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SUMMARY - Chickpea is a poor competitor to weeds because of slow growth rate and limited leaf area development at early stages of crop growth and establishment. In the Mediterranean region, however, chickpea is grown commonly as a spring crop and thus does not face a serious weed problem because of pre-sowing cultivation to control winter weeds. In winter sown chickpea weeds present a serious threat to the crop and yield losses up to 98% have been reported. Hand and mechanical weed control methods traditionally followed in the spring crop are not effective in winter.sown chickpea beside being costly and uneconomical. Because of the sensitivity of chickpea to herbicides, most effective herbicides are pre-sowing and pre-emergence soil-acting chemicals and their efficacy is highly dependent on soil type, moisture, temperature and wed flora. Post-emergence herbicides, particularly those for broad-leaf weeds are few. There is a need to identify more effective herbicides with broader spectrum of weed control and wide adaptability. An intergrated approach involving herbicides and cultural practices to improve crop competitiveness is needed to develop effective and economic control measure.

RESUME - "Contrôle des mauvaises herbes chez le pois chiche". Le pois chiche est une plante à faible pouvoir de compétition face aux adventices, du fait de sa croissance lente et de son faible indice foliaire durant la phase d'établissement de la culture. Cependant, dans la région méditerranéenne, le pois chiche est traditionnellement semé au printemps et les adventices ne posent pas de gros problème puisque les façons culturales de pré-semis détruisent les adventices à croissance hivernale. Par contre, en semis d'hiver, les adventices représentent une menace importante pour le pois chiche; les pertes de rendement pouvant aller jusqu'à 98%. Les méthodes de lutte traditionnelles, manuelles ou mécaniques, utilisées sur les semis de printemps ne sont pas rentables pour les semis d'hiver. Du fait de la sensibilité du pois chiche aux herbicides, les traitements les plus efficaces sont ceux de pré-semis et de pré-émergence, mais leur efficacité dépend du type de sol, de l'humidité, de la température et de la flore. Les herbicides de post-émergence utilisables sur pois chiche sont très peu nombreux, particulièrement les anti-dicotylédones. Il est nécessaire de rechercher des herbicides plus efficaces ayant un large spectre d'action et faciles d'emploi. Une lutte intégrée combinant le désherbage chimique et les techniques culturales pour améliorer la compétitivité de la culture, est indispensable pour obtenir un contrôle efficace et économique des adventices dans le pois chiche.

Introduction

Weeds are a serious constraint to increased production and easy harvesting in chickpea. Chickpea, however, is a poor competitor to weeds because of slow growth rate and limited leaf area development at early stages of crop growth and establishment. Yield losses due to weed competition vary considerably depending on the level of weed infestation and weed species prevailing. Nevertheless, almost all values reflect the seriousness of the weed problem. Yield losses were observed to vary between 40 to 94% in the Indian subcontinent (ICARDA, 1985a; Bhan and Kukula, 1987), between 40 to 75% in West Asia (ICARDA, 1982a to 1986a), 13 to 98% in North Africa (El-Brahli, 1988; Knott and Halila, 1988; ICARDA, 1982a to 1986a), and 35% in Italy (Calcagno *et al.*, 1987). Effective weed control may increase yield in chickpea by 17-105% (ICARDA-FSP, 1986).

In the Mediterranean region chickpea is usually grown as a spring crop and as such the weed problem is minimized by pre-sowing cultivation which controls most winter and early spring weeds. In some of the less developed farming systems in the West Asia and North Africa (WANA) region, however, the very wide range row spacing (1.0-2.0 m) practised to control weeds through inter-row cultivation is a major limitation to high yield in spring chickpea due to very low crop density.

The mechanical harvesting of chickpea, which is essential for horizontal expansion of production, is hindered by the presence of weeds because of non-uniform crop maturity and machine blockage caused by excessive weed biomass. The contamination of produce with weed seeds reduces the crop quality. Excessive weed competition may adversely affect seed size which is an important quality parameter in many areas in the Mediterranean region.

The problem of weeds in winter sown chickpea is so serious that lack of suitable weed control measure is hindering the transfer of winter sowing technology to many farmers in WANA. To exploit fully the potential of winter sowing, the crop should be planted at high population density (Saxena, 1987) which makes inter-row cultivation impossible, except at very early stage of crop growth. Weeds emerge with the winter sown crop and create sever competition unless controlled timely and effectively. Inter-row cultivation is not sufficient and intra-row hand weeding is necessary under most conditions. There is, therefore, an urgent need to move from the costly manual-mechanical weed control to an integrated control for winter sowing. In the more developed agricultural systems, herbicides have already replaced mechanical weed control (Klingman and Aston, 1982).

Weed flora

Weed species prevailing in the culture of a crop affect weed management pratices. A herbicide may be effective on a particular weed species but not others. As is true for other crops there is no weed flora specific to chickpea. The association of certain species with a crop is a function of adaptation, climate, soil type and its fertility, crop rotation, time of sowing, water management and weed control technology. There are more than 75 weed species that were reported to infest chickpea fields in the Mediterranean region (Calcagno *et al.*, 1987; El-Brahli, 1988; Loudyi, 1988). These species are mostly dicotyledons and belong to 26 different families.

The major weed species associated with chickpea in WANA include *Sinapis arvensis, Geranium tuberosum, Scandix* spp., *Carthamus syriacus, Polygonum* sp., *Vaccaria pyramidate, Amaranthus* sp., Galium sp., *Euphorbia* sp., *Vicia* sp., *Meliotus* sp., *Convolvulus arvensis, Avena sterilis, Phalaris brachystachis, Bromus* sp. and volunteer cereals (Giegy, 1969; ICARDA, 1979; Eshel *et al.*, 1979; ICARDA-FSP, 1986; El-Brahli, 1988). *Vaccaria pyramidata* and *Galium tricone* are difficult to control by many herbicides in the cereal phase and thus create a problem for the following chickpea crop. Both species compete with chickpea, but the later causes shattering problem in addition due to its sticky nature.

Parasitic weeds reported on chickpea are *Orobanche crenata, O. egyptiaca, Cuscuta campestris* (Graf *et al.*, 1982), and *C. hyaline* (Vyas and Joshi, 1975). Chickpea is known to be effective in inducing germination of *Orobanche* seeds (Krishnamoorthy *et al.*, 1977). The two *Orobanche* spp. and *Cuscuta* spp., were observed on winter chickpea in WANA though *Orobanche* infestation was not as serious as in faba bean and lentil. However, these weeds should be monitored as they may become a serious potential parasite on winter chickpea. The environmental conditions and the short season does not give an opportunity for these parasitic weeds to propagate effectively on spring sown chickpea.

Weed competition

Studies on weed competition in chickpea have been limited. The response of crop yield to weed competition is generally sigmoid in nature. Weed species have different effects on yield losses of chickpea depending on their growth habit, nutrient requirements and water uptake. For example, in North Syria, *Chenopodium album* was more competitive than *Polygonum polybigem* and *Avena ludaviciana* (Fig. 1). Competition is equally important in rainfed and irrigated chickpea (Bhan and Kukula, 1987). Chickpea crop faces competition mainly from annual broad-leaf weeds due to identical growth pattern of chickpea and weeds. Severity also increases with advance in growth.

The beneficial effect of reduced weed competition is apparent from the dry matter accumulation of chickpea under weed-free and weedy environments (Fig. 1) which is ultimately reflected on seed yield (Bhan and Kukula, 1987). Ahlawat *et al.* (1981) reported that weeding increased seed yield of chickpea by 107% and the first 4 to 6 weeks were most critical period for weed competition. The study in northern Syria (Fig. 1) showed that dry matter accumulation of the chickpea under the different weed levels followed more or less identical pattern up to 30 days. However, competition became more severe after 60 days and hence the first 30 to 60 days after emergence are the most critical for weed control as also indicated earlier by Saxena *et al.* (1976). Any control measure to ensure effective suppresion of weeds during this period should result in increased yield.

Weed control methods

Methods used to control weeds in various crops include manual, mechanical, cultural including crop rotations, crop competition, biological and chemical. The first two methods are common in the less developed farming systems while the last is dominant in the industrial-

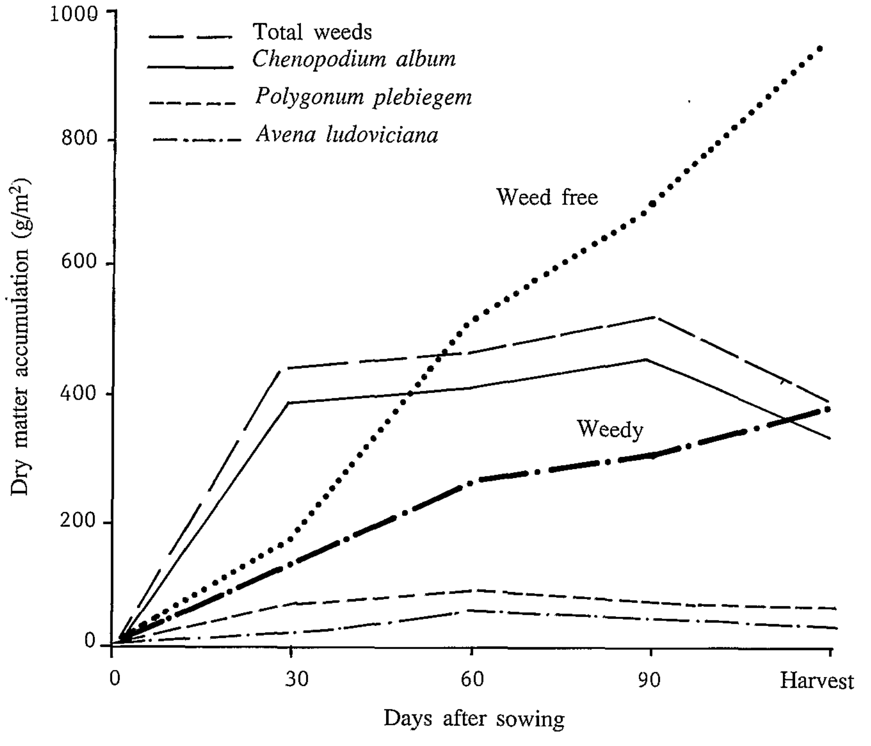

Fig. 1. Effect of weeding on dry matter accumulation in weed-free and weedy chickpea and the dry matter accumulation of total weeds and some weed species (Bhan and Kukula, 1987).

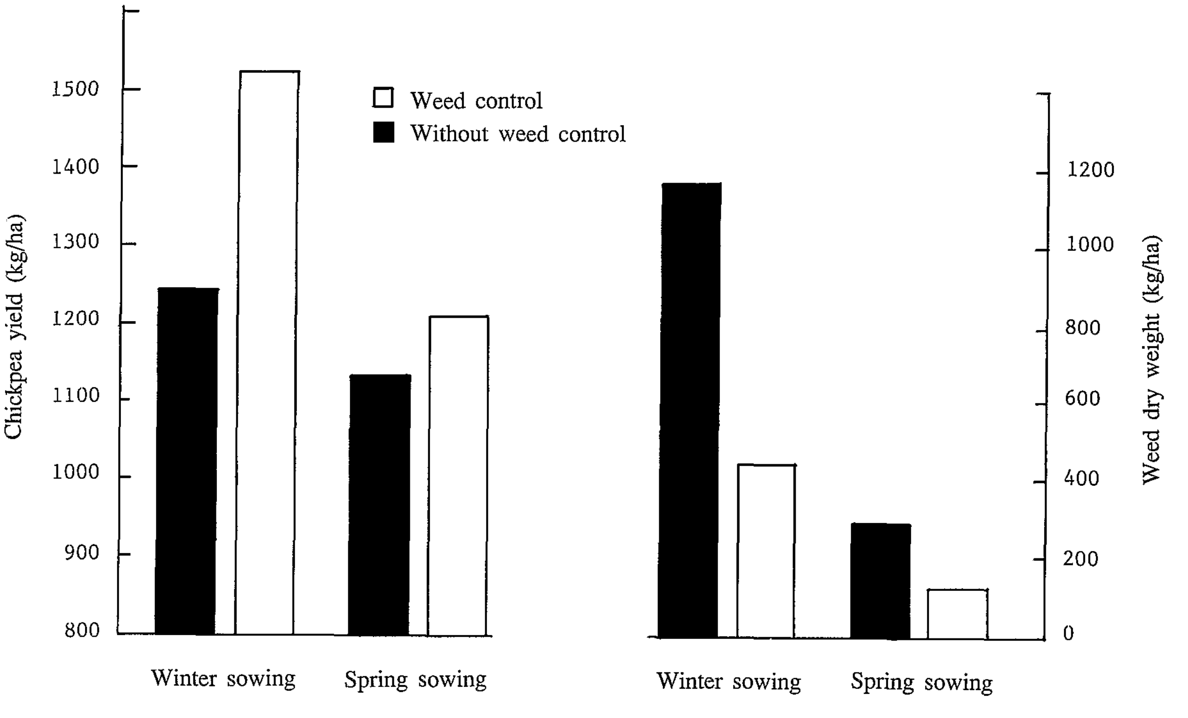

Fig. 2. Chickpea grain yield and weed dry matter production at different sowing dates as affected by weed control in Northwest Syria (average of 11 sites), 1985/86.

ized countries. Crop rotations, when well managed, can contribute greatly to reduce the weed infestation. In the Mediterranean region, chickpea is commonly grown in two-course or three-course rotations with cereals and fallow or summer crop (Saxena, 1987). Weeds are controlled effectively in the cereal phase through selective herbicides and by cultivation in the fallow or summer crop phase.

The current tendency in chickpea weed control in the Mediterranean region is to shift from the costly manual-mechanical energy yo the chemical energy through more usage of effective herbicides particularly with the increased adoption of winter sowing. So far, no single method seems to be fully effective and widely adapted to all environments and situations. Financial resources and technical-know-how capabilities of farmer are important considerations in the choice of the method. Under good management, an integrated approach involving chemical, cultural and mechanical methods will probably provide an effective weed control system in chickpea.

Manual and mechanical methods

Hand pulling, hoeing, spudding and tillage are the traditional methods practiced for a long time in WANA, the Indian-subcontinent and other parts of the world. The first three methods, involving manual weed control, have become increasingly expensive because of scarce hand labour in rural areas. These methods are effective when carried out 2 to 3 times at early stages of weed development. When the weeding is delayed until later stages irreversible damage from weed competition occurs and removal of bigger weeds requires more man-power, with little economic return, and serious physical damage to the crop.

Preparatory tillage indirectly contributes to weed control as good seedbed preparation reduces the weed population and gives advantage to the crop to grow rapidly thus improving its competitiveness with weeds especially in spring sown chickpea.

Inter-row cultivation using implements drawn by animal or tractor power contributes to weed control directly. This practice is commonly followed in WANA particularly in spring sown crop. In both Algeria and Morocco, farmers increase row spacings up to 2.0 m to facilitate inter-cultivation for weed control by the available implements (Haddad, 1988). The limited effectiveness of manual- mechanical weeding methods, particularly in winter sown chickpea, and the rising labour costs impose limitations on these methods. Besides, no cultivation during the growing season is preferable to preserve moisture under semi-arid conditions where chickpea is mainly grown. More emphasis should, therefore, be given to chemical control methods.

Table 1. Some herbicides tested on chickpea and gave satisfactory weed control and crop tolerance under certain conditions.

Herbicide (common name)	Reference (some as cited by Knott and Halila, 1988)
Mainly for broad-leaf weeds	
Alachlor[b]	Jai Prakash & Rahwa, 1977; Panwar & Pandy, 1977; Faroda & Singh, 1981; Dhingra *et al.*, 1982; Weiss, 1982.
Chlorazine[a]	Simrnov and Germantseva, 1966.
Chlorbromuron[a]	ICARDA, 1980; Malik *et al.*, ICARDA, 1985.
Cyanazine[a]	Saxena & Yadav, 1976; Kakula *et al.*, 1985.
Fluchloralin[a]	Bhan and Kukula, 1987.
Dinoseb amine[a]	Muehlbauer *et al.*, 1981.
MCPA[b]	Mahoney, 1981.
Mealachlor	Muehlbauer *et al.*, 1982.
Methabenzthiazuron[a]	Kolar *et al.*, 1982; Bhan Kukula, 1987.
Metribuzin[b]	Mahoney, 1981; Bhan and Kukula, 1987; Knott and Halila, 1988.
Nitrofen	Jai Prakash & Pahwa, 1977; Panwar & Pandy, 1977; Dhingra *et al.*, 1982; Yadav *et al.*, 1983.
Nitrofen-linuron	Calcagno *et al.*, 1982.
Oxyfluorfen[a]	Mahoney, 1981.
Pendimenthalin[a]	Eshel, 1979; Yadav *et al.*, 1983.
Penoxalin-linuron	Calcagno *et al.*, 1987.
Prometryne[a]	Laptiev, 1976; Panwar & Pandy, 1977; Dept. of Agri. New S. Wales, 1978; Ahlawat *et al.*, 1979.
Profluralin	Muehlbauer *et al.*, 1982.
Propham[b]	Mohaney, 1981.
Terbutryne[b]	Saxena & Yadav, 1976; Dept. Agr. New S. Wales, 1978; Eshel, 1979; Dhingra *et al.*, 1982; Kolar et al., 1982; Malik *et al.*, 1982; Weiss, 1982; Kukula *et al.*, 1985.
Terbutryne/terbuthylazine	Laptiev, 1976.
Trifuralin	Mahoney, 1981; Calcagno *et al.*, 1987.
Mainly for grass weeds	
Barbabn	Eshel, 1979.
Cyanazine	Saxena & Yadav, 1976; Kukula *et al.*, 1985.
Fluzifop-butyl[a]	Kukula, 1985.
Pronamide (Propyzamide)	Saxena & Yadav, 1976; ICARDA 1985; Weiss, 1982; Kukula *et al.*, 1985.
Tri-allate	Mahoney, 1981.
Trifluralin[a]	Mahoney, 1981. Calcagno *et al.*, 1987.

[a]/ Gave good control with practically no phytotoxicity to the crop.
[b]/ Gave reasonable control with varying degrees of phytotoxicity to the crop.

Chemical control

Studies since the late seventies tested more than 35 commercial herbicides on chickpea for weed control and crop tolerance. Several effective herbicides were identified to control broad-leaf and grass weeds (Table 1). Most of these herbicides are soil-acting chemicals applied pre - planting and pre-emergence and prevent the early establishment of seedling from germinating weed seeds. Like most grain legumes. chickpeas are more tolerant to pre-emergent compared to post-emergent herbicides. This explains why effective post-emergent herbicides are limited particularly those for broad-leaf weeds. Some pre-planting herbicides are also contact weed killers that destroy above ground parts of weeds. Volatile chemicals are incorporated in the soil before sowing for optimum effect. The selectivity and efficacy of these soil-acting herbicides is usually limited to specific agro-ecological conditions because of differences in soil type, moisture availability, temperature, and weed flora. Therefore, recommendations differ from one agro-climatic zone to another.

Effective herbicides

Efective pre-planting and soil incorporated (PPI) herbicides include fluchloralin, oxyfluorfen, trifluralin and triallate. Those effective as pre-emergent herbicides are alachlor, chlorobromuron, cyanazine, dinoseb amine, methabenzthiazuron, metribuzin, pronamide, prometryne and terbutryne. Post-emergent herbicides include dinoseb-acetate, fluazifop-butyl and fenoxprop-ethyl. Post-emergent aplications need great care with respect to stage of growth and air temperature to avoid phytotoxicity.

Experiments in Northern Syria and Lebanon during 1982-83 showed that the best herbicides treatments at Tel Hadya with 324 mm rainfall were chlorobromuron (1.5 kg a.i./ha), terbutryne (3.0 kg a.i./ha) and cyanazine (0.5 kg a.i./ha) applied pre-emergent (Bhan and Kukula, 1987). At Jindiress with 417 mm rainfall, cyanazine (1.0 kg a.i./ha) and a combination of cyanazine (1.0 kg a.i./ha) with pronamide (0.5 kg a.i./ha) were most effective. At Terbol in Lebanon with higher rainfall, the best treatments were pre-emergent application of methabenzthiazuron (3.0 kg a.i./ha) plus pronamide (0.5 kg a.i./ha) or terbutryne (3.0 kg a.i./ha); followed by post-emergent application of fluazifop-butyl (0.5 kg a.i../ha). Similar results were obtained in northern Syria in 1985/86 and 1986/87 seasons (ICARDA-FLIP, 1986 and 1987).

Chickpea International Weed Control Trials (CWCT) tested since 1980/81 in various countries of the WANA region showed that best treatments involved pre-emergent application of three herbicides terbutryne (2.5-4.0 kg a.i./ha), chlorobromuron (1.5 to 2.5 kg a.i./ha), and methabenzthiazuron (3.0 kg a.i./ha), either alone or with pronamide (0.5 kg a.i./ha) (ICARDA, 1981a to 1986a). Fluazifop-butyl (1.0 kg a.i./ha) gave good control on cereal volunteers when applied post-emergence when grasses are 10-15 cm tall (ICARDA, 1983a to 1987a). Cyanazine (0.5-1.0 kg a.i./ha) with pronamide (0.5 kg a.i./ha) was also effective in Algeria and northern Syria against annual broad-leaf, grasses and volunteer cereals (ICARDA, 1984a and 1985a; ITGC, 1987).

In a series of on-farm trials in northern Syria during 1985/86 chemical weed control (pre-emergence terbutryne at 2.0 kg a.i./ha with pronamide at 0.5 kg a.i./ha) increased yield by 26% and 6% in winter and spring sowing, respectively, compared to control (Fig. 2).

Cuscuta campestris was selectively controlled by pre-emergence application of pronamide with chlorthal dimethyl (Graf *et al.*, 1982).

Response of different weed species to herbicides

Prometryne and terbutryne were effective on the majority of the common species in south-central Morocco. Chlorbromuron over-all effectivity on weed species was acceptable. In the same country but at another location, terbutryne (3.0 kg a.i./ha) and pronamide (1.0 kg a.i./ha) succesfully controlled *Chenopodium album, Ridolfia segetum, Amaranthus* sp. and *Torils nodosa*. However, *Convolvulus arvensis*, a perennial weed, escaped from all herbicides tested (El-Brahli, 1988). Terbytryne did not control *Vicia sativa.* Pre-emergence application of nitrofen-linuron, peronaxlin-linuron and penoxalin and pre- planting application of trifluralin controlled most common weed species in chickpea fields in Italy (Calcagno *et al.*, 1987). It is apparent that most effective hebicides do not have very wide-spectrum effect on weed species.

Limitation of chemical control

Chemical control of weeds in chickpea is promising in spite of some technical limitations in its adoption in certain areas. Most of the effective soil-acting herbicides have limited persistence in the soil and these are only effective at early stages of crop development. The narrow adaptation of these herbicides and the inconsistency of their effect from season to season are other limitations. Herbicide efficacy being highly dependent on soil moisture, is bound to vary from one season to another in semiarid areas where rainfall is highly variable. Post-emergent herbicides that could effectively control broad leaf weeds satisfactorily are not available. The new post-emergent chemicals for grasses seem effective though the choice is limited and widen alternative should be sought for widen spectrum of control. Increased future attention by the agro-chemical industry to develop products for weed control in chickpea might improve the situation.

Non-technical limitations also constrain use of chemical control in the less industrialized countries. Effective herbicides are usually not available or not registered in the pesticide registration system of these countries. Herbicides usage requires skill and precision and availability of sufficient water and suitable equipment which are not always present. High price of some herbicides is also a limitation. Nevertheless, the trend will be to shift from the manual and mechanical weeding to the use of herbicides which are more effective particularly in winter chickpea.

Residual effect of herbicides

Chickpea generally follows cereals in a rotation, and thus no chemical residual hazards are expected because in most cases foliar-active herbicides are applied to cereals, which have little carry-over effect. But sometimes, soil-acting herbicides are used for the preceding crops in rotations and the chickpea may be seriously damaged depending on the type of herbicide involved. Residual effect must be checked for each case. For example diuron applied to cotton at 2 to 4 kg a.i./ha had a residual effect on chickpea as a following crop (Sheriff *et al.*, 1973).

Cereals in rotation following chickpea may also be damaged when soil-acting herbicides are used for chickpea. Methabenzthiazuron at 2.0 a.i./ha during the legume phase causes damage to cereals. Pronamide which is used for grass control in legumes is a very potent killer, but it normally degrades within the time span between the two crops, and hence should not affect the following cereals. In high elevation areas of Turkey, however summer temperture is low, very severe damage occurred on cereals following legume crops on which pronamide has been applied. In Algeria, use of trifluralin in chickpea resulted in damage to cereals in the following season (Haddad, 1988).

Herbicides effects on N_2-fixation

The effect of herbicides on nodulation and N_2- fixation in chickpea is either direct through the effect on rhizobium bacteria or indirect through the suppression of plant growth and development. Kumar *et al.* (1981) reported that the growth of chickpea *Rhizobium* in culture was reduced when the concentration of simazine and prometryne was increased from 1 to 20 mg/1. Though root nodule initiation was not affected at early stages, both production of late nodules and nodule growth were reduced particularly with simazine. N_2-fixation was greater in prometryne-treated plants and was nill in those treated with simazine. Doses higher than 1.5 kg a.i./ha for chlorobromuron and 2.5 a.i./ha for methabenzthiazuron had adverse effect on number of nodules per plant (Malik *et al.*, 1982).

Future research emphasis

Several areas of research should receive emphasis in future to develop effective weed control schedules for chickpea. The role of tillage and methods of sowing in the establishment of better crop stand to improve crop competitiveness should be explored. Adjustments in the date of sowing of winter chickpea in relation to weed control should be explored. More effective post-emergent herbicides to control broad-leaf weeds should be identified. Improvement in effectivity of pre-emergent herbicides in terms of longer persistance, wider adaption, and broader spectrum of weed control should be sought. Interaction between effective herbicides and cultural practices e.g. tillage practices, planting methods and planting pattern needs to be investigated. The system developed should be subjected to multi-location testing to assess its adaptability. Resisual effect of herbicides and their effect on biological nitrogen fixation should be given due attention before selecting a herbicide as a component of weed control package.

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