence Index, LSD = Least Significance Difference, d: days

4.2.7 Seeding depth

Seeding depth significantly affected the emergence of *E. dracunculoides* which decreased with increased seeding depth. Significantly maximum emergence (77.50%) (Fig. 4.2.7) occurred where seeds were placed on soil surface followed by those of 1 and 2 cm seeding depth. Minimum emergence (7.50%) was observed at 6 cm seeding depth which was not different statistically from those of 3, 4 and 5 cm. Significantly maximum EE was detected with surface soil seeds and remaining all other seeding depths failed to gain any successful reading (Table 4.2.7). Significantly maximum emergence index (1.16) was recorded at zero seeding depth followed by those of 1 and 2 cm. Emrgence index decreased with increased seeding depth and minimum EI (0.04) was observed at seeding depth of 6 cm which was statistically similar to those of 4 and 5 cm seeding depth.

Astragalus spp. exhibited the trend that with increase in seeding depth there was decrease in emergence (Fig. 4.2.8). Significantly maximum E percentage (37.50) and EI (0.57) was occurred in seeds placed at soil surface and emergence continued to decrease with increased depth (Table 4.2.7). Significantly minimum emergence (5%) and EI (0.02) were observed at highest seeding depth of 4 cm. Maximum EE (5) was observed in seeds placed at soil surface but remained statistically non-significant with that of all other seeding depths.

Our results suggested that both weeds were capable to germinate/emerge at wide range of seeding depths. There are different opinions of researchers e.g *Pistacia atlantica* seeds were sown at three different depths (0, 4 and 8 cm) but at 0 cm sowing depth, no seedlings emerged. Survival was greater at 4 cm than at 8 cm sowing depth (Hosseini *et al*., 2007). Soil surface seeds gave maximum germination of mulberry weed (*Fatoua villosa*) and seedling emergence whereas depth greater than 1.8 cm reduced the emergence more than 90% (Gina and Joseph, 2003). Whereas, Chantre *et al*. (2009) stated that *Lithospermum arvense* seed germinated from 55-65% at 2 cm and 5-30% at greater than 20 cm depth whereas in laboratory experiment germination of buried seed was unaffected. Among seeds placed at deeper depth, enforced dormancy was higher.

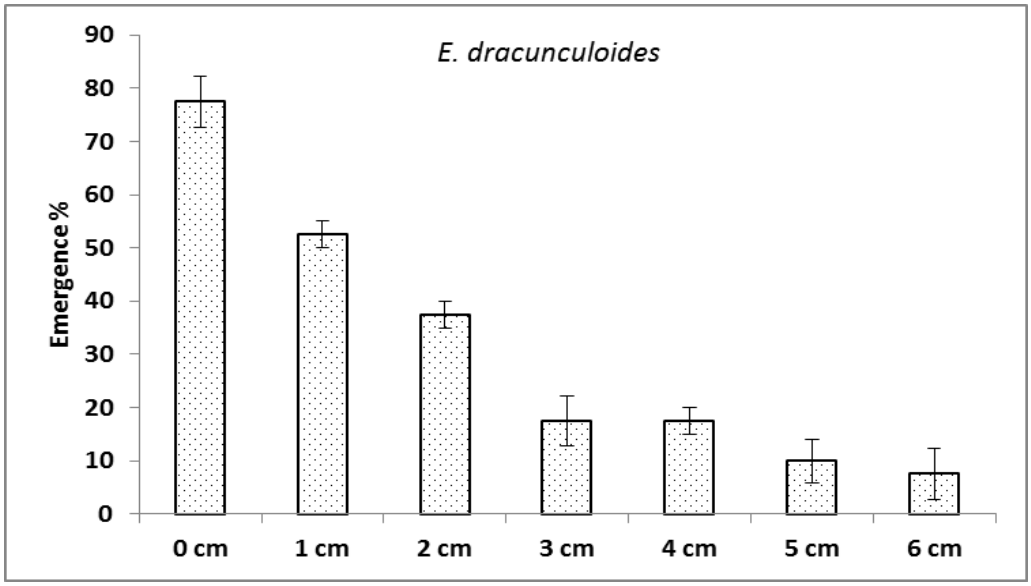

Fig. 4.2.7 Effect of seeding depth on seed emergence of *Euphorbia dracunculoides*.

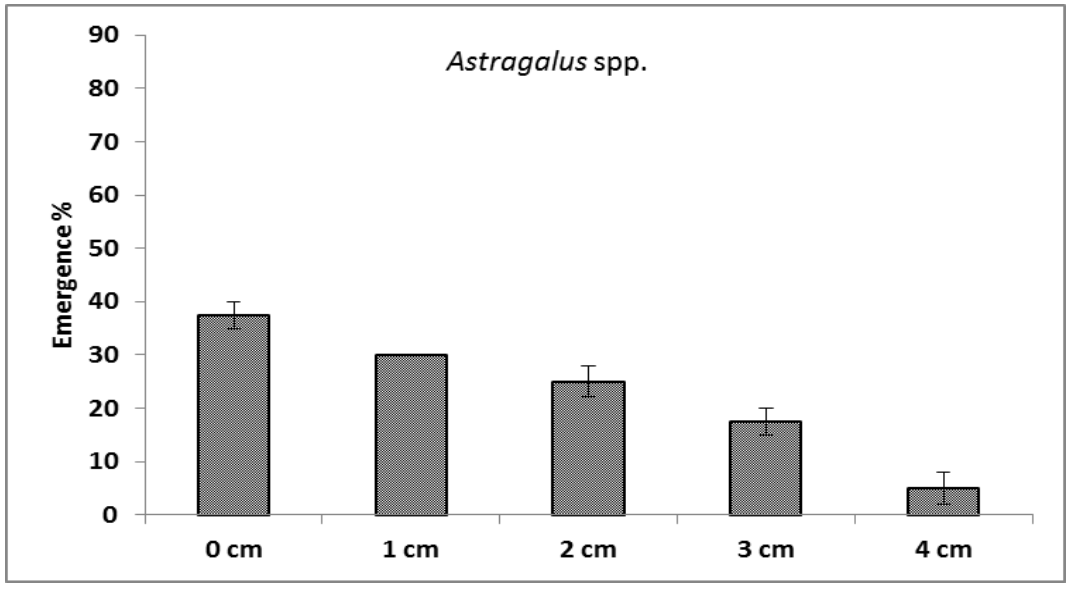

Fig. 4.8 Effect of seeding depth on emergence of *Astragalus* spp.

Table 4.2.7 Effect of seeding depth on emergence traits of *Euphorbia dracunculoides* and *Astragalus* spp.

Seeding depth (cm)	EE	EI	MET (d)	T_{50} (d)
E. dracunculoides				
0	15.00 a	1.16 a	8.62	6.18
1	0.00 b	0.57 b	10.79	9.31
2	0.00 b	0.27 c	14.50	13.95
3	0.00 b	0.17 d	10.66	10.37
4	0.00 b	0.12 de	14.75	10.00
5	0.00 b	0.06 e	12.12	11.75
6	0.00 b	0.04 e	9.37	9.12
LSD	3.208	0.104	NS	NS
Astragalus spp.				
0	5.00	0.57 a	7.23	6.37
1	2.50	0.43 b	8.24	7.37
2	0.00	0.25 c	10.87	9.00
3	0.00	0.13 d	13.12	11.87
4	0.00	0.027 e	9.00	9.87
LSD	NS	0.080	NS	NS

Means followed by the same letter in a column did not differ significantly according to LSD test ($p < 0.05$). EE: Emergence Energy, T_{50} = Time taken to 50% germination, MET = Mean Emergence time, EI = Emergence Index, LSD = Least Significance Difference, NS= non-significant,

d: days

Experiment: 4.3 Allelopathic potential of *Euphorbia dracunculoides* and *Astragalus* spp. against chickpea

4.3.1 Allelopathic effect of *Euphorbia dracunculoides* leaf extracts on germination and germination traits of chickpea

The data presented in table 4.3.1 show that germination percentage of chickpea was not significantly affected by leaf extract of *E. dracunculoides* concentration, habitat and their interaction. The data presented in table 4.3.2 show that effect of *E. dracunculoides* leaf extract concentration, interactive effect of concentration and habitat on chickpea germination energy (GE) was significant while that of habitat means was non-significant. Highest GE (49) was noted at 1% leaf extract concentration of irrigated habitat followed by its 2% and 1% leaf extract of *E. dracunculoides* of rainfed habitat. Minimum GE (0) was recorded with 5% *E. dracunculoides* leaf extract from irrigated habitat which was statistically similar with those of 5% leaf extract of *E. dracunculoides* from rainfed and 4% of irrigated *E. dracunculoides* leaf extract. Leaf extract of *E. dracunculoides* significantly affected the germination index of chickpea (Table 4.3.3). Habitat and its interaction with concentration remained non-significant. Significantly maximum GI (5.84) was observed at 1% *E. dracunculoides* leaf extract. Germination index decreased with increase in concentration. Significantly minimum GI (3.18) was observed at 5% leaf extract of *E. dracunculoides*.

Data depicted in table 4.3.4 show that leaf extract of *E. dracunculoides* significantly affected the mean germination time of chickpea while habitat and its interaction with concentration remained non-significant. Significantly minimum MGT (4.71) was observed at 1% leaf extract of *E. dracunculoides*. Mean germination time increased with increase in concentration of leaf extract. Significantly maximum MGT (7.99) was recorded at 5% concentration. Data presented in table 4.3.5 show that leaf extract of *E. dracunculoides* at different concentration significantly affected the time taken to 50% germination of chickpea. *Euphorbia dracunculoides* habitat and its interaction with concentration was observed to be non-significant. Minimum T_{50} (4.15) was recorded at 1% leaf extract of *E. dracunculoides* which was statistically similar with those of 2% leaf extract and T_{50} increased with increase in concentration of leaf extract. Significantly maximum T_{50} (7.27) was noted at 5%. These results revealed that with increase in leaf extract concentration there was a decrease in germination, GE and GI but increase in MGT and T_{50}.

Table 4.3.1 Allelopathic effect of leaf extract of *Euphorbia dracunculoides* from different habitats on germination percentage of chickpea

Concentration	Habitat		Concentration Mean
	Irrigated	Rainfed	
1%	100.00	100.00	100.00
2%	100.00	100.00	100.00
3%	100.00	100.00	100.00
4%	97.00	100.00	98.50
5%	97.00	98.00	97.50
Habitat Mean	98.80	99.60	

LSD= 5%, Concentrations= NS, Habitat= NS, Interaction= NS

Distilled Water (Control) germination: 100%

Means not sharing a letter in common differ significantly at 5% level of probability.

Table 4.3.2 Allelopathic effect of leaf extract of *Euphorbia dracunculoides* from different habitats on germination energy of chickpea

Concentration	Habitat		Concentration Mean
	Irrigated	Rainfed	
1%	49.00 A	36.00 BC	42.50 a
2%	38.00 B	32.00 C	35.00 b
3%	17.00 D	19.00 D	18.00 c
4%	4.00 F	12.00 E	8.00 d
5%	0.00 F	3.00 F	1.50 e
Habitat Mean	21.60	20.40	

LSD= 5%, Concentrations= 3.335, Habitat= NS, Interaction= 4.716

Distilled Water (Control) GE: 94%

Means not sharing a letter in common differ significantly at 5% level of probability.

Table 4.3.3 Allelopathic effect of leaf extract of *Euphorbia dracunculoides* from different habitats on germination Index of chickpea

Concentration	Habitat		Concentration Mean
	Irrigated	Rainfed	
1%	5.85	5.83	5.84 a
2%	5.28	5.37	5.33 b
3%	4.48	4.57	4.52 c
4%	3.73	4.42	4.08 c
5%	3.14	3.22	3.18 d
Habitat Mean	4.50	4.68	

LSD= 5%, Concentrations= 0.235, Habitat= NS, Interaction= NS

Distilled Water (Control) GI: 11.17

Means not sharing a letter in common differ significantly at 5% level of probability.

Table 4.3.4 Allelopathic effect of leaf extract of *Euphorbia dracunculoides* from different habitats on mean germination time of chickpea

Concentration	Habitat		Concentration Mean
	Irrigated	Rainfed	
1%	4.68	4.74	4.71 c
2%	5.11	4.97	5.04 c
3%	5.99	5.96	5.97 b
4%	7.04	6.10	6.57 b
5%	8.02	7.98	7.99 a
Habitat Mean	5.52	5.36	

LSD= 5%, Concentrations= 0.765, Habitat= NS, Interaction= NS

Distilled Water (Control) MGT: 2.42

Means not sharing a letter in common differ significantly at 5% level of probability.

Table 4.3.5 Allelopathic effect of leaf extract of *Euphorbia dracunculoides* from different habitats on time taken to 50% germination of chickpea

Concentration	Habitat		Concentration Mean
	Irrigated	Rainfed	
1%	4.02	4.28	4.15 d
2%	4.34	4.40	4.37 cd
3%	5.11	5.25	5.18 bc
4%	6.38	5.14	5.76 b
5%	7.16	7.39	7.27 a
Habitat Mean	4.76	4.67	

LSD= 5%, Concentrations= 0.826, Habitat= NS, Interaction= NS

Distilled Water (Control) T_{50}: 1.56

Means not sharing a letter in common differ significantly at 5% level of probability.

There might be some allelochemicals in extract which delayed germination. Our results are supported by those of Shanee *et al.* (2011) who stated that fruit extract at 1:20 (w/v) and leaf extract of *E. dracunculoides* at 1:10 (w/v) affected all the traits of chickpea and maximum germination (12%) reduction occurred with fruit extract while maximum MGT and minimum GI of chickpea were recorded with leaf extract. Shanee *et al.* (2011) also concluded that *E. dracunculoides* contains some compounds which might had phytotoxic effects on chickpea. Javaid *et al.* (2006) stated that leaf aqueous extracts (2, 4 and 8%) of *Alstonia scholaris, Azadirachta indica* and *Eucalyptus citriodora* reduced final germination (43-100%) of *Phalaris minor*. Generally higher concentration of leaf extract showed significant negative impact on germination of *P. minor* and with increase in *Chenopodium murali* residue in soil (5, 10, 20 and 40 g kg^{-1}), growth associated with *Cicer arietinum* and *Pisum sativum* was gradually declined. With this residue increase, chlorophyll contents also decreased (Batish *et al*., 2007).

4.3.2 Allelopathic effect of whole plant extracts of *Euphorbia dracunculoides* on germination traits of chickpea

Germination of chickpea was influenced significantly by individual as well as interaction of whole plant extract at different concentration and habitat of *E. dracunculoides* (Table 4.3.6). Maximum germination (98%) of chickpea was achieved at 1% whole plant extract of irrigated *E. dracunculoides* which was not different statistically with that of its 2%. There was a linear decrease in germination of chickpea with increase in whole plant concentration of *E. dracunculoides* from both habitats. Significantly minimum germination (15%) was detected at 5% whole plant extract of *E. dracunculoides* from rainfed habitat.

Data presented in table 4.3.7 show that individual as well as interaction effect of whole plant extract concentration and habitats of *E. dracunculoides* on GE was significant. Maximum GE (88) was observed at 1% whole plant extract of *E. dracunculoides* from irrigated habitat which was statistically alike with that of 1% whole plant extract concentration of *E. dracunculoides* from rainfed habitat followed by those of 2 and 3% whole plant extract concentration of *E. dracunculoides* from irrigated habitat. Germination energy decreased with

Table 4.3.6 Allelopathic effect of whole plant extract of *Euphorbia dracunculoides* from different habitats on germination percentage of chickpea

Concentration	Habitat		Concentration Mean
	Irrigated	Rainfed	
1%	98.00 A	88.75 BC	93.38 a
2%	93.00 AB	56.25 E	74.63 b
3%	90.00 BC	40.00 F	65.00 c
4%	85.00 CD	27.50 G	56.25 d
5%	81.00 D	15.00 H	48.00 e
Habitat Mean	89.40 a	45.50 b	

LSD= 5%, Concentrations= 4.334, Habitat= 2.741, Interaction= 6.129

Distilled Water (Control) germination: 100%

Means not sharing a letter in common differ significantly at 5% level of probability.

Table 4.3.7 Allelopathic effect of whole plant extract of *Euphorbia dracunculoides* from different habitats on germination energy of chickpea

Concentration	Habitat		Concentration Mean
	Irrigated	Rainfed	
1%	88.00 A	83.75 AB	85.87 a
2%	81.00 B	31.25 E	56.12 b
3%	80.00 B	22.50 F	51.25 c
4%	72.00 C	7.50 G	39.75 d
5%	60.00 D	6.25 G	33.12 e
Habitat Mean	79.20 a	30.25 b	

LSD= 5%, Concentrations= 3.625, Habitat= 2.293, Interaction= 5.127

Distilled Water (Control) GE: 94

Means not sharing a letter in common differ significantly at 5% level of probability.

Table 4.3.8 Allelopathic effect of whole plant extract of *Euphorbia dracunculoides* from different habitats on germination Index of chickpea

Concentration	Habitat		Concentration Mean
	Irrigated	Rainfed	
1%	8.43 A	6.50 C	7.46 a
2%	6.95 B	2.83 F	4.89 b
3%	7.05 B	1.99 G	4.52 c
4%	5.91 D	0.97 H	3.44 d
5%	4.89 E	0.53 I	2.71 e
Habitat Mean	6.65 a	2.56 b	

LSD= 5%, Concentrations= 0.269, Habitat= 0.170, Interaction= 0.380

Distilled Water (Control) GI: 11.17

Means not sharing a letter in common differ significantly at 5% level of probability.

Table 4.3.9 Allelopathic effect of whole plant extract of *Euphorbia dracunculoides* from different habitats on mean germination time of chickpea

Concentration	Habitat		Concentration Mean
	Irrigated	Rainfed	
1%	3.21 E	2.95 E	3.08 c
2%	3.68 DE	4.70 BC	4.19 b
3%	3.50 DE	4.89 B	4.19 b
4%	3.86 CDE	6.46 A	5.16 a
5%	4.38 BCD	6.37 A	5.37 a
Habitat Mean	3.72 b	5.07 a	

LSD= 5%, Concentrations= 0.719, Habitat= 0.454, Interaction= 1.017

Distilled Water (Control) MGT: 2.42

Means not sharing a letter in common differ significantly at 5% level of probability.

Table 4.3.10 Allelopathic effect of whole plant extract of *Euphorbia dracunculoides* from different habitats on time taken to 50% germination of chickpea

Concentration	Habitat		Concentration Mean
	Irrigated	Rainfed	
1%	2.56 DE	2.36 E	2.46 c
2%	2.81 CDE	3.79 B	3.30 b
3%	2.58 DE	3.31 BCD	2.94 bc
4%	3.07 BCDE	5.37 A	4.22 a
5%	3.60 BC	4.75 A	4.17 a
Habitat Mean	2.92 b	3.91 a	

LSD= 5%, Concentrations= 0.651, Habitat= 0.411, Interaction= 0.921

Distilled Water (Control) T_{50}: 1.56

Means not sharing a letter in common differ significantly at 5% level of probability.

an increase in whole plant extract concentration of *E. dracunculoides* from both habitats. Minimum GE (6.25) of chickpea was observed at 5% whole plant concentration of *E. dracunculoides* from rainfed habitat which was statistically similar with that of 4%.

Data presented in table 4.3.8 show that both whole plant concentration of *E. dracunculoides* and habitat individually and in a combined study significantly affected the GI of chickpea. Significantly maximum GI (8.43) was recorded at 1% whole plant extract concentration of *E. dracunculoides* from irrigated habitat followed by those of its 2 and 3% whole plant extract. Germination index decreased with increase in whole plant extract of *E. dracunculoides* from both habitats. Significantly minimum GI (0.53) was recorded at 5% whole plant extract of rainfed *E. dracunculoides*.

The data presented in table 4.3.9 show that MGT of chickpea was significantly affected by habitat, whole plant extract concentration and their interaction. Minimum MGT (2.95) was observed at 1% whole plant extract of *E. dracunculoides* from rainfed habitat which was not different statistically with those of 1, 2, 3 and 4% whole plant extract concentration of *E. dracunculoides* from irrigated habitat. Mean germination time increased with increased in whole plant extract concentration from two different habitat and maximum MGT (6.46) was recorded at 4% whole plant extract concentration of *E. dracunculoides* from rainfed habitat which was statistically similar with that of its 5%.

The data in table 4.3.10 reveal that individual and interactive effect of habitat and whole plant extract concentration of *E. dracunculoides* significantly affected the T_{50} of chickpea. Significantly minimum (2.36) was detected at 1% whole plant extract concentration of *E. dracunculoides* from rainfed habitat which was statistically similar with those of 1, 2, 3 and 4% whole plant extract concentration of *E. dracunculoides* from irrigated habitat. With increase in whole plant extract concentration of *E. dracunculoides* from irrigated and rainfed habitat. There was a gradual increase in T_{50} and maximum T_{50} (5.37) was observed at 4% whole plant extract concentration of *E. dracunculoides* from rainfed habitat which was statistically similar with that of its 5%.

Water availability in extracts might be very low due to more number of allelochemicals which restricted the uptake of water and delayed germination. Our results are in accordance with those of Li and Jin (2010) who stated that aqueous extracts of plants parts (leaf, stem and root) of *Mikania micranthai* differed in their effects and *Coix lacryma-jobi* was concentration

dependent of all plant parts. Leaf extract had a stronger inhibiting effect on seed germination and seedling growth of *C. lacryma-jobi* than any other. In another study, extract of *Hemistepta lyrata* strongly inhibited the germination of wheat (*Triticum aestivum*), rape (*Brassica campestris*) and radish (*Raphanus sativus*). At lower concentration the extract stimulated the growth of roots and hypocotyls, while inhibited the growth at higher concentrations (Gao *et al*., 2009). In another study Safdar *et al*. (2014) revealed that minimum G (30.0%), GI (2.01), GE (36.3), seedling length (3.3 cm), seedling biomass (10 mg) and seedling vigor index (99.0) of maize were observed with leaf extract followed by those of fruit and whole plant extracts of parthenium growing near the field border.

4.3.3 Allelopathic effect of leaf extract of *Euphorbia dracunculoides* on emergence traits of chickpea sown in pots

Habitat, leaf extract of *E. dracunculoides* and their interaction did not affect the emergence of chickpea significantly (Table 4.3.11). Leaf extract, habitat and their interaction had significant effect on EE of chickpea (Table 4.3.12). Significantly maximum EE (5) was recorded with leaf extract of rainfed *E. dracunculoides* while all other concentrations failed to produce any EE. *Euphorbia dracunculoides* leaf extract concentrations and habitat had significant effect on EI of chickpea (Table 4.3.13). Maximum EI (1.83) was observed at 1% which was not different statistically with that of 2% leaf extract. Later was followed by that of 3% leaf extract concentration. Emergence index decreased with increase in leaf extract concentration and significantly minimum EI (1.56) was noted at 5%. Irrigated *E. dracunculoides* resulted in significantly maximum EI (1.76) of chickpea while *E. dracunculoides* from rainfed habitat showed significantly minimum EI (1.67). Interaction study was non-significant.

The data reveal that *E. dracunculoides* leaf extract and habitat significantly affected the mean emergence time (Table 4.3.14) while their interaction was non-significant on chickpea. Significantly minimum MET (5.53) was observed with 1% leaf extract which was statistically alike with those of 2 and 3% leaf extract and MET of chickpea increased with increase in leaf extract concentration of *E. dracunculoides*. Significantly maximum MET

Table 4.3.11 Allelopathic effect of leaf extract of *Euphorbia dracunculoides* from different habitats on emergence percentage of chickpea sown in pots

Concentration	Habitat		Concentration Mean
	Irrigated	Rainfed	
1%	100.00	100.00	100.00
2%	100.00	100.00	100.00
3%	100.00	100.00	100.00
4%	100.00	100.00	100.00
5%	100.00	100.00	100.00
Habitat Mean	100.00	100.00	

LSD= 5%, Concentrations= NS, Habitat= NS, Interaction= NS

Distilled Water (Control) emergence: 100%

Means not sharing a letter in common differ significantly at 5% level of probability.

Table 4.3.12 Allelopathic effect of leaf extract of *Euphorbia dracunculoides* from different habitats on emergence energy of chickpea sown in pots

Concentration	Habitat		Concentration Mean
	Irrigated	Rainfed	
1%	0.00 B	5.00 A	2.50 a
2%	0.00 B	0.00 B	0.00 b
3%	0.00 B	0.00 B	0.00 b
4%	0.00 B	0.00 B	0.00 b
5%	0.00 B	0.00 B	0.00 b
Habitat Mean	0.00	1.00	

LSD= 5%, Concentrations= 1.864, Habitat= NS, Interaction= 2.636

Distilled Water (Control) EE: 25

Means not sharing a letter in common differ significantly at 5% level of probability.

Table 4.3.13 Allelopathic effect of leaf extract of *Euphorbia dracunculoides* from different habitats on emergence index of chickpea sown in pots

Concentration	Habitat		Concentration Mean
	Irrigated	Rainfed	
1%	1.83	1.82	1.83 a
2%	1.83	1.72	1.77 ab
3%	1.78	1.72	1.75 bc
4%	1.79	1.58	1.68 c
5%	1.60	1.52	1.56 d
Habitat Mean	1.76 a	1.67 b	

LSD= 5%, Concentrations= 0.077, Habitat= 0.049, Interaction= NS

Distilled Water (Control) EI: 2.11

Means not sharing a letter in common differ significantly at 5% level of probability.

Table 4.3.14 Allelopathic effect of leaf extract of *Euphorbia dracunculoides* from different habitats on mean emergence time of chickpea sown in pots

Concentration	Habitat		Concentration Mean
	Irrigated	Rainfed	
1%	5.50	5.57	5.53 c
2%	5.52	5.87	5.70 c
3%	5.70	5.90	5.80 bc
4%	5.67	6.45	6.06 b
5%	6.30	6.62	6.46 a
Habitat Mean	5.74 b	6.08 a	

LSD= 5%, Concentrations= 0.289, Habitat= 0.183, Interaction= NS

Distilled Water (Control) MET: 4.92

Means not sharing a letter in common differ significantly at 5% level of probability.

Table 4.3.15 Allelopathic effect of leaf extract of *Euphorbia dracunculoides* from different habitats on time taken to 50% emergence of chickpea sown in pots

Concentration	Habitat		Concentration Mean
	Irrigated	Rainfed	
1%	4.94	5.09	5.01 c
2%	4.89	5.38	5.14 c
3%	4.90	5.23	5.06 c
4%	5.07	5.99	5.53 b
5%	5.66	6.16	5.91 a
Habitat Mean	5.09 b	5.57 a	

LSD= 5%, Concentrations=0.358, Habitat= 0.226, Interaction= NS

Distilled Water (Control) T_{50} = 4.49

Means not sharing a letter in common differ significantly at 5% level of probability.

(6.46) was recorded with 5% leaf extract of *E. dracunculoides* from irrigated habitat on chickpea showed significantly minimum MET (5.74) while rainfed *E. dracunculoides* treated chickpea seeds showed significantly maximum MET (6.08). Leaf extract and habitat of *E. dracunculoides* significantly affected the T_{50} of chickpea while interaction remained non-significant (Table 4.3.15). Significantly minimum T_{50} (5.01) was observed at 1% leaf extract of *E. dracunculoides* which was statistically similar with those of 2 and 3%. Time taken to 50% emregnce increased with increase in concentration and significantly maximum T_{50} (5.91) was recorded at 5% leaf extract. Irrigated *E. dracunculoides* significantly reduced T_{50} (5.09).

Our results are related to those of Mishra *et al*. (2004) who reported that chickpea germination was reduced when high plant residue (4 tons ha^{-1}) of horse purslane was used. Extracts of *Solanum nigrum*, *Chenopodium album* and *Matricaria chamomilla* (10, 20 and 22.5%, respectively) inhibited the seed germination of chickpea. On the other hand, *Glycyrrhiza glabra*, *Sorghum halepense* and *Reseda lutea* extracts stimulated chickpea seed germination at 95, 94, and 93%, respectively, compared to that of control (Kadioglu *et al*., 2005). Gao *et al*. (2009) stated that extract of *Hemistepta lyrata* strongly inhibited the germination of wheat (*Triticum* aestivum), rape (*Brassica campestris*), and radish (*Raphanus sativus*).

4.3.4 Allelopathic effect of leaf extract of *Euphorbia dracunculoides* on shoot length, root length (cm) of chickpea

Effect of leaf extract of *E. dracunculoides* on shoot length and root length of chickpea reduced at higher concentration (Table 4.3.16, 4.3.17). Habitats as well as habitat and concentration interactive effect on shoot and root length was non-significant. Shoot length decreased with increase in leaf extract concentration and minimum shoot length (24.21) was recorded with 5% leaf extract concentration which was statistically at par with those of 3 and 4 % concentration. Significantly minimum root length (22.42) was recorded at 5% concentration.

Table 4.3.16 Allelopathic effect of leaf extract of *Euphorbia dracunculoides* from different habitats on shoot length (cm) of chickpea

Concentration	Habitat		Concentration Mean
	Irrigated	Rainfed	
1%	28.30	27.58	27.94 a
2%	26.87	27.21	27.04 a
3%	25.64	24.31	24.98 b
4%	25.55	24.06	24.81 b
5%	24.36	24.06	24.21 b
Habitat Mean	26.14	25.44	

LSD= 5%, Concentrations= 1.816, Habitat= NS, Interaction= NS

Distilled Water (Control) shoot length: 29.54

Means not sharing a letter in common differ significantly at 5% level of probability.

Table 4.3.17 Allelopathic effect of leaf extract of *Euphorbia dracunculoides* from different habitats on root length (cm) of chickpea

Concentration	Habitat		Concentration Mean
	Irrigated	Rainfed	
1%	28.50	29.30	28.90 a
2%	28.19	27.60	27.89 ab
3%	26.03	26.73	26.38 b
4%	24.20	25.12	24.66 c
5%	22.95	21.90	22.42 d
Habitat Mean	25.97	26.13	

LSD= 5%, Concentrations= 0.289, Habitat= NS, Interaction= NS

Distilled Water (Control) root length: 32.10

Means not sharing a letter in common differ significantly at 5% level of probability.

Our results are supported by those of Mehmood *et al*. (2014) who stated that soil infested by *Alternanthera philoxeriodes* and *A. sessilis* residue inhibited rice shoot and root length by 3-4% as compared to that of residue free soil.

4.3.5 Allelopathic effect of leaf extract of *Euphorbia dracunculoides* on seedling fresh weight and dry weight (g) of chickpea

Data regarding chickpea seedling fresh and dry weight presented in tables 4.3.18 and 4.3.19 show that the main effects as well as interaction effects were significant. Maximum fresh weight (9.76) was observed with 1% leaf extract of rainfed *E. dracunculoides* which was not different statistically with that of 2% of rainfed. Minimum fresh weight (6.88) was noted with 5% leaf extract of *E. dracunculoides* of irrigated habitat which was statistically alike with that of 4%. While maximum dry weight of chickpea seedling was measured at 2% which was not different statistically with that of 1% leaf extract of *E. dracunculoides* of rainfed habitat. Minimum dry weight (0.96) of chickpea was recorded with 5% leaf extract which was statistically similar with those of 3 and 4% leaf extract of *E. dracunculoides* of irrigated habitat.

Increase in concentration resulted in decrease in seedling fresh weight and dry weight of chickpea seedling. That might be due to presence of allelochemicals in leaf extract. The leaves aqueous extract of *Suregada multiflorum* completely inhibited the seedling growth of slender amaranth and leaf extract had a stronger inhibitor effect on seed germination and seedling growth of *C. lacryma-jobi* than any other part (Li and Jin, 2010; Laosinwattana *et al.*, 2010). Our findings are also lined with those of Mehmood *et al*. (2014) who stated that soil infested by *Alternanthera philoxeriodes* and *A. sessilis* residue inhibited rice shoot and root dry weight as compared to that of residue free soil.

Table 4.3.18 Allelopathic effect of leaf extract of *Euphorbia dracunculoides* from different habitats on seedling fresh weight (g) of chickpea

Concentration	Habitat		Concentration Mean
	Irrigated	Rainfed	
1%	8.36 BCD	9.76 A	9.06 a
2%	7.90 CD	9.13 AB	8.51 ab
3%	8.13 CD	8.55 BC	8.34 bc
4%	7.58 DE	7.99 CD	7.78 cd
5%	6.88 E	7.98 CD	7.43 d
Habitat Mean	7.77 b	8.68 a	

LSD= 5%, Concentrations= 0.570, Habitat= 0.361, Interaction= 0.807

Distilled Water (Control) fresh weight: 11.43

Means not sharing a letter in common differ significantly at 5% level of probability.

Table 4.3.19 Allelopathic effect of leaf extract of *Euphorbia dracunculoides* from different habitats on seedling dry weight (g) of chickpea

Concentration	Habitat		Concentration Mean
	Irrigated	Rainfed	
1%	1.22 DE	2.08 A	1.65 a
2%	1.34 DE	2.20 A	1.77 a
3%	1.15 EF	1.67 BC	1.41 b
4%	1.12 EF	1.68 B	1.41 b
5%	0.96 F	1.44 CD	1.21 c
Habitat Mean	1.161 b	1.816 a	

LSD= 5%, Concentrations= 0.163 Habitat= 0.103, Interaction= 0.231

Distilled Water (Control) dry weight: 2.30

Means not sharing a letter in common differ significantly at 5% level of probability.

4.3.6 Allelopathic effect of different plant parts extracts of *Astragalus* spp. on germination traits of chickpea

The significantly maximum germination (100%) of chickpea was achieved with distilled water (Fig. 4.3.1) followed by with that of fruit and root extract. The minimum G percentage (13) was recorded with leaf extract which was statistically similar to those of whole plant and stem extracts. The significantly maximum GE (100) and GI (11.31) was recorded with distilled water (Table 4.3.20). Minimum GE (0) and GI (0.34) was detected with leaf extract which was not different statistically with those of whole plant and stem extracts. Minimum MGT (2.37) and T_{50} (1.54) was recorded with distilled water which was statistically alike with those of fruit and root extracts. The significantly maximum MGT (9.82) and T_{50} (8.83) was recorded with leaf extract.

Frequent supply of water and ample uptake through control (distilled water) treatment made seeds to be germinated more easily than others. There might be some allelochemicals in extract of *Astragalus* spp. which delayed germination. These results are in line with those of Sing and Sangeeta (1991) who reported that aqueous extract of *P. hysterophorus* exhibited allelopathic effects on germination of cereals (rice and wheat) and especially pulses (black gram and chickpea). Overall, aerial part of *P. hysterophorus* showed more inhibitory effect than sub aerial parts. Javaid *et al*. (2006) stated that leaf aqueous extracts (2, 4 and 8%) of *Alstonia scholaris*, *Azadirachta indica* and *Eucalyptus citriodora* reduced final germination (43-100%) of *Phalaris minor*. Generally higher concentration of leaf extract showed significant negative impact on germination of *P. minor* and with increase in *Chenopodium murali* residue in soil (5, 10, 20 and 40 g kg^{-1}), growth associated with *Cicer arietinum* and *Pisum sativum* was gradually declined. With this residue increase, chlorophyll contents also decreased (Batish *et al*., 2007). In another study of Safdar *et al*. (2014) it was revealed that minimum G (30.0%), GI (2.01) and GE (36.3) of maize were observed with leaf extract followed by fruit and whole plant extracts of parthenium growing near the field border.

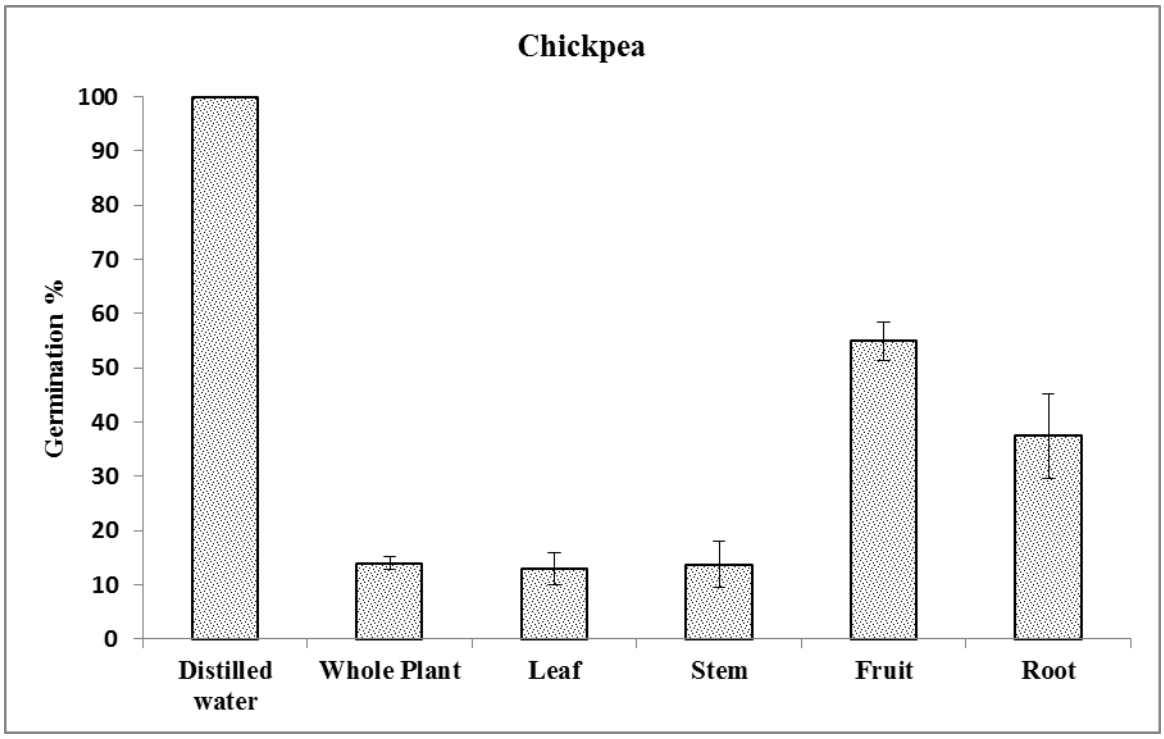

Fig. 4.3.1: Allelopathic effect of different plant parts extract of *Astragalus* spp. on germination percentage of chickpea

Table 4.3.20 Allelopathic effect of different plat parts extracts of *Astragalus* spp. on germination traits of chickpea

Treatments	GE	GI	MGT (d)	T_{50} (d)
Distilled water	100.00 a	11.31 a	2.37 d	1.54 d
Whole Plant	5.00 d	0.74 d	4.79 c	4.06 bc
Leaf	0.00 d	0.34 d	9.82 a	8.83 a
Stem	2.50 d	0.45 d	6.41 b	5.68 b
Fruit	51.2 b	3.89 b	3.04 d	2.50 cd
Root	32.50 c	2.30 c	3.46 d	2.66 cd
LSD	9.135	0.807	1.201	1.854

Means not sharing a letter in common differ significantly at 5% level of probability.

GE: Germination Energy, T_{50} = Time taken to 50% germination, MGT = Mean Germination time, GI = Germination Index, LSD = Least Significance Difference

4.3.7 Allelopathic effect of leaf extracts of *Astragalus* spp. on germination traits of chickpea

Maximum germination (100%) was recorded with distilled water which was statistically similar to those of 1, 2 and 3% *Astragalus* spp. leaf extract followed by that of 4 % (Fig. 4.3.2). Significantly minimum germination (13%) was occurred at 5% leaf extract. Significantly maximum GE (100) and GI (11.31) was recorded with distilled water (Table (4.3.21). Germination energy and GI of chickpea decreased with increase in leaf extract concentration. Significantly minimum GE (0) and GI (0.34) was recorded at highest leaf extract concentration (5%). Significantly minimum MGT (2.37) was recorded with distilled water. Mean germination time increased with increase in leaf extract concentration and significantly maximum MGT (9.82) was occurred at 5% leaf extract. Minimum time taken to 50% germination (1.54) of chickpea was achieved with distilled water which was not different statistically with that of 1% leaf extract. Time taken to 50% germination increased with increased in leaf extract concentration. Maximum T_{50} (8.83) was recorded at 5% leaf extract which was statistically similar with that of 4%.

Less water availability and uptake from extracts lead to less and delayed germination in extract treated plots. Probably there might be phenolics in extracts which inhibit or delayed the final germination. Our results are supported by those of Mishera *et al*. (2004) who found out that chickpea germination was reduced when high plant residue (4 tons ha^{-1}) of horse purslane was used. Extracts of *Solanum nigrum*, *Chenopodium album* and *Matricaria chamomilla* (10, 20 and 22.5%, respectively) inhibited the seed germination of chickpea. Mehmood *et al*. (2014) also concluded that aqueous leaf extract of *Alternanthera philoxeriodes* and *A. sessilis* inhibited rice seed germination (9-100 and 4-49%, respectively) with increase in concentration. On the other hand, *Glycyrrhiza glabra*, *Sorghum halepense* and *Reseda lutea* extracts stimulated chickpea seed germination at 95, 94, and 93%, respectively, compared to the control (Kadioglu *et al*., 2005). Aqueous extracts of plants parts (leaf, stem and root) of *Mikania micranthai* differed in their effects and effect on *C. lacryma-jobi* was concentration dependent. Leaf extract had a stronger inhibitory effect on seed germination and seedling growth of *C. lacryma-jobi* than any other (Li and Jin, 2010).

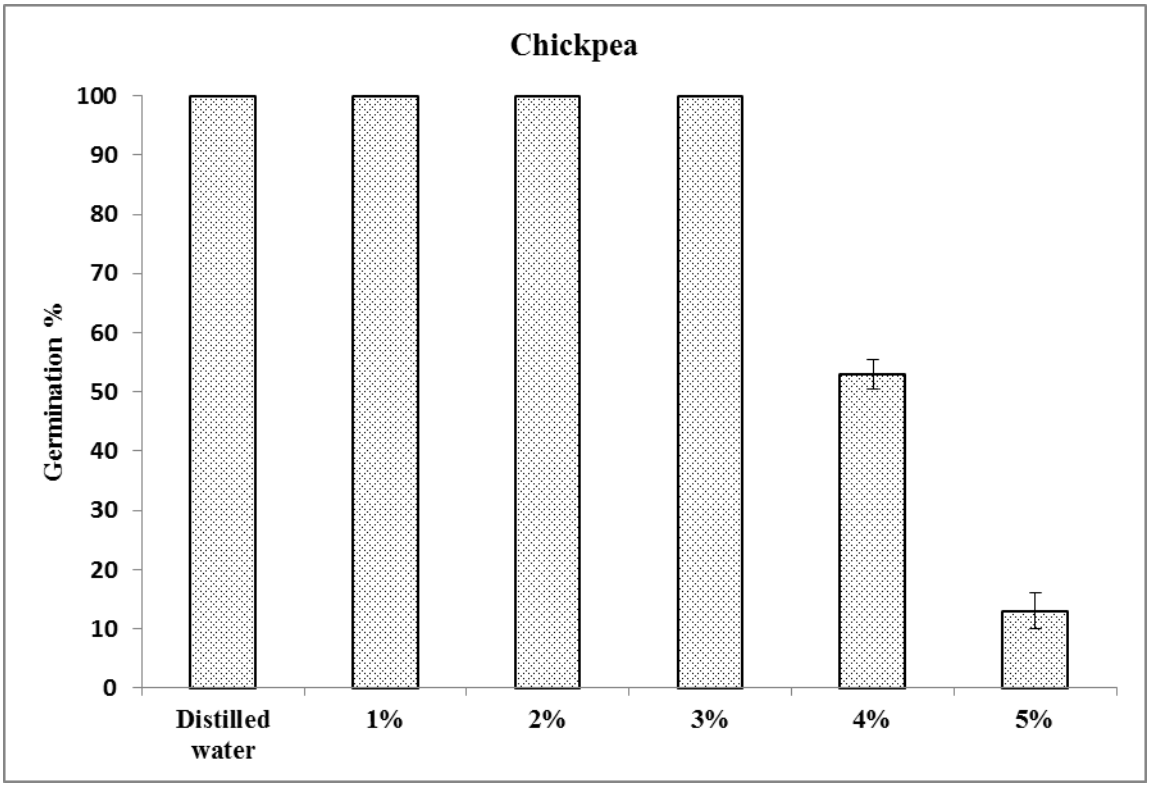

Fig. 4.3.2 Allelopathic effect of leaf extract of *Astragalus* spp. on germination of chickpea

Table 4.3.21 Allelopathic effect of leaf extracts of *Astragalus* spp. on germination traits of chickpea

Treatments	GE	GI	MGT (d)	T_{50} (d)
Distilled water	100.00 a	11.31 a	2.37 e	1.54 c
1%	88.00 b	7.75 b	3.49 d	2.62 bc
2%	83.00 b	6.90 c	3.90 cd	3.31 b
3%	52.00 c	5.74 d	4.59 c	3.94 b
4%	6.00 d	1.89 e	8.57 b	8.60 a
5%	0.00 e	0.34 f	9.82 a	8.83 a
LSD	5.193	0.560	1.072	1.715

Means not sharing a letter in common differ significantly at 5% level of probability.

GE: Germination Energy, T_{50} = Time taken to 50% germination, MGT = Mean Germination time, GI = Germination Index, LSD = Least Significance Difference

4.3.8 Effect of leaf extracts of *Astragalus* spp. on emergence of chickpea sown in pots

Leaf extract of *Astragalus* spp. had non-significant effects on seed emergence of chickpea when sown in pots (Fig. 4.3.3). The significantly maximum emergence energy (EE) (55) and EI (2.26) was recorded at control treatment and with increase in concentration of leaf extract there was decrease in EE and EI (Table 4.3.22). Minimum EE (0) and significantly minimum EI (1.68) was observed at highest concentration level. Significantly minimum MET (4.50) and T_{50} (3.91) was found at control treatment and increased with increase in concentration. Significantly maximum MET (6.00) and T_{50} (5.48) were observed at highest concentrations of leaf extract. Water availability in extracts might be very low due to more number of allelochemicals which restricted the uptake of water and delay in germination occurred. Gao *et al*. (2009) stated that extract of *Hemistepta lyrata* strongly inhibited the germination of wheat (*Triticum* aestivum), rape (*Brassica campestris*), and radish (*Raphanus sativus*).

4.3.9 Allelopathic effect of leaf extracts of *Astragalus* spp. on chickpea shoot length (cm), root length (cm), fresh weight and seedling dry weight (g)

Leaf extract of *Astragalus* spp. significantly reduced the shoot length, root length, fresh weight and dry weight of chickpea seedling (Table 4.3.23). Minimum shoot length (23.93), root length (17.90), fresh weight (6.29) and dry weight (1.12) was recorded with 5% leaf extract of *Astragalus* spp.

Increased leaf extract concentration resulted in decreased fresh weight and dry weight of chickpea seedling. That might be due to presence of allelochemicals in leaf extract. The leaves aqueous extract of *Suregada multiflorum* completely inhibited the seedling growth of slender amaranth and leaf extract had a stronger inhibitor effect on seedling growth of *C. lacryma-jobi* than any other plant part (Li and Jin, 2010; Laosinwattana *et al*. 2010). Similar results were reported by Mubeen *et al*. (2011) who found that leaf extract of *Trianthema portulacastrum* inhibited maximum reduction on shoot and root length of rice seedling whereas minimum shoot and root dry weight was occurred as a result of interactive effect of different weeds and their water extracts.

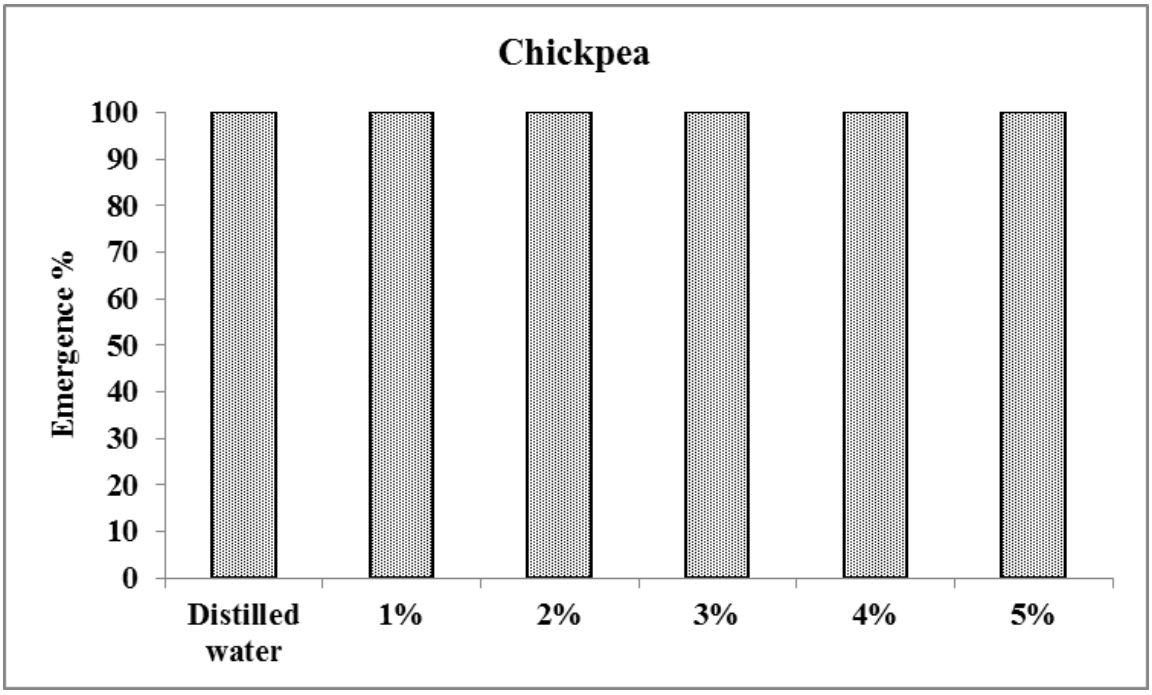

Fig. 4.3.3 Allelopathic effect of leaf extracts of *Astragalus* spp. on emergence of chickpea

Table 4.3.22 Allelopathic effect of leaf extracts of *Astragalus* spp. on emergence of chickpea

Treatments	EE	EI	MET (d)	T_{50} (d)
Distilled water	55.00 a	2.26 a	4.50 e	3.91 d
1%	17.50 b	2.05 b	4.92 d	4.45 c
2%	12.50 bc	2.02 bc	5.00 d	4.51 c
3%	10.00 bc	1.93 c	5.25 c	4.66 bc
4%	5.00 cd	1.82 d	5.60 b	4.97 b
5%	0.00 d	1.68 e	6.00 a	5.48 a
LSD	8.211	0.104	0.304	0.336

Means not sharing a letter in common differ significantly at 5% level of probability.

Table 4.3.23 Allelopathic effect of leaf extract of *Astragalus* spp. on shoot length, root length, fresh weight and dry weight of chickpea seedling

Treatments (%)	Shoot length (cm)	Root length (cm)	Seedling fresh weight (g)	Seedling dry weight (g)
1	26.99 a	24.12 ab	8.93 ab	1.76 a
2	26.46 ab	24.63 a	9.03 a	1.73 a
3	25.63 abc	21.73 b	7.71 bc	1.39 ab
4	24.23 bc	18.26 c	6.65 cd	1.15 b
5	23.93 c	17.90 c	6.29 d	1.12 b
LSD	2.281	2.789	1.239	0.465

Means not sharing a letter in common differ significantly at 5% level of probability.

Distilled Water (Control) shoot length: 29.54, Distilled Water (Control) root length: 32.10

Distilled Water (Control) fresh weight: 11.43, Distilled Water (Control) dry weight: 2.30

Table 4.3.24 Phytotoxins in aqueous *Euphorbia dracunculoides and Astragalus* spp. extracts.

Phenolics compounds	*E. dracunculoides* (Leaf)		*E. dracunculoides* (Whole plant)		*Astragalus* spp. (parts)				
	Irrigated	Rainfed	Irrigated	Rainfed	Leaf	stem	Fruit	Root	Whole plant
Chromatotropic	√		√						
Chlorogenic	√	√	√	√					
P-coumeric	√	√		√	√			√	
Ferrulic	√		√		√				√
Galic acid	√	√	√	√					
Caffeic acid		√		√	√				√
Hydroxy		√		√	√				
Methoxy bnzoic acid		√			√				
M-Coumeric acid		√						√	√
Syringic acid					√	√	√	√	√
Vanillic acid							√		

Table 4.3.25 Total amount (ug g^{-1}) of water soluble phenolics in extract of *E. dracunculoides and Astragalus* spp.

Plant Parts	*E. dracunculoides* (Iggigated)	*E. dracunculoides* (Rainfed)	*Astragalus* spp.
Whole plant	**304**	**545**	**355**
Leaves	**241**	**464**	**378**
Fruit	**--**	**--**	**137**
Stem	**--**	**--**	**336**
Roots	**--**	**--**	**207**

4.4 Field experiment: 1

Study on competition of *Euphorbia dracunculoides* and *Astragalus* spp. with chickpea.

4.4.1 Effect of weed competition periods on density (m^{-2}) of *Euphorbia dracunculoides*

Effect of weed-crop competition periods on density of *E. dracunculoides* is presented in Table 4.4.1. The year effect was significant. Weed density increased with increase in weed competition period from 45 DAS to full season. Maximum *E. dracunculoides* plants were counted in full season followed by 105 DAS during both the years of study. Significantly minimum weed density was recorded in plots where weed-crop competition was for 45 DAS during the both years of study. Linear and quadratic trend were significant while cubic was non-significant during both the years of study.

Increased weed density of *E. dracunculoides* with increased infestation duration was due to prolonged period as *E. dracunculoides* emerged in different flushes. The effect of different weed crop durations on density of *E. dracunculoides* was more distinct where *E. dracunculoides* was allowed to compete with crop for a longer period of time.

4.4.2 Effect of weed competition periods on fresh weight (g m^{-2}) of *Euphorbia dracunculoides*

Effect of weed-crop competition on the fresh weight of *E. dracunculoides* in chickpea is presented in table 4.4.2. The year effect was significant. Data revealed that with increase in weed-crop competition there was a gradual increase in fresh weight of *E. dracunculoides*. Full season weed-crop competition resulted in maximum fresh weight (1206.90 g m^{-2}) first year which was statistically similar with those of 105 and 90 DAS followed by 75 DAS. In second year of study, maximum fresh weight (1166.50 g m^{-2}) was recorded in full season weed crop competition period which was statistically at par with that of 105 DAS. Competition period of 45 DAS gave significantly minimum fresh weight during both the years of study. Linear and quadratic trend was significant, whereas, cubic was non-significant during both the years of study.

Table 4.4.1 Effect of weed competition periods on density (m^{-2}) of *Euphorbia dracunculoides*

Competition periods (days)	**2011-12**	**2012-13**
Control	--	--
45	45.41 e	42.25 f
60	55.50 d	53.25 e
75	73.58 c	68.91 d
90	77.83 b	74.74 c
105	83.08 a	79.50 b
Harvest	87.00 a	84.08 a
LSD	4.164	3.675
Year Effect	73.27 a	69.34 b
LSD	1.728	
Trend comparison		
Linear	**	**
Quadratic	**	**
Cubic	NS	NS

Means not sharing same letter in a column were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
NS=non-significant

Table 4.4.2 Effect of weed competition periods on fresh weight (g m^{-2}) of *Euphorbia dracunculoides*

Competition periods (days)	**2011-12**	**2012-13**
Control	--	--
45	876.40 c	813.70 e
60	944.10 c	903.40 d
75	1113.70 b	1041.80 c
90	1173.60 ab	1127.00 b
105	1181.60 ab	1130.40 ab
Harvest	1206.90 a	1166.50 a
LSD	89.077	37.667
Year Effect	1127.20 a	1103.10 b
LSD	18.712	
Trend comparison		
Linear	**	**
Quadratic	**	**
Cubic	NS	NS

Means not sharing same letter in a column were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
NS=non-significant

Increased fesh weight of *E. dracunculoides* could be due to increased weed density. Akhtar *et al.* (2000) also found that with the increase in weed-crop competition duration, weed biomass also increased.

4.4.3 Effect of weed competition periods on dry weight (g m^{-2}) of *Euphorbia dracunculoides*

The data regarding dry weight of *E. dracunculoides* is presented in table 4.4.3. The year effect was significant. There was a decrease in dry weight with decrease in weed-crop competition period. The data showed that maximum dry weight of *E. dracunculoides* (409.34, 402.69 g m^{-2}) was recoded where weeds were allowed to grow for whole the season which was statistically similar to that of 105 which was followed by 90 DAS during both the years of study. The significantly minimum dry weight was detected in the plots where weed-crop competition was minimum (45 DAS) during both the years of study. Trend comparison for different weed-crop competition showed that linear and quadratic trend was significant whereas, cubic was non-significant during both the years of study.

Increase in dry weight of *E. dracunculoides* with increase in weed-crop competition period was due to more fresh weight of *E. dracunculoides*. Our results are supported by those of Naeem *et al.* (2000) who stated linear increase in weed dry weight with increase in weed crop competition period in mungbean.

4.4.4 Effect of weed competition periods on NPK contents (%) of *Euphorbia dracunculoides*

The data presented in the table 4.4.4, 4.4.5 and 4.4.6 depicted the effect of weed-crop competition periods on NPK contents of *E. dracunculoides*. The year effect for NPK was significant. During both the years of study, significant differences in NPK contents were observed. The significantly maximum NPK contents in *E. dracunculoides* were observed in plots where *E. dracunculoides* plants were allowed to compete with the crop for 45 DAS during both the years of study.

Table 4.4.3 Effect of weed competition periods on dry weight (g m^{-2}) of *Euphorbia dracunculoides*

Competition periods (days)	**2011-12**	**2012-13**
Control	--	--
45	273.03 e	255.31 e
60	303.28 d	290.24 d
75	356.29 c	346.02 c
90	377.13 b	381.54 b
105	401.33 a	388.35 ab
Harvest	409.34 a	402.69 a
LSD	16.412	15.472
Year Effect	355.33 a	346.26 b
LSD	6.433	
Trend comparison		
Linear	**	**
Quadratic	*	**
Cubic	NS	NS

Means not sharing same letter in a column were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
NS=non-significant

Table 4.4.4 Effect of weed competition periods on N contents (%) of *Euphorbia dracunculoides*

Competition periods (days)	2011-12	2012-13
Control	--	--
45	1.28 a	1.31 a
60	1.20 b	1.23 b
75	1.04 c	1.08 c
90	1.00 cd	1.05 cd
105	0.98 de	1.02 d
Harvest	0.94 e	0.97 e
LSD	0.052	0.040
Year Effect	1.07 b	1.11 a
LSD	0.018	
Trend comparison		
Linear	**	**
Quadratic	*	*
Cubic	NS	NS

Means not sharing same letter in a column were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
NS=non-significant

Table 4.4.5 Effect of weed competition periods on P contents (%) of *Euphorbia dracunculoides*

Competition periods (days)	2011-12	2012-13
Control	--	--
45	0.29 a	0.31 a
60	0.27 ab	0.28 ab
75	0.25 bc	0.27 b
90	0.24 c	0.26 bc
105	0.21 cd	0.23 cd
Harvest	0.19 d	0.22 d
LSD	0.028	0.032
Year Effect	0.24 b	0.26 a
LSD	0.012	
Trend comparison		
Linear	**	**
Quadratic	NS	NS
*Cubic	NS	NS

Means not sharing same letter in a column were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
NS=non-significant

Table 4.4.6 Effect of weed competition periods on K contents (%) of *Euphorbia dracunculoides*

Competition periods (days)	**2011-12**	**2012-13**
Control	--	--
45	1.10 a	1.12 a
60	1.06 a	1.08 ab
75	1.01 b	1.06 bc
90	0.97 cd	1.02 c
105	0.94 de	0.97d
Harvest	0.91 e	0.95 d
LSD	0.038	0.049
Year Effect	1.00 b	1.03 a
LSD	0.016	
Trend comparison		
Linear	**	
Quadratic	NS	
Cubic	**	

Means not sharing same letter in a column were significantly different at 5% probability level.
**indicate significance at $p \leq 0.01$ level of probability.
NS=non-significant

There was a linear decrease in NPK contents of *E. dracunculoides* with increase in *E. dracunculoides* competition periods from 45 DAS to full season. The significantly minimum NPK contents of *E. dracunculoides* were recorded where *E. dracunculoides* plants were allowed to grow for whole the season during both the years of study. In trend comparison of different weed-crop competition duration for N, linear and quadratic was significant and cubic was non-significant during both the years of study but for P; linear was significant whereas quadratic and cubic was non-significant during both the years of study. In case of K, linear and cubic was significant while quadratic was non-significant.

Weeds are generally luxury feeders for NPK. High NPK contents of *E. dracunculoides* in treatment where it was allowed to compete with crop for short time was due to less number of weeds which had maximum choice to uptake them. The linear decrease in the NPK contents with the enhancement of *E. dracunculoides* competition periods may possibly owing to more number of weeds for same amount of nutrients and environmental resources to be used by *E. dracunculoides.*

4.4.5 Effect of weed competition periods on NPK uptake (kg ha^{-1}) by *Euphorbia dracunculoides*

All nutrients uptake increased with increase in competition period up to 90 DAS except P (Table 4.4.7, 4.4.8 and 4.4.9). The year effect for N and K was non-significant while for P it was significant. Maximum N and K uptake was recorded where weed competed with crop for 105 and 90 DAS, respectively. Minimum N and K uptake was detected at 45 DAS. Whereas, the maximum P uptake was occurred at 90 DAS which was statistically similar with those of 75, 105 DAS and full season during both the years. In trend comparisons of different weed-crop competition periods, linear and quadratic was significant while cubic was non-significant during both the years of study.

These results are supported by the research findings of Anjum *et al*. (2007) and Ikram *et al*. (2012) who reported that N uptake by weeds in cotton crop was more in weedy check. Similarly, Gaikwad and Pawar (2003) also reported that weeds removed 33.53 kg ha^{-1} of N and 15.78 kg ha^{-1} of P in weedy plots in soybean crop.

Table 4.4.7 Effect of weed competition periods on N uptake (kg ha^{-1}) by *Euphorbia dracunculoides*

Competition periods (days)	**Mean**
Control	--
45	34.35 c
60	36.21 b
75	37.58 b
90	39.43 a
105	39.86 a
Harvest	39.32 a
LSD	1.568
Trend comparison	
Linear	**
Quadratic	**
Cubic	NS

Means not sharing same letter in a column were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
NS=non-significant

Table 4.4.8 Effect of weed competition periods on P uptake (kg ha^{-1}) by *Euphorbia dracunculoides*

Competition periods (days)	**2011-12**	**2012-13**
Control	--	--
45	7.98 c	7.91 b
60	8.31 bc	8.25 ab
75	9.45 ab	8.74 ab
90	10.02 a	9.19 a
105	9.13 ab	8.81 ab
Harvest	9.03 abc	8.18 ab
LSD	1.142	1.015
Year Effect	8.98 a	8.51 b
LSD	0.424	
Trend comparison		
Linear	**	**
Quadratic	**	**
Cubic	NS	NS

Means not sharing same letter in a column were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
NS=non-significant

Table 4.4.9 Effect of weed competition periods on K uptake (kg ha^{-1}) by *Euphorbia dracunculoides*

Competition periods (days)	**Mean**
Control	--
45	29.42 d
60	31.98 c
75	36.60 b
90	38.25 a
105	38.09 ab
Harvest	38.15 a
LSD	1.644
Trend comparison	
Linear	**
Quadratic	**
Cubic	NS

Means not sharing same letter in a column were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
NS=non-significant

4.4.6 Effect of weed competition periods on density (m^{-2}) of *Astragalus* spp.

Density of *Astragalus* spp. increased with increased in competition period in both the years (Table 4.4.10). The year effect was significant. Maximum weed density (61.67 m^{-2}, 59.91 m^{-2} in 2011 and 2012, respectively) of *Astragalus* spp. was recorded in weed crop competition period where weeds remained till harvest which was statistically similar with that of 105 DAS during both the years of study. Significantly minimum weedy density (28.25 m^{-2}, 23.33 m^{-2} in 2011 and 2012, respectively) was observed at lowest competition period (45 DAS) in both the years. In trend comparison of different weed-crop competition periods linear and quadratic trend was significant, whereas, cubic trend was non-significant during both the years of study.

Increase in weed density of *Astragalus* spp. with increased competition duration was due to prolonged growth period because *Astragalus* spp. continued to emerge in different flushes throughout the growing season.

4.4.7 Effect of weed competition periods on fresh weight (g m^{-2}) of *Astragalus* spp.

Effect of weed-crop competition on the fresh weight of *Astragalus* spp. in chickpea is presented in table 4.4.11. The year effect was significant. Data revealed that with increase in weed-crop competition there was a gradual increase in fresh weight of *Astragalus* spp. and full season weed-crop competition resulted in maximum fresh weight (936.68 g m^{-2}, 824.75 g m^{-2} in 2011 and 2012, respectively) which was statistically similar with those of 105 DAS during both the years of study. Competition period of 45 DAS resulted in significantly minimum fresh weight during both the years of study. Linear and quadratic trend was significant, whereas, cubic was non-significant during both the years of study.

An increase in fresh weight of *Astragalus* spp. with increase in weed crop competition period was due to more weed population. Akhtar *et al.* (2000) also found that with the increase in weed-crop competition duration, weed biomass also increased.

Table 4.4.10 Effect of weed competition periods on density (m^{-2}) of *Astragalus* spp.

Competition periods (days)	**2011-12**	**2012-13**
Control	--	--
45	28.25 e	23.33 e
60	35.00 d	32.33 d
75	44.16 c	41.58 c
90	55.83 b	49.99 b
105	59.75 a	57.00 a
Harvest	61.67 a	59.91 a
LSD	3.892	4.566
Year Effect	47.44 a	44.02 b
LSD	1.580	
Trend comparison		
Linear	**	**
Quadratic	**	**
Cubic	NS	NS

Means not sharing same letter in a column were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
NS= non-significant

Table 4.4.11 Effect of weed competition periods on fresh weight (g m^{-2}) of *Astragalus* spp.

Competition periods (days)	**2011-12**	**2012-13**
Control	--	--
45	508.64 e	431.31 e
60	599.17 d	571.42 d
75	741.86 c	709.88 c
90	883.63 b	764.56 b
105	920.02 ab	811.38 ab
Harvest	936.68 a	824.75 a
LSD	48.275	50.334
Year Effect	765.00 a	685.55 b
LSD	18.425	
Trend comparison		
Linear	**	**
Quadratic	**	**
Cubic	NS	NS

Means not sharing same letter in a column were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
NS= non-significant

4.4.8 Effect of weed competition periods on dry weight (g m^{-2}) of *Astragalus* spp.

The data regarding dry weight of *Astragalus* spp. is presented in table 4.4.12. The year effect was significant. There was an increase in dry weight with increase in weed-crop competition period. The data showed that maximum dry weight (293.42 g m^{-2}, 258.35 g m^{-2} in 2011 and 2012, respectively) of *Astragalus* spp. was recoded where weeds were allowed to grow for whole the season which was statistically similar to that of 105. Later was followed by 90 days of competition during both the years of study. The significantly minimum dry weight was detected in the plots where weed-crop competition was minimum (45 DAS) during both the years of study. Trend comparison for different weed-crop competition showed that linear and quadratic trend was significant whereas, cubic was non-significant during both the years of study.

Increase in dry weight with an increase in weed-crop competition period might be due to more fresh weight of *Astragalus* spp..

4.4.9 Effect of weed competition periods on NPK contents (%) by *Astragalus* spp.

Data presented in table 4.4.13, 4.4.14 and 4.4.15 indicate the effect of different weed-crop competition periods on the NPK contents of *Astragalus* spp. The year effect regarding NPK contents was significant. Significant differences in NPK contents of *Astragalus* spp. were observed during both the study years. The significantly maximum NPK contents in *Astragalus* spp. were observed in plots where *Astragalus* spp. plants were allowed to compete with the crop for 45 DAS during both the years of study. There was a linear decrease in NPK contents of *Astragalus* spp. with increase in *Astragalus* spp. competition periods from 45 DAS to full season. The significantly minimum NPK contents of *Astragalus* spp. were recorded where *Astragalus* spp. plants were allowed to grow for whole the season during both the years of study. In trend comparison of different weed-crop duration for NP, linear and quadratic were significant and cubic was non-significant during both the years of study. Whereas for K, linear was significant and quadratic and cubic were non-significant during both the years of study.

Table 4.4.12 Effect of weed competition periods on dry weight (gm^{-2}) of *Astragalus* spp.

Competition periods (days)	**2011-12**	**2012-13**
Control	--	--
45	156.05 e	131.63 e
60	184.79 d	175.84 d
75	229.68 c	219.46 c
90	275.93 b	237.81 b
105	287.98 ab	253.77 ab
Harvest	293.42 a	258.35 a
LSD	15.896	16.240
Year Effect	212.31 a	237.98 b
LSD	5.999	
Trend comparison		
Linear	**	**
Quadratic	**	**
Cubic*	NS	NS

Means not sharing same letter in a column were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
NS= non-significant

Table 4.4.13 Effect of weed competition periods on N contents (%) of *Astragalus* spp.

Competition periods (days)	**2011-12**	**2012-13**
Control	--	--
45	1.62 a	1.68 a
60	1.50 b	1.59 b
75	1.45 c	1.50 c
90	1.42 c	1.41 d
105	1.35 d	1.36 e
Harvest	1.31 d	1.33 f
LSD	0.047	0.029
Year Effect	1.44 b	1.48 a
LSD	0.017	
Trend comparison		
Linear	**	**
Quadratic	**	**
Cubic	NS	NS

Means not sharing same letter in a column were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
NS= non-significant

Table 4.4.14 Effect of weed competition periods on P contents (%) of *Astragalus* spp.

Competition periods (days)	**2011-12**	**2012-13**
Control	--	--
45	0.36 a	0.39 a
60	0.34 a	0.36 ab
75	0.29 b	0.32 bc
90	0.27 bc	0.30 cd
105	0.24 c	0.28 de
Harvest	0.24 c	0.25 e
LSD	0.037	0.038
Year Effect	0.29 b	0.32 a
LSD	0.014	
Trend comparison		
Linear	**	**
Quadratic	*	*
Cubic	NS	NS

Means not sharing same letter in a column were significantly different at 5% probability level.
* and ** indicate significance at $p \leq 0.05$ and at $p \leq 0.01$ level of probability, respectively.
NS= non-significant

Table 4.4.15 Effect of weed competition periods on K contents (%) of *Astragalus* spp.

Competition periods (days)	**2011-12**	**2012-13**
Control	--	--
45	1.26 a	1.28 a
60	1.22 a	1.25 ab
75	1.21 ab	1.22 bc
90	1.16 bc	1.19 cd
105	1.12 cd	1.15 de
Harvest	1.11 d	1.13 e
LSD	0.052	0.047
Year Effect	1.18 b	1.20 a
LSD	0.019	
Trend comparison		
Linear	**	**
Quadratic	NS	NS
Cubic	NS	NS

Means not sharing same letter in a column were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
NS= non-significant

Initially weeds were lessened in numbers when allowed to compete for short duration and enjoyed maximum NPK contents. Increase in weed density with increase in weed-crop competition periods decreased the NPK contents because more weeds shared the same NPK resources.

4.4.10 Effect of weed competition periods on NPK uptake (kg ha^{-1}) by *Astragalus* spp.

The data regarding NP and K uptake is presented in table 4.4.16, 4.4.17 and 4.4.18. For nitrogen the year effect was significant. Nitrogen uptake increased up to 90 DAS in first year and 105 DAS in second year after these periods of competition the increase was static and did not increase significantly. The year effect for P was non-significant. Maximum P uptake (7.14 kg ha^{-1}) was observed at 105 DAS which was not different statistically with those of 75, 90 DAS and full season competition. Minimum P uptake (5.43 kg ha^{-1}) was recorded at 45 DAS. The year effect for K was significant. Maximum K uptake (32.63, 29.38 kg ha^{-1} in 2011 and 2012, respectively) was observed where weeds remained in competition for whole season during both the years of study. These results were statistically similar with those of 90 and 105 DAS during both the years of study and year effect was significant. In trend comparison for NP and K, the linear was significant while quadratic and cubic was non-significant during both the years of study.

Nutrient uptake by *Astragalus* spp. increased with increase in weed crop competition periods due to more weed density and biomass.

4.4.11 Effect of weed competition periods on total weed density (m^{-2}) of *Euphorbia dracunculoides* and *Astragalus* spp.

Total weed density of *E. dracunculoides* and *Astragalus* spp. increased with increased in competition period during both years of study (Table 4.4.19). The year effect was significant. Maximum weed density (153.67 m^{-2}) was recorded at harvest stage which was statistically similar with that of 105 DAS. Significantly minimum weed density (73.67 m^{-2}) was observed at 45 DAS.

Table 4.4.16 Effect of weed competition periods on N uptake (kg ha^{-1}) by *Astragalus* spp.

Competition periods (days)	**2011-12**	**2012-13**
Control	--	--
45	25.31 d	22.12 c
60	27.86 c	27.98 b
75	33.36 b	33.01 a
90	39.18 a	33.64 a
105	39.07 a	34.64 a
Harvest	38.66 a	34.48 a
LSD	2.419	2.660
Year Effect	33.90 a	30.98 b
LSD	0.979	
Trend comparison		
Linear	**	**
Quadratic	NS	NS
Cubic	NS	NS

Means not sharing same letter in a column were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
NS= non-significant

Table 4.4.17 Effect of weed competition periods on P uptake (kg ha^{-1}) by *Astragalus* spp.

Competition periods (days)	**Mean**
Control	--
45	5.43 c
60	6.31 b
75	6.93 a
90	6.32 ab
105	7.14 a
Harvest	6.78 ab
LSD	0.625
Trend comparison	
Linear	**
Quadratic	NS
Cubic	NS

Means not sharing same letter in a column were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
NS= non-significant

Table 4.4.18 Effect of weed competition periods on K uptake (kg ha^{-1}) by *Astragalus* spp.

Competition periods (days)	**2011-12**	**2012-13**
Control	--	--
45	19.75 d	16.88 d
60	22.64 c	21.96 c
75	27.91 b	26.78 b
90	32.14 a	28.29 ab
105	32.18 a	29.31 a
Harvest	32.63 a	29.38 a
LSD	2.331	2.115
Year Effect	27.87 a	25.43 b
LSD	0.843	
Trend comparison		
Linear	**	**
Quadratic	NS	NS
Cubic	NS	NS

Means not sharing same letter in a column were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
NS= non-significant

Table 4.4.19 Effect of weed competition periods on total weed density (m^{-2}) of *Euphorbia dracunculoides* and *Astragalus* spp.

Competition periods (days)	**2011-12**	**2012-13**
Control	--	--
45	73.67 e	65.59 f
60	92.75 d	85.59 e
75	119.33 c	110.50 d
90	136.83 b	128.41 c
105	148.08 a	141.00 b
Harvest	153.67 a	149.17 a
LSD	6.116	7.720
Year Effect	593.31 a	559.07 b
LSD	9.528	
Trend comparison		
Linear	**	**
Quadratic	**	**
Cubic	NS	NS

Means not sharing same letter in a column were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
NS= non-significant

In terms of trend comparison, linear and quadratic was significant and cubic was non-significant during both the years of study.

Increased weed crop competition periods resulted in maximum weed density because weeds availed more chances to emerge and grow.

4.4.12 Effect of weed competition periods on total dry weight (g m^{-2}) of *Euphorbia dracunculoides* and *Astragalus* spp.

As we can see the data regarding dry weight of both weeds increased with increase in competition periods duration in previous tables. In this context, total weed dry weight also increased. The year effect was significant. Maximum total dry weight was observed in plots where weeds remained for full growing season which was statistically similar with that of 105 DAS during both the years of study (Table 4.4.20). Significantly minimum total dry weight was recorded in least weed crop competition duration's treatment (45 DAS). In terms of trend comparison, linear and quadratic were significant and cubic was non-significant during both the years of study.

These results are in line with those of Naeem *et al*. (2000) who also reported linear increase in weed dry weight with increase in weed-crop competition period in mungbean.

4.4.13 Relative competitive index (RCI%)

Data regarding RCI is presented in Table 4.4.21. Relative competitive index is a factor to describe yield loss caused by weed infestation in comparison with weed free plots (Suria *et al*., 2011). Minimum RCI value reflects that the treatment is better than the higher values. In our experiment, RCI increased with increase in competition period and maximum RCI (52.71%) was detected at full season weed crop competition during first year. But in second year RCI value was higher than that of first year because of more weeds during second year of experimentation.

Table 4.4.20 Effect of weed competition periods on total weed dry weight (g m^{-2}) of *Euphorbia dracunculoides* and *Astragalus* spp.

Competition periods (days)	**2011-12**	**2012-13**
Control	--	--
45	429.08 e	386.94 e
60	488.08 d	468.13 d
75	586.84 c	568.85 c
90	655.23 b	623.28 b
105	693.34 a	643.18 ab
Harvest	707.28 a	664.07 a
LSD	22.53	27.971
Year Effect	120.72 a	113.38 b
LSD	2.602	
Trend comparison		
Linear	**	**
Quadratic	**	**
Cubic	NS	NS

Means not sharing same letter in a column were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
NS= non-significant

Table 4.4.21 Relative competitive index (RCI %)

Competition periods (days)	2011-12	2012-13
Control	--	--
45	15.15	13.26
60	22.66	24.51
75	36.31	34.91
90	42.78	44.41
105	51.89	51.30
Harvest	52.71	54.21

4.4.14 Effect of weed competition periods on relative density, dry weight and summed dominance ratio of *Euphorbia dracunculoides* and *Astragalus* spp.

Euphorbia dracunculoides was found to be dominant weed (SDR 54-63% in first year and 55-66% in second weed) over *Astragalus* spp. (Table 4.4.22). Generally *E. dracunculoides* SDR (%) decreased with increase in weed crop competition period while SDR of *Astragalus* spp. increased with an increase in weed crop competition duration.

This kind of study has already been studied by Al Mamun *et al*. (2013) in mix weeds of direct seeded rice.

Table 4.4.22 Effect of weed competition periods on relative density, relative dry weight and summed dominance ratio of *Euphorbia dracunculoides* and *Astragalus* spp.

Competition days	*E. dracunculoides*			*Astragalus* spp.		
	2012					
	RD (%)	**RDW (%)**	**SDR (%)**	**RD (%)**	**RDW (%)**	**SDR (%)**
Weed free	-	-	-	-	-	-
45	61.64	65.59	63.61	38.35	36.37	37.36
60	59.84	61.38	60.61	37.74	37.86	37.80
75	61.66	59.68	60.67	37.01	39.14	38.07
90	56.88	55.80	56.34	40.80	42.11	41.46
105	56.10	52.52	54.31	40.35	41.54	40.94
Full season	56.61	52.71	54.66	40.13	41.49	40.81
	2013					
Control	-	-	-	-	-	-
45	64.42	67.51	65.96	35.57	34.02	34.79
60	62.22	61.24	61.73	37.77	37.56	37.67
75	62.36	57.59	59.98	37.63	38.58	38.10
90	58.20	56.33	57.27	38.93	38.15	38.54
105	56.38	54.17	55.28	40.43	39.46	39.94
Full season	56.37	54.26	55.31	40.16	38.90	39.53

4.4.15 Plant height (cm)

Different weed-crop competition periods significantly affected the plant height of chickpea during both years of experimentation (Table 4.4.23). The year effect was non-significant. Maximum chickpea plant height (70.88 cm) was recorded in weed free plot. Plant height decreased with increase in weed crop competition duration and minimum plant height was recorded at full season competition which was statistically not different with that of 105 DAS competition. In trend comparison, linear was significant while quadratic and cubic was non-significant.

Competition between weeds and crop plants for environmental resources resulted in reduction of chickpea plant height. Our findings are comparable with the findings of Khan and Marwat (2006) and Oad *et al*. (2007). They reported reduction in plant height of wheat with increasing competition period and weeds densities.

4.4.16 Primary branches

Increase in competition duration of *E. dracunculoides* and *Astragalus* spp. with crop significantly decreased the number of primary branches (Table 4.4.24) of chickpea during both experimental years. The year effect was significant. Maximum primary branches of chickpea (4.90 and 5.30) were observed in weed free plots followed by 45 DAS competition (4.30 and 4.60) during the year 2012 and 2013, respectively. Minimum chickpea primary branches (2.75) were recorded in plots where weeds were allowed to compete throughout the growing season which was statistically similar with those of 105 and 90 DAS first year. In trend comparison, linear was significant while quadratic and cubic trends were non-significant.

This reduction in primary branches of chickpea with increase in number of days for competition could be due to the less availability of space for lateral growth of chickpea and higher competition. These findings are in line with results of Mohammadi *et al*. (2005), who reported that prolonged presence of weeds caused reduction in number of branches of chickpea.

Table 4.4.23 Effect of weed competition period on chickpea plant height (cm)

Competition periods (days after sowing) DAS	**Mean**
Zero (Weed free)	70.88 a
45	62.88 b
60	59.30 c
75	56.95 c
90	51.83 d
105	48.43 de
Full season	47.25 e
LSD	3.474
Trend comparison	
Linear	**
Quadratic	NS
Cubic	NS

Means not sharing same letter in a column were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
NS= non-significant.

Table 4.4.24 Effect of weed competition period on chickpea primary branches per plant

Competition periods (days after sowing) DAS	**2011-12**	**2012-13**
Zero (Weed free)	4.90 a	5.30 a
45	4.30 b	4.60 b
60	3.75 bc	4.15 bc
75	3.50 cd	3.90 c
90	3.10 de	3.65 cd
105	2.85 e	3.15 de
Full season	2.75 e	2.90 e
LSD	0.590	0.529
Year Effect	3.95 a	3.59 b
LSD	0.200	
Trend comparison		
Linear	**	**
Quadratic	NS	NS
Cubic	NS	NS

Means not sharing same letter in a column were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
NS= non-significant.

4.4.17 Secondary branches

Different competition periods of *E. dracunculoides* and *Astragalus* spp. significantly affected the number of chickpea secondary branches (Table 4.4.25). Increase in weed competition period, significantly decreased secondary branches of chickpea. Maximum secondary branches of chickpea (20.80 and 23.45) were noted in weed free plots followed by those of 45 DAS. Minimum secondary branches of chickpea were found where weeds were remained for maximum growing season. The year effect was significant. In trend comparison, linear was significant while quadratic and cubic was non-significant.

Reduction in secondary branches of chickpea with prolonged competition period was mainly due to the increased competition for resources. Similar results were reported by Mohammadi *et al*. (2005), who reported that long competition of weeds with crop caused reduction in number of branches of chickpea.

4.4.18 Pods per plant

Number of pods per plant is an important variable contributing considerably to the final crop yield in chickpea. Table 4.4.26 shows the effect of various weed competition periods on the number of pods per plant of chickpea. Number of pods per plant was considerably affected by different weed competition periods during both the years of study. Maximum pods per plant (62.90 and 70.10) were recorded in plots where no weeds were present to compete with chickpea crop. These results were followed by 45 days competition of weeds with crop. There was a gradual decrease in number of pods per plant with increase in duration of competition. Statistically minimum pods per plant (29.45 and 31.35) were observed in plots where weeds were allowed to compete with chickpea crop for full crop season which was not different statistically with that of 105 DAS during both the years of study. The year effect was significant. In trend comparison, linear and cubic were significant while quadratic was non-significant.

Complete control of weed plants in weed free treatment might have facilitated the chickpea crop to take full advantage of growth and development, hence generated more number of pods per plant. While the weed plants competing with chickpea for short time or entire season obtained highest opportunity to make use of environmental reserves to the detriment of chickpea crop. It eventually resulted into a fewer number of pods per plant in

Table 4.4.25 Effect of weed competition period on chickpea secondary branches per plant

Competition periods (days after sowing) DAS	**2011-12**	**2012-13**
Zero (Weed free)	20.80 a	23.45 a
45	17.00 b	19.40 b
60	15.05 bc	17.15 bc
75	13.25 c	15.55 cd
90	10.10 d	13.75 de
105	9.30 d	11.75 e
Full season	9.10 d	11.30 e
LSD	2.086	3.325
Year Effect	13.51 b	16.05 a
LSD	0.991	
Trend comparison		
Linear	**	**
Quadratic	NS	NS
Cubic	NS	NS

Means not sharing same letter in a column were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
NS= non-significant.

Table 4.4.26 Effect of weed competition period on chickpea pods per plant

Competition periods (days after sowing) DAS	**2011-12**	**2012-13**
Zero (Weed free)	62.90 a	70.10 a
45	53.65 b	63.10 b
60	48.55 c	56.20 c
75	40.70 d	46.65 d
90	37.05 d	41.40 e
105	30.05 e	34.05 f
Full season	29.45 e	31.35 f
LSD	4.220	4.129
Year Effect	43.19 b	48.97 a
LSD	1.546	
Trend comparison		
Linear	**	**
Quadratic	NS	NS
Cubic	*	*

Means not sharing same letter in a column were significantly different at 5% probability level.
* and ** indicate significance at $p \leq 0.05$ and at $p \leq 0.01$ level of probability, respectively.
NS= non-significant.

chickpea.

Furthermore, fewer accessibility of space to chickpea plants owing to higher competition period might possibly had became the explanation of lesser number of pods. Our results are supported by the findings of Aslam *et al.* (2007) and Mohmammadi *et al* (2005) who reported less number of pods per plant with weedy check. Our findings are further supported by Hassan and Khan (2007) and Mohammad *et al.* (2011) who reported highest number of pods per plant of chickpea with hand weeding.

4.4.19 Seeds per pod

Effect of different competition periods on number of seeds per pod of chickpea was significant (Table 4.4.27). The year effect was non-significant. It is evident from the data that maximum number of seeds per pod of chickpea (2.48) was recorded in weed free plots followed by those of 45 and 60 DAS competition period. Number of seeds per pod decreased with increase in weed crop competition and minimum number of seeds per pod (1.48) was recorded in plots where weeds remained in field for full growing season which was not different statistically different from those of 105 and 90 DAS. However, removal of weeds after 75 days of competition did not significantly decreased the number of seeds per pod. In trend comparison, linear was significant while cubic and quadratic were non-significant.

Reduction in number of seeds per pod with increasing competition period was mainly due to the increase in competition for nutrients, moisture and other resources between weeds and chickpea crop. More number of seeds per pod of chickpea was reported by Aslam *et al*. (2007) in weeds free plots.

4.4.20 100-Seed weight (g)

Table 4.4.28 showed the effect of different competition periods on 100-seed weight of chickpea. It is evident from the data that increase in competition period significantly reduced the 100-seed weight of chickpea. The year effect was significant. Maximum 100-seed weight of chickpea (23.20) was recorded in weed free plots followed by 45, 60 and 75 DAS. Minimum 100-seed weight of chickpea (16.34) was recorded in plots where weeds were remained for full season in crop which was not different statistically with those of 105 and 90 DAS competition. However removal of weeds after 75 days of competition during

Table 4.4.27 Effect of weed competition period on chickpea seeds per pod

Competition periods (days after sowing) DAS	**Mean**
Zero (Weed free)	2.48 a
45	2.22 b
60	2.02 bc
75	1.80 cd
90	1.62 de
105	1.52 e
Full season	1.48 e
LSD	0.232
Trend comparison	
Linear	**
Quadratic	NS
Cubic	NS

Means not sharing same letter in a column were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
NS= non-significant.

Table 4.4.28 Effect of weed competition period on chickpea 100-seed weight (g)

Competition periods (days after sowing) DAS	**2011-12**	**2012-13**
Zero (Weed free)	23.20 a	22.26 a
45	22.31 b	21.46 a
60	21.61 b	20.34 ab
75	20.06 bc	18.70 bc
90	18.86 cd	17.46 cd
105	17.29 d	16.15 d
Full season	16.34 d	15.71 d
LSD	2.561	2.069
Year Effect	19.95 a	18.87 b
LSD	0.883	
Trend comparison		
Linear	**	**
Quadratic	NS	NS
Cubic	NS	NS

Means not sharing same letter in a column were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
NS= non-significant.

both years of study did not significantly decreased the 100-seed weight of chickpea. In trend comparison, linear was significant while quadratic and cubic trends were non-significant.

Reduction in 100-seed weight of chickpea might be due to the reduction in the availability of light, moisture, space and nutrients which resulted in less production of photosynthates and ultimately their deposition in seeds. Our findings are in line with the findings of Aslam *et al*. (2007) who observed more chickpea 100-seed weight in weed free plots. Our results are also supported by those of Mohammadi *et al*. (2005) who reported that prolonged interface of weeds caused reduction in 100 seed weight which ultimately resulted in low seed yield of chickpea.

4.4.21 Seed yield (kg ha^{-1})

Significant effect of different weed competition periods on seed yield of chickpea was recorded during both experimental years (Table 4.4.29). Increase in weed competition periods considerably decreased the seed yield of chickpea. The year effect was significant. Maximum seed yield of chickpea (2291.40 and 2414.50) was recorded in zero day weed crop competition period followed by that of 45 DAS during both the years of study. Seed yield decreased with increase in competition. Statistically minimum seed yield of chickpea was recorded in plots where weeds were allowed to compete with chickpea crop for full season which was statistically similar with that of 105 DAS competition period, during both the years of study. The yield loss increased 13 to 54% with increase in competition duration. In trend comparison, linear and cubic were significant while quadratic was non-significant.

The decrease in seed yield with increase in competition period was due to decrease in the major components of seed yield like number of pods per plant, number of grains per pod and 100-seed weight. The results further led to the revelation that weed crop competition with extended competition duration had an adverse effect on yield potential of chickpea. Similar results were obtained by Lyon and Wilson (2005) and Mohammadi *et al.* (2005) who stated that full season weed crop competition caused reduction in number of branches, pods per plant and 100 seed weight which ultimately resulted in low yield. He also reported 34 to 66.4% higher chickpea seed yield with weed free plots than weedy check. Seed yield losses were 85% in weed check where weeds were left to grow for whole season as compared to weed free yield in chickpea (Frenda *et al*., 2013).

Table 4.4.29 Effect of weed competition period on chickpea seed yield (kg ha^{-1})

Competition periods (days after sowing) DAS	2011-12	2012-13	Estimation of yield loss (%) 2011-12	Estimation of yield loss (%) 2012-13
Zero (Weed free)	2291.40 a	2414.50 a	--	--
45	1944.30 b	2094.30 b	15.15	13.26
60	1772.10 c	1822.60 c	22.66	24.51
75	1459.50 d	1571.60 d	36.31	34.91
90	1311.10 e	1342.10 e	42.78	44.41
105	1102.50 f	1175.90 ef	51.89	51.30
Full season	1083.50 f	1105.50 f	52.71	54.21
LSD	143.64	214.38		
Year Effect	1566.30 b	1646.60 a		
LSD	68.777			
Trend comparison				
Linear	**	**		
Quadratic	NS	NS		
Cubic	**	**		

Means not sharing same letter in a column were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
NS= non-significant.

4.4.22 Biological yield (kg ha^{-1})

Significant effect of various competition periods on biological yield of chickpea is presented in Table 4.4.30. The year effect was significant. Data showed that maximum biological yield of chickpea (6335.50 during 2011-12 and 6603.20 during 2012-13) was recorded in plots with zero day weed crop competition followed by that of 45 days weed crop competition in first year. Biological yield reduced with increase in competition duration and minimum biological yield of chickpea (3502.10 and 3600.70) was recorded in plots with full season weed crop competition during both the years of study. In trend comparison, linear, quadratic and cubic were significant.

Our findings showed that with increase in competition period, biological yield of chickpea was decreased. This reduction in biological yield of chickpea was mainly due to limited availability of resources like space, moisture, nutrients and light with increasing competition period. More above ground biomass of chickpea was certainly due to more number of primary and secondary branches. Similarly, Abbas *et al.* (2010) noted a reduction in biological yield of wheat with increasing *E. australis* densities.

4.4.23 Harvest index (%)

Harvest index represents the physiological efficacy to translocate assimilates into the economic or seed yield. Different competition periods of weeds with chickpea crop affected the harvest index (Table 4.4.31). The year effect was non-significant. Maximum harvest index of chickpea crop (36.40) was calculated in plots of zero day weed crop competition which was not different statistically from those of 45 and 60 DAS. Minimum harvest index (29.33) was recorded in plots where weeds were allowed to compete with chickpea crop up to 105 days which was statistically similar with those of 75, 90 DAS and full season weed crop competition. In trend comparison, linear was significant while quadratic and cubic were non-significant.

Results of our findings showed that increasing competition period decreased the chickpea harvest index. This might be due to reduction in weed crop competition for available resources. In weed free plots more assimilates were accumulated into seeds due to ample chickpea growth and resulted in higher seed yield. Our findings are comparable with

Table 4.4.30 Effect of weed competition period on chickpea biological yield (kg ha^{-1})

Competition periods (days after sowing) DAS	**2011-12**	**2012-13**
Zero (Weed free)	6335.50 a	6603.20 a
45	5900.40 b	6018.90 b
60	5202.50 c	5404.30 c
75	4702.40 d	4788.00 d
90	4185.40 e	4315.60 e
105	3771.30 f	3928.60 f
Full season	3502.10 g	3609.70 g
LSD	199.40	195.14
Year Effect	4799.90 b	4952.6 a
LSD	72.403	
Trend comparison		
Linear	**	**
Quadratic	**	**
Cubic	**	**

Means not sharing same letter in a column were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability, respectively.

Table 4.4.31 Effect of weed competition period on harvest index (%) of chickpea

Competition periods (days after sowing) DAS	**Mean**
Zero (Weed free)	36.40 a
45	33.87 ab
60	33.92 ab
75	31.92 bc
90	31.18 bc
105	29.33 c
Full season	31.15 bc
LSD	2.938
Trend comparison	
Linear	**
Quadratic	NS
Cubic	NS

Means not sharing same letter in a column were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
NS= non-significant.

those of Abbas *et al*. (2010) who reported negative effect of weeds infestation on harvest index of wheat.

4.4.24 Nitrogen concentration (%)

Weed competition duration had a significant effect on N concentration in chickpea seed. Increase in weeds competition period considerably decreased the N concentration of chickpea seed (Table 4.4.32). The year effect was non-significant. Maximum N contents (3.92) were recorded in plots of zero day weed crop competition which was statistically similar with that of 45 DAS. Later was followed by 60 and 75 DAS. Minimum N concentration in chickpea seed (3.13) was observed in plots where weeds were allowed to compete with chickpea crop for full season which was not different statistically with those of 90 and 105 DAS. In trend comparison, linear was significant while quadratic and cubic were non-significant.

This reduction in N concentration in chickpea seed was mainly due to increased competition of weeds with crop for nutrients with increasing competition period. Our results are supported by (Sing *et al*., 2004a) who stated that full season weed crop competition led to reduced nutrient accumulation in chickpea as compared to weed free treatment.

4.4.25 Phosphorus concentration (%)

Effect of different weed-crop competition periods on the P concentration in chickpea seed was significant during both the years of study (Table 4.4.33). The year effect was significant. Significantly maximum P concentration (0.42) was recorded in plots with zero day weed crop competition which was statistically similar with that of 45 DAS. Later was followed by 60 DAS. Phosphorus concentration decrease with increase in weed crop duration. Minimum P contents in chickpea seeds (0.21) was recorded in plots where weeds were allowed to compete with chickpea for full season which was statistically similar with those of 90 and 105 DAS. Similar trend was observed in second year. In trend comparison, linear was significant while quadratic and cubic were non-significant.

Reduction in P concentration of chickpea seeds was largely due to an increase in competition period of weeds which competed for nutrients uptake with main crop.

Table 4.4.32 Effect of weed competition period on N contents (%) of chickpea seeds

Competition periods (days after sowing) DAS	**Mean**
Zero (Weed free)	3.92 a
45	3.78 ab
60	3.50 bcd
75	3.56 bc
90	3.33 cde
105	3.23 de
Full season	3.13 e
LSD	0.280
Trend comparison	
Linear	**
Quadratic	NS
Cubic	NS

Means not sharing same letter in a column were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
NS= non-significant.

Table 4.4.33 Effect of weed competition period on P contents (%) of chickpea seeds

Competition periods (days after sowing) DAS	**2011-12**	**2012-13**
Zero (Weed free)	0.42 a	0.37 a
45	0.37 ab	0.35 a
60	0.33 bc	0.32 ab
75	0.29 cd	0.27 bc
90	0.26 de	0.22 cd
105	0.22 e	0.20 d
Full season	0.21 e	0.19 d
LSD	0.066	0.067
Year Effect	0.30 a	0.27 b
LSD	0.023	
Trend comparison		
Linear	**	**
Quadratic	NS	NS
Cubic	NS	NS

Means not sharing same letter in a column were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability, respectively.
NS= non-significant.

4.4.26 Potassium concentration (%)

It is evident from the Table 4.4.34 that significant differences were observed for K concentration in chickpea seed in different weed crop competition periods. The year effect was non-significant. Maximum K concentration in chickpea seed (1.43) was observed in plots with zero day weed crop completion which was statistically at par with that of 45 DAS and followed by 60 DAS. Minimum K concentration (1.23) was recorded in plots where weeds were competing for full season with crop. It was which was not different statistically with those of 105 and 90 DAS, followed by 75 DAS. In trend comparison, linear was significant while quadratic and cubic were non-significant.

This reduction in K concentration of chickpea seeds was mainly due to an increase in competition for available K between weeds and chickpea. Our results are supported by Sing *et al*. (2004a) who stated that full season weed crop competition led to reduced nutrient accumulation in chickpea as compared to weed free treatment.

4.4.27 Crude Protein contents (%)

Seed protein is used to evaluate the nutritional and cooking worth of seed and more protein contents in seeds considered of high-quality. Data showed that increasing competition period of weeds with chickpea had significantly decreased protein content of chickpea seed (Table 4.4.35). The year effect was non-significant. Maximum crude protein contents (24.50) in seed were recorded in plots with zero day weed crop competition which was statistically similar with that of 45 DAS competition. Minimum seed crude protein contents (19.56) were observed in plots where weeds were allowed to compete with chickpea for full season which was statistically similar with those of 90 and 105 DAS. In trend comparison, linear was significant while quadratic and cubic were non-significant.

This reduction in crude protein contents in chickpea seed was mainly due to an increase in the competition of weeds for nutrients particularly N. Our results are in contradiction with those of Yadav *et al.* (2007) who stated that different treatments did not cause significant variation in protein content of chickpea seeds.

Table 4.4.34 Effect of weed competition period on K contents (%) of chickpea seeds

Competition periods (days after sowing) DAS	**Mean**
Zero (Weed free)	1.43 a
45	1.38 ab
60	1.35 bc
75	1.30 cd
90	1.27 de
105	1.24 e
Full season	1.23 e
LSD	0.049
Trend comparison	
Linear	**
Quadratic	NS
Cubic	NS

Means not sharing same letter in a column were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
NS= non-significant.

Table 4.4.35 Effect of weed competition period on crude protein (%) of chickpea seeds

Competition periods (days after sowing) DAS	**Mean**
Zero (Weed free)	24.50 a
45	23.63 ab
60	21.87 c
75	22.27 bc
90	20.85 cd
105	19.81 d
Full season	19.56 d
LSD	1.713
Trend comparison	
Linear	**
Quadratic	NS
Cubic	NS

Means not sharing same letter in a column were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
NS= non-significant.

4.5 Field Experiment: 2

Chemical control of *Euphorbia dracunculoides* and *Astragalus* spp. in chickpea by using pre-emergence herbicides

4.5.1 Effect of herbicide application on density of *Euphorbia dracunculoides* at 40, 60 and 80 days after emergence (DAE) and at harvest

The data presented in the Table (4.5.1, 4.5.2, 4.5.3 and 4.5.4) illustrate the effect of herbicides application on the *E. dracunculoides* density at 40, 60, 80 DAE and at harvest. The year effect for 40, 60 and 80 DAE was non-significant while at harvest it was significant. Statistically maximum *E. dracunculoides* density (39.41 m^{-2}) was recorded in weedy check plots at 40 DAE. These results were followed by herbicide application of metribuzin @ 150 g a.i. ha^{-1} (12.16 to 20.59 m^{-2}) at 40, 60, 80 DAE and at harvest. Lowest density of *E. dracunculoides* (0.0 to 7.42 m^{-2}) at 40, 60, 80 DAE and at harvest were recorded in manual hoeing plots during both years of study.

Among different herbicide and their application rates lowest *E. dracunculoides* density (6.04 to 7.37 m^{-2}) was recorded in metribuzin @ 187.5 g a.i. ha^{-1} treated plots at 40 and 60 DAE while at 80 DAE and at harvest pendimethalin + prometryn at 450 + 600 g a.i. ha^{-1} application gave lowest *E. dracunculoides* density (9.75 to 13.09 m^{-2}) during both years of study. Metribuzin application @ 150 g a.i. ha^{-1} resulted in highest *E. dracunculoides* density (12.16 to 20.59 m^{-2}) at 40, 60, 80 DAE and at harvest among herbicides.

Contrast comparison (Weedy check vs all, Weedy check vs Manual Hoeing, Weedy check vs Herbicide and Manual Hoeing vs Herbicide) for *E. dracunculoides* density at 40, 60, 80 DAE and at harvest showed significant effect during both years of experimentation. Contrast comparison of pendimethalin+prometryn vs metribuzin was non-significant at 40, 60 and 80 DAE. While at harvest it was significant during experimental year 2010-11 and non-significant during subsequent year.

Lowest densities of *E. dracunculoides* with pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1} application rate was due to better efficacy of this herbicide against *E. dracunculoides* as compared to 450 + 600 g a.i. ha^{-1} and 300 + 400 g a.i. ha^{-1} application rate of same herbicide. Our findings are supported from the results of Bhalla *et al*. (1998) and Marwat *et al*. (2004) who reported maximum weeds control in chickpea with application of Stomp 330-

Table 4.5.1 Effect of herbicides on density (m^{-2}) of *Euphorbia dracunculoides* at 40 DAE

Treatments	**Mean**
Weedy check	39.41 a
Manual Hoeing	--
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	7.62 c
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	7.50 c
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	10.12 b
Metribuzin @ 187.5 g a.i. ha^{-1}	6.04 c
Metribuzin @ 150 g a.i. ha^{-1}	12.16 b
LSD	2.474
Contrast	
Weedy check vs all	39.41 vs 7.24**
Weedy check vs Manual Hoeing	39.41 vs 0.00**
Weedy check vs Herbicide	39.41 vs 8.68**
Manual Hoeing vs Herbicide	0.00 vs 8.68**
Pendimethalin+prometryn vs metribuzin	8.41 vs 9.10^{NS}

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
DAE indicates days after emergence.
NS =non-significant

Table 4.5.2 Effect of herbicides on density (m^{-2}) of *Euphorbia dracunculoides* at 60 DAE

Treatments	**Mean**
Weedy check	63.45 a
Manual Hoeing	--
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	8.87 de
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	11.24 cd
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	12.87 bc
Metribuzin @ 187.5 g a.i. ha^{-1}	7.37 e
Metribuzin @ 150 g a.i. ha^{-1}	15.04 b
LSD	3.229
Contrast	
Weedy check vs all	63.45 vs 9.23**
Weedy check vs Manual Hoeing	63.45 vs 0.00**
Weedy check vs Herbicides	63.45 vs 11.07**
Manual Hoeing vs Herbicides	0.00 vs 11.07**
Pendimethalin+prometryn vs metribuzin	10.99 vs 11.21^{NS}

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
DAE indicates days after emergence.
NS =non-significant

Table 4.5.3 Effect of herbicides on density (m^{-2}) of *Euphorbia dracunculoides* at 80 DAE

Treatments	**Mean**
Weedy check	86.87 a
Manual Hoeing	3.83 e
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	9.75 d
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	11.62 cd
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	15.21 bc
Metribuzin @ 187.5 g a.i. ha^{-1}	10.83 d
Metribuzin @ 150 g a.i. ha^{-1}	16.87 b
LSD	4.098
Contrast	
Weedy check vs all	86.87 vs 11.35**
Weedy check vs Manual Hoeing	86.87 vs 3.83**
Weedy check vs Herbicides	86.87 vs 12.85**
Manual Hoeing vs Herbicides	3.83 vs 12.85**
Pendimethalin+prometryn vs metribuzin	12.19 vs 13.85^{NS}

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
DAE indicates days after emergence.
NS =non-significant

Table 4.5.4 Effect of herbicides on density (m^{-2}) of *Euphorbia dracunculoides* at harvest

Treatments	**2010-11**	**2011-12**
Weedy check	89.14 a	101.66 a
Manual Hoeing	6.83 e	7.42 e
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	12.50 d	13.09 d
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	17.16 bc	18.00 bc
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	18.00 b	18.59 bc
Metribuzin @ 187.5 g a.i. ha^{-1}	13.33 cd	13.92 cd
Metribuzin @ 150 g a.i. ha^{-1}	19.50 b	20.59 b
LSD	3.860	4.779
Year Effect	25.26 b	27.60 a
LSD	1.526	
Contrast		
Weedy check vs all	89.14 vs 14.55**	95.41 vs 15.10**
Weedy check vs Manual Hoeing	89.14 vs 6.83**	95.41 vs 7.33**
Weedy check vs Herbicides	89.14 vs 16.09**	95.41 vs 16.65**
Manual Hoeing vs Herbicides	6.83 vs 16.309**	7.33 vs 16.65**
Pendimethalin+prometryn vs metribuzin	15.89 vs 16.42*	16.33 vs 17.13^{NS}

Means not sharing same letter were significantly different at 5% probability level.
* and ** indicate significance at $p \leq 0.05$ and at $p \leq 0.01$ level of probability, respectively.
NS =non-significant

EC (pendimethalin). Similarly, Singh *et al*. (2009) recorded lowest weeds population in alachlor treated plots followed by pendimethalin and simazine in maize crop.

4.5.2 Effect of herbicide application on fruits per plant of *Euphorbia dracunculoides*

The data presented in the Table 4.5.5 indicate the effect of different herbicides application on the number of fruits per plant of *E. dracunculoides*. The year effect was significant. Data revealed that maximum number of fruits per plant (272.95 and 258.95 in 2010 and 2011, respectively) of *E. dracunculoides* was recorded with manual hoeing plots during both experimental years and it was statistically similar with that of pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1} during experimental year 2011-12. Lowest number of fruits per plant (91.65 and 83.60 in 2010 and 2011, respectively) of *E. dracunculoides* was recorded in weedy check. Among herbicide applications lowest number of fruits per plant (193.05 and 176.40 in 2010 and 2011, respectively) of *E. dracunculoides* was recorded with metribuzin applied @ 150 g a.i. ha^{-1} while maximum (245.20 and 235.30 in 2010 and 2011, respectively) was counted with pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1} application rate.

All contrasts for numbers of fruits per plant of *E. dracunculoides* were significant during both years of experimentation. Maximum number of fruits per plant of *E. dracunculoides* in manual hoeing plots was due to lowest weeds density which favored the growth of shoots and branches under limited weeds plant.

4.5.3 Effect of herbicide application on seeds per triloculate of *Euphorbia dracunculoides*

The data presented in the Table 4.5.6 indicate the effect of different herbicides application on the seed per triloculate of *E. dracunculoides*. The effects of different herbicide on seeds per triloculate of *E. dracunculoides* were non-significant.

Table 4.5.5 Effect of herbicides on fruits per plant of *Euphorbia dracunculoides* at maturity

Treatments	**2010-11**	**2011-12**
Weedy check	91.65 e	83.60 f
Manual Hoeing	272.95 a	258.95 a
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	256.75 ab	212.45 cd
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	245.20 bc	235.30 b
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	228.45 c	197.40 d
Metribuzin @ 187.5 g a.i. ha^{-1}	231.55 c	219.40 bc
Metribuzin @ 150 g a.i. ha^{-1}	193.05 d	176.40 e
LSD	24.464	18.302
Year Effect	217.09 a	197.64 b
LSD	7.721	
Contrast		
Weedy check vs all	91.65 vs 237.99**	83.60 vs 216.65**
Weedy check vs Manual Hoeing	91.65 vs 272.95**	83.60 vs 258.95**
Weedy check vs Herbicides	91.65 vs 231.00**	83.60 vs 208.19**
Manual Hoeing vs Herbicides	272.95 vs 231.00**	258.95 vs 208.19**
Pendimethalin+prometryn vs metribuzin	243.47 vs 212.30**	215.05 vs 197.90**

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.

Table 4.5.6 Effect of herbicides on seed/triloculate of *Euphorbia dracunculoides* at maturity

Treatments	Mean
Weedy check	3.00
Manual Hoeing	3.00
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	3.00
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	3.00
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	3.00
Metribuzin @ 187.5 g a.i. ha^{-1}	3.00
Metribuzin @ 150 g a.i. ha^{-1}	3.00
LSD	NS

Means not sharing same letter were significantly different at 5% probability level.
NS=non-significant

4.5.4 Effect of herbicides on *Euphorbia dracunculoides* seeds per plant at maturity

Data regarding number of seeds per plant of *E. dracunculoides* is presented in Table 4.5.7. The year effect was significant. It is evident from the data that maximum number of seeds per plant (812.80 and 780.00 in 2010 and 2011, respectively) of *E. dracunculoides* was observed in manual hoeing plots. These results were statistically similar with application of pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1} during the year 2011-12. Minimum number of seeds per plant (273.70 and 251.40 in 2010 and 2011, respectively) of *E. dracunculoides* was observed in weedy check plots. Among herbicide applications lowest number of seeds per plant (579.25 and 530.70 in 2010 and 2011, respectively) of *E. dracunculoides* was recorded with metribuzin @ 150 g a.i. ha^{-1} while maximum (735.60 and 711.40 in 2010 and 2011, respectively) was counted with pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1} application rate.

All contrast comparisons for number of seeds per plant of *E. dracunculoides* were significant during both years of experimentation. Maximum number of seeds per plant of *E. dracunculoides* in manual hoeing plot was due to more number of fruits per plant.

4.5.5 Effect of herbicides on *Euphorbia dracunculoides* seed weight per plant (g) at maturity

Significant effect of different weeds control measurements was recorded on *E. dracunculoides* seed weight per plant (g) at maturity during both years of experimentation (Table 4.5.8). The year effect was significant. Statistically maximum seed weight (3.93 and 3.69 in 2010 and 2011, respectively) per plant of *E. dracunculoides* was recorded in manual hoeing plots which was followed by that of pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1} during 2010-11 and pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1} during year 2011-12. Minimum seed weight (1.26 and 1.10 in 2010 and 2011, respectively) per plant of *E. dracunculoides* was observed in weedy check plots.

Among herbicide applications lowest seed weight per plant (2.70 and 2.47 in 2010 and 2011, respectively) of *E. dracunculoides* was recorded with metribuzin @ 150 g a.i. ha^{-1} application while maximum (3.34 and 3.51 in 2010 and 2011, respectively) was recorded with pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}.

Table 4.5.7 Effect of herbicides on seeds per plant of *Euphorbia dracunculoides* at maturity

Treatments	**2010-11**	**2011-12**
Weedy check	273.70 e	251.40 f
Manual Hoeing	812.80 a	780.00 a
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	763.65 ab	642.10 c
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	735.60 bc	711.40 b
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	686.60 c	590.40 d
Metribuzin @ 187.5 g a.i. ha^{-1}	694.65 c	661.15 c
Metribuzin @ 150 g a.i. ha^{-1}	579.25 d	530.70 e
LSD	61.686	48.347
Year Effect	649.46 a	595.31 b
LSD	19.855	
Contrast		
Weedy check vs all	273.70 vs 12.09**	251.40 vs 652.63**
Weedy check vs Manual Hoeing	273.70 vs 12.80**	251.40 vs 780.00**
Weedy check vs Herbicides	273.70 vs 91.95**	251.40 vs 627.15**
Manual Hoeing vs Herbicides	812.80 vs 91.95**	780.00 vs 627.15**
Pendimethalin+prometryn vs metribuzin	728.62 vs 36.95**	647.97 vs 595.93**

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability, respectively.

Table 4.5.8 Effect of herbicides on seed weight per plant (g) of *Euphorbia dracunculoides* at maturity

Treatments	**2010-11**	**2011-12**
Weedy check	1.16 f	1.26 f
Manual Hoeing	3.69 a	3.93 a
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	2.98 c	3.56 b
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	3.34 b	3.51 bc
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	2.76 d	3.20 d
Metribuzin @ 187.5 g a.i. ha^{-1}	3.09 c	3.26 cd
Metribuzin @ 150 g a.i. ha^{-1}	2.47 e	2.70 e
LSD	0.198	0.266
Year Effect	2.788 b	3.06 a
LSD	0.084	
Contrast		
Weedy check vs all	1.16 vs 3.06**	1.26 vs 3.36**
Weedy check vs Manual Hoeing	1.16 vs 3.69**	1.26 vs 3.93**
Weedy check vs Herbicides	1.16 vs 2.92**	1.26 vs 3.25**
Manual Hoeing vs Herbicides	3.69 vs 2.92**	3.93 vs 3.25**
Pendimethalin+prometryn vs metribuzin	3.03 vs 2.78**	3.42 vs 2.98**

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability, respectively.

All contrast comparisons for seed weight per plant of *E. dracunculoides* were significant during both years of experimentation. Maximum seed weight per plant of *E. dracunculoides* in manual hoeing plot was due to lesser or few number of weed plants in thise plot which grown vigorously and produced more branches and fruits per plant.

4.5.6 Effect of herbicides on *Euphorbia dracunculoides* 1000-seed weight (g)

It was found that different weed control strategies significantly affected the 1000-seed weight of *E. dracunculoides* during both years of experimentation (Table 4.5.9). The year effect was significant. Heavier *E. dracunculoides* seeds (4.84 and 4.74 g in 2010 and 2011, respectively) were observed in manual hoeing plots which were followed by those where weeds were controlled with pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}. Minimum 1000-seed weight (4.59 and 4.55 g in 2010 and 2011, respectively) of *E. dracunculoides* was weighed in weedy check plots. Among herbicide applications maximum 1000-seed weight (4.78 and 4.69 g in 2010 and 2011, respectively) of *E. dracunculoides* was recorded with pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1} while maximum (4.66 g and 4.64 g) were recorded with application of pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}.

All contrast comparisons for 1000-seed weight of *E. dracunculoides* were significant during both years of experimentation. Manual hoeing showed significantly more 1000-seed weight of *E. dracunculoides* as compared to weedy check and other herbicide application treatments during both the years of study. This might be due to adequate weed control during the cropping period and fewer numbers of weeds present in this plot, which provided maximum moisture and nutrients for plant growth and hence fruit formation which ultimately led towards heavier seeds of *E. dracunculoides*. Decrease in 1000-seed weight in weedy check plot was due to the presence of more *E. dracunculoides* plants which competed with one another and main crop.

4.5.7 Effect of herbicides on *Euphorbia dracunculoides* fresh weight (g m^{-2}) at harvest

Table 4.5.10 showed that different weeds control strategies significantly affected the fresh weight of *E. dracunculoides* during both years of experimentation. The year effect was

Table 4.5.9 Effect of herbicides on 1000-seed weight (g) of *Euphorbia dracunculoides* at maturity

Treatments	**2010-11**	**2011-12**
Weedy check	4.59 d	4.55 d
Manual Hoeing	4.84 a	4.74 a
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	4.68 c	4.69 b
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	4.78 b	4.69 b
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	4.66 c	4.64 c
Metribuzin @ 187.5 g a.i. ha^{-1}	4.69 c	4.69 b
Metribuzin @ 150 g a.i. ha^{-1}	4.66 c	4.65 c
LSD	0.304	0.035
Year Effect	4.70 a	4.66 b
LSD	0.013	
Contrast		
Weedy check vs all	4.59 vs 4.72**	4.55 vs 4.68**
Weedy check vs Manual Hoeing	4.59 vs 4.84**	4.55 vs 4.74**
Weedy check vs Herbicides	4.59 vs 4.69**	4.55 vs 4.67**
Manual Hoeing vs Herbicides	4.84 vs 4.69**	4.74 vs 4.67**
Pendimethalin+prometryn vs metribuzin	4.71 vs 4.68**	4.67 vs 4.67**

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.

significant. Maximum fresh weight (1133.60 g and 1445.90 g in 2010 and 2011, respectively) of *E. dracunculoides* was recorded in weedy check plots followed by plots treated with metribuzin @ 150 g a.i. ha^{-1} during both experimental years. Minimum fresh weight (190.00 g and 194.80 g in 2010 and 2011, respectively) was observed in manual hoeing plots. Among herbicide application treatments maximum fresh weight (398.50 g and 428.80 g in 2010 and 2011, respectively) of *E. dracunculoides* was recorded in plots treated with metribuzin @ 150 g a.i. ha^{-1}. While minimum fresh weight (309.50 g and 308.20 g) of *E. dracunculoides* was recorded in plots treated with pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}.

All contrast comparisons for fresh weight of *E. dracunculoides* except pendimethalin+prometryn vs metribuzin in 2010 were significant. Our data showed that fresh weight of *E. dracunculoides* was directly proportional to its density. More density of *E. dracunculoides* was recorded in weedy check plot and hence it's fresh weight. Similarly, among herbicide treated plots maximum *E. dracunculoides* plant m^{-2} were recorded with metribuzin @ 150 g a.i. ha^{-1} and ultimately its fresh weight was heighest. Fresh weight of *E. dracunculoides* in plot with pendimethalin+prometryn at 375 + 500 and 450 + 600 g a.i. ha^{-1} application was due to better *E. dracunculoides* control with herbicide at these doses.

Findings of our experiment are in line with those of Marwat *et al*. (2005a) who recorded minimum weeds and their biomass with herbicide in chickpea. Hamid and Metwally (2008) reported that fresh weight of weeds in soybean was significantly decreased at higher doses of herbicides application.

4.5.8 Effect of herbicides on dry weight (g m^{-2}) of *Euphorbia dracunculoides* at harvest

The data given in the Table 4.5.11 describe the effect of the application of different herbicides on dry weight of *E. dracunculoides*. The analyzed data of dry weight of *E. dracunculoides* showed the variations between dry weight of *E. dracunculoides* in herbicide treatments and check treatment during both the years of study. All weed control treatments significantly decreased the dry weight of *E. dracunculoides*. The year effect was significant.

Table 4.5.10 Effect of herbicides on fresh weight (g) of *Euphorbia dracunculoides* at harvest

Treatments	**2010-11**	**2011-12**
Weedy check	1133.60 a	1445.90 a
Manual Hoeing	190.00 e	194.80 f
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	309.50 d	308.20 e
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	392.10 b	370.80 cd
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	380.80 bc	401.40 bc
Metribuzin @ 187.5 g a.i. ha^{-1}	334.20 cd	338.40 de
Metribuzin @ 150 g a.i. ha^{-1}	398.50 b	428.80 b
LSD	47.116	50.248
Year Effect	448.37 b	498.31 a
LSD	17.265	
Contrast		
Weedy check vs all	1133.60 vs 34.18**	1445.90 vs 40.40**
Weedy check vs Manual Hoeing	1133.60 vs 90.00**	1445.90 vs 94.80**
Weedy check vs Herbicides	1133.60 vs 63.02**	1445.90 vs 69.52**
Manual Hoeing vs Herbicides	190.00 vs 363.02**	194.8 vs 369.52**
Pendimethalin+prometryn vs metribuzin	360.80 vs 366.35^{NS}	360.13 vs 383.60**

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
NS =non-significant

Maximum dry weight (361.55 g and 461.99 g in 2010 and 2011, respectively) of *E. dracunculoides* was recorded in weedy check plots followed by those treated with metribuzin @ 150 g a.i. ha^{-1} during both experimental years. Minimum dry weight (57.84 g and 59.03 g in 2010 and 2011, respectively) was observed in manual hoeing plots. Among herbicide application treatments maximum dry weight (125.22 g and 135.07 g in 2010 and 2011, respectively) of *E. dracunculoides* was recorded in plots treated with metribuzin @ 150 g a.i. ha^{-1}. While minimum dry weight (96.58 g and 95.46 g in 2010 and 2011, respectively) of *E. dracunculoides* was recorded in plots treated with pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}. Contrast comparisons for dry weight of *E. dracunculoides* were significant during both experimental years except pendimethalin+prometryn vs metribuzin, which was non-significant during year 2010-11 and significant during 2011-12.

Maximum dry weight of *E. dracunculoides* in weedy check plot was due to continuous growth of weeds till maturity. Manual weed control and herbicide pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1} application proved to be more effective in controlling *E. dracunculoides* and hence reducing dry weight. Finding of our experiments are comparable with those of Lyon and Wilson (2005) who reported less dry weight of weeds in chickpea with the use of herbicides. Similarly Chhokar *et al.* (2008) and Dixit and Singh (2008) also reported reduction in weeds biomass with herbicide application.

4.5.9 Effect of herbicides on Nitrogen (%) of *Euphorbia dracunculoides* at harvest

The data presented in the Table 4.5.12 indicate the effect of different herbicide treatments on the N content of *E. dracunculoides* at harvest. Nitrogen content of *E. dracunculoides* was variable and also significantly affected by the different weeds control measurements in both the years of study. The year effect was significant. Maximum N concentration in *E. dracunculoides* plant (1.40% and 1.39% in 2010 and 2011, respectively) was observed with pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1} application which was statistically similar to manual hoeing plots. Minimum N concentration in *E. dracunculoides* plant (1.17% and 1.15% in 2010 and 2011, respectively) was observed in weedy check plots. Nitrogen concentration increased where weeds were controlled and were in less numbers.

Table 4.5.11 Effect of herbicides on dry weight (g m^{-2}) of *Euphorbia dracunculoides* at harvest

Treatments	**2010-11**	**2011-12**
Weedy check	361.55 a	461.99 a
Manual Hoeing	57.84 d	59.03 f
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	96.58 c	95.46 e
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	122.82 b	115.72 cd
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	119.46 b	126.13 bc
Metribuzin @ 187.5 g a.i. ha^{-1}	103.93 c	105.77 de
Metribuzin @ 150 g a.i. ha^{-1}	125.22 b	135.07 b
LSD	14.786	16.809
Year Effect	141.06 b	157.02 a
LSD	5.614	
Contrast		
Weedy check vs all	361.55 vs 04.31**	461.99 vs 106.20**
Weedy check vs Manual Hoeing	361.55 vs 57.84**	461.99 vs 59.03**
Weedy check vs Herbicides	361.55 vs 13.60**	461.99 vs 115.63**
Manual Hoeing vs Herbicides	57.84 vs 113.60**	59.03 vs 115.63**
Pendimethalin+prometryn vs metribuzin	112.95 vs 114.58^{NS}	112.44 vs 120.42**

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
NS =non-significant

Table 4.5.12 Effect of herbicides on N contents (%) of *Euphorbia dracunculoides* at harvest

Treatments	**2010-11**	**2011-12**
Weedy check	1.17 f	1.15 d
Manual Hoeing	1.37 ab	1.36 a
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	1.32 cd	1.29 b
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	1.40 a	1.39 a
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	1.27 de	1.25 bc
Metribuzin @ 187.5 g a.i. ha^{-1}	1.32 bc	1.29 b
Metribuzin @ 150 g a.i. ha^{-1}	1.25 e	1.21 c
LSD	0.048	0.056
Year Effect	1.302	1.278
LSD	0.018	
Contrast		
Weedy check vs all	1.17 vs 1.32**	1.15 vs 1.30**
Weedy check vs Manual Hoeing	1.17 vs 1.37**	1.15 vs 1.36**
Weedy check vs Herbicides	1.17 vs 1.31**	1.15 vs 1.29**
Manual Hoeing vs Herbicides	1.37 vs 1.31**	1.36 vs 1.29**
Pendimethalin+prometryn vs metribuzin	1.33 vs 1.29**	1.31 vs 1.25**

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.

All contrast comparisons for N concentration in *E. dracunculoides* plants were significant during both experimental years. Higher N concentration in *E. dracunculoides* plants with weedy check was due to more weeds throughout the growing season.

4.5.10 Effect of herbicides on Phosphorus (%) of *Euphorbia dracunculoides* at harvest

The effects of different herbicides on the P content of *E. dracunculoides* are presented in the Table 4.5.13. All the herbicides significantly affected P concentration of *E. dracunculoides* during both years of experimentation. The year effect was significant. The data showed that maximum P contents of *E. dracunculoides* (0.32% and 0.30% in 2010 and 2011, respectively) was found in plots where hand weeding was carried out, which was statistically similar to that of pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}. Minimum P contents (0.14% and 0.17% in 2010 and 2011, respectively) were observed in weedy check plots. Phosphorus concentration increased where weed was controlled and was in less numbers and vice versa.

All contrast comparisons for P concentrations in *E. dracunculoides* plants were significant during both experimental years. Maximum *E. dracunculoides* plant P contents with manual hoeing and application of pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1} was mainly due to excellent weed control and ultimately less weed competition for resources particularly nutrients. This led to increase in P content in weed plants. Minimum P concentration in *E. dracunculoides* plants of weedy check plot was due to presence of more number of weeds which competed for nutrients and other resources.

4.5.11 Effect of herbicides on potassium (%) of *Euphorbia dracunculoides* at harvest

Effect of different weed control strategies significantly affected the *E. dracunculoides* plant K concentration during both years of experimentation (Table 4.5.14). The year effect was significant. It is evident from the data that maximum *E. dracunculoides* plant K concentration (1.21% and 1.19% in 2010 and 2011, respectively) was observed in hand weeding plots which was statistically at par to that of pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}. Pendimethalin+prometryn at 375+ 500 g a.i. ha^{-1} and metribuzin @ 187.5 g

Table 4.5.13 Effect of herbicides on P contents (%) of *Euphorbia dracunculoides* at harvest

Treatments	**2010-11**	**2011-12**
Weedy check	0.17 d	0.14 d
Manual Hoeing	0.35 a	0.32 a
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	0.26 bc	0.24 bc
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	0.32 a	0.30 a
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	0.28 a	0.25 b
Metribuzin @ 187.5 g a.i. ha^{-1}	0.24 bc	0.23 bc
Metribuzin @ 150 g a.i. ha^{-1}	0.23 c	0.21 c
LSD	0.430	0.035
Year Effect	0.26 a	0.24 b
LSD	0.014	
Contrast		
Weedy check vs all	0.17 vs 0.28**	0.14 vs 0.26**
Weedy check vs Manual Hoeing	0.17 vs 0.35**	0.14 vs 0.32**
Weedy check vs Herbicides	0.17 vs 0.26**	0.14 vs 0.25**
Manual Hoeing vs Herbicides	0.35 vs 0.26**	0.32 vs 0.25**
Pendimethalin+prometryn vs metribuzin	0.29 vs 0.24**	0.26 vs 0.22**

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.

Table 4.5.14 Effect of herbicides on K contents (%) of *Euphorbia dracunculoides* at harvest

Treatments	**2010-11**	**2011-12**
Weedy check	0.95 d	0.89 e
Manual Hoeing	1.21 a	1.19 a
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	1.17 ab	1.16 ab
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	1.20 a	1.14 bc
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	1.12 bc	1.11 cd
Metribuzin @ 187.5 g a.i. ha^{-1}	1.17 ab	1.12 bcd
Metribuzin @ 150 g a.i. ha^{-1}	1.09 c	1.07 d
LSD	0.063	0.049
Year Effect	1.13 a	1.09 b
LSD	0.020	
Contrast		
Weedy check vs all	0.95 vs 1.16**	0.89 vs 1.13**
Weedy check vs Manual Hoeing	0.95 vs 1.21**	0.89 vs 1.19**
Weedy check vs Herbicides	0.95 vs 1.15*	0.89 vs 1.12**
Manual Hoeing vs Herbicides	1.21 vs 1.15**	1.19 vs 1.12**
Pendimethalin+prometryn vs metribuzin	1.16 vs 1.13**	1.14 vs 1.10**

Means not sharing same letter were significantly different at 5% probability level.
* and ** indicate significance at $p \leq 0.05$ and at $p \leq 0.01$ level of probability, respectively.

a.i. ha-^{1} during year 2011-12 only. Minimum K concentration in *E. dracunculoides* plant (0.95% and 0.89% in 2010 and 2011, respectively) was recorded in weedy check plots during both years of study. Potassium concentration decreased where weed were not controlled and were in more numbers and vice versa.

All contrast comparisons for K concentrations in *E. dracunculoides* plants were significant during both years of experimentation. Reduction of K concentration in *E. dracunculoides* plant in weedy check plot was mainly due to high weed density and an increase in competition for limited available K.

4.5.12 Effect of herbicides on Zn contents (ppm) of *Euphorbia dracunculoides* at harvest

The data presented in the Table 4.5.15 indicate the effect of different herbicide treatments on Zn content of *E. dracunculoides* plant at harvest. Results indicate that Zn contents of *E. dracunculoides* plant were significantly affected by the application of different herbicide treatments during both experimental years. The year effect was significant. Maximum Zn concentration of *E. dracunculoides* plant (32.17 and 29.86 ppm in 2010 and 2011, respectively) was observed in manual hoeing plots followed by that of pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}. Minimum Zn concentration of *E. dracunculoides* plant (9.05 and 8.90 ppm in 2010 and 2011, respectively) was observed in weedy check plots. All contrast comparisons for Zn concentration in *E. dracunculoides* plants were highly significant during both years of experimentation.

The significantly maximum Zn concentration of *E. dracunculoides* plant in manual hoeing treatment was due to the more favorable growth and development of *E. dracunculoides* plants.

Table 4.5.15 Effect of herbicides on Zinc (ppm) of *Euphorbia dracunculoides* at harvest

Treatments	**2010-11**	**2011-12**
Weedy check	9.05 e	8.90 e
Manual Hoeing	32.17 a	29.86 a
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	24.84 bc	23.34 c
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	26.13 b	26.07 b
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	22.83 c	21.89 c
Metribuzin @ 187.5 g a.i. ha^{-1}	23.63 bc	22.13 c
Metribuzin @ 150 g a.i. ha^{-1}	19.53 d	18.79 d
LSD	2.805	2.194
Year Effect	22.59 a	21.57 b
LSD	0.892	
Contrast		
Weedy check vs all	9.05 vs 24.86**	8.90 vs 23.68**
Weedy check vs Manual Hoeing	9.05 vs 32.17**	8.90 vs 29.86**
Weedy check vs Herbicides	9.05 vs 23.39**	8.90 vs 22.44**
Manual Hoeing vs Herbicides	32.17 vs 23.39**	29.86 vs 22.44**
Pendimethalin+prometryn vs metribuzin	24.60 vs 21.58**	23.77 vs 20.46**

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability, respectively.

4.5.13 Effect of herbicides on Mn contents (ppm) of *Euphorbia dracunculoides* at harvest

Effect of herbicides application on Mn concentration of *E. dracunculoides* plant was significant during both the years of study (Table 4.5.16). The year effect was significant. The significantly maximum Mn concentration of *E. dracunculoides* plant (57.65 and 57.12 ppm in 2010 and 2011, respectively) was recorded in manual hoeing plots which was statistically at par with pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1} during study year 2010-11. Minimum Mn concentration of *E. dracunculoides* plant (29.02 and 27.06 ppm in 2010 and 2011, respectively) was recorded in weedy check plots during both years. All contrast comparisons for Mn concentrations in *E. dracunculoides* plants were highly significant during both years of experimentation.

Minimum Mn concentration in *E. dracunculoides* plants in weedy check plot was due to more number of weeds present in a unit area.

4.5.14 Effect of herbicides on Fe contents (ppm) of *Euphorbia dracunculoides* at harvest

Effect of different weeds control strategies significantly affected the *E. dracunculoides* plant Fe concentration during both years of experimentation (Table 4.5.17). The year effect was significant. It is evident from the data that maximum *E. dracunculoides* plant Fe concentration (74.77 and 70.32 ppm in 2010 and 2011, respectively) was observed in hand weeded plots which was statistically at par with pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}. Minimum Fe concentration of *E. dracunculoides* plant (38.30 and 34.12 ppm in 2010 and 2011, respectively) was recorded in weedy check plots. Iron concentration decreased with increased weed population because same Fe was used by more weed population. All contrast comparisons for Fe concentrations in *E. dracunculoides* plants were significant during both years of experimentation.

Table 4.5.16 Effect of herbicides on Mn (ppm) of *Euphorbia dracunculoides* at harvest

Treatments	**2010-11**	**2011-12**
Weedy check	29.02 f	27.06 d
Manual Hoeing	57.65 a	57.12 a
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	46.41 cd	44.78 b
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	52.20 b	54.07 a
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	43.86 d	38.69 c
Metribuzin @ 187.5 g a.i. ha^{-1}	48.70 bc	46.63 b
Metribuzin @ 150 g a.i. ha^{-1}	37.30 e	35.68 c
LSD	3.560	3.518
Year Effect	45.02 a	43.43 b
LSD	1.268	
Contrast		
Weedy check vs all	29.02 vs 47.69**	27.06 vs 46.16**
Weedy check vs Manual Hoeing	29.02 vs 57.65**	27.06 vs 57.12**
Weedy check vs Herbicides	29.02 vs 45.69**	27.06 vs 43.97**
Manual Hoeing vs Herbicides	57.65 vs 45.69**	57.12 vs 43.97**
Pendimethalin+prometryn vs metribuzin	47.49 vs 43.00**	45.85 vs 41.16**

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.

Table 4.5.17 Effect of herbicides on Fe (ppm) of *Euphorbia dracunculoides* at harvest

Treatments	**2010-11**	**2011-12**
Weedy check	38.30 e	34.12 e
Manual Hoeing	74.77 a	70.32 a
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	66.27 b	62.61 b
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	71.53 a	67.92 a
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	59.97 c	55.91 c
Metribuzin @ 187.5 g a.i. ha^{-1}	64.28 bc	60.41 b
Metribuzin @ 150 g a.i. ha^{-1}	52.50 d	46.47 d
LSD	4.891	4.168
Year Effect	61.09 a	55.86 b
LSD	1.618	
Contrast		
Weedy check vs all	38.30 vs 64.89**	34.12 vs 60.61**
Weedy check vs Manual Hoeing	38.30 vs 74.77**	34.12 vs 70.32**
Weedy check vs Herbicides	38.30 vs 62.91**	34.12 vs 58.66**
Manual Hoeing vs Herbicides	74.77 vs 62.91**	70.32 vs 58.66**
Pendimethalin+prometryn vs metribuzin	65.92 vs58.39**	62.15 vs 53.44**

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.

4.5.15 Effect of herbicides on Mg (ppm) contents of *Euphorbia dracunculoides* at harvest

Table 4.5.18 indicates the effects of different weeds control strategies on Mg concentrations in *E. dracunculoides* plants. It is obvious from the data that different weed control methods significantly affected the Mg concentrations in *E. dracunculoides* plants. The year effect was significant. Maximum Mg concentration of *E. dracunculoides* plant (35.65 ppm) was observed by application of pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1} which was statistically at par with those of manual hoeing and pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1} and followed by metribuzin @ 187.5 g a.i. ha^{-1}. Significantly minimum (16.05 ppm) Mg concentration of *E. dracunculoides* was recorded in weedy check plants. While during experimental year 2011-12 maximum Mg concentration of *E. dracunculoides* plant (34.02 ppm) was observed in manual hoeing plots which was statistically at par with those of pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1} and metribuzin @ 187.5 g a.i. ha^{-1}. Minimum Mg concentration of *E. dracunculoides* plant (16.05 and 14.58 ppm in 2010 and 2011, respectively) was observed in weedy check plots. All contrast comparisons for Mg concentrations in *E. dracunculoides* plants were highly significant during both years of experimentation.

Minimum Mg concentration in *E. dracunculoides* plants in weedy check plots was due to more number of weeds present in a unit area.

4.5.16 Effect of herbicides on *Euphorbia dracunculoides* Cu contents (ppm) at harvest

The data given in the Table 4.5.19 describe the effect of the application of different herbicides on Cu concentration of *E. dracunculoides* plant. The analyzed data of Cu concentration of *E. dracunculoides* plant showed the variations between different treatments during both the years of study. The year effect was significant. Maximum Cu concentration (8.41 and 8.18 ppm in 2010 and 2011, respectively) of *E. dracunculoides* was recorded in manual hoeing plots followed that of pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}. Minimum Cu concentration (4.53 and 4.27 ppm in 2010 and 2011, respectively) of *E. dracunculoides* was observed in weedy check during both the years of study.

Table 4.5.18 Effect of herbicides on Mg (ppm) of *Euphorbia dracunculoides* at harvest

Treatments	**2010-11**	**2011-12**
Weedy check	16.05 d	14.58 e
Manual Hoeing	33.04 ab	34.02 a
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	32.83 ab	30.39 b
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	35.65 a	32.76 ab
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	25.12 c	23.17 c
Metribuzin @ 187.5 g a.i. ha^{-1}	30.73 b	32.19 ab
Metribuzin @ 150 g a.i. ha^{-1}	22.51 c	19.40 d
LSD	3.352	3.002
Year Effect	27.99 a	26.64 b
LSD	1.180	
Contrast		
Weedy check vs all	16.05 vs 29.98**	14.58 vs 28.66**
Weedy check vs Manual Hoeing	16.05 vs 33.04**	14.58 vs 34.02**
Weedy check vs Herbicides	16.05 vs 29.37**	14.58 vs 27.58**
Manual Hoeing vs Herbicides	33.04 vs 29.37**	34.02 vs 27.58**
Pendimethalin+prometryn vs metribuzin	31.20 vs 26.62**	28.77 vs 25.80**

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.

Table 4.5.19 Effect of herbicides on Cu (ppm) of *Euphorbia dracunculoides* at harvest

Treatments	**2010-11**	**2011-12**
Weedy check	4.53 f	4.27 g
Manual Hoeing	8.41 a	8.18 a
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	6.78 c	6.81 d
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	7.84 b	7.55 b
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	5.94 d	5.84 e
Metribuzin @ 187.5 g a.i. ha^{-1}	7.09 c	7.16 c
Metribuzin @ 150 g a.i. ha^{-1}	5.51 e	5.22 f
LSD	0.347	0.292
Year Effect	6.58 a	6.43 b
LSD	0.120	
Contrast		
Weedy check vs all	4.53 vs 6.93**	4.27 vs 6.79**
Weedy check vs Manual Hoeing	4.53 vs 8.41**	4.27 vs 8.18**
Weedy check vs Herbicides	4.53 vs 6.63**	4.27 vs 6.51**
Manual Hoeing vs Herbicides	8.41 vs 6.63**	8.18 vs 6.51**
Pendimethalin+prometryn vs metribuzin	6.85 vs 6.30**	6.73 vs 6.19**

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.

All contrast comparisons for Cu concentration in *E. dracunculoides* plants were highly significant during both years of experimentation.

Minimum Cu concentration in *E. dracunculoides* plants in weedy check plot was due to continuous growth of weeds till maturity which resulted in maximum biomass and hence lowest Cu concentrations in *E. dracunculoides* plants due to dilution. Manual weed control and herbicide application proved to be more effective in controlling *E. dracunculoides* and hence reducing biomass and increasing Cu concentration in *E. dracunculoides* plants.

4.5.17 Effect of herbicides on NPK uptake (kg ha^{-1}) by *Euphorbia dracunculoides* at harvest

The data given in the Table 4.5.20, 4.5.21 and 4.5.22 describe the effect of the application of different herbicides on NPK uptake by *E. dracunculoides* plant. The year effect for NPK was significant. The analyzed data of NPK uptake by *E. dracunculoides* plant showed the variations between different treatments and significantly maximum NPK uptake were observed in weedy check plots. While minimum NPK uptake was recorded with manual hoeing plots. All contrast comparisons for NPK uptake by *E. dracunculoides* plants except pendimethalin+prometryn vs metribuzin were highly significant during both years of experimentation.

More uptake of NPK by *E. dracunculoides* could be attributed to higher *E. dracunculoides* dry weight in weedy check plot. Results of our findings are supported by those of Anjum *et al*. (2007) and Ikram *et al*. (2012) who reported that N uptake by weeds in cotton increased in weedy check and reduced under weed control strategies. Similarly, Gaikwad and Pawar (2003) also reported that weeds in soybean removed 33.53 Kg ha^{-1} of N in weedy plot.

Table 4.5.20 Effect of herbicides on N uptake (kg ha^{-1}) by *Euphorbia dracunculoides* at harvest

Treatments	**2010-11**	**2011-12**
Weedy check	42.32 a	53.11 a
Manual Hoeing	7.95 e	8.04 e
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	12.75 d	12.36 d
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	17.22 b	16.09 bc
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	15.22 bc	15.76 bc
Metribuzin @ 187.5 g a.i. ha^{-1}	13.82 cd	13.70 cd
Metribuzin @ 150 g a.i. ha^{-1}	15.65 bc	16.35 b
LSD	2.132	2.537
Year Effect	17.84 b	19.34 a
LSD	0.834	
Contrast		
Weedy check vs all	42.32 vs 13.77**	53.11 vs 13.72**
Weedy check vs Manual Hoeing	42.32 vs 7.95**	53.11 vs 8.04**
Weedy check vs Herbicides	42.32 vs 14.93**	53.11 vs 14.85**
Manual Hoeing vs Herbicides	7.95 vs 14.93**	8.04 vs 14.85**
Pendimethalin+prometryn vs metribuzin	15.06 vs 14.74^{NS}	14.74 vs 15.03^{NS}

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
NS =non-significant

Table 4.5.21 Effect of herbicides on P uptake (kg ha^{-1}) by *Euphorbia dracunculoides* at harvest

Treatments	**2010-11**	**2011-12**
Weedy check	5.25 a	7.95 a
Manual Hoeing	1.89 e	2.09 d
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	2.34 de	2.50 cd
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	3.68 b	3.76 b
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	2.98 c	3.53 b
Metribuzin @ 187.5 g a.i. ha^{-1}	2.44 d	2.63 cd
Metribuzin @ 150 g a.i. ha^{-1}	2.66 cd	3.13 bc
LSD	0.487	0.834
Year Effect	3.03 b	3.65 a
LSD	0.243	
Contrast		
Weedy check vs all	5.25 vs 2.67**	7.95 vs 2.94**
Weedy check vs Manual Hoeing	5.25 vs 1.89**	7.95 vs 2.09**
Weedy check vs Herbicides	5.25 vs 2.82**	7.95 vs 3.11**
Manual Hoeing vs Herbicides	1.89 vs 2.82**	2.09 vs 3.11**
Pendimethalin+prometryn vs metribuzin	3.00 vs 2.55^{NS}	3.26 vs 2.88^{NS}

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
NS =non-significant

Table 4.5.22 Effect of herbicides on K uptake (kg ha^{-1}) by *Euphorbia dracunculoides* at harvest

Treatments	**2010-11**	**2011-12**
Weedy check	34.36 a	41.28 a
Manual Hoeing	6.99 e	7.04 d
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	11.33 d	11.09 c
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	14.76 b	13.19 bc
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	13.31 bc	13.97 b
Metribuzin @ 187.5 g a.i. ha^{-1}	12.19 cd	11.81 bc
Metribuzin @ 150 g a.i. ha^{-1}	13.75 bc	14.48 b
LSD	1.649	2.758
Year Effect	15.24 b	16.12 a
LSD	0.801	
Contrast		
Weedy check vs all	34.36 vs 12.06**	41.28 vs 11.93**
Weedy check vs Manual Hoeing	34.36 vs 6.99**	41.28 vs 7.04**
Weedy check vs Herbicides	34.36 vs 13.06**	41.28 vs 12.91**
Manual Hoeing vs Herbicides	6.99 vs 13.06**	7.04 vs 12.91**
Pendimethalin+prometryn vs metribuzin	13.13 vs 12.97^{NS}	12.75 vs 13.15^{NS}

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
NS =non-significant

4.5.18 Effect of herbicides on Zn and Mn uptake (g ha^{-1}) by *Euphorbia dracunculoides* at harvest

Effect of different weeds control strategies on Zn and Mn uptake by *E. dracunculoides* was also significant (Table 4.5.23, 4.5.24). The year effect for Zn and Mn was non-significant. Significantly maximum Zn and Mn uptake was recorded in weedy check plots and significantly minimum was observed in manual hoeing plots. Uptake of Zn and Mn increased with increase in dry weight of *E. dracunculoides*. All contrast comparisons for Zn and Mn uptake by *E. dracunculoides* plants except pendimethalin+prometryn vs metribuzin were significant.

Higher Zn and Mn uptake by *E. dracunculoides* in weedy check treatment was due to the more favorable growth and development of *E. dracunculoides* plants throughout the cropping season.

4.5.19 Effect of herbicides on Fe (g ha^{-1}), Mg uptake (kg ha^{-1}) and Cu (g ha^{-1}) by *Euphorbia dracunculoides* at harvest

The data given in the Table 4.5.25, 4.5.26 and 4.5 27 describe the effect of the application of different herbicides on Fe, Mg and Cu uptake by *E. dracunculoides* plant. The year effect for Fe was significant while the year effect for Mg was non-significant. The year effect for Cu was significant. Significantly maximum Fe and Mg uptake was noted in weedy check plots followed by pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1} for Fe uptake during both the years of study. Significantly minimum Fe was observed with manual hoeing plots. As regard Mg uptake weedy check was followed by that of pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1} and the minimum was noted with manual hoeing plots. Significantly maximum Cu uptake was recorded in weedy check plots and significantly minimum Cu uptake was observed with manual hoeing during both the years of study. All contrast comparisons for Fe and Cu uptake by *E. dracunculoides* plants except pendimethalin+prometryn vs metribuzin during first year were significant. While, contrast comparisons for Mg uptake by *E. dracunculoides* plants except pendimethalin+prometryn vs metribuzin were found significant.

Higher Fe and Mg uptake by *E. dracunculoides* plants in weedy check plots could be attributed to more dry weight of *E. dracunculoides* plants.

Table 4.5.23 Effect of herbicides on Zn uptake (g ha^{-1}) by *Euphorbia dracunculoides* at harvest

Treatments	**Mean**
Weedy check	36.96 a
Manual Hoeing	18.11 e
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	23.22 d
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	31.20 b
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	27.47 c
Metribuzin @ 187.5 g a.i. ha^{-1}	23.97 d
Metribuzin @ 150 g a.i. ha^{-1}	24.92 cd
LSD	3.460
Contrast	
Weedy check vs all	36.96 vs 24.82**
Weedy check vs Manual Hoeing	36.96 vs 18.11**
Weedy check vs Herbicides	36.96 vs 26.15**
Manual Hoeing vs Herbicides	18.11 vs 26.15**
Pendimethalin+prometryn vs metribuzin	27.30 vs 24.45^{NS}

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
NS =non-significant

Table 4.5.24 Effect of herbicides on Mn uptake (g ha^{-1}) by *Euphorbia dracunculoides* at harvest

Treatments	**Mean**
Weedy check	115.03 a
Manual Hoeing	33.57 e
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	43.80 d
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	63.31 b
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	50.63 c
Metribuzin @ 187.5 g a.i. ha^{-1}	49.91 cd
Metribuzin @ 150 g a.i. ha^{-1}	47.51 cd
LSD	6.744
Contrast	
Weedy check vs all	115.03 vs 48.12**
Weedy check vs Manual Hoeing	115.03 vs 33.57**
Weedy check vs Herbicides	115.03 vs 51.03**
Manual Hoeing vs Herbicides	33.57 vs 51.03**
Pendimethalin+prometryn vs metribuzin	52.58 vs 48.71^{NS}

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
NS =non-significant

Table 4.5.25 Effect of herbicides on Fe uptake (g ha^{-1}) by *Euphorbia dracunculoides* at harvest

Treatments	**2010-11**	**2011-12**
Weedy check	124.69 a	177.21 a
Manual Hoeing	40.72 d	44.16 d
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	60.48 c	63.28 c
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	83.47 b	82.66 b
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	66.74 c	75.73 bc
Metribuzin @ 187.5 g a.i. ha^{-1}	62.57 c	67.88 c
Metribuzin @ 150 g a.i. ha^{-1}	58.20 c	70.85 bc
LSD	10.536	13.92
Year Effect	70.98 b	83.11
LSD	4.37	
Contrast		
Weedy check vs all	124.69 vs 62.03**	177.21 vs 67.43**
Weedy check vs Manual Hoeing	124.69 vs 40.72**	177.21 vs 44.16**
Weedy check vs Herbicides	124.69 vs 66.29**	177.21 vs 72.08**
Manual Hoeing vs Herbicides	40.72 vs 66.29**	44.16 vs 72.08**
Pendimethalin+prometryn vs metribuzin	70.23 vs 60.39^{NS}	73.89 vs 69.37**

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
^{NS} =non-significant

Table 4.5.26 Effect of herbicides on Mg uptake (kg ha^{-1}) by *Euphorbia dracunculoides* at harvest

Treatments	**Mean**
Weedy check	6.26 a
Manual Hoeing	1.96 e
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	3.03 cd
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	4.08 b
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	2.96 cd
Metribuzin @ 187.5 g a.i. ha^{-1}	3.30 c
Metribuzin @ 150 g a.i. ha^{-1}	2.72 d
LSD	0.426
Contrast	
Weedy check vs all	6.26 vs 3.01**
Weedy check vs Manual Hoeing	6.26 vs 1.96**
Weedy check vs Herbicides	6.26 vs 3.22**
Manual Hoeing vs Herbicides	1.96 vs 3.22**
Pendimethalin+prometryn vs metribuzin	3.36 vs 3.01^{NS}

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
NS =non-significant

Table 4.5.27 Effect of herbicides on Cu uptake (g ha^{-1}) by *Euphorbia dracunculoides* at harvest

Treatments	**2010-11**	**2011-12**
Weedy check	16.39 a	19.76 a
Manual Hoeing	4.87 d	4.83 d
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	6.54 c	6.50 c
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	9.64 b	8.74 b
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	7.10 c	7.36 c
Metribuzin @ 187.5 g a.i. ha^{-1}	7.37 c	7.58 bc
Metribuzin @ 150 g a.i. ha^{-1}	6.90 c	7.05 c
LSD	0.944	1.357
Year Effect	8.40 b	8.83 a
LSD	0.421	
Contrast		
Weedy check vs all	16.39 vs 7.07**	19.76 vs 7.01**
Weedy check vs Manual Hoeing	16.39 vs 4.87**	19.76 vs 4.83**
Weedy check vs Herbicides	16.39 vs 7.51**	19.76 vs 7.45**
Manual Hoeing vs Herbicides	4.87 vs 7.51**	4.83 vs 7.45**
Pendimethalin+prometryn vs metribuzin	7.76 vs 7.14^{NS}	7.53 vs 7.32**

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
^{NS} =non-significant

4.5.20 Effect of herbicide application on density of *Astragalus* spp. at 40, 60 and 80 days after emergence (DAE) and at harvest

Data regarding *Astragalus* spp. density (m^{-2}) at 40, 60 and 80 days after crop emergence (DAE) and at harvest are pre presented in Tables 4.5.28, 4.5.29, 4.5.30 and 4.5.31. The year effect for 40 DAE was significant and more weeds were observed during study year 2011-12. Data reveal that maximum *Astragalus* spp. density (25.75 and 28.41 m^{-2} in 2010 and 2011, respectively) at 40 days after emergence (DAE) was observed in weedy check plots while minimum *Astragalus* spp. density (3.16 and 3.50 m^{-2} in 2010 and 2011, respectively) at 40 DAE was recorded with metribuzin @ 187.5 g a.i. ha^{-1}. Manual hoeing plots were weeds free during both study years at 40 DAS. All contrast comparisons for *Astragalus* spp. density at 40 DAE were significant except pendimethalin+prometryn vs metribuzin during both years of experimentation.

The year effect for *Astragalus* spp. at 60 and 80 DAS was non-significant. Data regarding *Astragalus* spp. densities at 60 and 80 DAE showed that maximum *Astragalus* spp. density (36.54 and 46.83 m^{-2} in 2010 and 2011, respectively) were found in weedy check plots while, statistically minimum density (4.24 and 5.54 m^{-2} in 2010 and 2011, respectively) was recorded with metribuzin @ 187.5 g a.i. ha^{-1} at 60 and 80 DAE. All contrast comparisons for *Astragalus* spp. density (m^{-2}) at 60 and 80 DAE were significant except pendimethalin+prometryn vs metribuzin at 60 DAE during study year 2011-12 and at 80 DAE for both experimental years were non-significant.

Maximum *Astragalus* spp. density (52.75 and 57.66 m^{-2} in 2010 and 2011, respectively) at harvest was observed in weedy check plots during both years of experimentation (Table 4.5.31). The year effect was significant. These results were followed by that of metribuzin @ 150 g a.i. ha^{-1} during both years of experimentation. Minimum *Astragalus* spp. density (3.50 and 3.75 in 2010 and 2011, respectively) at harvest was observed in manual hoeing plots. Among herbicide treatments minimum *Astragalus* spp. density (7.91 m^{-2} and 8.16 m^{-2}) at harvest was observed with pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1} during both study years. More weeds densities were observed during

Table 4.5.28 Effect of herbicides on density (m^{-2}) of *Astragalus* spp. at 40 DAE

Treatments	**2010-11**	**2011-12**
Weedy check	25.75 a	28.41 a
Manual Hoeing	--	--
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	4.83 c	4.91 de
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	5.16 c	5.50 cd
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	6.66 b	7.16 b
Metribuzin @ 187.5 g a.i. ha^{-1}	3.16 d	3.50 e
Metribuzin @ 150 g a.i. ha^{-1}	6.83 b	6.66 bc
LSD	1.346	1.526
Year Effect	8.73 b	9.36 a
LSD	0.548	
Contrast		
Weedy check vs all	25.75 vs 4.44**	28.41 vs 4.62**
Weedy check vs Manual Hoeing	25.75 vs 0.00**	28.41 vs 0.00**
Weedy check vs Herbicides	25.75 vs 5.32**	28.41 vs 5.55**
Manual Hoeing vs Herbicides	0.00 vs 5.32**	0.00 vs 5.55**
Pendimethalin+prometryn vs metribuzin	5.55 vs 5.00^{NS}	5.86 vs 5.08^{NS}

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
DAE indicates days after emergence.
NS =non-significant

Table 4.5.29 Effect of herbicides on density (m^{-2}) of *Astragalus* spp. at 60 DAE

Treatments	**Mean**
Weedy check	36.54 a
Manual Hoeing	--
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	5.37 de
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	6.62 cd
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	7.45 c
Metribuzin @ 187.5 g a.i. ha^{-1}	4.24 e
Metribuzin @ 150 g a.i. ha^{-1}	8.70 b
LSD	1.251
Contrast	
Weedy check vs all	36.54 vs 5.40**
Weedy check vs Manual Hoeing	36.54 vs 0.00**
Weedy check vs Herbicides	36.54 vs 6.47**
Manual Hoeing vs Herbicides	0.00 vs 6.47**
Pendimethalin+prometryn vs metribuzin	6.48 vs 6.47^{NS}

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
DAE indicates days after emergence.
NS =non-significant

Table 4.5.30 Effect of herbicides on density (m^{-2}) of *Astragalus* spp. at 80 DAE

Treatments	**Mean**
Weedy check	46.83 a
Manual Hoeing	3.16 f
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	6.12 de
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	7.91 c
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	7.20 cd
Metribuzin @ 187.5 g a.i. ha^{-1}	5.54 e
Metribuzin @ 150 g a.i. ha^{-1}	10.04 b
LSD	1.297
Contrast	
Weedy check vs all	46.83 vs 6.66**
Weedy check vs Manual Hoeing	46.83 vs 3.16**
Weedy check vs Herbicides	46.83 vs 7.36**
Manual Hoeing vs Herbicides	3.16 vs 7.36**
Pendimethalin+prometryn vs metribuzin	7.08 vs 7.79^{NS}

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
DAE indicates days after emergence.
NS =non-significant

Table 4.5.31 Effect of herbicides on density (m^{-2}) of *Astragalus* spp. at harvest

Treatments	**2010-11**	**2011-12**
Weedy check	52.75 a	57.66 a
Manual Hoeing	3.50 e	3.75 e
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	7.91 cd	8.16 cd
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	8.41 c	8.91 bcd
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	9.58 bc	9.83 bc
Metribuzin @ 187.5 g a.i. ha^{-1}	6.58 d	7.33 d
Metribuzin @ 150 g a.i. ha^{-1}	10.58 b	10.75 b
LSD	1.755	2.223
Year Effect	14.19 b	15.02 a
LSD	0.749	
Contrast		
Weedy check vs all	52.75 vs 8.12**	57.66 vs 7.76**
Weedy check vs Manual Hoeing	52.75 vs 3.75**	57.66 vs 3.50**
Weedy check vs Herbicides	52.75 vs 8.99**	57.66 vs 8.61**
Manual Hoeing vs Herbicides	3.75 vs 8.99**	3.50 vs 8.61**
Pendimethalin+prometryn vs metribuzin	8.97 vs 9.04^{NS}	8.63 vs 8.58^{NS}

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability, respectively.
NS =non-significant

study year 2011-12. All contrast comparisons for *Astragalus* spp. densities at harvest were significant except pendimethalin+prometryn vs metribuzin during both years of experimentation.

Lowest densities of *Astragalus* spp. with pendimethalin+prometryn at 375 + 500 and 450 + 600 g a.i. ha^{-1} application rate were due to better efficacy against *Astragalus* spp. as compared to 300 + 400 g a.i. ha^{-1} application rate of same herbicide. Our findings are supported from the results of Bhalla *et al*. (1998) and Marwat *et al*. (2004) who reported maximum weed control in chickpea with application of Stomp 330-EC (pendimethalin). Similarly, Singh *et al*. (2009) recorded lowest weeds population in alachlor treated plot followed by pendimethalin and simazine in maize crop.

4.5.21 Effect of herbicides on *Astragalus* spp. pods per plant at maturity

Different herbicide application treatments significantly affected the number of pods per plat of *Astragalus* spp. at maturity during both years of experimentation (Table 4.5.32). The year effect was significant. It is evident from data that maximum number of pods per plant at maturity (75.14 and 70.38 in 2010 and 2011, respectively) of *Astragalus* spp. was recorded in manual hoeing plots which was statistically similar to that of pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1} during both years of experimentation and pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1} and metribuzin @ 187.5 g a.i. ha^{-1} during 2011-12. Statistically minimum number of pods per plant at maturity (44.89 and 42.03 in 2010 and 2011, respectively) of *Astragalus* spp. was recorded in weedy check plots. Among herbicide, application of pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1} produced maximum pods per plant while metribuzin @ 150 g a.i. ha^{-1} produced lowest number of pods per plant. More number of pods per plant at maturity of *Astragalus* spp. was recorded during study year 2010-11.

All contrast comparisons for number of pods per plant at maturity of *Astragalus* spp. were significant during both years of experimentation. Maximum number of pods per plat at maturity (75.14 and 70.38 in 2010 and 2011, respectively) of *Astragalus* spp. in manual hoeing plots and with application of pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1} was due to better control of weeds which resulted in lowest number of weed plants that favored the growth of weed plants.

Table 4.5.32 Effect of herbicides on pods per plant of *Astragalus* spp. at maturity

Treatments	**2010-11**	**2011-12**
Weedy check	44.89 e	42.03 d
Manual Hoeing	75.14 a	70.38 a
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	70.67 b	68.80 ab
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	73.78 a	69.64 a
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	67.05 c	65.83 b
Metribuzin @ 187.5 g a.i. ha^{-1}	68.78 bc	68.78 ab
Metribuzin @ 150 g a.i. ha^{-1}	62.18 d	59.17 c
LSD	2.271	3.054
Year Effect	66.07 a	63.52 b
LSD	0.999	
Contrast		
Weedy check vs all	44.89 vs 69.60**	42.03 vs 67.10**
Weedy check vs Manual Hoeing	44.89 vs 75.14**	42.03 vs 70.38**
Weedy check vs Herbicides	44.89 vs 68.49**	42.03 vs 66.44**
Manual Hoeing vs Herbicides	75.14 vs 68.49**	70.38 vs 66.44**
Pendimethalin+prometryn vs metribuzin	70.50 vs 65.48**	68.09 vs 63.98**

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance $p \leq 0.01$ level of probability.

4.5.22 Effect of herbicides on number of seeds per pod of *Astragalus* spp.

Significant effect of different weed control methods on *Astragalus* spp. number of seeds per pod at maturity was recorded during both years of experimentation (Table 4.5.33). The year effect was significant. Maximum number of seeds per pod (13.25 and 13.55 in 2010 and 2011, respectively) of *Astragalus* spp. at maturity was observed in manual hoeing plots which was statistically at par with that of pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1} during both years of experimentation. Minimum number of seeds per pod (7.75 and 8.70 in 2010 and 2011, respectively) of *Astragalus* spp. at maturity was observed in weedy check plots during both years. Among herbicide application treatments lowest number of seeds per pod was observed with application of metribuzin @ 150 g a.i. ha^{-1} while maximum number of seeds per pod was recorded in pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1} application.

All contrast comaprisons for number of seeds per pod of *Astragalus* spp. were significant during both years of experimentation. Maximum number of seeds per pod of *Astragalus* spp. in manual hoeing plot was due to fewer number of weed plants with healthy growth.

4.5.23 Effect of herbicides on seeds per plant of *Astragalus* spp.

The data presented in the Table 4.5.34 indicate the effect of different herbicides on the number of seeds per plant of *Astragalus* spp. The year effect was non-significant. Maximum number of seeds per plant (974.78) of *Astragalus* spp. were recorded in manual hoeing plots which was followed by that of application of pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}. Minimum number of seeds per plant (356.65) of *Astragalus* spp. was recorded in weedy check plots.

All contrast comaprisons for number of seeds per plant of *Astragalus* spp. was significant during both the years of experimentation. More number of seeds per plant of *Astragalus* spp. in manual hoeing plot was due to more number of pods per plant.

Table 4.5.33 Effect of herbicides on seeds per pod of *Astragalus* spp. at maturity

Treatments	**2010-11**	**2011-12**
Weedy check	7.75 d	8.70 d
Manual Hoeing	13.25 a	13.55 a
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	10.85 b	11.35 bc
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	12.55 a	12.85 a
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	9.60 c	10.80 bc
Metribuzin @ 187.5 g a.i. ha^{-1}	11.00 b	11.55 b
Metribuzin @ 150 g a.i. ha^{-1}	9.05 c	10.30 c
LSD	0.888	1.143
Year Effect	10.57 b	11.30 a
LSD	0.361	
Contrast		
Weedy check vs all	7.75 vs 11.05**	8.70 vs 11.73**
Weedy check vs Manual Hoeing	7.75 vs 13.25**	8.70 vs 13.55**
Weedy check vs Herbicides	7.75 vs 10.61**	8.70 vs 11.37**
Manual Hoeing vs Herbicides	13.25 vs 10.61**	13.55 vs 11.37**
Pendimethalin+prometryn vs metribuzin	11.00 vs 10.03**	11.67 vs 10.93**

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.

Table 4.5.34 Effect of herbicides on seeds per plant of *Astragalus* spp. at maturity

Treatments	**Mean**
Weedy check	356.65 f
Manual Hoeing	974.78 a
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	773.78 c
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	910.58 b
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	677.78 d
Metribuzin @ 187.5 g a.i. ha^{-1}	776.25 c
Metribuzin @ 150 g a.i. ha^{-1}	586.49 e
LSD	52.103
Contrast	
Weedy check vs all	356.65 vs 783.28**
Weedy check vs Manual Hoeing	356.65 vs 974.78**
Weedy check vs Herbicides	356.65 vs 744.97**
Manual Hoeing vs Herbicides	974.78 vs 744.97**
Pendimethalin+prometryn vs metribuzin	787.38 vs 681.37**

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.

4.5.24 Effect of herbicides on seed weight/plant (g) of *Astragalus* spp.

The table 4.5.35 indicates the effect of different herbicide treatments on seed weight per plant of *Astragalus* spp. The year effect was significant. Data reveal that maximum seed weight per plant (1.22 and 1.16 g in 2010 and 2011, respectively) of *Astragalus* spp. was recorded in manual hoeing plots followed by that of pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}. Minimum seed weight per plant (0.38 and 0.36 g in 2010 and 2011, respectively) of *Astragalus* spp. was observed in weedy check plots.

All contrast comparisons for seed weight per plant of *Astragalus* spp. were significant during both years of experimentation. More seed weight per plant of *Astragalus* spp. in manual hoeing plot was due to fewer number of weed plants present in this plot with vigorous growth and hence more seed weight per plant.

4.5.25 Effect of herbicides on 1000-seed weight (g) of *Astragalus* spp.

Different weed control treatments significantly affected the 1000-seed weight of *Astragalus* spp. during both years of experimentation (Table 4.5.36). The year effect was significant. Statistically maximum 1000-seed weight (1.23 g and 1.21 g in 2010 and 2011, respectively) of *Astragalus* spp. was observed in manual hoeing plots which was statistically at par with that of pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1} during study year 2010-11. Minimum 1000-seed weight (1.06 g and 1.02 g in 2010 and 2011, respectively) of *Astragalus* spp. was recorded in weedy check plots.

All contrast comparisons for 1000-seed weight of *Astragalus* spp. were significant during both years of experimentation. More 1000-seed weight of *Astragalus* spp. in manual hoeing plot as compared with those of other weed control strategies could be due to adequate weed control during the cropping period and fewer numbers of weeds present in this plot. These weed palnts availed maximum moisture and nutrients for their growth which ultimately led towards heavier seeds of *Astragalus* spp.

Table 4.5.35 Effect of herbicides on seed weight/plant (g) of *Astragalus* spp. at maturity

Treatments	**2010-11**	**2011-12**
Weedy check	0.38 f	0.36 f
Manual Hoeing	1.22 a	1.16 a
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	0.92 c	0.90 c
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	1.12 b	1.04 b
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	0.79 d	0.73 d
Metribuzin @ 187.5 g a.i. ha^{-1}	0.93 c	0.90 c
Metribuzin @ 150 g a.i. ha^{-1}	0.65 e	0.62 e
LSD	0.074	0.108
Year Effect	0.86 a	0.81 b
LSD	0.302	
Contrast		
Weedy check vs all	0.38 vs 0.94**	0.36 vs 0.89**
Weedy check vs Manual Hoeing	0.38 vs 1.22**	0.36 vs 1.16**
Weedy check vs Herbicides	0.38 vs 0.88**	0.36 vs 0.84**
Manual Hoeing vs Herbicides	1.22 vs 0.88**	1.16 vs 0.84**
Pendimethalin+prometryn vs metribuzin	0.94 vs 0.79**	0.89 vs 0.76**

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.

Table 4.5.36 Effect of herbicides on 1000-seed weight (g) of *Astragalus* spp. at maturity

Treatments	**2010-11**	**2011-12**
Weedy check	1.06 f	1.02 e
Manual Hoeing	1.23 a	1.21 a
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	1.19 bc	1.17 b
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	1.21 ab	1.17 b
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	1.14 d	1.11 c
Metribuzin @ 187.5 g a.i. ha^{-1}	1.18 c	1.16 b
Metribuzin @ 150 g a.i. ha^{-1}	1.10 e	1.06 d
LSD	0.029	0.028
Year Effect	1.16 a	1.13
LSD	0.010	
Contrast		
Weedy check vs all	1.06 vs 1.18**	1.02 vs 1.15**
Weedy check vs Manual Hoeing	1.06 vs 1.23**	1.02 vs 1.21**
Weedy check vs Herbicides	1.06 vs 1.16**	1.02 vs 1.13**
Manual Hoeing vs Herbicides	1.23 vs 1.16**	1.21 vs 1.13**
Pendimethalin+prometryn vs metribuzin	1.18 vs 1.14**	1.15 vs 1.11**

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.

4.5.26 Effect of herbicides on fresh weight (g m^{-2}) of *Astragalus* spp.

The Table 4.5.37 indicates the effect of different herbicide treatments on fresh weight of *Astragalus* spp. Analysis of the data showed that all the weed control treatments had significant effect on fresh weight of *Astragalus* spp. during both years of study. The year effect was significant. Maximum fresh weight (802.55 and 819.00 g m^{-2} in 2010 and 2011, respectively) of *Astragalus* spp. was recorded in weedy check plots followed by that of metribuzin @ 150 g a.i. ha^{-1}. Minimum fresh weight (73.13 and 72.78 g m^{-2} in 2010 and 2011, respectively) of *Astragalus* spp. was recorded in manual hoeing plots. Among herbicide minimum fresh weight (130.54 and 152.51 g m^{-2} in 2010 and 2011, respectively) of *Astragalus* spp. was recorded with pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}.

All contrast comparisons for fresh weight of *Astragalus* spp. were significant during both years of experimentation. The fresh weight of weeds is a signal of the growth potential of weeds and is a better standard for the judgment of weed crop competition than weed density. The data reveal that herbicide treatments significantly reduced *Astragalus* spp. fresh weight. Maximum fresh weight of *Astragalus* spp. in weedy check was due to presence of *Astragalus* spp. throughout the growth period of crop. These results are in great analogy with those of Tanveer *et al.* (2003) who reported that herbicide application in cotton reduced fresh weight of weeds and variation in fresh weight of weeds in different herbicide treated plots was due to their different effectiveness in controlling weeds. Similarly, Singh and Singh (1992) also reported significant reduction in the weed biomass with pendimethalin in pigeon pea.

4.5.27 Effect of herbicides on dry weight (g) of *Astragalus* spp. at harvest

Dry weight of *Astragalus* spp. at harvest is given in Table 4.5.38. The data revealed that different weed control treatments significantly affected dry weight of *Astragalus* spp. during both years of experimentation. The year effect was significant. Maximum dry weight (250.25 and 253.21 g m^{-2} in 2010 and 2011, respectively) of *Astragalus* spp. was recorded in weedy check plots followed by that of metribuzin @ 150 g a.i. ha^{-1}. Minimum dry weight (22.16 and 22.19 g m^{-2} in 2010 and 2011, respectively) of *Astragalus* spp. was recorded in manual hoeing plots. Among herbicide application minimum dry weight (40.03 and 47.88 g m^{-2} in 2010 and 2011, respectively) of *Astragalus* spp. was recorded with application of

Table 4.5.37 Effect of herbicides on fresh weight (g m^{-2}) of *Astragalus* spp. at harvest

Treatments	**2010-11**	**2011-12**
Weedy check	802.55 a	819.00 a
Manual Hoeing	73.13 f	72.78 e
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	130.54 e	152.51 d
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	160.01 cd	180.08 c
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	170.53 bc	198.48 b
Metribuzin @ 187.5 g a.i. ha^{-1}	144.50 de	161.40 d
Metribuzin @ 150 g a.i. ha^{-1}	187.45 b	208.80 b
LSD	20.242	10.358
Year Effect	238.39 b	256.12 a
LSD	6.01	
Contrast		
Weedy check vs all	802.55 vs 144.36**	819.00 vs 162.34**
Weedy check vs Manual Hoeing	802.55 vs 73.13**	819.00 vs 72.78**
Weedy check vs Herbicides	802.55 vs 158.60**	819.00 vs 180.25**
Manual Hoeing vs Herbicides	72.78 vs 158.60**	72.78 vs 180.25**
Pendimethalin+prometryn vs metribuzin	153.69 vs 165.98**	177.02 vs 185.10**

Means not sharing same letter were significantly different at 5% probability level.
* and ** indicate significance at $p \leq 0.05$ and at $p \leq 0.01$ level of probability, respectively.

Table 4.5.38 Effect of herbicides on dry weight (g m^{-2}) of *Astragalus* spp. at harvest

Treatments	**2010-11**	**2011-12**
Weedy check	250.25 a	253.21 a
Manual Hoeing	22.16 f	22.19 f
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	40.03 e	47.88 e
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	49.16 cd	56.32 d
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	53.04 bc	61.98 c
Metribuzin @ 187.5 g a.i. ha^{-1}	44.39 de	49.55 e
Metribuzin @ 150 g a.i. ha^{-1}	59.04 b	65.20 b
LSD	6.949	2.570
Year Effect	74.43 b	79.54 a
LSD	1.959	
Contrast		
Weedy check vs all	250.25 vs 44.64**	253.21 vs 50.52**
Weedy check vs Manual Hoeing	250.25 vs 22.16**	253.21 vs 22.19**
Weedy check vs Herbicides	250.25 vs 49.13**	253.21 vs 56.19**
Manual Hoeing vs Herbicides	22.16 vs 49.13**	22.19 vs 56.19**
Pendimethalin+prometryn vs metribuzin	47.41 vs 51.72**	55.39 vs 57.38**

Means not sharing same letter were significantly different at 5% probability level.
* and ** indicate significance at $p \leq 0.05$ and at $p \leq 0.01$ level of probability, respectively.

pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1} during both years of study.

All contrast comparisons for dry weight of *Astragalus* spp. were significant during both years of experimentation. Manual weed control and pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1} application proved to be more effective in controlling *Astragalus* spp. and hence reducing dry weight. These results are in accordance with those of Chattha *et al.* (2007) who found maximum reduction in dry biomass of different weeds with different herbicides application in mungbean. Maximum dry weight of *Astragalus* spp. was recorded in weedy check where no herbicide was applied all through the crop growing period. These results are almost in agreement with those of Giri *et al*. (2006) and Oad *et al*. (2007a). They recorded maximum dry weight of weeds in the weedy control treatment in cotton.

4.5.28 Effect of herbicides on nitrogen contents (%) of *Astragalus* spp.

Data regarding N contents of *Astragalus* spp. at harvest is presented in Table 4.5.39. The year effect was non-significant. Data reveal that maximum N contents (1.73%) of *Astragalus* spp. were analyzed in manual hoeing plots which was statistically at par with that of pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}. Minimum N concentration (1.47%) was recorded in weedy check plots.

All contrast comparisons for N concentration of *Astragalus* spp. were significant during both years of experimentation. Higher N concentration of *Astragalus* spp.in manual hoeing plot was due to less number of weeds as compared to other treatments, which resulted in less competition for N, hence high N concentration.

4.5.29 Effect of herbicides on phosphorus contents (%) of *Astragalus* spp. at harvest

The data presented in the table 4.5.40 indicates the effect of different weed control treatments on the P contents of *Astragalus* spp. at harvest. Phosphorus contents of *Astragalus* spp. were variable and also significantly affected by the different weed control measurements during both years of study. The year effect was significant. Maximum P contents (0.49% and 0.46% in 2010 and 2011, respectively) of *Astragalus* spp. were recorded in manual hoeing plots followed by application of pendimethalin+prometryn at 375 + 500 g a.i.

Table 4.5.39 Effect of herbicides on N contents (%) of *Astragalus* spp. at harvest

Treatments	**Mean**
Weedy check	1.47 f
Manual Hoeing	1.73 a
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	1.68 bc
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	1.70 ab
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	1.59 d
Metribuzin @ 187.5 g a.i. ha^{-1}	1.66 c
Metribuzin @ 150 g a.i. ha^{-1}	1.55 e
LSD	0.029
Contrast	
Weedy check vs all	1.47 vs 1.65**
Weedy check vs Manual Hoeing	1.47 vs 1.73**
Weedy check vs Herbicides	1.47 vs 1.63**
Manual Hoeing vs Herbicides	1.73 vs 1.63**
Pendimethalin+prometryn vs metribuzin	1.66 vs 1.61**

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.

Table 4.5.40 Effect of herbicides on P contents (%) of *Astragalus* spp. at harvest

Treatments	**2010-11**	**2011-12**
Weedy check	0.25 e	0.21 d
Manual Hoeing	0.49 a	0.46 a
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	0.39 c	0.37 bc
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	0.43 b	0.41 b
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	0.28 d	0.25 d
Metribuzin @ 187.5 g a.i. ha^{-1}	0.38 c	0.33 c
Metribuzin @ 150 g a.i. ha^{-1}	0.27 de	0.23 d
LSD	0.035	0.042
Year Effect	0.35 a	0.32 b
LSD	0.013	
Contrast		
Weedy check vs all	0.25 vs 0.37**	0.21 vs 0.34**
Weedy check vs Manual Hoeing	0.25 vs 0.49**	0.21 vs 0.46**
Weedy check vs Herbicides	0.25 vs 0.35**	0.21 vs 0.31**
Manual Hoeing vs Herbicides	0.49 vs 0.35**	0.46 vs 0.31**
Pendimethalin+prometryn vs metribuzin	0.37 vs 0.33**	0.34 vs 0.28**

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.

ha^{-1}. Minimum P contents (0.25% and 0.21% in 2010 and 2011, respectively) of *Astragalus* spp. were recorded in weedy check plots.

All contrast comparisons for P concentration of *Astragalus* spp. were significant during both years of experimentation. Maximum P concentration in *Astragalus* spp. with manual hoeing and pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1} was mainly due to effective weed control which resulted in less number of weed plants.

4.5.30 Effect of herbicides on Potassium contents (%) of *Astragalus* spp. at harvest

Different weed control strategies significantly affected the *Astragalus* spp. plant potassium concentration during both years of experimentation (Table 4.5.41). The year effect was significant. Data reveal that maximum *Astragalus* spp. plant potassium concentration (1.35% and 1.32% in 2010 and 2011, respectively) was observed in manual hoeing plots which was followed by pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1} during both years of experimentation. Statistically minimum K concentration of *Astragalus* spp. plants (1.13% and 1.13% in 2010 and 2011, respectively) was recorded in weedy check plots.

All contrast comparisons for K concentration of *Astragalus* spp. were significant during both years of experimentation. Lowest concentration of potassium in *Astragalus* spp. plants in weedy check plot could be due to maximum number of this weed plants present in this plot which competed with one another and with main crop for nutrients.

4.5.31 Effect of herbicides on Zn contents (ppm) of *Astragalus* spp. at harvest

The data (Table 4.5.42) reveal that different weed control strategies significantly affected the Zn concentration of *Astragalus* spp. during both years of experimentation. The year effect was also significant and being maximum during study year 2010-11. Maximum Zn concentration of *Astragalus* spp. (39.71 and 37.02 ppm in 2010 and 2011, respectively) was recorded in weedy check plot which was statistically similar with that of pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1} during 2011-12. Minimum Zn concentration of *Astragalus* spp. (12.51 and 12.13 ppm in 2010 and 2011, respectively) was recorded in weedy check plot.

Table 4.5.41 Effect of herbicides on K contents (%) of *Astragalus* spp. at harvest

Treatments	**2010-11**	**2011-12**
Weedy check	1.13 e	1.13 f
Manual Hoeing	1.35 a	1.32 a
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	1.25 c	1.24 c
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	1.29 b	1.28 b
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	1.20 d	1.19 de
Metribuzin @ 187.5 g a.i. ha^{-1}	1.26 bc	1.22 cd
Metribuzin @ 150 g a.i. ha^{-1}	1.19 d	1.18 e
LSD	0.035	0.037
Year Effect	1.24 a	1.22 b
LSD	0.013	
Contrast		
Weedy check vs all	1.13 vs 1.26**	1.13 vs 1.24**
Weedy check vs Manual Hoeing	1.13 vs 1.35**	1.13 vs 1.32**
Weedy check vs Herbicides	1.13 vs 1.24**	1.13 vs 1.22**
Manual Hoeing vs Herbicides	1.35 vs 1.24**	1.32 vs 1.22**
Pendimethalin+prometryn vs metribuzin	1.25 vs 1.23**	1.24 vs 1.20**

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.

Table 4.5.42 Effect of herbicides on Zn contents (ppm) of *Astragalus* spp. at harvest

Treatments	**2010-11**	**2011-12**
Weedy check	12.51 e	12.13 e
Manual Hoeing	39.71 a	37.02 a
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	33.43 bc	31.04 b
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	36.21 b	34.41 a
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	20.22 d	20.34 c
Metribuzin @ 187.5 g a.i. ha^{-1}	31.64 c	29.59 b
Metribuzin @ 150 g a.i. ha^{-1}	17.54 d	17.03 d
LSD	2.908	2.880
Year Effect	27.32 a	25.94 b
LSD	1.120	
Contrast		
Weedy check vs all	12.51 vs 29.79**	12.13 vs 28.24**
Weedy check vs Manual Hoeing	12.51 vs 39.71**	12.13 vs 37.02**
Weedy check vs Herbicides	12.51 vs 27.81**	12.13 vs 26.48**
Manual Hoeing vs Herbicides	39.71 vs 27.81**	37.02 vs 26.48**
Pendimethalin+prometryn vs metribuzin	29.95 vs 24.59**	28.60 vs 23.31**

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.

All contrast comparisons for Zn concentration in *Astragalus* spp. were significant during both years of experimentation. Maximum Zn concentration in *Astragalus* spp. plant in manual hoeing plot could be due to less number of weed plants and less competition which resulted in higher Zn concentration.

4.5.32 Effect of herbicides on Mn contents (ppm) of *Astragalus* spp. at harvest

The data presented in the Table 4.5.43 indicate the effect of different herbicide treatments on Mn contents of *Astragalus* spp. plant at harvest. The year effect was significant. Results indicate that Mn contents of *Astragalus* spp. plant were significantly affected by the application of different herbicide treatments during both experimental years. Maximum Mn concentration of *Astragalus* spp. plant (68.76 and 66.15 ppm in 2010 and 2011, respectively) was observed in manual hoeing plot which was statistically same with that of pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}. Minimum Mn concentration of *Astragalus* spp. plant (39.36 and 35.19 ppm in 2010 and 2011, respectively) was observed in weedy check plots. Results also showed the significant difference between years regarding the Mn concentration of *Astragalus* spp.

All contrast comparisons for Mn concentration of *Astragalus* spp. were significant during both years of experimentation. Maximum concentration of Mn in *Astragalus* spp. plants in manual hoeing plot and pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1} might be due to less number of weeds in these plots.

4.5.33 Effect of herbicides on Fe contents (ppm) of *Astragalus* spp. at harvest

The data presented in the Table 4.5.44 indicate the effect of different herbicide treatments on the Fe content of *Astragalus* spp. at harvest. The year effect was significant. Results indicate that Fe contents of *Astragalus* spp. were significantly affected by the application of different herbicide treatments in both the years of study. The significantly maximum Fe contents in *Astragalus* spp. plants (91.45 and 88.53 ppm in 2010 and 2011, respectively) were found in manual hoeing plot followed by pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1} during both the years of experimentation.

Minimum Fe contents in *Astragalus* spp. plants (47.37 and 44.05 ppm in 2010 and 2011, respectively) were observed in weedy check plot during both the year of study.

Table 4.5.43 Effect of herbicides on Mn contents (ppm) of *Astragalus* spp. at harvest

Treatments	**2010-11**	**2011-12**
Weedy check	39.36 d	35.19 d
Manual Hoeing	68.76 a	66.15 a
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	63.26 b	62.06 b
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	67.52 a	68.21 a
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	61.33 b	59.89 b
Metribuzin @ 187.5 g a.i. ha^{-1}	62.14 b	61.09 b
Metribuzin @ 150 g a.i. ha^{-1}	52.64 c	50.17 c
LSD	3.073	3.174
Year Effect	59.28 a	57.53 b
LSD	1.106	
Contrast		
Weedy check vs all	39.36 vs 62.61**	35.19 vs 61.26**
Weedy check vs Manual Hoeing	39.36 vs 68.76**	35.19 vs 66.15**
Weedy check vs Herbicides	39.36 vs 61.38**	35.19 vs 60.28**
Manual Hoeing vs Herbicides	68.76 vs 61.38**	66.15 vs 60.28**
Pendimethalin+prometryn vs metribuzin	64.04 vs 57.39**	63.39 vs 55.63**

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.

Table 4.5.44 Effect of herbicides on Fe contents (ppm) of *Astragalus* spp. at harvest

Treatments	**2010-11**	**2011-12**
Weedy check	47.37 g	44.05 f
Manual Hoeing	91.45 a	88.53 a
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	82.30 c	79.50 bc
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	86.77 b	82.12 b
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	62.43 e	64.30 d
Metribuzin @ 187.5 g a.i. ha^{-1}	75.48 d	76.93 c
Metribuzin @ 150 g a.i. ha^{-1}	54.13 f	50.36 e
LSD	3.702	4.091
Year Effect	71.42 a	69.40 b
LSD	1.378	
Contrast		
Weedy check vs all	47.37 vs 75.43**	44.05 vs 73.62**
Weedy check vs Manual Hoeing	47.37 vs 91.45**	44.05 vs 88.53**
Weedy check vs Herbicides	47.37 vs 72.22**	44.05 vs 70.64**
Manual Hoeing vs Herbicides	91.45 vs 72.22**	88.53 vs 70.64**
Pendimethalin+prometryn vs metribuzin	77.17 vs 64.81**	75.31 vs 63.65**

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.

All contrast comparisons for Fe concentration of *Astragalus* spp. were significant during both years of experimentation. Minimum Fe concentration in *Astragalus* spp. plants in weedy check plot was due to more number of weeds present in a unit area.

4.5.34 Effect of herbicides on Mg contents (%) of *Astragalus* spp. at harvest

It is evident from Table 4.5.45 that significant differences in Mg contents of *Astragalus* spp. in different herbicide treatments were observed during both years of experimentation. Results also showed the significant difference between years regarding the Mg concentration of *Astragalus* spp. Maximum Mg concentration of *Astragalus* spp. plant (46.70% and 45.50% in 2010 and 2011, respectively) was observed in manual hoeing plots which was statistically similar with that of pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}. Minimum Mg concentration of *Astragalus* spp. plant (21.54% and 19.68% in 2010 and 2011, respectively) was observed in weedy check plot.

All contrast comparisons for Mg concentration of *Astragalus* spp. were significant during both years of experimentation. Minimum Mg concentration in *Astragalus* spp. plants in weedy check plot was due to continuous growth of weeds till maturity which resulted in maximum biomass and hence lowest Mg concentrations due to dilution. Manual weed control and herbicide application proved to be more effective in controlling *Astragalus* spp. and hence reducing biomass and ultimately maximum Mg concentrations in left over few *Astragalus* spp. plants.

4.5.35 Effect of herbicides on Cu contents (ppm) of *Astragalus* spp. at harvest

The data presented in the Table 4.5.46 indicate the effect of different herbicide treatments on the Cu contents of *Astragalus* spp. at harvest. The year effect was non-significant. Maximum Cu contents (10.09 ppm) of *Astragalus* spp. were recorded in manual hoeing plots followed by that of pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}. Minimum Cu contents (5.09 ppm) of *Astragalus* spp. were recorded in weedy check plots.

Table 4.5.45 Effect of herbicides on Mg (%) of *Astragalus* spp. at harvest

Treatments	**2010-11**	**2011-12**
Weedy check	21.54 e	19.68 e
Manual Hoeing	46.70 a	45.50 a
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	42.95 b	40.40 b
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	43.51 ab	43.75 a
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	37.21 c	35.32 c
Metribuzin @ 187.5 g a.i. ha^{-1}	41.03 b	39.66 b
Metribuzin @ 150 g a.i. ha^{-1}	30.43 d	27.84 d
LSD	3.437	2.442
Year Effect	37.62 a	36.02 b
LSD	1.093	
Contrast		
Weedy check vs all	21.54 vs 40.31**	19.68 vs 38.75**
Weedy check vs Manual Hoeing	21.54 vs 46.70**	19.68 vs 45.50**
Weedy check vs Herbicides	21.54 vs 39.03**	19.68 vs 37.39**
Manual Hoeing vs Herbicides	46.70 vs 39.03**	45.5 vs 37.39**
Pendimethalin+prometryn vs metribuzin	41.22 vs 35.73**	39.82 vs 33.75**

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.

Table 4.5.46 Effect of herbicides on Cu (ppm) of *Astragalus* spp. at harvest

Treatments	**Mean**
Weedy check	5.09 e
Manual Hoeing	10.09 a
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	8.28 c
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	9.24 b
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	6.51 d
Metribuzin @ 187.5 g a.i. ha^{-1}	8.12 c
Metribuzin @ 150 g a.i. ha^{-1}	6.17 d
LSD	0.477
Contrast	
Weedy check vs all	5.09 vs 8.07**
eedy check vs Manual Hoeing	5.09 vs 10.09**
Weedy check vs Herbicides	5.09 vs 7.66**
Manual Hoeing vs Herbicides	10.09 vs 7.66**
Pendimethalin+prometryn vs metribuzin	8.01 vs 7.15**

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.

All contrast comparisons for Cu concentration of *Astragalus* spp. were significant during both years of experimentation. Maximum Cu concentration in *Astragalus* spp.in manual hoeing and pendimethalin+prometryn application at 375 + 500 g a.i. ha^{-1} was mainly due to effective weed control which resulted in less number of weed plants for more Cu uptake.

4.5.36 Effect of herbicides on N Uptake (kg ha^{-1}) by *Astragalus* spp. at harvest

Effect of different weeds control strategies on N uptake by *Astragalus* spp. was significant during both the years of study (Table 4.5.47). The year effect was significant. Significantly maximum N uptake by *Astragalus* spp. (37.66 and 36.48 kg ha^{-1} in 2010 and 2011, respectively) was recorded in weedy check where *Astragalus* spp. was allowed to grow throughout the season followed by that of metribuzin @ 150 g a.i. ha^{-1}. Minimum N uptake by *Astragalus* spp. (3.86 and 3.82 kg ha^{-1} in 2010 and 2011, respectively) was recorded in manual hoeing plots during both the years of study.

All contrast comparisons for N uptake by *Astragalus* spp. were significant during both years of experimentation. Higher N uptake by *Astragalus* spp.at harvest in weedy check plot could be attributed to higher *Astragalus* spp. dry weight. Results of our findings are supported those of by Anjum *et al*. (2007) and Ikram *et al*. (2012) who reported that N uptake by weeds in cotton increased in weedy check and reduced under weed control strategies. Similarly, Gaikwad and Pawar (2003) also reported that in soybean, weeds removed 33.53 kg ha^{-1} of N in weedy plots.

4.5.37 Effect of herbicides on P uptake (kg ha^{-1}) by *Astragalus* spp. at harvest

Effect of herbicides on P uptake by *Astragalus* spp. was significant (Table 4.5.48). The year effect was also significant. The significantly maximum P uptake (5.43 and 6.25 kg ha^{-1} in 2010 and 2011, respectively) was recorded in weedy check plots followed by that of pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}. The minimum P uptake (1.02 and 1.09 kg ha^{-1} in 2010 and 2011, respectively) was recorded in plots with manual hoeing.

All the contrasts comparisons were found significant during both years of experimentation. The significant variation in uptake of P by *Astragalus* spp. in different treatments was observed which might be due to variation in its dry weight. More P uptake by

Table 4.5.47 Effect of herbicides on N uptake (kg ha^{-1}) by *Astragalus* spp. at harvest

Treatments	**2010-11**	**2011-12**
Weedy check	37.66 a	36.48 a
Manual Hoeing	3.86 e	3.82 d
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	6.69 d	8.13 c
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	8.37 bc	9.63 b
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	8.405 bc	9.94 b
Metribuzin @ 187.5 g a.i. ha^{-1}	7.313 cd	8.37 c
Metribuzin @ 150 g a.i. ha^{-1}	9.12 b	10.20 b
LSD	1.113	0.621
Year Effect	11.63 b	12.36 a
LSD	0.340	
Contrast		
Weedy check vs all	37.66 vs 7.36**	36.48 vs 8.35**
eedy check vs Manual Hoeing	37.66 vs 3.86**	36.48 vs 3.82**
Weedy check vs Herbicides	37.66 vs 8.05**	36.48 vs 9.25**
Manual Hoeing vs Herbicides	3.86 vs 8.05**	3.82 vs 9.25**
Pendimethalin+prometryn vs metribuzin	7.82 vs 8.41**	9.23 vs 9.29**

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.

Table 4.5.48 Effect of herbicides on P uptake (kg ha^{-1}) by *Astragalus* spp. at harvest

Treatments	**2010-11**	**2011-12**
Weedy check	5.43 a	6.25 a
Manual Hoeing	1.02 d	1.09 d
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	1.48 c	1.89 c
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	2.01 b	2.44 b
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	1.35 c	1.78 c
Metribuzin @ 187.5 g a.i. ha^{-1}	1.47 c	1.89 c
Metribuzin @ 150 g a.i. ha^{-1}	1.39 c	1.76 c
LSD	0.313	0.288
Year Effect	2.02 b	2.44 a
LSD	0.111	
Contrast		
Weedy check vs all	5.43 vs 1.45**	6.25 vs 1.81**
eedy check vs Manual Hoeing	5.43 vs 1.02**	6.25 vs 1.09**
Weedy check vs Herbicides	5.43 vs 1.54**	6.25 vs 1.95**
Manual Hoeing vs Herbicides	1.02 vs 1.54**	1.09 vs 1.95**
Pendimethalin+prometryn vs metribuzin	1.61 vs 1.43**	2.04 vs 1.83**

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.

Astragalus spp. in weedy check plot than weed control treatments could be due to more number of weeds. These results are in line with those of Gaikwad and Pawar (2003) who reported higher P uptake in weedy plots.

4.5.38 Effect of herbicides on K uptake (kg ha^{-1}by *Astragalus* spp. at harvest

Effect of different weeds control treatments significantly affected the K uptake by *Astragalus* spp. plant during both years of experimentation (Table 4.5.49). The year effect was significant. Data reveal that maximum K uptake by *Astragalus* spp. (28.59 and 28.47 kg ha^{-1} in 2010 and 2011, respectively) was recorded in weedy check plots followed by that of metribuzin @ 150 g a.i. ha^{-1}. Minimum K uptake by *Astragalus* spp. (2.93 and 2.99 kg ha^{-1} in 2010 and 2011, respectively) was recorded in manual hoeing plots during both the years of study.

All the contrast comparisons for K uptake by *Astragalus* spp. were found significant during both years of experimentation. More uptake of K by *Astragalus* spp. could be attributed to higher *Astragalus* spp. dry weight in weedy check plot. Results of our experiments are in line with findings of Anjum *et al*. (2007) who reported maximum K uptake in weedy plots in cotton. Similar results were also reported by Gaikwad and Pawar (2003) in soybean.

4.5.39 Effect of herbicides on Zn Uptake (g ha^{-1}) by *Astragalus* spp. at harvest

Effect of different weeds control treatments on Zn uptake by *Astragalus* spp. was also significant during both the years of study (Table 4.5.50). The year effect was significant. Significantly maximum Zn uptake by *Astragalus* spp. was recorded in weedy check plots (30.77 and 31.31 g ha^{-1} in 2010 and 2011, respectively) followed by that of pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1} during both years of experimentation. Minimum Zn uptake by *Astragalus* spp. plant (8.18 and 8.79 g ha^{-1} in 2010 and 2011, respectively) was recorded in manual hoeing plots.

All the contrast comparisons for Zn uptake by *Astragalus* spp. were found significant during both years of experimentation. Higher Zn uptake by *Astragalus* spp. in weedy check treatment was due to more dry weight of *Astragalus* spp.

Table 4.5.49 Effect of herbicides on K uptake (kg ha^{-1}) by *Astragalus* spp. at harvest

Treatments	**2010-11**	**2011-12**
Weedy check	28.59 a	28.47 a
Manual Hoeing	2.93 e	2.99 d
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	4.97 d	6.02 c
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	6.31 c	7.29 b
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	6.32 c	7.46 b
Metribuzin @ 187.5 g a.i. ha^{-1}	5.44 d	6.26 c
Metribuzin @ 150 g a.i. ha^{-1}	6.96 b	7.79 b
LSD	0.555	0.546
Year Effect	8.79 b	9.47 a
LSD	0.210	
Contrast		
Weedy check vs all	28.59 vs 5.49**	28.47 vs 6.30**
eedy check vs Manual Hoeing	28.59 vs 2.93**	28.47 vs 2.99**
Weedy check vs Herbicides	28.59 vs 6.00**	28.47 vs 6.96**
Manual Hoeing vs Herbicides	2.93 vs 6.00**	2.99 vs 6.96**
Pendimethalin+prometryn vs metribuzin	5.87 vs 6.20**	6.92 vs 7.03^{NS}

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
NS = non-significant

Table 4.5.50 Effect of herbicides on Zn uptake (g ha^{-1}) by *Astragalus* spp. at harvest

Treatments	**2010-11**	**2011-12**
Weedy check	30.77 a	31.31 a
Manual Hoeing	8.18 e	8.79 e
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	12.39 cd	15.99 c
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	16.93 b	20.41 b
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	10.80 cd	12.53 d
Metribuzin @ 187.5 g a.i. ha^{-1}	13.12 c	15.66 c
Metribuzin @ 150 g a.i. ha^{-1}	10.04 de	11.46 d
LSD	2.575	2.036
Year Effect	14.60 b	16.59 a
LSD	0.887	
Contrast		
Weedy check vs all	30.77 vs 11.91**	31.31 vs 14.14**
Weedy check vs Manual Hoeing	30.77 vs 8.18**	31.31 vs 8.79**
Weedy check vs Herbicides	30.77 vs 12.65**	31.31 vs 15.21**
Manual Hoeing vs Herbicides	8.18 vs 12.65**	8.79 vs 15.21**
Pendimethalin+prometryn vs metribuzin	13.37 vs 11.58**	16.31 vs 13.56**

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.

4.5.40 Effect of herbicides on Mn uptake (g ha^{-1}) by *Astragalus* spp. at harvest

The data presented in the Table 4.5.51 indicate the effect of different herbicide treatments on Mn uptake by *Astragalus* spp. at harvest. The year effect was significant. Uptake of Mn by *Astragalus* spp. plants was significantly affected by different weed control treatments during both the years of study. Significantly maximum Mn uptake by was *Astragalus* spp. (89.15 and 98.48 g ha^{-1} in 2010 and 2011, respectively) was recorded in weedy check plots followed by that of pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1} during both years of experimentation. Minimum Mn uptake by *Astragalus* spp. plant (14.64 and 15.25 g ha^{-1} in 2010 and 2011, respectively) was recorded in manual hoeing plots.

All contrast comparisons for Mn uptake by *Astragalus* spp. plants were significant except pendimethalin+prometryn vs metribuzin during both years of experimentation. Higher Mn uptake by *Astragalus* spp. plants in weedy check plot could be attributed to higher dry weight of *Astragalus* spp. plants.

4.5.41 Effect of herbicides on Fe uptake (g ha^{-1}) by *Astragalus* spp. at harvest

The data presented in the Table 4.5.52 indicate the effect of different herbicide treatments on Fe uptake by *Astragalus* spp. at harvest. The year effect was non-significant. Maximum Fe uptake by *Astragalus* spp. (115.21 g ha^{-1}) was recorded in weedy check plots followed by that of pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}. Minimum Fe uptake by *Astragalus* spp. plant (19.95 g ha^{-1}) was recorded in manual hoeing plots.

All the contrasts for Fe uptake by *Astragalus* spp. were found significant during both years of experimentation. Low Fe uptake by *Astragalus* spp. plants in manual hoeing and other herbicide treated plots could be attributed to lower dry weight of *Astragalus* spp. plants.

Table 4.5.51 Effect of herbicides on Mn uptake (g ha^{-1}) by *Astragalus* spp. at harvest

Treatments	**2010-11**	**2011-12**
Weedy check	89.15 a	98.48 a
Manual Hoeing	14.64 e	15.25 d
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	24.83 d	30.30 c
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	33.52 b	38.04 b
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	31.75 bc	38.02 b
Metribuzin @ 187.5 g a.i. ha^{-1}	27.12 cd	30.79 c
Metribuzin @ 150 g a.i. ha^{-1}	29.63 bcd	34.29 bc
LSD	5.496	4.542
Year Effect	35.81 b	40.74 a
LSD	1.830	
Contrast		
Weedy check vs all	89.15 vs 26.92**	98.48 vs 31.12**
eedy check vs Manual Hoeing	89.15 vs 14.64**	98.48 vs 15.25**
Weedy check vs Herbicides	89.15 vs 29.37**	98.48 vs 34.29**
Manual Hoeing vs Herbicides	14.64 vs 29.37**	15.25 vs 34.29**
Pendimethalin+prometryn vs metribuzin	30.03 vs 28.38^{NS}	35.45 vs 32.54^{NS}

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
NS = non-significant

Table 4.5.52 Effect of herbicides on Fe uptake (g ha^{-1}) by *Astragalus* spp. at harvest

Treatments	**Mean**
Weedy check	115.21 a
Manual Hoeing	19.95 d
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	35.50 c
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	44.44 b
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	36.47 c
Metribuzin @ 187.5 g a.i. ha^{-1}	35.81 c
Metribuzin @ 150 g a.i. ha^{-1}	32.39 c
LSD	4.336
Contrast	
Weedy check vs all	115.21 vs 34.09**
eedy check vs Manual Hoeing	115.21 vs 19.95**
Weedy check vs Herbicides	115.21 vs 36.92**
Manual Hoeing vs Herbicides	19.95 vs 36.92**
Pendimethalin+prometryn vs metribuzin	38.80 vs 34.10**

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.

4.5.42 Effect of herbicides on Mg uptake (kg ha^{-1}) by *Astragalus* spp. at harvest

The data presented in the Table 4.5.53 indicate the effect of different herbicide treatments on Mg uptake by *Astragalus* spp. at harvest. Uptake of Mg by *Astragalus* spp. was significantly affected by the application of different weed control treatments during both the years of study. The year effect was significant and higher uptake was noted during study year 2011-12. Significantly maximum Mg uptake by *Astragalus* spp. (4.97 and 5.39 kg ha^{-1} in 2010 and 2011, respectively) was recorded in weedy check plots followed by that of pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1} during both years of experimentation. Minimum Mg uptake by *Astragalus* spp. plant (1.01 and 1.03 kg ha^{-1} in 2010 and 2011, respectively) was recorded in manual hoeing plots

All contrast comparisons for Mg uptake by *Astragalus* spp. plants were significant except pendimethalin+prometryn vs metribuzin during both years of experimentation. Higher Mg uptake by *Astragalus* spp. plants in weedy check plot could be attributed to higher dry weight of *Astragalus* spp. plants.

4.5.43 Effect of herbicides on Cu uptake (g ha^{-1}) by *Astragalus* spp. at harvest

The data presented in the Table 4.5.54 indicate the effect of different weeds control measurements on Cu uptake by *Astragalus* spp. at the harvest of chickpea. The year effect was non-significant. Data indicate that all the treatments significantly affected the Cu uptake of *Astragalus* spp. Maximum Cu uptake by *Astragalus* spp. (12.82 g ha^{-1}) was recorded in weedy check plots followed by that of pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}. Minimum Cu uptake by *Astragalus* spp. plant (2.24 g ha^{-1}) was recorded in manual hoeing plots.

All contrast comparisons for Cu uptake by *Astragalus* spp. plants were significant during both years of experimentation except pendimethalin+prometryn vs metribuzin. Higher Cu uptake by *Astragalus* spp. plants in weedy check plot could be attributed to higher dry weight of *Astragalus* spp. plants.

Table 4.5.53 Effect of herbicides on Mg uptake (kg ha^{-1}) by *Astragalus* spp. at harvest

Treatments	**2010-11**	**2011-12**
Weedy check	4.97 a	5.39 a
Manual Hoeing	1.01 e	1.03 e
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	1.62 d	2.06 cd
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	2.15 b	2.45 b
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	1.87 c	2.30 bc
Metribuzin @ 187.5 g a.i. ha^{-1}	1.76 cd	2.03 cd
Metribuzin @ 150 g a.i. ha^{-1}	1.64 d	1.98 d
LSD	0.202	0.299
Year Effect	2.14 b	2.46 a
LSD	0.941	
Contrast		
Weedy check vs all	4.97 vs 1.67**	5.39 vs 1.97**
eedy check vs Manual Hoeing	4.97 vs 1.0.01**	5.39 vs 1.03**
Weedy check vs Herbicides	4.97. vs 1.81**	5.39 vs 2.16**
Manual Hoeing vs Herbicides	1.01 vs 1.81**	1.03 vs 2.16**
Pendimethalin+prometryn vs metribuzin	1.88 vs 1.70^{NS}	2.27 vs 2.01^{NS}

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
NS = non-significant

Table 4.5.54 Effect of herbicides on Cu uptake (g ha^{-1}) by *Astragalus* spp. at harvest

Treatments	**Mean**
Weedy check	12.82 a
Manual Hoeing	2.24 d
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	3.63 c
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	4.87 b
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	3.74 c
Metribuzin @ 187.5 g a.i. ha^{-1}	3.80 c
Metribuzin @ 150 g a.i. ha^{-1}	3.83 c
LSD	0.515
Contrast	
Weedy check vs all	12.82 vs 3.69**
eedy check vs Manual Hoeing	12.82 vs 3.24**
Weedy check vs Herbicides	12.82 vs 3.97**
Manual Hoeing vs Herbicides	2.24 vs 3.97**
Pendimethalin+prometryn vs metribuzin	4.08 vs 3.82*

Means not sharing same letter were significantly different at 5% probability level.
* and ** indicate significance at $p \leq 0.05$ and at $p \leq 0.01$ level of probability, respectively.

4.5.44 Effect of herbicides on total weed density (m^{-2}) at harvest

Data regarding total weed density of *E. dracunculoides* and *Astragalus* spp. at harvest revealed that different weeds control strategies significantly affected density of both weeds (Table 4.5.55). The year effect was non-significant. Maximum total weed density (150.75 m^{-2}) was recorded in weedy check plots followed by that of pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}. Significantly minimum (10.75 m^{-2}) total weed density was observed with manual hoeing.

All contrast comparisons except pendimethalin+prometryn vs metribuzin were significant. Our findings are supported from the results of Bhalla *et al*. (1998) and Marwat *et al*. (2004) who reported maximum weeds control in chickpea with application of Stomp 330-EC (pendimethalin). Similarly, Singh *et al*. (2009) recorded lowest weed population in alachlor treated plots followed by pendimethalin and simazine in rainfed maize.

4.5.45 Effect of herbicides on total weed dry weight (m^{-2}) at harvest

Data regarding total dry weight of *E. dracunculoides* and *Astragalus* spp. at harvest revealed that different weeds control treatments significantly affected the dry weight of *Astragalus* spp. (Table 4.5.56). The year effect was significant. Maximum total weed dry weight (611.81 and 715.20 m^{-2} in 2010 and 2011, respectively) was recorded in weedy check plots followed by that of pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1} during first year only. Significantly minimum (80.03 and 81.19 m^{-2} in 2010 and 2011, respectively) total weed dry weight was observed with manual hoeing during both the years of study.

All contrast comparisons were significant. These results are in accordance with those of Chattha *et al.* (2007) who found maximum reduction in dry biomass of different weeds with different herbicides application. Maximum dry weight of *Astragalus* spp. was recorded in weedy check where no herbicide was applied all through the crop growing period. These results are almost in agreement with those of Giri *et al*. (2006) and Oad *et al*. (2007a). They recorded maximum dry weight of weeds in cotton in the weedy control treatment.

Table 4.5.55 Effect of herbicides on total weed density (m^{-2}) at harvest

Treatments	**Mean**
Weedy check	150.75 a
Manual Hoeing	10.75 e
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	20.88 d
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	26.25 c
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	28.00 bc
Metribuzin @ 187.5 g a.i. ha^{-1}	20.58 d
Metribuzin @ 150 g a.i. ha^{-1}	30.71 b
LSD	3.477
Contrast	
Weedy check vs all	150.75 vs 22.86**
eedy check vs Manual Hoeing	150.75 vs 10.75**
Weedy check vs Herbicides	150.75 vs 25.28**
Manual Hoeing vs Herbicides	10.75 vs 25.28**
Pendimethalin+prometryn vs metribuzin	25.04 vs 25.65^{NS}

Means not sharing same letter were significantly different at 5% probability level.
* and ** indicate significance at $p \leq 0.05$ and at $p \leq 0.01$ level of probability, respectively.
^{NS} = non-significant

Table 4.5.56 Effect of herbicides on total weed dry weight (g m^{-2}) at harvest

Treatments	**2010-11**	**2011-12**
Weedy check	611.81 a	715.20 a
Manual Hoeing	80.03 d	81.19 f
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	144.47 c	135.49 e
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	179.15 b	164.88 cd
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	181.43 b	179.17 bc
Metribuzin @ 187.5 g a.i. ha^{-1}	153.48 c	150.17 de
Metribuzin @ 150 g a.i. ha^{-1}	190.42 b	194.11 b
LSD	15.097	16.548
Year Effect	220.11 b	231.46 a
LSD	5.626	
Contrast		
Weedy check vs all	611.81 vs 154.83**	715.20 vs 150.84**
Weedy check vs Manual Hoeing	611.81 vs 80.03**	715.20 vs 81.19**
Weedy check vs Herbicides	611.81 vs 169.79**	715.20 vs 164.76**
Manual Hoeing vs Herbicides	80.03 vs 169.79**	81.19 vs 164.76**
Pendimethalin+prometryn vs metribuzin	168.35 vs 171.95**	159.85 vs 172.14**

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.

Chickpea parameters

4.5.46 Chlorophyll contents (mg g^{-1}) at 40, 60 and 80 DAS

Tables 4.5.57, 4.5.58 and 4.5.59 indicate the effects of different weed control strategies on chlorophyll contents of chickpea at 40, 60 and 80 DAS, respectively. It is obvious from the data that different weeds control methods significantly affected the chickpea plant chlorophyll contents at different intervals. The year effect for 40 DAS was significant. Maximum chlorophyll contents of chickpea at 40 DAS (1.27 and 1.22 mg g^{-1} in 2010 and 2011, respectively) were recorded in plants of manual hoeing which was statistically similar with that of pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1} during study year 2011-12. Significantly minimum (0.79 and 0.73 mg g^{-1} in 2010 and 2011, respectively) chlorophyll contents were recorded in weedy check plots during both the year of study. The year effect for 60 DAS was non-significant. While at 60 DAS maximum chickpea chlorophyll contents (1.62 mg g^{-1}) were recorded in plots treated with pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1} which was not different statistically with that of manual hoeing plots. Significantly minimum (1.05 mg g^{-1}) chlorophyll contents were recorded in plants of weedy check. The year effect for 80 DAS was non-significant. Similarly at 80 DAS maximum chickpea plant chlorophyll contents (0.94 mg g^{-1}) were measured in manually hoeing plots followed by that of pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}. Minimum chickpea chlorophyll contents at 80 DAS (0.60 mg g^{-1}) were measured in plants of weedy check which was statistically similar with those of pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1} and metribuzin @ 187.5 g a.i. ha^{-1}.

All the contrast comparisons at 40, 60 and 80 DAS except pendimethalin+prometryn vs metribuzin at 80 DAS were significant. Lower chlorophyll contents in plants of weedy check and herbicide treated plots were due to presence of weeds which competed for nutrients and light. Our results are supported by the finding of Yadav *et al.* (2007) who stated that chlorophyll contents decreased at higher doses of herbicides (pendimethalin, fluchloralin and metolachlor) and were at par with weedy check.

Table 4.5.57 Effect of herbicides on chickpea chlorophyll contents (mg g^{-1}) at 40 DAE

Treatments	**2010-11**	**2011-12**
Weedy check	0.79 f	0.73 d
Manual Hoeing	1.27 a	1.22 a
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	1.02 c	0.96 b
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	1.15 b	1.18 a
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	1.05 c	0.99 b
Metribuzin @ 187.5 g a.i. ha^{-1}	0.88 e	0.83 c
Metribuzin @ 150 g a.i. ha^{-1}	0.96 d	1.00 b
LSD	0.066	0.060
Year Effect	1.02 a	0.98 b
LSD	0.024	
Contrast		
Weedy check vs all	0.79 vs 1.06**	0.73 vs 1.03**
Weedy check vs Manual Hoeing	0.79 vs 1.27**	0.73 vs 1.22**
Weedy check vs Herbicides	0.79 vs 1.01**	0.73 vs 0.99**
Manual Hoeing vs Herbicides	1.27 vs 1.01**	1.22 vs 0.99**
Pendimethalin+prometryn vs metribuzin	1.07 vs 0.92**	1.04 vs 0.92**

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
DAE indicates days after emergence.

Table 4.5.58 Effect of herbicides on chickpea chlorophyll contents (mg g^{-1}) at 60 DAE

Treatments	**Mean**
Weedy check	1.05 f
Manual Hoeing	1.62 a
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	1.16 e
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	1.62 a
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	1.51 b
Metribuzin @ 187.5 g a.i. ha^{-1}	1.27 d
Metribuzin @ 150 g a.i. ha^{-1}	1.41 c
LSD	0.042
Contrast	
Weedy check vs all	1.05 vs 1.43**
Weedy check vs Manual Hoeing	1.05 vs 1.62**
Weedy check vs Herbicides	1.05 vs 1.39**
Manual Hoeing vs Herbicides	1.62 vs 1.39**
Pendimethalin+prometryn vs metribuzin	1.43 vs 1.34*

Means not sharing same letter were significantly different at 5% probability level.
* and ** indicate significance at $p \leq 0.05$ and at $p \leq 0.01$ level of probability, respectively.
DAE indicates days after emergence.

Table 4.5.59 Effect of herbicides on chickpea chlorophyll contents (mg g^{-1}) at 80 DAE

Treatments	**Mean**
Weedy check	0.60 e
Manual Hoeing	0.94 a
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	0.64 e
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	0.88 b
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	0.82 c
Metribuzin @ 187.5 g a.i. ha^{-1}	0.65 e
Metribuzin @ 150 g a.i. ha^{-1}	0.72 d
LSD	0.053
Contrast	
Weedy check vs all	0.60 vs 0.78**
Weedy check vs Manual Hoeing	0.60 vs 0.94**
Weedy check vs Herbicides	0.60 vs 0.74**
Manual Hoeing vs Herbicides	0.94 vs 0.74**
Pendimethalin+prometryn vs metribuzin	0.78 vs 0.69^{NS}

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
DAE indicates days after emergence.
NS= non-significant

4.5.47 Plant height (cm)

Plant height at maturity is a key function of the genetic, nutritional and environmental factors. Different herbicide application significantly affected the chickpea plant height (Table 4.5.60). The year effect was non-significant. Tallest plants (70.39) were measured in plots with manual hoeing followed by that of pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}. Shortest chickpea plants (50.67) were observed in pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1} treatment which was not different statistically with that of weedy chick plots. Later was followed by that of metribuzin @ 150 g a.i. ha^{-1}.

Application of different herbicides as well as weed free treatment showed better plant height of chickpea as compared to weedy check treatment. Maximum chickpea plant height in manual hoeing plots could be due to the reason that weeds were controlled effectively in these plots through manual hoeing in comparison with weedy check plot throughout the cropping season and chickpea plants attain maximum height due to no or less weed-crop competition for light, space and nutrients. All contrast comparisons for plant height of chickpea were significant except pendimethalin+prometryn vs metribuzin. Our findings are comparable with those of Aslam *et al*. (2007) in chickpea crop. Similarly Lyon and Wilson (2005) and Hassan and Khan (2007) reported reduction in plant height of chickpea with application of imazethapyr and metribuzin, respectively.

4.5.48 Primary branches

Data regarding effect of different weed control methods on number of primary branches of chickpea is presented in Table 4.5.61. Various weed control strategies significantly affected the number of primary branches of chickpea during both years of experimentation. The year effect was significant. Maximum chickpea primary branches (5.15 and 5.00 in 2010 and 2011, respectively) were observed in plots with manual hoeing. These results were statistically similar with those of pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1} during both years of experimentation. Minimum chickpea primary branches (2.50 and 2.40 in 2010 and 2011, respectively) were recorded in weedy check plot.

Table 4.5.60 Effect of herbicides on chickpea plant height (cm) at harvest

Treatments	**Mean**
Weedy check	50.71 e
Manual Hoeing	70.39 a
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	50.67 e
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	65.89 b
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	60.62 c
Metribuzin @ 187.5 g a.i. ha^{-1}	54.91 d
Metribuzin @ 150 g a.i. ha^{-1}	57.25 d
LSD	2.947
Contrast	
Weedy check vs all	50.71 vs 59.96**
Weedy check vs Manual Hoeing	50.71 vs 70.39**
Weedy check vs Herbicides	50.71 vs 57.86**
Manual Hoeing vs Herbicides	70.39 vs 57.86**
Pendimethalin+prometryn vs metribuzin	59.06 vs 56.08^{NS}

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
NS= non-significant

Table 4.5.61 Effect of herbicides on number of primary branches per plant of chickpea

Treatments	**2010-11**	**2011-12**
Weedy check	2.50 d	2.40 d
Manual Hoeing	5.15 a	5.00 a
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	3.25 c	3.05 c
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	4.90 a	4.75 a
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	4.45 b	4.10 b
Metribuzin @ 187.5 g a.i. ha^{-1}	3.45 c	3.25 c
Metribuzin @ 150 g a.i. ha^{-1}	4.15 b	3.90 b
LSD	0.393	0.459
Year Effect	3.97 a	3.77 b
LSD	0.150	
Contrast		
Weedy check vs all	2.50 vs 4.23**	2.40 vs 4.01**
Weedy check vs Manual Hoeing	2.50 vs 5.15**	2.40 vs 5.00**
Weedy check vs Herbicides	2.50 vs 4.04**	2.40 vs 3.81**
Manual Hoeing vs Herbicides	5.15 vs 4.04**	5.00 vs 3.81**
Pendimethalin+prometryn vs metribuzin	4.20 vs 3.80^{NS}	3.97 vs 3.58^{NS}

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
NS= non-significant

Reduction in number of primary branches per plant of chickpea with application of pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1} was due to insufficient weed control. Reduction in number of primary branches per plant of chickpea above aforesaid dose was because of crop injury due to higher dose of herbicide. Table 4.5.59 showed that at higher dose of both herbicides, chlorophyll contents were least and were statistically at par with that of weedy check. All contrast comparisons for primary branches per plant of chickpea were significant except pendimethalin+prometryn vs metribuzin. Results of our experiment are in line with the findings of Tanveer *et al*. (2010). More chickpea primary branches with manual hoeing and herbicide application of pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1} might be due to better efficacy of herbicide against weeds and less suppressive effect on chickpea crop.

4.5.49 Secondary branches

Significant effect of different weed control measurements on number of secondary branches per plant of chickpea was observed during both experimental years (Table 4.5.62). The year effect was significant. It is evident from the data presented in table that maximum chickpea secondary branches (23.15) were recorded with application of pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}, which was statistical at par (22.35) with those of manual hoeing and pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1} plots during experimental year 2010-11. While, during crop season 2011-12 maximum chickpea secondary branches (22.10) were recorded in manual hoeing plots, statistically similar (22.00) with that of the pendimethalin+prometryn application at 375 + 500 g a.i. ha^{-1}. Minimum secondary branches per plant of chickpea (14.25 and 13.60 in 2010 and 2011, respectively) were recorded in weedy check plots.

Reduction in secondary branches of chickpea below pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1} was possibly due to less weed control, which increased the weed-crop competition for space, light, moisture and nutrients. Whereas, decreased number of chickpea secondary branches with pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1} might be due to the crop injury by over dose application. Table 4.5.59 showed that at higher dose of both herbicides, chlorophyll contents were least and were statistically at par with that of weedy check. All contrast comparisons for secondary branches per plant of chickpea were

Table 4.5.62 Effect of herbicides on number of secondary branches per plant of chickpea

Treatments	**2010-11**	**2011-12**
Weedy check	14.25 e	13.60 d
Manual Hoeing	22.35 a	22.10 a
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	16.15 de	15.20 d
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	23.15 a	22.00 a
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	21.05 ab	19.15 b
Metribuzin @ 187.5 g a.i. ha^{-1}	17.95 cd	16.00 cd
Metribuzin @ 150 g a.i. ha^{-1}	19.70 bc	18.35 bc
LSD	2.159	2.749
Year Effect	19.22	18.05
LSD	0.877	
Contrast		
Weedy check vs all	14.25 vs 20.06**	13.60 vs 18.80**
Weedy check vs Manual Hoeing	14.25 vs 22.35**	13.60 vs 22.10**
Weedy check vs Herbicides	14.25 vs 19.60**	13.60 vs 18.14**
Manual Hoeing vs Herbicides	22.35 vs 19.60**	22.10 vs 18.14**
Pendimethalin+prometryn vs metribuzin	20.12 vs 18.83^{NS}	18.78 vs 17.18^{NS}

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
^{NS}= non-significant

significant except pendimethalin+prometryn vs metribuzin. Similar results were reported by Tanveer *et al.* (2010) who observed decreased plant growth due to plant injury caused by over dose application of herbicide. Singh and Tewari (1992) also found similar results in pigeon pea

4.5.50 Pods per plant of chickpea

The data presented in the Table 4.5.63 show the effect of different herbicide treatments on the number of pods per plant of chickpea. Number of pods per plant of chickpea was considerably affected by different weed control methods during both the years of study. The year effect was significant. Highest number of pods per plant of chickpea (65.04 and 62.53 in 2010 and 2011, respectively) was recorded in manual hoeing plots, which was statistically similar with that of pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}. Minimum pods per plant of chickpea (31.03 and 27.53 in 2010 and 2011, respectively) were recorded in weedy check plots which were not different statistically with those of pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1} during both the years of study.

Lesser number of pods per plant of chickpea in weedy check plot might be due to the higher number of weeds present in this plot that severely competed with chickpea crop for light, space, moisture and nutrients, which lead to stunted plant growth and ultimately pods setting per plant of chickpea. All contrast comparisons for pods per plant of chickpea were significant except pendimethalin+prometryn vs metribuzin. Our results are in line with those of Singh and Singh (1998) and Aslam *et al.* (2007) who exhibited lesser pods per plant of chickpea in weedy check plots. Similar results were also reported by Hassan and Khan (2007) and Mohammad *et al.* (2011) who reported that maximum number of pods per plant of chickpea was gained with manual hoeing and in plots treated with metribuzin.

4.5.51 Seeds per pod of chickpea

The data presented in the Table 4.5.64 show the effect of different herbicides application on the number of seeds per pod of chickpea. The year effect was non-significant. Results reveal that manual hoeing treatment gained maximum number of seeds per pod (2.32) which was not different statistically with that of pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}. Significantly minimum seeds per pod of chickpea (1.37) were recorded in

Table 4.5.63 Effect of herbicides on number of chickpea pods per plant

Treatments	**2010-11**	**2011-12**
Weedy check	31.03 d	27.53 d
Manual Hoeing	65.04 a	62.53 a
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	35.57 cd	31.47 d
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	60.16 a	57.49 a
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	50.30 b	48.92 b
Metribuzin @ 187.5 g a.i. ha^{-1}	39.82 c	37.94 c
Metribuzin @ 150 g a.i. ha^{-1}	46.01 b	42.15 c
LSD	5.552	5.794
Year Effect	46.85 a	44.01 b
LSD	2.057	
Contrast		
Weedy check vs all	31.03 vs 49.48**	27.53 vs 46.75**
Weedy check vs Manual Hoeing	31.03 vs 65.04**	27.53 vs 62.53**
Weedy check vs Herbicides	31.03 vs 46.372**	27.53 vs 43.59**
Manual Hoeing vs Herbicides	65.04 vs 46.372**	62.53 vs 43.59**
Pendimethalin+prometryn vs metribuzin	48.68 vs 42.92^{NS}	45.96 vs 40.05^{NS}

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
^{NS}= non-significant

Table 4.5.64 Effect of herbicides on number of chickpea seeds per pod

Treatments	**Mean**
Weedy check	1.37 c
Manual Hoeing	2.32 a
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	1.72 b
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	2.17 a
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	1.85 b
Metribuzin @ 187.5 g a.i. ha^{-1}	1.70 b
Metribuzin @ 150 g a.i. ha^{-1}	1.75 b
LSD	0.243
Contrast	
Weedy check vs all	1.37 vs 1.92**
Weedy check vs Manual Hoeing	1.37 vs 2.32**
Weedy check vs Herbicides	1.37 vs 1.83**
Manual Hoeing vs Herbicides	2.32 vs 1.83**
Pendimethalin+prometryn vs metribuzin	1.91 vs 1.73^{NS}

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
NS= non-significant

weedy check plots.

All contrast comparisons for seeds per pod of chickpea were significant. The improvement in number of seeds per pod of chickpea under different weed control treatments could be attributed to comparative reduction in weed growth which in turn improved the crop growth and ultimately number of seeds per pod of chickpea. These results are quite in collaboration with those of Khan *et al*. (2011). Similar results were also reported by Aslam *et al*. (2007) who observed more number of seeds per pod of chickpea in hand weeding plot followed by that of pendimethalin application.

4.5.52 100-seed weight (g)

Mean 100-seed weight is an important yield contributing factor, which plays an influential role in showing the potential of a crop. It was found that different weed control strategies significantly affected the 100-seed weight of chickpea during both years of experimentation (Table 4.5.65). The year effect was significant. Heavier chickpea seeds (23.44 g) were produced by plants of manual hoeing plots which were statistically similar with that of pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1} during 2010-11 and in second year maximum 100-seed weight (22.29 g) was recorded in manual plots which was statistically similar with those of pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1} and pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}. Lighter chickpea seeds (17.90 and 16.70 g in 2010 and 2011, respectively) were produced in weedy check plants.

All contrast comparisons except pendimethalin+prometryn vs metribuzin in second year was significant. Manual hoeing showed significantly better 100-seed weight of chickpea as compared to weedy check and other herbicide application treatments during both the years of study. This might be due to adequate weed control during the cropping period, which provided maximum moisture and nutrients for healthy plant growth and hence pod formation which ultimately led towards better seed weight. Decrease in 100-seed weight with herbicide application and in weedy check plot was due to the presence of weed plants which competed with main crop. Our findings are in line with those of Aslam *et al*. (2007). Who reported maximum 100-seed weight of chickpea in manual hoeing plots followed by herbicide treated plots. Similar results have also been discussed by Khaliq *et al*. (2002) and Ashrafi (2009) in mungbean and wheat, respectively.

Table 4.5.65 Effect of herbicides on 100-seed (g) weight of chickpea

Treatments	**2010-11**	**2011-12**
Weedy check	17.90 d	16.70 e
Manual Hoeing	23.44 a	22.29 a
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	19.86 bc	18.13 de
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	23.06 a	21.74 ab
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	21.26 b	20.68 abc
Metribuzin @ 187.5 g a.i. ha^{-1}	19.25 cd	18.44 cde
Metribuzin @ 150 g a.i. ha^{-1}	20.70 bc	19.60 bcd
LSD	1.548	2.389
Year Effect	20.78 a	19.65 b
LSD	0.708	
Contrast		
Weedy check vs all	17.90 vs 21.26**	16.70 vs 20.15**
Weedy check vs Manual Hoeing	17.90 vs 23.44**	16.70 vs 22.29**
Weedy check vs Herbicides	17.90 vs 20.83*	16.70 vs 19.71**
Manual Hoeing vs Herbicides	23.44 vs 20.83**	22.29 vs 19.71**
Pendimethalin+prometryn vs metribuzin	21.39 vs 19.98**	20.18 vs 19.02^{NS}

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability, respectively.
^{NS}= non-significant

4.5.53 Seed yield of chickpea (kg ha^{-1})

Chickpea seed yield was significantly affected by different weed control practices during both years of study (Table 4.5.66). The year effect was significant. Maximum chickpea seed yield (2376.30 and 2175.70 kg ha^{-1} in 2010 and 2011, respectively) was recorded in manual hoeing plots which was statistically similar with that of pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1} followed by pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1} during first year while in second year it was not different statistically from those of pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1} and metribuzin @ 150 g a.i. ha^{-1}. Minimum chickpea seed yield (1429.90 and 1371.30 kg ha^{-1} in 2010 and 2011, respectively) was recorded in weedy check plots. Manual hoeing resulted in 58-66% yield increase over weedy check during both the years of study. All the other herbicides increased yield from 20 to 61% over weedy check.

All contrast comparisons except pendimethalin+prometryn vs metribuzin were significant. Lowest chickpea seed yield in weedy check plot was due to lowest yield contributing factors such as pods per plant, seed per pod and 100-seed weight of chickpea. These results are in line with the findings of Hassan and Khan (2007) who exhibited minimum seed yield of chickpea in weedy chick plot. Highest chickpea seed yield in manual hoeing plot and those treated with pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1} was due to improved yield components of chickpea plants. Similar results were reported by Lyon and Wilson (2005) and Mohammadi *et al.* (2005). They reported higher chickpea seed yield in weed free plot as compared to weed infested plots.

4.5.54 Biological yield of chickpea (kg ha^{-1})

Weed control by either method reveal significant differences among one another during both years of experimentation (Table 4.5.67). The year effect was significant. Perusal of data revealed that maximum biological yield of chickpea (6600.90 and 5960.60 kg ha^{-1} in 2010 and 2011, respectively) was observed in manual hoeing plots which was followed by that of pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}, metribuzin @ 150 g a.i. ha^{-1} and pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1} during study year 2011-12. Lowest

Table 4.5.66 Effect of herbicides on seed yield (kg ha^{-1}) of chickpea

Treatments	**2010-11**	**2011-12**	**Percent yield increase over weedy check 2010-11**	**Percent yield increase over weedy check 2011-12**
Weedy check	1429.90 f	1371.30 e	--	--
Manual Hoeing	2376.30 a	2175.70 a	66.19	58.66
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	1811.80 e	1651.70 d	26.71	20.45
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	2306.40 ab	2145.90 a	61.30	56.49
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	2180.70 bc	1905.10 bc	52.51	38.93
Metribuzin @ 187.5 g a.i. ha^{-1}	1917.30 de	1760.40 cd	34.09	28.37
Metribuzin @ 150 g a.i. ha^{-1}	2075.10 cd	2008.70 ab	45.12	46.48
LSD	166.58	172.63		
Year Effect	2013.9 a	1859.8 b		
LSD	58.800			
Contrast				
Weedy check vs all	1429.90 vs 2111.27**	1371.30 vs 1941.25**		
Weedy check vs Manual Hoeing	1429.90 vs 2376.30**	1371.30 vs 2175.70**		
Weedy check vs Herbicides	1429.90 vs 2058.26**	1371.30 vs 1894.36**		
Manual Hoeing vs Herbicides	2376.30 vs 2058.26**	2175.70 vs 1894.36**		
Pendimethalin+prometryn vs metribuzin	2099.63 vs 1996.20^{NS}	1900.90 vs 1884.55^{NS}		

Means not sharing same letter were significantly different at 5% probability level.
** indicate significance at $p \leq 0.01$ level of probability.
^{NS}= non-significant

Table 4.5.67 Effect of herbicides on biological yield (kg ha^{-1}) of chickpea

Treatments	**2010-11**	**2011-12**
Weedy check	5106.10 d	5278.00 c
Manual Hoeing	6600.90 a	5960.60 a
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	6251.40 bc	5453.50 bc
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	6404.90 b	5871.80 a
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	6227.70 c	5602.20 b
Metribuzin @ 187.5 g a.i. ha^{-1}	6180.30 c	5500.50 b
Metribuzin @ 150 g a.i. ha^{-1}	6291.60 bc	5907.10 a
LSD	166.26	208.78
Year Effect	6151.8 a	5653.4 b
LSD	69.364	
Contrast		
Weedy check vs all	5106.10 vs 6326.13**	5278.00 vs 715.95**
Weedy check vs Manual Hoeing	5106.10 vs 6600.90**	5278.0 vs 5960.60**
Weedy check vs Herbicides	5106.10 vs 6271.18**	5278.0 vs 5667.02**
Manual Hoeing vs Herbicides	6600.9 vs 6271.18**	5960.60 vs 5667.02**
Pendimethalin+prometryn vs metribuzin	6294.67 vs 6235.95*	5642.50 vs 5703.80^{NS}

Means not sharing same letter were significantly different at 5% probability level.
* and ** indicate significance at $p \leq 0.05$ and at $p \leq 0.01$ level of probability, respectively.
^{NS}= non-significant

chickpea biological yield (5106.10 and 527.00 kg ha^{-1} in 2010 and 2011, respectively) was noted in weedy check plots during both the experimental years.

All contrast comparisons were significant. More chickpea biological yield recorded with hand weeding and herbicide treated plot than that of weedy check was certainly due to effective weed control in those plots which minimize the competition of chickpea with weeds. More plant height, number of primary and secondary branches also contributed in increasing biological yield of chickpea. These results are in agreement with those of Chattha *et al* (2007) who found an increasing trend in mungbean biomass with methabenzthiazuron application as compared to weedy check treatment.

4.5.55 Harvest index (%)

Accumulation of photosynthates in the economic parts varied a great deal by different weeds control measurements during both years of experimentation (Table 4.5.68). The year effect was non-significant. It reveals that maximum harvest index of chickpea (36.55%) was recorded in manual hoeing plots which was statistically similar with that of pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1} followed by pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}. Significantly minimum harvest index of chickpea (26.98%) was observed in weedy chick plot.

All contrast comparisons except pendimethalin+prometryn vs metribuzin were significant. Highest percentage of harvest index in hand weeding and plot treated with pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1} was due to more economic yield (kg ha^{-1}). These results are in line with those of Chattha *et al.* (2007) who found a significant difference in harvest index of mungbean by different weed control practices with maximum value in hand weeding treatment.

4.5.56 Crude protein (%)

Seed protein contents are one of the important quality parameters. Data showed that various weeds control method significantly affected crude protein content of chickpea seed (Table 4.5.72). The year effect was significant. Maximum seed protein contents of chickpea (23.35% and 25.15% in 2010 and 2011, respectively) were observed in plot where weeds were controlled by the application of pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1} which

Table 4.5.68 Effect of herbicides on harvest index (%) of chickpea

Treatments	**Mean**
Weedy check	26.98 e
Manual Hoeing	36.55 a
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	29.62 d
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	36.00 ab
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	34.52 bc
Metribuzin @ 187.5 g a.i. ha^{-1}	31.53 d
Metribuzin @ 150 g a.i. ha^{-1}	33.50 c
LSD	1.935
Contrast	
Weedy check vs all	26.98 vs 33.62**
Weedy check vs Manual Hoeing	26.98 vs 36.55**
Weedy check vs Herbicides	26.98 vs 33.03**
Pendimethalin+prometryn vs metribuzin	36.55 vs 33.03**
Pendimethalin+prometryn vs metribuzin	33.38 vs 32.52^{NS}

Means not sharing same letter were significantly different at 5% probability level.
* and ** indicate significance at $p \leq 0.05$ and at $p \leq 0.01$ level of probability, respectively.
^{NS}= non-significant

Table 4.5.69 Effect of herbicides on crude protein (%) of chickpea seed

Treatments	**2010-11**	**2011-12**
Weedy check	20.85 b	21.20 c
Manual Hoeing	23.19 a	24.52 ab
Pendimethalin+prometryn at 450 + 600 g a.i. ha^{-1}	21.59 ab	22.07 c
Pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1}	23.35 a	25.15 a
Pendimethalin+prometryn at 300 + 400 g a.i. ha^{-1}	22.16 ab	23.12 bc
Metribuzin @ 187.5 g a.i. ha^{-1}	21.34 b	22.76 bc
Metribuzin @ 150 g a.i. ha^{-1}	22.04 ab	23.15 bc
LSD	1.758	1.990
Year Effect	22.07 b	23.14 a
LSD	0.661	
Contrast		
Weedy check vs all	20.85 vs 22.28*	21.20 vs 23.46*
Weedy check vs Manual Hoeing	20.85 vs 23.19*	21.20 vs 24.52**
Weedy check vs Herbicides	20.85 vs 22.09^{NS}	21.20 vs 23.25*
Manual Hoeing vs Herbicides	23.19 vs 22.09*	24.52 vs 23.25*
Pendimethalin+prometryn vs metribuzin	22.37 vs 21.69^{NS}	23.45 vs 22.96^{NS}

Means not sharing same letter were significantly different at 5% probability level.
* and ** indicate significance at $p \leq 0.05$ and at $p \leq 0.01$ level of probability, respectively.
^{NS}= non-significant

was statistically similar with those of all treatments except metribuzin @ 187.5 g a.i. ha^{-1} and weedy check during 2010-11. Minimum crude protein contents of chickpea seed (20.85% and 21.20% in 2010 and 2011, respectively) were recorded in weedy check plots.

All the contrast comparisons except pendimethalin+prometryn vs metribuzin were significant. This reduction in protein concentration in chickpea seed in weedy check plot was mainly due to an increase in weed competition for nutrients particularly nitrogen with chickpea. Our results are contradictory to finding of Yadav *et al.* (2007) who stated different herbicides treatments (pendimethalin, fluchloralin and metolachlor) did not cause significant variation in protein content of chickpea grain.

4.5.57 Economic analysis of herbicide usage in chickpea during 2011, 2012

The economic analysis of weed control practices is essential to look at the results from farmer's point of view as the farmers are more interested in costs and benefits. The tables (4.5.70, 4.5.72) indicate that all weed control practices gave higher net benefits than weedy check treatment. The maximum net benefits (136513/Rs) was obtained in the plot which were kept weed free. It was followed by plot where pendimethalin+prometryn @ 375 + 500 g a.i ha^{-1} was applied during both the years of experimentation.

4.5.58 Marginal analyses of herbicide usage in chickpea during 2011, 2012

A net benefit is not a final criterion for recommendation to a common farmer; hence, marginal analysis was performed to determine the most profitable weed control treatment. It is calculated by comparing the total variable cost with net benefits. The table 4.5.71 and 4.5.73 show the marginal analysis during 2011 and 2012. The results showed that marginal rate of return was higher (2803%) in chickpea plot where metribuzin @ 187.5 g a.i. ha^{-1} was applied followed by that of pendimethalin+prometryn @ 375 + 500 g a.i. ha^{-1} during 2010. In 2011 maximum marginal rate of return (5416%) was gained by application of pendimethalin+prometryn @ 375 + 500 g a.i. ha^{-1} followed by that of metribuzin @ 187.5 g a.i. ha^{-1}.

4.5.59 Dominance analyses of herbicide usage in chickpea during 2011, 2012

A treatment was considered dominated if its variable cost was greater than the previous treatment however its net benefits were lower. Such treatment was considered dominated (D). The dominated treatment was not included in the calculation of marginal rate of return (MRR). The dominance analyses of different treatments are presented in the table 4.5.70 and 4.5.72. The treatments where metribuzin @ 150 g a.i. ha^{-1} and pendimethalin+prometryn @ 450 + 600 g a.i. ha^{-1} were applied, were dominated as their net benefits did not increase with the increase in variable cost during both the years of study.

Table 4.5.70 Economic analysis of herbicide usage in chickpea during 2010-2011

Parameters	T_1	T_2	T_3	T_4	T_5	T_6	T_7	Remarks
Seed yield	1429.90	2376.30	1811.80	2306.40	2180.70	2075.10	1917.30	kg ha^{-1}
Adjusted yield	1286.91	2138.67	1630.62	2075.76	1962.63	1867.59	1725.57	kg ha^{-1}
Value	83649.15	139013.55	105990.3	134924.4	127570.95	121393.35	112162.05	Rs. 2600/40 kg
Gross benefits	83649	139013	105990	134924	127570	121393	112162	Rs ha^{-1}
Cost of herbicide	-	-	1650	1375	1100	400	500	Rs. 550/1 L Rs. 500/250g
Cost of Manual hoeing	-	2500	-	-	-	-	-	Rs. 2500 ha^{-1}
Labour cost	-	-	750	750	750	750	750	Rs 750 ha^{-1}
Sprayer rent	-	-	150	150	150	150	150	Rs. 150 ha^{-1}
Cost that vary	-	2500	2550	2275	2000	1300	1400	Rs ha^{-1}
Net benefits	83649	136513	103440	132649	125570	120093	110762	Rs ha^{-1}

1 US dollar in 2011= 84.20 PKR, T_1: Control; T_2: Manual hoeing; T_3: Pendimethalin + Prometryn @ 450 + 600 g a.i. ha^{-1}; T_4: Pendimethalin + Prometryn @ 375 + 500 g a.i. ha^{-1}; T_5: Pendimethalin + Prometryn @ 300 + 400 g a.i. ha^{-1}; T_6: Metribuzin @ 150 g a.i. ha^{-1}; T_7: Metribuzin @ 187.5 g a.i. ha^{-1}

Table 4.5.71 Marginal analysis of herbicide usage in chickpea during 2010-2011

Treatments	Cost that vary (Rs. ha^{-1})	Marginal cost (Rs. ha^{-1})	Net benefits (Rs. ha^{-1})	Marginal Net (Rs. ha^{-1})	Marginal rate of return (%)
Control	-	-	83649	-	-
T_7	1300	1300	120093	36444	2803
T_6	1400	100	110762	0	D
T_5	2000	600	125570	14808	2468
T_4	2275	275	132649	7078	2573
T_2	2500	225	136513	3864	1717
T_3	2550	50	103440	0	D

D: dominance 1 US dollar in 2011:= 84.20 PKR

T_1: Control; T_2: Manual hoeing; T_3: Pendimethalin + Prometryn @ 450 + 600 g a.i. ha^{-1}; T_4: Pendimethalin + Prometryn @ 375 + 500 g a.i. ha^{-1}; T_5: Pendimethalin + Prometryn @ 300 + 400 g a.i. ha^{-1}; T_6: Metribuzin @ 150 g a.i. ha^{-1}; T_7: Metribuzin @ 187.5 g a.i. ha^{-1}

Table 4.5.72 Economic analysis of herbicide usage in chickpea during 2011-2012

Parameters	T_1	T_2	T_3	T_4	T_5	T_6	T_7	Remarks
Seed yield	1371.30	2175.70	1651.70	2145.90	1905.10	2008.70	1760.40	Kg ha^{-1}
Adjusted yield	1234.17	1958.13	1486.53	1931.31	1714.59	1807.83	1584.36	Kg ha^{-1}
Value	86391.90	137069.10	104057.10	135191.70	120021.30	126548.10	110905.20	Rs. 2800/40 kg
Gross benefits	86391	137069	104057	135191	120021	126548	110905	Rs ha^{-1}
Cost of herbicide	-	-	1650	1375	1100	400	500	Rs. 550/1 L Rs. 500/250g
Cost of Manual hoeing	-	2500	-	-	-	-	-	Rs. 2500 ha^{-1}
Labour cost	-	-	750	750	750	750	750	Rs 750 ha^{-1}
Sprayer rent	-	-	150	150	150	150	150	Rs. 150 ha^{-1}
Cost that vary	-	2500	2550	2275	2000	1300	1400	Rs ha^{-1}
Net benefits	86391	134569	101507	132916	118021	125248	109505	Rs ha^{-1}

1 US dollar in 2012: 90.70 PKR

T_1: Control; T_2: Manual hoeing; T_3: Pendimethalin + Prometryn @ 450 + 600 g a.i. ha^{-1}; T_4: Pendimethalin + Prometryn @ 375 + 500 g a.i. ha^{-1}; T_5: Pendimethalin + Prometryn @ 300 + 400 g a.i. ha^{-1}; T_6: Metribuzin @ 150 g a.i. ha^{-1}; T_7: Metribuzin @ 187.5 g a.i. ha^{-1}

Table 4.5.73 Marginal analysis of herbicide usage in chickpea during 2011-2012

Treatments	Cost that vary (Rs. ha^{-1})	Marginal cost (Rs. ha^{-1})	Net benefits (Rs. ha^{-1})	Marginal Net (Rs. ha^{-1})	Marginal rate of return (%)
Control	-	-	86391.	-	-
T_7	1300	1300	125248	38856	2988
T_6	1400	100	109505	0	D
T_5	2000	600	118021	8516	1419
T_4	2275	275	132916	14895	5416
T_2	2500	225	134569	1652	734
T_3	2550	50	101507	0	D

D: dominance 1 US dollar in 2012: 90.70 PKR

T_1: Control; T_2: Manual hoeing; T_3: Pendimethalin + Prometryn @ 450 + 600 g a.i. ha^{-1}; T_4: Pendimethalin + Prometryn @ 375 + 500 g a.i. ha^{-1}; T_5: Pendimethalin + Prometryn @ 300 + 400 g a.i. ha^{-1}; T_6: Metribuzin @ 150 g a.i. ha^{-1}; T_7: Metribuzin @ 187.5 g a.i. ha^{-1}.

Chapter 5 Summary

Chickpea (*Cicer arietinum* L.) is an important grain legume used as a source of human and animal nutrition. Chickpea is grown on 0.99 million hectares in Pakistan with total production of 0.67 million tons. Punjab province constitutes 80% area of total grown, 92% of which is rainfed "Thal" contributing about 77% to the total chickpea production of Pakistan with an average national yield of 0.67 t ha^{-1}. The majour factors which contribute to lower yield include, environmental (moisture shortage due to inadequate and erratic rains, low temperature stress (frost) during early crop growth), sowing on marginal land, low or no use of fertilizers and presence of weeds. Among these factors weed infestation pose a major threat to chickpea's successful production. To tackle with *E. dracunculoides* and *Astragalus* spp. problem in chickpea, two most important weeds, we planned different experiments to evaluate dormancy, ecology of these weeds, allelopathic potential, critical weed crop competition period of *E. dracunculoides* and *Astragalus* spp. and most effective pre-emergence herbicide for their control. Results of our study are summarized as under.

Laboratory experiments

Study regarding effect of different dormancy breaking chemicals (GA_3, KNO_3 and thiourea) on *E. dracunculoides* and *Astragalus* spp. revealed that

- Germination (G) percentage and germination energy (GE) of *E. dracunculoides* was maximum (89 and 22, respectively) at 250 ppm concentration of GA_3. The respective values were 81.50 and 11.50 at 15000 ppm concentration of KNO_3. Whereas G percentage and GE of *Astragalus* spp. was maximum (28 and 19, respectively) at lowest concentration of GA_3 (50 ppm).
- Thioureea at 250 and 300 ppm resulted in maximum G percentage (51) and GE (25.50) of *E. dracunculoides*.
- On the other hand 5000 ppm and 150 ppm concentration of KNO_3 and thiourea showed maximum GE (19.5) and G percentage (28) of *Astragalus* spp., respectively.
- Effective dormancy breaking chemicals against *E. dracunculoides* was GA_3 (250 ppm) while in *Astragalus* spp. all the chemicals failed to break seed dormancy to a

considerable extent. These results showed that both weeds seeds have dormancy in their habit.

In second laboratory experiment varying levels of environmental factors e.g. temperature, light, pH, water stress, salt stress and seeding depth were studied on *E. dracunculoides* and *Astragalus* spp. germination/emergence.

- *Euphorbia dracunculoides* and *Astragalus* spp. germination decreased with an increase in temperature and maximum germination (50, 40%, respectively) was observed at 15ºC. Time to 50% germination (T_{50}), time to start germination, germination index (GI) and mean germination time (MGT) were significantly decreased with an increase in temperature from 15 to 25ºC.

- Effect of light or dark was significant on time to start. T_{50} and MGT of *E. dracunculoides* and non-significant for *Astragalus* spp., however light resulted in highest GI (2.87, 2.23, respectively) and germination percentage (66, 43%, respectively) of *E. dracunculoides* and *Astragalus* spp.

- A considerable germination (52, 38%) of *E. dracunculoides* and *Astragalus* spp., respectively was measured at all levels of pH from 6.00 to 9.00; however maximum *E. dracunculoides* and *Astragalus* spp. germination was occurred at pH 7.00. Increase in pH from 6 to 9 resulted a decrease in time to start germination, time to 50% germination, MGT and GI.

- Germination and GI of *E. dracunculoides* and *Astragalus* spp. was decreased with an increase in water stress from 2.5-15% (PEG concentration). However, germination of *E. dracunculoides* and *Astragalus* spp. was completely inhibited above 12.5% drought stress.

- An increase in salt stress from 0 to 150 mM resulted a decrease in germination percentage, time to start and 50% germination, MGT and GI of *E. dracunculoides* and *Astragalus* spp. Germination of *E. dracunculoides* was completely inhibited above 100 mM NaCl but *Astragalus* spp. germinated (11%) at highest level of NaCl stress (150 mM).

- Emergence percentage and EI of *E. dracunculoides* and *Astragalus* spp. was decreased withan increase in seed burial depth (1-6 cm). A varying response of *E. dracunculoides* and *Astragalus* spp. in respect of time to start emergence, T_{50} and MET was observed.

In third experiment, allelopathic effect of *Euphorbia dracunculoides* and *Astragalus* spp. on seed germination of chickpea was studied.

- *Euphorbia dracunculoides* whole plant extract (1-5%) significantly reduced chickpea seed germination and inhibition (85%) was more at 5% concentration.
- Whole plant extract (1-5%) of *Euphorbia dracunculoides* from rainfed habitat proved to be more inhibitory than that of irrigated.
- Among different plant parts extract of *Astragalus* spp., leaf extract caused maximum seed germination inhibition (87%) followed by those of stem (86.25%) and whole plant extract (86%) each at 5%.
- Shoot length, root length and seedling dry weight of chickpea reduced with an increase in leaf extract (1-5%) concentrations of both weeds.

Field experiment 1

Field experiment 1 was carried out at farmer's field in the years 2010-11 and 2011-12 during chickpea growing season (October to April). The crop was sown in the field where there was a heavy infestation of *E. dracunculoides* and *Astragalus* spp. in the previous year. Experiment was comprised of six weed competition durations e.g. 45, 60, 75, 90, 105 and full season. Control (*E. dracunculoides* and *Astragalus* spp. free plots) was included for comparison. Randomized Complete Block Design with four replications was used to run the experiment.

- With an increase in *E. dracunculoides* and *Astragalus* spp. competition duration, their fresh and dry weight was increased gradually. Maximum dry weight (293.42 and 409.34 g m^2) of *E. dracunculoides* and *Astragalus* spp., respectively was recorded in plots where weeds grew for full season.

- Number of primary branches, secondary branches per plant, pods per plant, seeds per pod, 100-seed weight, seed yield, biological yield and harvest index of chickpea were

decreased progressively with an increase in *E. dracunculoides* and *Astragalus* spp. competition duration. Maximum number of primary branches (5.30), secondary branches per plant (22.45), pods per plant (70.10), seeds per pod (2.48), 100-seed weight (23.20 g), biological yield (6603.20 kg ha^{-1}), seed yield (2414.5 kg ha^{-1}) and H.I (36.4%) of chickpea was observed with *E. dracunculoides* and *Astragalus* spp. free plots followed by that of where these weeds remained in competition for 45 DAS.

- Weed crop competition up to 45 DAS was critical to interfere the growth and yield of rainfed chickpea to a significant extent.
- *Euphorbia dracunculoides* density remained dominant (54-65%) as compared to *Astragalus* spp. (34-42%).
- Seed yield losses due to infestation of *E. dracunculoides* and *Astragalus* spp. ranged 13-54% and maximum yield loss was observed where weeds were allowed to grow for full season in both the years.

Field Experiment 2

This experiment was conducted to study the effect of pre-emergence application of penthalin plus-35 EC (pendimethalin+prometryn) and Sencor 75 DF (metribuzin) on control of *E. dracunculoides* and *Astragalus* spp. in chickpea. Experiment was comprised of seven treatments viz. pendimethalin+prometryn @ 450 + 600 g a.i. ha^{-1}, pendimethalin+prometryn @ 375 + 500 g a.i. ha^{-1}, pendimethalin+prometryn @ 300 + 400 g a.i. ha^{-1}, metribuzn @ 150 g a.i. ha^{-1} and metribuzn @ 187.5 g a.i. ha^{-1}. Manual weed control (manual hoeing) and weedy check were also included in the experiment for comparison. Experiment was laid out in RCB design with four replicates.

- Pendimethalin+prometryn @ 450 + 600 g a.i. ha^{-1} resulted in maximum control of *E. dracunculoides* and *Astragalus* spp. followed by that of metribuzn @ 187.5 g a.i. ha^{-1}.

- More increase in seed yield of chickpea (66.19%) was recorded by manual hoeing followed by that of pendimethalin+prometryn @ 375 + 500 g a.i. ha^{-1} (61.30%) over weedy check.

- Manual hoeing and pendimethalin+prometryn @ 375 + 500 g a.i. ha^{-1} resulted in highest (23.15) chickpea secondary branches per plant. Lowest (13.60) secondary branches were recorded in weedy check.

- Maximum pods of chickpea per plant (65.04) were recorded with manual hoeing and it was followed by 60.16 pods per plant with pendimethalin+prometryn @ 375 + 500 g a.i. ha^{-1}. Minimum pods of chickpea per plant (27.53) were recorded in weedy check.

- Pendimethalin+prometryn @ 375 + 500 g a.i. ha^{-1} resulted in maximum (2.17) seeds per pod which waere not different with from that of manual hoeing and weedy check resulted in minimum seeds per pod (1.37).

- Maximum chickpea 100-seed weight (23.44 g) was noted with manual hoeing which was statistically similar with that of pendimethalin+prometryn @ 375 + 500 g a.i. ha^{-1} spray. Minimum chickpea 100-seed weight (16.70 g) was recorded in weedy check treatment.

- Highest chickpea seed yield (2376.30 kg ha^{-1}) was achieved in manual hoeing plot which was statistically similar with that of pendimethalin+prometryn @ 375 + 500 g a.i. ha^{-1} spray.

- Maximum chlorophyll contents in chickpea leaves (1.27 mg g^{-1} at 40 DAE), (1.62 mg g^{-1} at 60 DAE) and (0.94 mg g^{-1} at 80 DAE) were recorded in manual hoeing treatment followed by those of pendimethalin+prometryn @ 375 + 500 g a.i. ha^{-1}. Minimum chickpea chlorophyll contents were measured in weedy check.

- Macro (5-62 kg ha^{-1}) and micro (12-177 g ha^{-1}) nutrients uptake by weeds increased with an increase in weed duration.

- Weed control with pendimethalin+prometryn @ 450 + 600 g was maximum but chickpea grew well with pendimethalin+prometryn @ 375 + 500 g a.i. ha^{-1}. A decline in chickpea vegetative (primary and secondary branches, plant height) and yield components was noted with pendimethalin+prometryn @ 450 + 600 g a.i. ha^{-1}.
- Maximum marginal rate of return (2803%) was achieved with metribuzin @ 150 g a.i. ha^{-1} in first year and with pendimethalin+prometryn at 375 + 500 g a.i. ha^{-1} in second year (5416%).

Conclusion

1. Optimum temperature for *E. dracunculoides* and *Astragalus* spp. seed germination was 15 ºC.

2. Germination of *E. dracunculoides* and *Astragalus* spp. was adversely affected at a salt stress above 50 mM and water stress above 5%.

3. *Euphorbia dracunculoides* and *Astragalus* spp. can emerge better on soil surface and at 1 to 2 cm seeding depth.

4. Chickpea seed yield losses of 13 to 54% was recorded with *E. dracunculoides* and *Astragalus* spp. infestation.

5. Critical weed crop competition period of 45 DAS was the finding of our research.

6. Pre-mergence application of pendimethalin+prometryn @ 375 + 500 g a.i. ha^{-1} and manual hoeing (40 and 60 DAE) were most effective practices for control of *E. dracunculoides* and *Astragalus* spp. and resulted in highest chickpea seed yield (2370.30 and 2306.40 kg ha^{-1}, respectively).

7. Highest net benefits (Rs. 136513/-) was obtained with manual hoeing followed by that of pre-mergence application of pendimethalin+prometryn @ 375 + 500 g a.i. ha^{-1}.

Recommendation

Euphorbia dracunculoides and *Astragalus* spp. can tolerate a wide range of ecological factors and their emergence was maximum in upper 1-2 cm of soil. Critical weed

crop competition to control *E. dracunculoides* and *Astragalus* spp. is 45 days after sowing. Pre-emergence spray of pendimethalin+prometryn @ 375 + 500 g a.i. ha^{-1} and manual hoeing is recommeneded for effective control of *E. dracunculoides* and *Astragalus* spp. in chickpea to get maximum economic and net benefits.

Future Thrusts

- Competitive effect of *E. dracunculoides* and *Astragalus* spp. individually, below 45 days after sowing should be studied.
- Extract of allelopathic crops and herbicide in mixture should be examined on chickpea weeds.
- The evaluation of the allelochemicals and their isolation, identification, release, and movement under field conditions are important for future research guidelines.
- Mixed cropping (barley, wheat and sarsoon) along with chickpea should be studied for weed control.
- Pre and post-emergence herbicides with different application methods under different moisture levels should be evaluated in rainfed chickpea.

Literature cited

Abbas, R.N., A. Tanveer, A. Ali and Z. Zaheer. 2010. Simulating the effect of *Emex australis* densities and sowing dates on agronomic traits of wheat. Pak. J. Agric. Sci. 47(2): 104-110.

Achuo, E.A., E. Prinseh and M. Hofte. 2006. Influence of drought, salt stress and abscisic acid on the resistance of tomato to Botrytis cinerea and Oidium neolycopersici. Pl. Pathol., 55: 178-186.

Adelusi, A.A., G.T. Odufeko and A.M. Makinde. 2006. Interference of *Euphorbia heterophylla* Linn. On the growth and reproductive yield of soybean (*Glycine max* Linn). Merill. Res. J. Bot. 1(2): 85-94.

Agic, D., G. Bukvic, S. Grljusic, D. Beslo, J. Horvatic and D. Novoselovic. 2009. Effect of pH on α-Amylase activity and early seedling growth of red clover (*Trifolium pratense* L.). Not. Bot. Hort. Agrobot. Cluj, 37: 77-80.

Ahmad, R. and A.S. Sheikh. 2003. Common weeds of wheat and their control. Pak. J. Water Resources, 7: 73-74.

Akhtar, M., A. Mahmood, J. Ahmad and K. Iqbal. 2000. Nitrogen uptake efficiency in wheat (*Triticum aestivum* L.) as influenced by nitrogen level and weed crop competition duration. Pak. J. Biol. Sci., 3: 1002-1003.

Akhtar, P. and F. Hussain. 2009. Growth performance of *Vicia sativa* L. under saline conditions. Pak. J. Bot., 41: 3075-3080.

Al Mamun, M.A., R. Sultana, M.M. Rana and A.J. Mridha. 2013. Economic threshold density of multi species weed for direct sedded rice. Asian J. Agri and Rural Deve., 3(8): 523-531.

Alatar, A.A. 2011. Effect of temperature and salinity on germination of *Achillea fragrantissima* and *Moringa peregrina* from Saudi Arabia. African Journal of Biotech., 10(17): 3393-3398.

Ali, H.H., A. Tanveer, M.A. Nadeem and H.N. Asghar. 2011. Methods to break seed dormancy of *Rhynchosia capitata*, a summer annual weed. Chil. J. Agric. Res., 71(3): 483-487.

Ali, T., P. Hossein, F. Asghar, Z. Salman and Z.C.M. Ali. 2010. The effect of different treatments on improving seed germination characteristics in medicinal species of *Descurainia sophia* and *Plantago ovate*. African. J. Biotech., 9: 6588-6593.

Almansouri, M., J.M. Kinet and S. Lutts. 2001. Effect of salt and osmotic stresses on germination in durum wheat (*Triticum durum* Desf.). Plant Soil, 231: 243-254.

Al-Taisan, W.A. 2010. Comparative Effects of Drought and Salt Stress on Germination and Seedling Growth of *Pennisetum divisum* (Gmel.) Henr. American Journal of Applied Sci., 7 (5): 640-646.

Amri, E. 2010. Germination of *Terminalia sericea* Buch ex Dc. Seeds: Effects of Temperature Regime, Photoperiod, Gibberellic Acid and Potassium Nitrate. American-Eurasian J. Agric. & Environ. Sci., 8 (6): 722-727.

Anjum, F.H., A. Tanveer, M.A. Nadeem, M. Tahir and A. Aziz. 2007. Effect of split application of nitrogen and integrated weed management on nutrient uptake by *Trianthema portulacastrum* (itsit) in cotton. Pak. J. Agri. Sci., 44(3): 423-429.

Anonymous, 2012. Weeds and weed control. 2012. http://vasat.icrisat.org/crops/chickpea/_practices/ppweed_control.htm.

Ansar, M., A. Anwar, M. Arif, M. Nadeem and A. Zahid. 2010. Screening of pre and post-emergence herbicides against chickpea (*Cicer arietinum* L.*)* weeds under semi rainfed conditions of Pothohar, Pakistan. Pak. J. Weed Sci. Res. 16(4): 421-430.

Arnon, D.I. 1949. Copper enzymes in isolated chloroplasts Poly-phenoloxidase in *Beta vulgaris*. Plant Physiol. 24: 1-15.

Ashrafi, Z. 2009. Study effects of planting methods and tank mixed herbiciedes on weeds controlling and wheat yield. J. Agric. Sci. 1(1): P: 101.

Aslam, M., H.K. Ahmad, E. Ahmad, Himayatullah, M.A. Khan and A.G. Sagoo. 2007. Effect of sowing methods and weed control techniques on yield and yield components of chickpea (*Cicer arietinum* L.). Pak. J. Weed Sci. Res. 13(1-2): 49-61.

Association of Official Analytical Chemists (AOAC). 1984. Official methods of analysis of the AOAC. 14th ed. AOAC, Washington, DC.

Association of Official Seed Analysis (AOSA). 1990. Rules for testing seeds. J. Seed Sci. Technol. 12: 1-112.

Aydın, I. and F. Uzun. 2001. The effects of some applications on germination rate of Gelemen Clover seeds gathered from natural vegetation in Samsun. Pak. J. Biol. Sci. 4: 181-183.

Babar, H.B., A. Tanveer, M. Tahir, A. Aziz, A.U.H. Ahmad, M.A. Nadeem and M.M. Javaid. 2009. Allelopathic potential of wild onion (*Asphodelus tenuifolius*) on the germination and seedling growth of chickpea (*Cicer arietinum*). Weed Biol. Manag., 9: 146–151.

Bararpour, M. T., R. E. Talbert and R. E. Frans. 1994. Spotted Spurge (*Euphorbia maculata*) Interference with Cotton (*Gossypium hirsutum* L.). Weed Sci., 42: 553-555.

Basbag, M., O. Toncer and S. Basbag. 2009. Effects of different temperatures and duration on germination of caper (*Capparis ovata*) seeds. J. Envion. Bio., 30: 621-624.

Baskin, C.C., P. Milberg, L. Andersson and J.M. Baskin. 2004. Germination ecology of seeds of the annual weeds *Capsella bursa-pastoris* and *Descurainia sophia* originating from high northern latitudes. Weed Res., 44(1): 60-68.

Batish, D.R., K. Lavanya, H.P. Singh and R.K. Kohli. 2007. Phenolic allelochemicals released by *Chenopodium murale* affect the growth, nodulation and macromolecule content in chickpea and pea. Pl. Growth Regulation, 51(2): 119-128.

Batish, D.R, H.P. Singh, J.K. Pandher, V. Arora and R.K. Kohli. 2002. Phytotoxic effect of parthenium residues on the growth of radish and chickpea and selected soil properties. Weed Biol. Manag., 2: 73–78.

Batish, D.R., H.P. Singh, S. Kaur and R.K. Kohli. 2006. Phytotoxicity of *Ageratum conyzoides* residues towards growth and nodulation of *Cicer arietinum*. Agric., Ecosystems & Envir., 113: 399-401.

Batlla, D. and R.L. Benech-Arnold. 2007. Predicting changes in dormancy level in weed seed soil banks: Implications for weed management. Crop Prot., 26: 189–197.

Begum, M., A.S. Juraimi, R. Amartalingam, A. Bin Man and S.O. Bin Syed Rastans. 2006. The effects of sowing depth and flooding on the emergence, survival and growth of *Fimbristylis miliacea* (L.) Vahl. Weed Biol. Manage. 6(3): 157-164.

Benvenuti, S., M. Macchia and S. Miele. 2001. Light, temperature and burial depth effects on *Rumex obtusifolius* seed germination and emergence. Weed Res., 41(2): 177-186.

Benvenuti, S., M. Macchia and S. Miele. 2001. Quantitave anyalysis of emergence of seedlings from buried weed seeds with increasing soil depth. Weed Sci. 49: 528-535.

Berg, V.D.L. and Y.J. Zeng. 2006. Response of south African indigenous grass species to drought stress induced by polyethylene glycol (PEG) 6000, S. African. J. Bot., 72: 284-286.

Berti, M.T. and B.L. Johnson. 2008. Seed germination response of cuphea to temperature. Ind. Crops Prod., 27: 17-21.

Bhalla, C.S., S.P. Kurchania and N.R. Paradkar. 1998. Herbicidal weed control in chickpea (*Cicer arietinum* L.). World Weeds, 5: 121-124.

Brkić, S., Z. Milaković, A. Kristek and M. Antunović, 2004. Pea yield and its quality depending on inoculation, nitrogen and molybdenum fertilization. Plant Soil Environ., 50(1): 39-45.

Budhar, M.N. and N. Tamilselvan. 2003. Weed dynamics, yield and economics in sorghum (*Sorghum bicolor*) + pulses inter-cropping system under rainfed condition. Indian J. Agron. 48(2): 93-95.

Byerlee, D., 1988. From agronomic data to farmers recommendations. An Economics Training Manual. pp: 31-33. CIMMYT. Mexico.

Cetinbas, M. and F. Koyuncu. 2006. Improving germination of *Prunus avium* L. seeds by gibberellic acid, potassium nitrate and thiourea. Hort. Sci., 33(3): 119–123.

Chachalis, D., N. Korres and E.M. Khah. 2008. Factors affecting seed germination and emergence of venice mallow (*Hibiscus trionum*). Weed Sci. 56(4): 509-515.

Chantre, G.R., M. R. Sabbatini and G. A. Orioli. 2009. Effect of burial depth and soil water regime on the fate of *Lithospermum arvense* seeds in relation to burial time. Weed Res., 49(1): 81-89.

Chattha, M.R., M. Jamil and T.Z. Mahmood. 2007. Yield and Yield Components of Mungbean as Affected by various weed control methods under rain-fed conditions of Pakistan. Int. J. Agri. Bio., 9(1): 114-119.

Chauhan, B. S., G. Gill and C. Preston. 2006b. Factors affecting seed germination of annual sowthistle (*Sonchus oleraceus*) in southern Australia. Weed Sci., 54(5): 854-860.

Chauhan, B.S. and D.E. Johnson, 2008. Seed germination and seedling emergence of giant sensitive plant (*Mimosa invisa*). Weed Sci., 56(2): 244-248.

Chauhan, B.S. and D.E. Johnson, 2010. The role of seed ecology in improving weed management strategies in the tropics. Adv. Agron., Chapter 6, p. 221-262.

Chauhan, B.S. and D.E. Johnson. 2008. Germination ecology of two troublesome Asteraceae species of rainfed rice: Siam weed (*Chromolaena odorata*) and coat buttons (*Tridax procumbens*). Weed Sci., 56: 567-573.

Chauhan, B.S. and D.E. Johnson. 2009. Germination ecology of spiny (*Amaranthus spinosus*) and slender amaranth (*A. viridis*): troublesome weeds of direct-seeded rice. Weed Sci., 57: 379-385.

Chauhan, B.S. and D.E. Johnson. 2009b. Germination, emergence, and dormancy of *Mimosa pudica*, Weed Bio. Manag., 9(1): 38-45.

Chauhan, B.S., G. Gill and C. Preston. 2006. Seed germination and seedling emergence of threehorn bedstraw (*Galium tricornutum*). Weed Sci., 54(5): 867-872.

Chejara, V.K., P.Kristiansen, R.D B. Whalley, B.M. Sindel and C. Nadolny. 2008. Factors affecting germination of coolatai grass (*Hyparrhenia hirta*). Weed Sci., 56: 543-548.

Chhokar, R., S. Singh and R. Sharma. 2008. Herbicides for control of isoproturon-resistant littleseed canarygrass (*Phalaris minor*) in wheat. Crop Prot. 27(3-5): 719-726.

CIMMYT. 1988. From agronomic data to farmer recommendations: An economic training handbook. Econ. Programme, CIMMYT, Mexico, D.F. Cleavers (*Galium aparine*) and wheat (*Triticum aestivum*) planted at different times. Pak. J. Agric. Sci. 46(4): 258-265.

Collins A.S., C.A. Chase, W.M. Stall and C.M. Hutchinson. 2008. Optimum densities of three leguminous cover crops for suppression of smooth pigweed (*Amaranthus hybridus*). Weed Sci. 56: 753-761.

Coolbear P., A. Francis and D. Grierson. 1984. The effect of low temperature pre–sowing treatment on the germination performance and membrane integrity of artificially aged tomato seeds. J. Exp. Bot. 35: 1609-1617.

Damalas, C.A. 2004. Herbicide Tank Mixture: Common interactions. International Journal of agriculture and biology, 6 (1): 209-212.

Datta, A., B.M. Sindel, P. Kristiansen, R.S. Jessop and W.L. Felton. 2009. Effect of isoxaflutole on the growth, nodulation and nitrogen fixation of chickpea (*Cicer arietinum* L.). Crop Prot. Q., 28: 923–927.

Datta, A., B.M. Sindel, P. Kristiansen, R.S. Jessop and W.L. Felton. 2008. The effect of soil pH on chickpea (*Cicer arietinum* L.) genotypes sensitivity to isoxaflutole. Plant and Soil, 303(1-2): 49-54.

Deen, W., R. Cousens, J. Warringa. 2003. An evaluation of four crop:weed competition models using a common data set. Weed Res., 43: 116-129.

Dixit, A. and V.P. Singh. 2008. Efficacy of a ready mix application of carfentrazon plus isoproturon (affinity) to control weed in wheat (*Triticum aestivum*). Ind. J. Agric. Sci. 78(6): 495-497.

Dongre, P.N., A.K. Singh. 2007. Inhibition effects of weeds on growth of wheat seedlings. Allelopathy J., 20(2): 387-394.

Duan, D., X. Liu, M. A. Khan and B. Gul. 2004. Effects of salt and water stress on the germination of *Chenopodium glaucum* L., seed. Pak. J. Bot., 36: 793-800.

Ebrahimi , E. and S.V. Eslami. 2012. Effect of environmental factors on seed germination and seedling emergence of invasive *Ceratocarpus arenarius*. Weed Res., 52: 50–59.

Ellis, R.A. and E.H. Roberts. 1981. The quantification of aging and survival in orthodox seeds. Seed Sci. Techn., 9:373-409.

Erez, A. 2005. Thiourea, a Growth Promoter of Callus Tissues. J. of Exp. Bot., 29(1): 159-165.

Evans, S.P., S.Z. Knezevic, J.L. Lindquist, C.A. Shapiro, and E.E. Blankenship. 2003. Nitrogen application influences the critical period for weed control in corn. Weed Sci., 51: 408-417.

Farooq, M., S.M.A. Basra, and A. Wahid. 2006. Priming of field-sown rice seed enhances germination, seedling establishment, allometry and yield. Plant Growth Regul., 49: 285–294.

Fatma, K. 2005. Breaking seed dormancy in black mulberry (*Morus nigra* L.) by cold stratification and exogenous application of gibberellic acid. Botanica, 4: 23–26.

Fenner, M. and K. Thompson. 2005. The ecology of seeds. Cambridge, UK: Cambridge University Press.

Finch-Savage, W.E. and G. Leubner-Metzger. 2006. Seed dormancy and the control of germination. New Phytologist, 171: 501-523.

Frans, R., R. Talbert, D. Marx and H. Crowley. 1986. Experimental design and techniques for measuring and analyzing plant response to weed control practices. In N. D. Camper, ed. Research Methods in Weed Science. 3rd ed. Champaign, IL: Southern Weed Science Society. pp. 29–46.

Frenda, A.S., P. Ruisi, S. Saia, B. Frangipane, G.D. Miceli, G. Amato and D. Giambalvo. 2013. The Critical Period of Weed Control in Faba Bean and Chickpea in Mediterranean. Weed Science 61(3):452-459.

Gaikwad, R.P. and V.S. Pawar. 2003. Effect of Herbicides on Soybean crop and weeds. Indian J. Weed Sci., 35(1&2):145-147.

Gao, X., M. Li, Z. Gao and C. Li. 2009. Allelopathic effects of *Hemistepta lyrata* on the germination and growth of wheat, sorghum, cucumber, rape, and radish seeds. Weed Bio. Manag., 9: 243–249.

Ghahfarokhi, A.R. and R.T. Afshari. 2007. Methods of dormancy breaking and germination of Galbanum seeds (*Ferrula Gummosa*). Asi. J. pl. sci., 6(4): 611-616.

Gina, M.P. and C.N. Joseph. 2003. Light, temperature, seed burial, and mulch effects on mulberry weed (*Fatoua villosa*) seed germination. Weed Tech., 17(2): 213-218.

Giri, A.N., M.N. Deshmukh and S.B. Gore. 2006. Effect of cultural and integrated methods of weed control on cotton, intercrop yield and weed control efficiency in cotton-based cropping systems. Indian J. Agron., 51(1): 34-36

Gosheh, H.Z. and M.K. Shatnawi. 2005. Broad leaf weeds control in chickpea (*Cicer arietinum* L.), fababeans (*Vicia faba*) and lentil (*Lens culinaris*). Acta Agronomica Hungarica, 51(4): 437-444.

Govt. of Pakistan. 2013. Economic Survey of Pakistan, 2009-10. Ministry of finance, Islamabad, pp: 23.

Gracia, F.P., J.M. Pita, M.E.G. Benito and J.M. Iriondo. 2005. Effect of light, temperature and seed priming on germination of celery seeds (*Apium graveolens* L.). Seed Sci. and Tech., 23: 377–383.

Gu, X-Y., F. Kianian, and M.E. Foley. 2004. Multiple loci and epistases control genetic variation for seed dormancy in weedy rice (*Oryza sativa*). Genetics, 166:1503-1516.

Gulzar, S., M.A. Khan and I.A. Ungar. 2001. Effect of salinity and temperature on the germination of *Urochondra setulosa* (Trin.) C. E. Hubbard. Seed Sci. & Technol., 29: 21-29.

Guma, I.R., M.A. Padrón-Mederos, A.S. Guerra and J.A. Reyes-Betancort. 2008. Effect of temperature and salinity on germination of *Salsola vermiculata* L. (Chenopodiaceae) from Canary Islands. J. of Arid Environ., 10(1):310-314.

Hamid, A.M.T. and I.M. El-Metwally. 2008. Growth, nodulation and yield of soybean and associated weeds as affected by weed management. Planta Daninha, 26(4): 855-863.

Hassan, G. and I. Khan. 2007. Post-emergence herbicidal control of *Asphodelus tenuifolius* in desi chickpea (*Cicer arietinum* L.). Pak. J. Weed Sci. Res. 13(1-2): 33-38.

Hassan, M.M., M.G. Osman, A.M. Fatoma, E.A. Elhadi and A.E. Babiker. 2010. Effect of salinity on *Striga hermonthica* seed germination and incidence on infested sorghum. Current Res. J. Biol. Sci., 2: 210-213.

Hoque, A.T.M.R., M.B.A.R. Uddin and M.K. Hossain. 2003. Allelopathic effect of different concentration of water extracts of *Acacia auriculiformis* leaf on some initial growth parameters of five common agricultural crops. Pak. J. Agron., 2: 92-100.

Hosseini, S.M., S. Gholami and E. Sayad. 2007. Effect of Weed Competition, Planting Time and Depth on *Pistacia atlantica* Seedlings in a Mediterranean Nursery in Iran. Silva Lusitana, 15(2): 189-199.

Hussain, F. 1980. Allelopathic Effects of Pakistani weeds: *Euphorbia granulata* Forssk. Oecologia (Berl.), 45: 267-269.

Hussain, F., S. Ghulam, Z. Sher and B. Ahmad. 2011. Allelopathy by *Lantana camara* L. Pak. J. Bot., 43: 2373-2378.

Hussain, F.S., K. Khattak and N.M. Khattak. 1985. Allelopathic effects of Pakistani weeds: *Euphorbia helioscopia*. Proc. Ist National weed science workshop, NARC, Islamabad, Pakistan, January 20-23.

Iglesias, R.G. and M.J. Babiano. 1997. Endogenous abscisic acid during the germination of chickpea seed. Physiol. Plant., 100: 500-504.

Ikram, R.M., M.A. Nadeem, A. Tanveer, M. Yasin, A.U. Mohsin, R.N. Abbas, H. Rehman, M. Sibtain and M. Irfan. 2012. Comparative efficacy of different pre-emergence herbicides in controlling weeds in cotton (*Gossypium hirsutum* L.). Pak. J. Weed Sci. Res. 18(2): 209-222.

Jan, G., M.A. Kahan, M. Ahmad, Z. Iqbal, A. Afzal, M. Afzal, G.M. Shah, A. Majid, M. Fiaz, M. Zafar, A. Waheed and F. Gul. 2011. Nutritional analysis, micronutrients and chlorophyll contents of *Cichorium intybus* L. J. Med. Plants Res., 5(12) 2452-2456.

Javaid, A., S. Shafique and S. Shafique. 2006. Herbicidal potential of aqueous leaf extract of allelopathic trees against *Phalaris minor*. Pak. J. Weed Sci. Res., 12: 339-346.

Jensen, P.K. 2008. Effect of light environment during soil disturbance on germination and emergence pattern of weeds. Annals of Applied Bio., 127: 561-571.

Jolliffe P.A., A.N. Minjas, V.C. Runeckles. 1984. A reinterpretation of yield relationships in replacement series experiments. J. Appl. Ecol., 21:227–243.

Kadioglu, I., Y.Yanar and U. Asav. 2005. Allelopathic effects of weeds extracts against seed germination of some plants. J. Environ. Bio., 26: 169-173.

Karam N.S., and AL-Salem M.M. 2001. Breaking dormancy in *Arbutus andrachna* L. seeds by stratification and gibberellic acid. Seed Sci. and Tech., 29: 51–56.

Kaya, M., G. Kaya, M.D. Kaya, M. Atak, S. Saglam, K.M. Khawar and C.Y. Ciftci. 2008. Interaction between seed size and NaCl on germination and early seedling growth of some Turkish cultivars of chickpea (*Cicer arietinum* L.). J. Zhejiang Univ. Sci., 9(5): 371-377.

Keshtkar, A.R., H.R. Keshtkar, S.M. Razavi and S. Dalfardi. 2008a. Methods to break seed dormancy of *Astragalus cyclophyllon*. African. J. of Biotech., 7: 3874-3877.

Keshtkar, H.R., H. Azarnivand, V. Etemad and S.S. Moosavi. 2008b. Seed dormancy-breaking and germination requirements of *Ferula ovina* and *Ferula gummosa*. Desert., 13: 45-51.

Khaliq, A., Z. Aslam and Z.A. Cheema. 2002. Efficacy of Different Weed Management Strategies in Mungbean (*Vigna Radiata* L.). Int. J. Agri. Bio., 4(2): 237-239.

Khan M.A., B. Gul and D.J. Weber. 2000. Germination responses of *Salicornia rubra* to temperature and salinity. J. Arid Envir., 45: 207-214.

Khan, I.J., G. Hassan, Ihsanullah and I.A. Khatak. 2007. Effect of wild oats (*Avena fatua*) densities and proportions on yield and yield components of wheat. J. Agril. Biol. Sci. (1): 26-31.

Khan, M.A. and I.A. Ungar. 1999. Effect of salinity on the seed germination of *Triglochin maritima* under various temperature regimes. Great Basin Naturalist, 59: 144–150.

Khan, M.A. and K.B. Marwat. 2006. Impact of crop and weed densities on competition between wheat and *Silybum marianum* Gaertn. Pak. J. Bot. 38(4): 1205-1215.

Khan, M.A. and S. Gulzar. 2003. Light, salinity and temperature effects on the seed germination of perennial grasses. Amer. J. Bot., 90: 131–134.

Khan, M.A., B. Gul and D.J. Weber. 2004. Action of plant growth regulators and salinity on seed germination of *Ceratoides lanata*. Can. J. Bot., 82: 37–42.

Khan, M.A., I.A. Ungar and B. Gul. 2003. Alleviation of salinity-enforced seed dormancy in *Atriplex prostrate*. Pak. J. Bot., 35(5): 906-912.

Khan, M.I. and F. Shah. 2011. Effect of potassium nitrate and thiourea on seed germination of crops and weeds. African Crop Science Conference Proceedings, 10: 461-463.

Khan, M.M., M. Usman, R. Waseem and M.A. Ali. 2002. Role of gibberellic acid (GA3) on citrus seed germination and study of some morphological characteristics. Pak. J. Agri. Sci., 39(2): 113-118.

Khan, R.U., A. Rashid and M.S. Khan. 2011. Impact of various rates of pendimethalin herbicide on weed control, seed yield and economic returns in mungbean under rainfed conditions. J. Agric. Res., 49(4): 491-498.

Koger, C.H., K.N. Reddy and D.H. Poston. 2004. Factors affecting seed germination, seedling emergence and survival of texasweed (*Caperonia palustris*). Weed Sci. 52(6): 989-995.

Koyuncu, F. 2005. Breaking seed dormancy in black mulberry (*Morus nigra* l.) by cold stratification and exogenous application of gibberellic acid. Acta Biologica Cracoviensia Series Botanica, 47(2): 23–26.

Kumar, M., S. Siangshaii and B. Singh. 2007. Allelopathic influence of two dominant weeds on agricultural crops of Mizoram, India. Pak J. Weed Sci. Res., 13: 83-92.

Laosinwattana, L., C. Boonleom, S. Thitavasanta, M. Teerarak and P. Charoenying. 2010. Potential allelopathic effects of *Suregada* multiflorum and the influence of soil type on its residue's efficacy. Weed Bio. Manag., 10: 153-159.

Li, J. and Z. Jin. 2010. Potential allelopathic effects of *Mikania micrantha* on the seed germination and seedling growth of *Coix lacryma-jobi*. Weed Bio. Manag., 10: 194-201.

Liu , G.X. and J.G. Han. 2008. Seedling establishment of wild and cultivated *Leymus chinensis* (Trin.) Tzvel. under different seeding depths. J. Arid Environ., 72(3): 279-284.

Lu, P., W. Sang and K. Ma. 2006. Effects of environmental factors on germination and emergence of crofton weed (*Eupatorium adenophorum*). Weed Sci. 54(3): 452-457.

Lyon, D.J. and R.G. Wilson. 2005. Chemical weed control in dry land and irrigated chickpea. Weed Tech. 19(4): 959-965.

Maloof, J.N., J.O. Borevitz, D. Weigel and J. Chory. 2000. Natural variation in phytochrome signaling. Seminars in Cell and Developmental Biology, 11: 523-530.

Mandal, S. 2001. Allelopathic activity of root exudates from *Leonurus sibiricus* L. (Raktodrone). Weed Bio. Manag., 1(3): 170-175.

Martin, S.G., R.C. Van Acker and L.F. Friesen. 2001. Critical period of weed control in spring canola. Weed Sci., 49: 326-333.

Marwat, K.B., I.A. Khan, G. Hussan and N.U. Khan. 2004. Efficacy of different pre-and post-emergence herbicides for controlling weeds in chickpea. Pak. J. Weed Sci. Res. 10(1-2): 51-54.

Marwat, K.B., I.A. Khan, M.I. Khan, Z. Hussain and H. Khan. 2005a. Herbicide evaluation for weed control in chickpea. Pak. J. Weed Sci. Res. 11(3-4): 57-60.

Mehmood, A., A. Tanveer, M.A. Nadeem and Z.A. Zahir. 2014. Comparative allelopathic potential of metabolites of two *Alternanthera* species against germination and seedling growth of rice. Planta Daninha, 32 (1): 1-10.

Mennan, H. and B. H. Zandstra. 2006. The Effects of Depth and Duration of Seed Burial on Viability, Dormancy, Germination, and Emergence of Ivyleaf Speedwell (*Veronica hederifolia*). Weed Tech., 20(2): 438-444.

Milberg, P., L. Andersson and A. Naronha. 1996. Seed germination after short duration light exposure. Implication for the photo-control of weeds. J. Appl. Ecol. 33: 1469-1478.

Ming, H.P. and G.J. Qin. 2003. A study on dormancy release of weed seeds of Brassicaceae. Weed Sci., China 1: 11.

Mishra, J.S. and V.P. Singh. 2003. Interference of *Euphorbia geniculata* in Soybean-Chickpea cropping system. Ind. J. Weed Sci., 35: 225-227.

Mishra, J.S., D. Swain and V.P. Singh. 2004. Studies on germination and allelopathic potential of horse purslane (*Trianthema portulacastrum* L.). Ind. J. Pl. Phsiology, 19(2): 181-184.

Mishra, J.S., V.P. Singh and N.T. Yaduraju. 2006. Wild onion (*Asphodelus tenuifolius* Cav.) interference in lentil and chickpea crops and its management through competitive cropping. Weed Biol. Manage. 6(3): 151-156.

Misra, N. and U.N. Dwivedi. 2004. Genotypic differences in salinity tolerance of green gram cultivars. J. Plant Sci., 166: 1135-1142.

Mochizuki, N., J.A. Brusslan, R. Larkin, A. Nagatani and J. Chori. 2001. Arabidopsis genomes uncoupled 5 (GUNS) mutant reveals the involvement of Mg-chelatase H subunit in plastid to nucleus signal transduction. Proc. Natl. Acad. Sci. U.S.A., 98: 2053-2058.

Mohammad, N., A. Sattar, M. Ashiq, and I. Ahmad. 2011. Efficacy of pre and post emergence herbicides to control weeds in chickpea (*Cicer arietinum* L.). Pak. J. Weed Sci. Res. 17(1): 17-24.

Mohammadi, G., A. Javanshir, F.R. Khooie, S.A. Mohammadi and S.Z. Salmasi. 2005. Critical period of weed interference in chickpea. Weed Res. 45(1): 57-63.

Mubeen, K., M. A. Nadeem, A. Tanveer and Z. A. Zahir. 2011. Allelopathic effect of Aqueous extracts of weeds on the germiantion and seedling growth of rice (*Oryza sativa* L.). Pak. J. life soc. Sci., 9(1): 7-12.

Mut, Z., H. Akay and N. Aydin. 2010. Effects of seed size and drought stress on germination and seedling growth of some oat genotypes (*Avena sativa* L.). African Journal of Agriculture Res., 5(10):1101-1107.

Naeem M., S. Ahmed and Z.A. Cheema. 2000. Yield of mungbean as affected by different durations of weed competition under high phosphorus status. Int. J. Agri. Bio., 2(1-2): 133-135.

Nakamura, C. and M.A. Hossain. 2009. Factors affecting the seed germination and seedling emergence of redflower ragleaf (*Crassocephalum crepidioides*). Weed Bio. Manag., 9: 315–322.

Nandula, V.K., T.W. Eubank, D.H. Poston, C.H. Koger and K.N. Reddy. 2006. Factors affecting germination of horseweed (*Conyza canadensis*). Weed Sci. 54(5): 898-902.

Narwal, S.S. 2004. Allelopathy in crop Production, Scientific Publishers, Jodhapur, India.

Nepomuceno, A.L., D.M. Oosterhuis and J. M. Stewart. 1998. Physiological responses of cotton leaves and roots to water deficit induced by polyethylene glycol. Environ. Exp. Bot., 40: 29-41.

Oad, F., M. Siddiqui and U. Buriro. 2007. Growth and yield losses in wheat due to different weed densities. Asian J. Plant Sci. 6173-6176.

Oad, F.C., M.H. Siddiqui, U.A. Buriro and G.S. Solangi. 2007a. Weed management practices in cotton crop. Asian J. Pl. Sci., 6 (2): 344-348.

Oliveira, M.J. and J.K. Norsworthy. 2006. Pitted morningglory (*Ipomoea lacunosa*) germination and emergence as affected by environmental factors and seeding depth. Weed Sci. 54(5): 910-916.

Olorunmaiye, K.S. and R.T. Ogunfolaji. 2002. Effect of density and duration of *Euphorbia heterophylla* (L) on the performance of cowpea (*Vigna unguiculata*) (Walp). NISEB J. 2(1): 17-22.

Ortega-Baes P. and M. Rojas-Arechiga. 2007. Seed germination of *Trichocereus terscheckii* (Cactaceae): Light, temperature and gibberellic acid effects. J. Arid Environ. 69: 169-176.

Ozhan, Boz. 2005. Economic thresholds of wild radish (*Raphanus raphanistrum* L.) control in wheat. Turkey J. Agric. 29: 173-177.

Paolini, R., F. Faustini, F. Saccardo and P. Crino. 2006. Competitive interactions between chick-pea genotypes and weeds. Weed Res., 46: 335–344.

Patel B.D., V.J. Patel, J.B. Patel and R.B. Patel. 2006. Effect of fertilizers and weed management practices on weed control in chickpea (*Cicer arietinum* L.) under middle Gujarat conditions. Ind. J. Crop Sci., 1: 180-183.

Rahman, M.H., M.S. Haque, M.A. Karim and M. Ahmed. 2006. Effects of gibberellic Acid (GA3) on breaking dormancy in garlic (*Allium sativum* L.). Int. J. Agri. Bio., 8: 63-65.

Ramzan, A., I.A. Hafiz, T. Ahmad and N.A. Abbasi. 2010. Effect of priming with potassium nitrate and dehusking on seed germination of gladiolus (*Gladiolus Alatus*). Pak. J. Bot., 42(1): 247-258.

Rao, N., L.Y. Dong, J.Li and H.J. Zhang. 2008. Influence of environmental factors on seed germination and seedling emergence of american sloughgrass (*Beckmannia syzigachne*). Weed Sci. 56(4): 529-533.

Rashid, A., R.U. Khan and S.K. Marwat. 2009. Importance of weed control in chickpea under rainfed condition. American-Eurasian J. Agric. & Environ. Sci., 5: 456-459.

Rejili, M., A.M. Vadel, A. Guetet, M. Mahdhi, B. Lachiheb, A. Ferchichi and M. Mars. 2009. Influence of temperature and salinity on the germination of *Lotus creticus* (L.) from the arid land of Tunisia. Afr. J. Ecol., 48(2): 329-337.

Rice, E.L. 1984. Allelopathy. 2nd edition. Academic Press, Inc, Florida (USA).

Rizzardi, M.A., A.R. Luiz, A.R. Roman and E.S. Vargas. 2009. Effect of cardinal temperature and water potential on morning glory (*Ipomoea triloba*) seed germination. Planta Daninha, 27: 13-21.

Rogis, C., L.R. Gibson, A.D. Knapp and R. Horton. 2004. Can solid matrix priming with GA3 break seed dormancy in eastern gamagrass? Rangeland Ecology & Manag., 57: 656-660.

Ruan, S., Q. Xue, and K. Tylkowska. 2002. The influence of priming on germination of rice (*Oryza sativa* L.) seeds and seedling emergence and performance in flooded soils. Seed Sci. Technol., 30: 61–67.

Sadeghi, S., Z.Y. Ashrafi, F. Tabatabai and H.M. Alizade. 2009. Study methods of dormancy breaking and germination of common madder (*Rubia tinctorum* L.) seed in laboratory conditions. Botany Research International, 2: 7-10.

Safdar, M.E., A. Tanveer, A. Khaliq and M.S. Naeem. 2014. Allelopathic action of parthenium and its rhizospheric soil on maize as influenced by growing conditions. Planta daninha, viçosa-mg, 32(2): 243-253.

Sangli, W., X. Liu and J.C. Axmacher. 2011. Germination and emergence of Ambrosia artemisiifolia L. under changing environmental conditions in China. Plant Species Bio., 26(2): 125–133.

Schutz, W., P. Milberg and B.B. Lamont. 2002. Germination requirements and seedling responses to water availability and soil type in four eucalyptus species. Acta Oecol., 23: 23-30.

Shah, T.M., J.I. Mirza, M.A. Haq and B.M. Atta. 2006. Induced genetic variability in chickpea (*Cicer arietinum* L.) I. frequency and spectrum of chlorophyll mutations. Pak. J. Bot., 38: 1217-1226.

Shanee, S., A. Tanveer, M.M. Javaid, K.M. Chaudhry, A. Aziz, A. Khaliq, M.N. Chaudhry, M.A. Pervez and I.U. Awan. 2011. Phytotoxic effects of *Euphorbia*

dracunculoides: a weed of rainfed chickpea-chickpea cropping system. Spanish J. Agric. Res., 9(2): 580-588.

Singh, B.D. and B.P. Singh. 1998. Effect of weed management practices and phosphorus levels on weed infestation, nodulation and yield of chickpea + mustard inter-cropping system. Ind. J. Weed Sci. 30(3-4): 124-128.

Singh, H.P., D.R. Batish, S. Kaur, R.K. Kohli and K.S. Dogra. 2004. Allelopathic interference of *Ageratum conyzoides* L. against some crop plants. Weed management: balancing people, planet, profit. Proceeding of 14th Australian Weeds Conference held in Wagga Wagga, New South Wales, Australia, 6-9 September.

Singh, H.P., R.K. Kohli and D.R. Batish. 2001. Allelopathy in agro ecosystems: an overview. J. Crop Prod., 4: 1–41.

Singh, K.K. and Tewari A.N. 1992. Weed management in inter-cropped pigeonpea. Ind. J. Weed Sci. 24(3-4): 21-25.

Singh, M., S.P. Kumar, C.V. Sairam and A. Kumar. 2009. Evaluation of different weed management practices in rainfed maize on farmer's fields. Pak. J. Weed Sci. Res. 15(2-3): 183-189.

Singh, M.K., R.P. Singh and R.K. Singh. 2004a. Influence of crop geometry, cultivar and weed-management practice on crop-weed competition in chickpea (*Cicer arietinum*). Indian Journal of Agronomy, 49(4): 258-261.

Singh, S.P. and M. Sangeeta. 1991. Allelopathic influences of aqueous extracts of congress grass (*Parthenium hysterophorus* L.) were investigated on germination and seedling vigour of cereals (rice and wheat) and pulses (black gram and chick pea). J. Agron. and Crop Sci., 167(3): 201-206.

Singh, V.K. and R.P. Singh. 1992. Chemical weed control in blackgram (*Vigna mungo* L.). Indian J. Weed Sci., 20 (4):81-82.

Steel, R.G.D., J.H. Torrie and D.A. Dickey. 1997. Principles and procedures of statistics. A biometrical approach 3rd Ed. McGraw Hill Book Co., Inc., Singapore: 172-177.

Steenhagen, D.A. and R.H. Zimdahl. 1979. Allelopathy of leafy spurge (*Euphorbia esula*). Weed Sci., 27: 1-3.

Suria, J., A.S.M., A.S. Juraimi, M.M. Rahman, A.B. Man and A. Selamat. 2011. Efficacy and economics of different herbicides in aerobic rice system. African J. Biotech. 10: 8007-8022.

Suthar, A.C., V.R. Naik and R.M. Mulani. 2009. Seed and seed germination in *Solanum nigrum* Linn. American-Eurasian J. Agric. & Environ. Sci., 5: 179-183.

Taisan, W.A.A. 2010. Comparative Effects of drought and salt stress on germination and seedling growth of *Pennisetum divisum* (Gmel.) Henr. Amer. J. Applied Scis., 7: 640-646.

Tang, D.S., M. Hamayun, Y.M. Ko, Y.P. Zhang, S.M. Kang and I.J. Lee. 2008. Role of Red Light, Temperature, Stratification and Nitrogen in Breaking Seed Dormancy of *Chenopodium album* L. J. Crop Sci. Biotech., 11 (3):199-204.

Tanveer, A., A. Rehman, M.M. Javaid, R.N. Abbass, M. Sibtain, A. Haqahmad, M. Sahid ibin-i-zamir, K.M. Chaudhary and A. Aziz. 2010. Allelopathic potential of *Euphorbia helioscopia* L. against wheat (*Triticum aestivum* L.), chickpea (*Cicer arietinum* L.) and lentil (*Lens culinaris* Medic.). Turk. J. Agric. For., 34: 75-81.

Tanveer, A., N.H. Chaudhry, M. Ayub and R. Ahmad. 2003. Effect of cultural and chemical weed control methods on weed population and yield of cotton. Pak. J. Bot. 35(2): 161-166.

Tanveer, A., S. Imran, M. Ayub and M. Yasin. 2010. Response of chickpea (*Cicer arietinum* L.) and *Euphorbia dracunculoides* to pre and post-emergence herbicides. Pak. J. Weed Sci. Res. 16(3): 267-277.

Taylor, I.N., S.R. Walker and S.W. Adkins. 2005. Burial depth and cultivation influence emergence and persistence of *Phalaris paradoxa* seed in an Australian sub-tropical environment. Weed Res., 45(1): 33-40.

Teketay, D. 1998. Germination of *Acacia origena, A. pilispina and Pterolobium stellatumin* response to different pre-sowing seed treatments, temperature and light. J. Arid Environ. 38: 551–560.

Tlig, T., M. Gorai and M. Neffati. 2008. Germination responses of *Diplotaxis harra* to temperature and salinity. Flora, 203: 421-428.

Trasoff, C.S., D.A. Ball and C.A. Mallory-smith. 2007. Extreme ionic and temperature effect on germination of weeping alkaligrass (*Puccinellia distans*), Nuttall's alkaligrass (*Puccinellia nuttalliana*) and Kentucky bluegrass (*Poa pratensis*). Weed Sci., 55: 305-310.

Tulku, F. and E.U. EK. 2005. Effects of stratification, temperature and storage on germination in three provenances of *Fraxinus angustifolia* subsp. oxycarpa seeds. Turk J. Agric For., 29: 323-330.

Turkoglu, N., E. Alp and A. Cıg. 2009. Effect of temperature on germınatıon biology ın Centaurea specıes. African. J. Agric. Res., 4: 259-261.

Uysal, I., S. Celik and K. Ozkan. 2006. Studies on the germination of an endemic species *Centaurea tomentella* hand.-mazz., Pak. J. Bot., 38(4): 983-989.

Vangessel, M.J., D.W. Monks and Q.R. Johnson. 2000. Herbicides for potential use in Lima bean (*Phaseolus lunatus*) production. Weed Tech., 14: 279-286.

Vieira, A.R., M. das G.G.C. Vieira, A.C. Fraga, J.A. Oliveira and C.D. dos Santos. 2002. Action of gibberellic acid (KNO_3) on dormancy and activity of α-amylase in rice seeds. Rev. bras. Sementes, 24(2):43-48.

Wakjira, M., G. Berecha and B. Bulti. 2006. Allelopathic effects of *Parthenium hysterophorus* extracts on seed germination and seedling growth of lettuce. Tropical Sci., 45(4): 159-162.

Watanabe, H., Y. Kusagaya and M. Saigusa. 2002. Environmental factors affecting germination of apple of Peru. Weed Sci., 50: 152-156.

Wei, S., C. Zhang, X. Chen, X. Li, B. Sui, H. Huang, H. Cui, Y. Liu, M. Zhang and F. Guo. 2010. Rapid and effective methods for breaking seed dormancy in buffalobur (*Solanum rostratum*). Weed Sci., 58: 141-146.

Whish, J. P. M., B.M. Sindel, R.S. Jessop and W.L. Felton. 2002. The effect of row spacing and weed density on yield loss of chickpea. Aust. J. Agric. Res., 53: 146-151.

Wilson Jr, D., M. Burton, J. Spears and A. York. 2006. Doveweed (*Murdannia nudiflora*) germination and emergence as affected by temperature and seed burial depth. Weed Sci. 54(6): 1000-1003.

Xiao, C., X. Wanga, J. Xia and G. Liu. 2010. The effect of temperature, water level and burial depth on seed germination of *Myriophyllum spicatum* and *Potamogeton malaianus*. Aquatic Bot., 92: 28–32.

Yadav, P.K., A.H. Khan and A.S. Yadav. 2007. Effect of herbicides on biochemical and growth parameters of chickpea. (*Cicer arietinum* L.). Ind. J. Agric. Sci. 77(8): 542-543.

Yadav, P.K., A.H. Khan, R. Murti and R.K. Upadhyay. 2006. Effects of herbicides on germination, growth and nodulation in chickpea (*Cicer arietinum* L.). Indain J. Agric. Scis. 76(11): 682-684.

Yucel, D.O., A. E. Anlarsal, D. Mart and C. Yacel. 2010. Effect of Drought Stress on Early Seedling Growth of Chickpea (*cicer arietinum* L.) Genotypes. World Applied Sciences J., 11(4): 478-485.

Zaman S., S. Padmesh, N.R. Bhat and H. Tawfiq. 2009. Germination characteristics and storage behavior of *Tamarix aucheriana* (decne.) seeds. Eur. J. Scientific Res., 26): 532-538.

Zhang, Z.P. 2003. Development of chemical weed control and integrated weed management in China. Weed Bio. Manag., 3: 197-203.

Zhou, J.K., E.L. Deckard, and W.H. Ahrens. 2005. Factors affecting germination of hairy nightshade (*Solanum sarrachoides*) seeds. Weed Sci., 53: 41-45.

Zhu, X.W., Z.Y. Huang, Y.C., S. M. Zhang, H.D. Liu and M. Dong. 2004. Effects of burial in sand and seed size on seed germination and seedling emergence in two leguminous shrubs in the Otindag Sandland, China. Israel J. Pl. Sci., 52(2): 133-142.

Zia, S. and M.A. Khan. 2002. Comparative effect of NaCl and seawater on seed germination of *Limonium stocksii*. Pak. J. Bot., 34: 345-350.