Chemical Science Review and Letters ISSN 2278-6783

Review Article

A Review on Weed Management in Onion under Indian Tropical Condition

R. Sathya Priya*, C. Chinnusamy, P. Murali Arthanari and V. Hariharasudhan

Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore - 641 003, Tamil Nadu, India

Abstract

Weed is creating the havoc all over the world. It is a silent killer of crop. Productivity goes down making the farmers baffled. In India, on an average 37 per cent of the total annual loss in crop productivity is due to weed. Weeds are unwanted and undesirable plants that interfere with the utilization of land and water resources that adversely affect crop production. Weeds pose a serious problem in successful cultivation of onion. Manual weeding, a traditional practice in the developing countries is costly and cumbersome. With the advent of herbicide technology, numerous herbicides with high potency and environmental safety are becoming available for effective control of weeds in field crops. Herbicide discovery and development is a continuing process, because there is always a need for newer herbicides to meet the changing weed situations in agricultural systems to achieve greater efficacy and economy in chemical weed control and to minimize risks through toxicity and residues to the environment. Also, the efficiency of an herbicide in controlling weeds depends on the weed spectrum, herbicide dose, time and method of application. Hence, a brief review is presented on the nature of weed spectrum in onion, competition between crops and weeds, their effect on growth and yield, different weed control methods, herbicides bio-efficacy, rate as well as time of application and their residual toxicity on the succeeding crops.

Keywords: Onion, crop weed competition, weed management, nutrient depletion, economics

***Correspondence**

Author: R. Sathya Priya

Email: sathyapriyaagri@gmail.com

Introduction

Onion (*Allium cepa* var. *aggregatum* L.) belonging to the family *Alliaceae* is one of the important bulbous vegetable crop of economic importance and widely cultivated all over the world, with particular distribution in the Asian continent and in Europe. Onion is popularly known as *"Queen of kitchen"* because of its characterstic flavour. Many researchers have reported that onion plants are poor competitor of weeds [1-3]. This poor competitive ability with its initial growth and lack of adequate foliage makes onion weak against weeds. In addition, their cylindrical upright leaves do not shade the soil to block weed growth. Uncontrolled weed growth reduces the bulb yield upto 40-80 per cent depending upon the nature of intensity and duration of weed competition in onion field [4]. Critically viewing, the manual and mechanical methods of weed control in onion, besides being less effective, costly and time demand as well as need to be repeated at frequent intervals. Moreover, due to non-availability of timely labour, weeds are not controlled at the proper stage of the crop resulting in production of unhealthy seedlings and bulbs in onion. In addition continuous rains during early crop growth stages hinder the cultural and mechanical practices of weed control. Under such situations, chemical method of weed control has shown good promise in a variety of crops with the advancement of agriculture and technology. Several workers have found pendimethalin, oxyfluorfen and oxadiazon to be efficient in controlling weeds in onion. Phytotoxicity is one of the undesirable results of herbicide use in onion [5]. Many research findings established that pre-emergence application of oxyfluorfen at reduced dose would provide effective early season broad leaved weed control in onion without significant crop injury [6]. Hence, a brief review is presented on the nature of weed spectrum in onion, competition between crops and weeds, their effect on growth and yield, different weed control methods, herbicides bio-efficacy, rate as well as time of application and their residual toxicity on the succeeding crops.

Common weed flora in onion field

Weed flora differ widely in their diversity depending upon environmental and soil conditions and hence the information on the weed spectrum in onion field will be of great use for the formulation of effective weed management practices. The major weed flora of onion in vertisols of Dharwad composed of *Cyperus rotundus*, *Cynodon dactylon*, *Setaria glauca*, *Digitaria sanguinalis*, *Panicum isachne*, *Commelina benghalensis* among monocots while, the predominant dicots were *Parthenium hysterophorus*, *Phyllanthus niruri*, *Hibiscus panduriformis*, *Trianthema monogyna*, *Eclipta alba*, *Amaranthus viridis*, *Portulaca oleraceae*, *Cocculus hirsutus* and *Corchorus trilocularis* [7]. According to Dandge and Satao (1999) [8] the major weed flora of onion in slightly alkaline sandy clay loam soil during the *rabi* season were *Parthenium hysterophorus*, *Physalis minima*, *Euphorbia spp*., *Chenopodium album*, *Anagalis arvensis*, *Amaranthus viridis* and *Argemone mexicana* among the broad leaved weeds and *Cyperus rotundus*, *Commelina benghalensis*, *Cynodon dactylon*, *Dinebra retroflexa* and *Panicum spp*., among the narrow leaved weeds. In Karnal, the weed flora of onion field included *Cyperus rotundus* (28%), *Coronopus didymus* (48%), *Anagallis arvensis* (6%) and other weed (20%) which included *Convolvulus arvensis*, *Melilotus spp*., *Chenopodium album* and *Poa annua.* In sandy loam soil, *Coronopus didymus* was the dominant broad leaved weed and *Cyperus rotundus* was dominant among sedges and grasses [9]. Weed flora such as *Cyperus rotundus*, *Parthenium hysterophorus*, *Phyllanthus niruri*, *Euphorbia geniculata* and *Dinebra retroflexa* were noticed in black clay soil of Karanataka during *kharif* season as given by Channappagoudar and Biradar (2007) [10]. Sharma *et al*. (2009) [11] observed that *Cyperus rotundus* (0.35%), *Rumex dentatus* (2.4%), *Melilotus alba* (0.35%), *Chenopodium album* (0.35%), *Fumaria parviflora* (1.0%), *Anagallis arvensis* (1.25%), *Veronica agrestis* (0.35%), *Spergula arvensis* (20.3%), *Trigonella polycerata* (1.4%), *Medicago denticulata* (1.05%), *Lepidium sativa* (41.7%) and *Aerva spp*., (29.5%) were the predominant weed species of onion field in sandy loam soils of Punjab. The dominant grassy weed species were *Cynodon dactylon*, *Acrachne racemosa* and *Dactyloctenium aegyptium.* Among the broad leaved weeds *Boerhaavia diffusa*, *Parthenium hysterophorus* and *Digeria arvensis* were the dominant weeds. *Cyperus rotundus* was the only sedge present in the experimental field in Western Zone of Tamil Nadu [12].

Studies by Mishra et al. (1986) [13] revealed a wide range of weeds were *Cyperus rotundus*, *Cynodon dactylon*, *Scirpus moritimus*, *Asphodelus tennifolius*, *Trianthema portulacastrum*, *Melilotus indica*, *Anagallis arvensis*, *Canabis sativa*, *Acalypha indica*, *Euphorbia microphyla*, *Vicia sativa*, *Convolvulus arvensis*, *Amaranthus viridis*, *Cirsium arvensis* and *Launea pinnatiful* in onion raised in sandy loam soil during rabi season. Balraj Singh et al. (1998) [14] reported that *Chenopodium album*, *Portulaca oleraceae, Echinochloa crusgalli and Cyperus spp*., were the dominant weeds in onion during *rabi* season. The dominant weed species in *rabi* onion at Gurgaon were *Cyperus rotundus, Chenopodium album, Chenopodium murale, Digeria arvensis, Cynodon dactylon and Anagallis arvensis* [15]. The predominant weed species infesting the *rabi* season onion were *Galinsoga parviflora, Brachiaria ramosa, Cyperus rotundus, Cannabis sativa, Polygonum plebjum, Fumaria parviflora, Phalaris minor* and *Oxalis latifolia* [16].

Critical period of crop weed competition

The critical period can be defined as "the shortest span of time in the ontogeny of crop growth when weeding will result in higher economic return". A fundamental principle of plant competition is that early occupants on a soil tend to exclude the later ones. This principle finds application in practical weed control. Weeds are capable of accumulating dry weight faster than the crop plants. Thus the duration of weed infestation and time of weed removal has a significant influence on crop growth and economic yield. Critical period of crop weed competition is the prime factor, which decides the growth and yield of onion. Several workers have reported different critical periods ranging from 30 to 60 DAS and established that critical period of weed competition in between two to eight weeks after sowing. Onion faces weed competition during the early stage of crop growth. So the field should be kept weed free for a period of 45 days [17]. According to Roberts (1976) [18] there was no adverse effect on onion bulb yield, when maintained a weed free condition for about five weeks after crop establishment. Studies by Labrada (1977) [19] revealed that the critical period of weed competition was between 30 to 40 days after transplanting of onion. Purwito (1978) [20] indicated that a shorter period of 20 to 30 days is the most critical period for weed competition in transplanted onion. Onion crop was susceptible to weed competition between two to ten weeks [21].

First one month was apparently the most critical stage of crop weed competition in onion [22]. Bhalla (1987) [23] observed a longer period of first six to eight weeks or more after crop emergence as critical period and weeds that emerging subsequently did not affect the yield. Babiker *et al*. (1987) [24] reported that unrestricted weed growth reduced crop yield by 98 per cent and onion was more sensitive to weed competition between two to six weeks after its emergence. Some studies pointed out that single weed removal at proper time may help in avoiding onion yield

losses. This proper time may be 21-56 days after the germination of 50 per cent of onion. According to the findings of several investigators, neither single nor repeated weed removal at optimal period helps to avoid the yield decrease in onion [25].

Weed competition during the first 15 vegetation days does not influence negatively onion crop. If the crop is preserved without weeds only for the first 15 days and later on weeds are not destroyed, the yield decreases was estimated to be 81 per cent [26]. Weed competition throughout the crop period on an average caused 82.2 per cent reduction in bulb yield. Weed infestation prevailed upto 15, 30, 45 and 60 days after transplanting registered 1.2, 39.8, 56.1 and 69.3 per cent reduction in bulb yield over weedy condition throughout the crop. However, there was no significant difference in bulb yield due to weedy situations upto 60 days and weedy conditions throughout crop season [27]. Onion is very sensitive to weed competition during the entire vegetation period, since luxuriant growth of leaves is arrested, which would otherwise cover inter-rows and prevent weed germination. The competitive power of onion was the weakest one against weeds [28].

Effect of competition on growth and yield components

Growth components of onion

The plant growth parameters in onion such as height, leaves per plant, fresh and dry weight of plants were measured significantly higher under weed free situation as well as pre-emergence control of weeds with pendimethalin. Singh and Singh (1994) [29] reported that plant height and number of leaves increased significantly with treatments which were kept weed free till harvest due to least crop weed competition for nutrients, moisture, space and sunlight between crop and weeds. Similarly, Verma and Singh (1997) [30] observed that plant height, leaves per plant, fresh and dry weight of plant were significantly higher under weed free condition. Vora and Mehta (1999) [31] indicated that maximum number of leaves per plant and neck thickness was recorded under weed free check. Dandge and Satao (1999) [32] found that weed free treatment recorded maximum plant height and number of leaves per plant. In onion the maximum number of leaves per plant at 90 days after transplanting and at harvest was observed in oxyfluorfen applied plots due to reduction in weed population as noticed by Ravinder Singh *et al*. (2001) [33].

Yield and yield components of onion

The highest yield in *kharif* onion with the application of oxyfluorfen at 0.12 to 0.25 kg ha^{-1} which more economical and found equally effective to that was of hand weeding [34]. It was observed that with the increase of one kg dry matter of weeds per ha, there was decrease in bulb yield by 20 kg ha^{-1}. Vora and Mehta (1999) [35] observed that, yield attributes like bulb diameter, number of cloves per plant, 100 cloves weight, bulb yield per plant and total bulb yield of garlic was most favourable under weed free check. This might have been due to lesser crop weed competition for light, space, nutrients and moisture. Satao *et al*. (1999) [36] indicated the highest 100 bulb weight, increase in diameter of bulbs and maximum bulb yield per ha in *rabi* onion at Akola under weed free treatment and herbicidal treatments.

According to Ramachandra Prasad (2000) [37] uncontrolled weeds reduced the bulb yield by 75 per cent due to severe weed competition, particularly due to the presence of grasses and broad leaved weeds as weed competition could lower the bulb diameter and bulb weight considerably. Vedprakash *et al*. (2000) [38] reported that, bulb yield of onion showed better performance under herbicides combined with hand weeding treatment over herbicides alone owing to effective control of weed through herbicides during initial stage and later on by hand weeding.

Sixty one per cent reductions in bulb yield in the weedy check compared with oxyfluorfen followed by hand weeding were reported by Mondal *et al.* (2005) [39]. Oxyfluorfen 0.15 kg ha^{-1} supplemented with one hand weeding on 35 DAT was found significantly superior to all the other herbicidal treatments. Chopra and Chopra (2007) [40] reported that the bulb diameter was significantly reduced in weedy check compared with weed control treatments. The reduction was 24.8 per cent in weedy check compared with oxyfluorfen at 0.15 kg ha^{-1} supplemented with hand weeding at 35 DAT. The maximum plant height and bulb yield was recorded in pendimethalin coupled with cultural practices and this may be due to higher weed control efficiency, reduced weed index, higher chlorophyll content and maximum photosynthetic rate [41].

Nutrient depletion by weeds and uptake by crops

Higher uptake of N, P and K (51.0, 11.4 and 23.2 kg ha^{-1}, respectively) by crop was noticed with the application of oxyfluorfen 0.25 kg ha^{-1} combined with one hand weeding on 40 DAS and this was resulted in the better bulb yield of

onion of 30.4 t ha^{-1} compared to 4.5 t ha^{-1} in weedy control [42]. Balasubrahmanyam *et al.* (1999) [43] estimated that one tonne of onion bulb removed 3.88 kg of N, 1.39 kg of P and 3.06 kg of K and with the bulb yield of 18 tonnes per acre. The total removal of nutrients was about 70 kg of N, 25 kg of P and 55 kg of K. Kolhe (2001) [44] reported that the lower nutrient uptake by onion was recorded in weedy check which was due to the lowest bulb yield.

The minimum N, P and K removal (7.45, 0.62, 8.00 kg ha^{-1}, respectively) by weeds was observed when oxyfluorfen at 0.25 kg ha^{-1} was supplemented with hand weeding at 40 DAT followed with the application of oxyfluorfen at 0.37 kg ha^{-1}. Maximum uptake of N, P and K by onion bulbs was obtained with the application of oxyfluorfen at 0.25 kg ha^{-1} + hand weeding at 40 DAT followed by oxyfluorfen applied at 0.37 kg ha^{-1} [45]. Kathepuri *et al*. (2007) [46] observed higher amount of nitrogen uptake under hand weeding twice at 20 and 40 DAS after transplanting and this was followed by application of pendimethalin 1.0 kg ha^{-1} + HW at 40 DAS and oxyfluorfen 0.2 kg ha^{-1} + HW at 40 DAS in onion.

Weed management methods

A much wider range and intensity of weeds occur in groundnut and onion. Weeds vary in their growth habit and life cycle. Therefore, no single weed control method may provide effective control of weed. Various weed management practices are in vogue in groundnut and onion and each have its own merits and demerits. Weed control is achieved through direct methods (hand weeding, herbicide application and mechanical weeding) used within systems and indirect methods such as land preparation, water management, planting method and fertility management. The final choice of any weed control method depends on its effectiveness and economics.

Manual and cultural methods of weed management

The largest bulb size was observed under hand weeding treatment however; it was found uneconomical when compared to application of ronstar at 3.0 litre per ha as pre emergence treatment [47]. Prasad and Singh (1998) [48] indicated that in *rabi* onion repeated hand weeding at 30, 60 and 80 days after transplanting resulted in the best weed control with highest bulb yield and greatest profits. According to Banafar and Gaur (1993) [49] manual weeding twice was the most effective treatment in reducing weeds and increasing onion yields. Calamai and Martini (1994) [50] obtained 86 per cent weed control efficiency with hoeing alone in onion. Saraf *et al*. (1994) [51] indicated that hand weeding at 45 DAP gave more yield due to minimum crop weed competition for resources. Highest bulb yield was obtained with three hand weeding and it was statistically on par with fluchloralin 1.0 kg ha^{-1} and pendimethalin 1.25 kg ha^{-1} with one hand weeding for each as noticed by Rajvir Sharma and Mehta (1994) [52].

Hand weeding was significantly better in increasing the bulb diameter, bulb weight, bulb yield and loss of bulb weight when compared with the control. The two year experimental evidences from Raipur, revealed that mulching on 30 days after transplanting gave maximum bulb yield (263.34 q ha^{-1}) followed by three hand weeding at 30, 60 and 90 days after transplanting [53]. Melander and Hartvig (1997) [54] indicated that hoeing close to the row leaving 5 cm untilled strip, has the potential of saving labour cost for hand weeding in non herbicidal growing system of onion. The highest bulb and weed control efficiency were recorded in the weed free treatment followed by three hand weeding at 20, 40 and 60 days after transplanting [55]. Comparable weed control efficiency of 89.8 per cent could be achieved with manual weeding with that of pendimethalin at 0.75 kg ha^{-1} + hand weeding (90.6%) or Metalachlor 1.25 kg ha^{-1} + hand weeding (77%) or oxyfluorfen 0.07 kg ha^{-1} + hand weeding (74.0%) was reported by Tewari *et al*., (1999) [56]. Ishwar Singh *et al*. (2000) [57] reported that weed management by hoeing gave the highest yield closely followed by the application of oxadiazon and pendimethalin.

Chemical method of weed management

In modern agriculture, herbicides are commonly used as an alternative method to traditional methods of hand weeding at initial period for better control of weeds. In India however the herbicide consumption is only 15 per cent of total pesticide consumption. However, the consumption of herbicide in India has increased rapidly from 4100 metric tonnes (MT) in 1988-89 to 11,000 MT in 2001-02 [58]. The selection of herbicides will depend on the crop type, its potential use, the variety, crop growth stage, condition of the foliage, soil type and weeds present in the field [59].

Pre-emergence application of herbicides

Considerable yield increase in onion could be obtained by effective control of weeds for longer duration with use of

herbicides [60]. Chemical herbicides have been found very promising in controlling weeds in onion [61]. A mixture of 0.75 kg oxyfluorfen with either 1.0 kg of methazole or 1.5 kg methabenzthiazuran per ha gave the best control of weeds and gave the higher bulb weight and yield of first grade onion [62]. Saraf *et al*. (1994) [63] experimented in transplanted onion during *kharif* season in clay loam soils of Madhya Pradesh revealed that application of oxyfluorfen 0.25 kg ha^{-1} increased the bulb yield similar to weed free treatment and followed by oxadiazon with hand weeding on 30 DAP, while the highest yield loss of 72.59 per cent was recorded in weedy check.

Mc Intyre and Barbe (1995) [64] indicated that chemical weed control with oxyfluorfen or oxadiazon was superior to hand weeding. Porwal (1995) [65] observed that pre-emergence application of oxyfluorfen at 0.2 kg ha^{-1} and oxadiazon at 1.0 kg ha^{-1} supplemented with one manual weeding on 40 DAS effectively reduced the weed biomass but gave considerably less yield (15.7 to 16.4 q ha^{-1}) as compared to their lower doses of 0.15 kg ha^{-1} (21.2 q ha^{-1}) and 0.75 kg ha (17.0 q ha^{-1}). Balraj Singh (1996) [66] observed that hand weeding at 45 days after transplanting in combination with herbicides showed improved yield attributes and yield as compared to herbicides alone in three years of experimentation.

A study conducted by El-naggar *et al*. (1996) [67] showed that at 45 days after sowing oxyfluorfen gave the most effective weed control and highest bulb yield. Singh *et al*. (1997) [68] indicated that oxyfluorfen at 0.37 kg ha^{-1} was the most effective treatment for reducing populations of *Poa annua, Coronopus didymus* and *Medicago denticulata* in sandy soils of Himachal Pradesh. Ravinder Singh *et al*. (1998) [69] noticed least dry weight of weed in oxyfluorfen treatment at higher concentration and lower concentrations along with hand weeding on 40 DAP. Balraj Singh *et al*. (1998) [70] stated that oxyfluorfen at lower dose of 0.15 kg ha^{-1} alone or with one hand weeding found to be superior in controlling weeds when compared to other herbicidal treatments. Shimi and Maillet (1998) [71] stated that the best weed control in onion was achieved with oxyfluorfen (2 litres ha^{-1}) and ioxynil + sethoxynil + sethoxydim which resulted in better control of broad leaved weeds. Tewari *et al*. (1999) [72] indicated that supplementing one hand weeding along with pre-emergence application of herbicides registered sharp decline in dry matter of weeds over sole application of different herbicides except in case of oxyfluorfen. Ramachandra Prasad (2000) [73] reported that pendimethalin and oxyfluorfen were most effective in lowering dry weight of grassy weeds as compared to alachlor and metalachlor.

Bulb yield was higher under pre emergence application of pendimethalin at 1.5 kg ha^{-1}, oxyfluorfen at 0.15 kg ha^{-1} and pendimethalin at 1.0 kg ha^{-1} with one hand weeding on 50 days after transplanting [74]. According to Vedprakash *et al*. (2000) [75] pre-emergence spray of alachlor at 2.0 kg ha^{-1} with hand weeding on 45 DAP resulted in low weed density and higher bulb yield of onion. According to Ranpise and Patil (2001) [76] pre-emergence application of oxyfluorfen at 0.4 kg ha^{-1} produced maximum yield (242.2 q ha^{-1}) followed by oxyfluorfen 0.2 kg ha^{-1} (233.3 q ha^{-1}) as compared to the lowest yield under control (50 q ha^{-1}) due to maximum weed intensity. Kolhe (2001) [77] indicated that dry matter of weeds was significantly reduced due to application of pendimethalin, metalachlor, oxyfluorfen either alone or in combination with hand weeding at 35 DAP compared to weedy check. Presently herbicides are widely applied for weed destruction and oxyfluorfen is very effective herbicide suitable for weed destruction in onion and cabbage [78]. Pre-emergence application of oxyfluorfen at 200 g ha^{-1} recorded higher bulb yield due to better control of weeds at critical stages thus providing favourable environmental condition for better growth and development leading to enhance bulb yield [79].

Ghoshen (2004) [80] conducted experiments to evaluate the efficacy of herbicides for control of broad leaved weeds which were applied only once in irrigated onion. Oxyfluorfen and oxadiazon were used as pre and post emergence and visual ratings estimated 65 days after crop emergence indicated that weed control was adequate in oxyfluorfen and oxadiazon treatments but onion plants were damaged, particularly in oxyfluorfen treated plots. Schumacher *et al*. (2007) [81] suggested that a reduced bromoxynil or oxyfluorfen dose at lower spray volumes to one-leaf onion may provide sufficient early-season *Chenopodium album* and *Amaranthus retroflexus* control so that post-emergence application of bromoxynil plus oxyfluorfen to larger onion provide more effective broad leaved weed control. Residue of oxyfluorfen dissipated faster in plant than in soil with a half-life of 6.1 and 11.2 days, respectively [82].

Mechanical method of weed management

Mechanical weed control is comparatively faster and less labour intensive than hand weeding [83]. Power weeder was found useful for weeding in between standing rows of cash crops like cotton, tapioca and grape. The weeder could cover an average of one ha day^{-1} of eight hours. The cost of weeding by this machine came to only one-third of the weeding cost by manual labourers [84].

Mechanical weed control not only uproot the weeds between the crop rows but also keep the soil surface loose, ensuring better soil aeration and water intake capacity [85]. Weed morphology and stage of growth would influence the selection and efficacy of weeding implement. It is found that the physical damage by burial to 1 cm depth is effective for controlling weeds followed by cutting at the soil surface [86]. Gore *et al*. (2010) [87] reported that cycle hoe weeder produced significantly highest grain yield and found to be effective in controlling grass as well as broad leaved weeds (69 and 44%) and (63 and 67%) at 30 and 60 DAS in soybean. Effective and economical weed management in rainfed pigeonpea was obtained either by pre-emergence application of pendimethalin at 0.75 kg ha^{-1} on 3 DAS followed by one weeding with oleo weeder on 45 DAS or pre-emergence application of pendimethalin at 0.75 kg ha^{-1} on 3 DAS followed by one weeding with wheel hoe weeder on 45 DAS [88].

Economics of herbicidal weed management in onion

Ravinder Singh *et al*. (1998) [89] obtained maximum net return during both the year of study from oxyfluorfen at 0.25 kg ha^{-1} + hand weeding at 40 DAP (Rs.59,813 ha^{-1} and Rs.61,211 ha^{-1}, respectively) which was followed by oxyfluorfen at 0.37 kg ha^{-1} (Rs.39,766 ha^{-1} and Rs.50,738 ha^{-1}, respectively) as compared to weedy check (Rs.3,874 ha^{-1} and Rs.13,74 ha^{-1}, respectively). Yadav *et al*. (2000) [90] suggested that use of chemicals such as oxyfluorfen and pendimethalin was a better option for getting higher bulb yield and net income in onion. The pre-emergence application of pendimethalin at 1.5 kg ha^{-1} supplemented with one hand weeding gave the highest net return of Rs.83,278 ha^{-1} which was 43.4 per cent higher than farmers practice as noticed by Rameshwar *et al*. (2002) [91].

Ranpise and Patil (2001) [92] registered maximum cost benefit ratio with oxyfluorfen 0.40 kg ha^{-1} followed by oxyfluorfen 0.20 kg ha^{-1}. Ravinder Singh *et al*. (2001) [93] recorded highest bulb yield and net return from treatment having oxyfluorfen 0.25 kg ha^{-1} + hand weeding at 40 DAP followed by oxyfluorfen 0.37 kg ha^{-1}. Kolhe (2001) [94] found that pre-emergence application of oxyfluorfen at 0.15 kg ha^{-1} + hand weeding at 35 DAT recorded higher net return (Rs.92,680 ha^{-1}) and benefit cost ratio owing to lower cost of weed control as compared to hand weeding twice. Nandal and Ravinder Singh (2002) [95] revealed that the economic analysis of maximum return was observed when oxyfluorfen at 0.25 kg ha^{-1} was supplemented with hand weeding at 40 DAT (Rs.60,196 ha^{-1}) followed by oxyfluorfen at 0.75 kg ha^{-1} (Rs.54,978 ha^{-1}) and pendimethalin at 1.00 kg ha^{-1} + hand weeding at 40 DAT (Rs.51,162 ha^{-1}). There was net loss of Rs.2,624 ha^{-1} where weeds were not controlled under weedy check.

Mondal *et al*. (2005) [96] reported that the highest net monetary returns were obtained with pre emergence application of oxyfluorfen at 100 g ha^{-1} supplemented with one hand weeding at 25 DAT (Rs.33,650 ha^{-1}) followed by fluchloralin at 750 g ha^{-1} + hand weeding (Rs.31,983 ha^{-1}) pendimethalin at 750 g ha^{-1} + hand weeding (Rs.31,450 ha^{-1}) and oxyfluorfen at 200 g ha^{-1} (Rs.31,400 ha^{-1}). There was net loss of Rs.3,900 ha^{-1} under weedy check. Economic analysis of weed management practices by Channappagoudar and Biradar (2007) [97] indicated that the pre-emergence application of pendimethalin at 1.00 kg ha^{-1} supplemented with one hand weeding gave highest net return of Rs.51,296 ha^{-1} with maximum benefit cost ratio of 8.77.

Conclusion

Pre-emergence application of oxyfluorfen at 200 g ha^{-1} or pendimethalin 750 g ha^{-1} followed by one hand weeding on 40 DAS can keep the weed density and dry weight reasonably at lower level and enhance the productivity of onion resulting in higher economic returns.

References

[1] Carlson, H.L. and D. Kirby. 2005. Effect of herbicide rate and application timing on weed control in dehydrator onions. University of Florida, Intermountain Research and Extension Centre, Number, 115, P.4.
[2] Qasem, J.R. 2006. Chemical weed control in seedbed sown onion (Alium cepa L.). Crop Prot., 25 (6): 618-622.
[3] Smith, R., S.A. Fennimore, S. Orloff and G.J. Poole. 2008. IPM-Pest management Guidelines: onion and Garlic University of California, Agriculture and Natural Resources. Publication p. 3453.
[4] Prakash, V., A.K. Pandey, R.D. Singh and V.P. Mani. 2000. Integrated weed management in winter onion (Allium cepa L.) under mid-hills conditions of north-western Himalayas. Indian J. Agron., 45: 816-821.
[5] Uygur, S., R. Gurbuz and F.N. Uygur. 2010. Weeds on onion fields and effects of some herbicides on weeds in Cukurova region, Turkey. Afr. J. Biotechnol., 9 (42): 7037-7042.
[6] Schumacher, C.E., M. Harlene and M. Hatterman Valenti. 2007. Effect of dose and spray volume on early-season broad leaved weed control in Allium using herbicides. Crop Prot., 26: 1178-1185.

[7] Nadagouda, B.T., C.B. Kudrikeri, S.R. Salakinkop, C.S. Hunshal and S.L. Patil. 1996. Integrated weed management in drill sown onion (Allium cepa L.). Fmg. Syst., 13 (3&4): 22-27.
[8] Dandge, M.S. and R.N. Satao. 1999. Evaluation of trifluralin in onion. Pestol., 23 (10): 30-33.
[9] Chopra, N. and N.K. Chopra. 2007. Production of weed free mother bulb on onion (Allium cepa L.) through integration of herbicides and weeding. Indian J. Agron., 52 (1): 80-82.
[10] Channappagoudar, B.B. and N.R. Biradar. 2007. Physiological studies on weed control efficiency in direct sown onion. Karnataka J. Agric. Sci., 20 (2): 375-376.
[11] Sharma, S.P., G.S.B. Sudeep Singh and D.S. Khurana. 2009. Comparative efficacy of pendimethalin and oxyfluorfen for controlling weeds in onion (Allium cepa L.) nursery. Indian J. Weed Sci., 41 (1 & 2): 76-79.
[12] Sathya Priya, R., C. Chinnusamy, P. Manickasundaram and P. Murali Arthanari. 2013. Evaluation of new formulation of oxyfluorfen (23.5% EC) for weed control efficacy and bulb yield in onion. American J. Plant Sci., 4: 890-895.
[13] Mishra, H.P., S.J. Singh and S.S. Mishra. 1986. Effect of herbicides on weed control efficiency and production potential in onion (Allium cepa L.). Indian J. Weed Sci., 18 (3): 187-191.
[14] Balraj Singh, B.D., Yadav and Yogesh Kumar. 1998. A note on economics of weed control with herbicides in rabi onion (Allium cepa L.). Haryana J. Hort. Sci., 27 (1): 59-60.
[15] Chauhan, D.R., O.P. Kataria and R.S. Balyan. 1998. Weed management studies in rabi onion (Allium cepa L.). Haryana J. Agron., 14 (2): 193-195.
[16] Vedprakash, A., K. Pandey, R.D. Singh and V.P. Mani. 2000. Integrated weed management in winter onion (Allium cepa L.) under mid hill conditions of north-western Himalayas. Indian J. Agron., 45 (4): 816-821.
[17] Bhan, V.M., M. Singh and R.A. Maurya. 1971. Crop weed competition studies in groundnut. Indian J. Weed Sci., 3: 32-36.
[18] Roberts, H.A. 1976. Weed competition in vegetable crops. Ann. Applied. Biol., 83 (2): 321-324.
[19] Labrada, R. 1977. Weeds and their control in beans and other horticultural crops. Boletin de Resenas serie: Agricultura., 4 (8): 45.
[20] Purwito, 1978. Competition of purple nutsedge (Cyperus rotundus L.) with onion (Allium cepa L.) and its possible control with ACR 1308 glyphosate and nitrogen. Weed Abst., 28 (8): 2412.
[21] Thomas, M.N. and C.J. Wright. 1984. A study of the factors affecting the onset of the critical period of weed competition in the onion crop (Allium cepa L.). Scientific Hort., 35: 94-100.
[22] Mishra, H.P., S.J. Singh and S.S. Mishra. 1986. Effect of herbicides on weed control efficiency and production potential in onion (Allium cepa L.). Indian J. Weed Sci., 18 (3): 187-191.
[23] Bhalla, P.L. 1987. Weed competition, crop losses and chemical weed control in onion (Allium cepa L.). A review. Pestol., 11 (2): 25-39.
[24] Babiker, A.G.T., M. Khogali, M.N.M. Osman and A.A. Hamada. 1987. Weed control and management in onions. Rep. Gezira Res. Station and Substations. pp.1979 -1980.
[25] Bond, W. and S. Burston. 1996. Timing the removal of weeds from drilled salad onions to prevent crop losses. Crop Prodn., 15 (2): 205-210.
[26] Shuaib O.S.B. 2001. Critical period of weed competition in onion (Allium cepa L.). University of Aden J. Natural and Applied Sci., 5 (2): 355–360.
[27] Tewari, A.N, S.N. Tiwari, J.P.S. Rathi, B. Singh and A.K. Tripathi. 2003. Studies on crop-weed competition in kharif onion (Allium cepa L.). Indian J. Weed Sci., 41 (1&2): 76-79.
[28] Kavaliauskaite, D. 2009. Influence of herbicides spraying time and frequency on onion crop weediness. Scientific works of the Lithuanian Institute Horticulture and Lithuanian University of Agriculture, Sodininkyste Darzininkyste. pp. 105-108.
[29] Singh, M.P. and K.P. Singh. 1994. Effect of crop weed competition on growth and yield of kharif onion. Indian J. Weed Sci., 26 (3&4): 18-21.
[30] Verma, S.K. and T. Singh. 1997. Effect of weed control measures and fertility on growth and productivity of rainy season onion (Allium cepa L.) Indian J. Agron., 42 (3): 540-543.
[31] Vora, V.D. and D.R. Mehta. 1999. Studies on growth, yield and yield attributes of garlic as influenced by herbicides and weeds. Agric. Sci. Digest., 19(2): 129-133.
[32] Dandge, M.S. and R.N. Satao. 1999. Evaluation of trifluralin in onion. Pestol., 23 (10): 30-33.
[33] Ravinder Singh, T.R. Nandal and Y.R. Shukla. 2001. Weed intensity and onion bulb yield as influenced by different weed management practices. Crop Res., 22 (1): 32-37.

[34] Singh, S.J., K. Sinha, S.S. Mishra, S.S. Thakur and N.K. Choudhary. 1992. Studies on weed management in onion (Allium cepa). Indian J. Weed Sci., 24: 6-10.
[35] Vora, V.D. and D.R. Mehta. 1999. Studies on growth, yield and yield attributes of garlic as influenced by herbicides and weeds. Agric. Sci. Digest., 19 (2): 129-133.
[36] Satao, R.N., M.S. Dandge, A.P. Karunakar and R.V. Nalamwar. 1999. Nutrient uptake, yield and yield attributes as influenced by weed control in onion. Pestol., 23 (1): 12-14.
[37] Ramachandra Prasad, T.V. 2000. Integrated weed management in vegetables (transplanted onion), All India Coordinated Research Project on Weed Control, Bangalore Centre (ICAR), 22nd. Annual Progress Report, pp. 27-40.
[38] Vedprakash, A., K. Pandey, R.D. Singh and V.P. Mani. 2000. Integrated weed management in winter onion (Allium cepa L.) under mid hill conditions of north-western Himalayas. Indian J. Agron., 45 (4): 816-821.
[39] Mondal, D.C., A. Hossiain and B. Duary. 2005. Chemical weed control in onion (Allium cepa L.) under lateritic belt of West Bengal. Indian J. Weed Sci. 37 (3-4): 281-282.
[40] Chopra, N. and N.K. Chopra. 2007. Production of weed free mother bulb on onion (Allium cepa L.) through integration of herbicides and weeding. Indian J. Agron., 52 (1): 80-82.
[41] Channappagoudar, B.B. and N.R. Biradar. 2007. Physiological studies on weed control efficiency in direct sown onion. Karnataka J. Agric. Sci., 20 (2): 375-376.
[42] Ravinder Singh, T.R. Nandal and U.K. Kohli. 1998. Efficacy and economics of some herbicides for weed control in onion (Allium cepa L.). Ann. Agric. Res., 19 (2): 153-157.
[43] Balasubrahmanyam, V.R., A.V. Dhake and P. Moitra. 1999. Improvement of onion cultivation. Agro India, p. 24-27.
[44] Kolhe, S.S. 2001. Integrated weed management in onion (Allium cepa L.). Indian J. Weed Sci., 33 (1&2): 26-29.
[45] Nandal, T.R. and R. Ravinder Singh. 2002. Integrated weed management in onion (Allium cepa L.) under Himachal Pradesh conditions. Indian J. Weed Sci., 34 (1&2): 72-75.
[46] Kathepuri, J.V., V.Y. Sankpal, H.L. Ghadage and S.M. Jawale. 2007. Weed management in irrigated onion (Allium cepa L.) under plane zone of western Maharastra. Madras Agric. J., 94 (1&6): 127-130.
[47] Sharma, R.M. and M. Singh. 1990. Note on chemical weed control in onion crop. Veg. Sci., 17 (1): 70-72.
[48] Prasad, R.K. and K.P. Singh. 1998. A note on the chemical weed control in onion. Haryana J. Horti. Sci., 17: 282-284.
[49] Banafar, R.N.S. and G.S. Gaur. 1993. Influence of weedicides and hand weeding on growth and yield of onion. Indian Cocoa, Arecanut and Spices J., 17 (1&2): 13-14.
[50] Calamai, P. and A. Martini. 1994. Technique of burning weeds for control of infestation in onion and pepper. Informatore Agrario, 50: 17, 87-92.
[51] Saraf, R.K., J.P. Tiwari and S.K. Yadav. 1994. Productivity and Economic viability of kharif onion as influenced by herbicidal weed control in satpura plateau of Madhya Pradesh. World Weeds, 1: 89-94.
[52] Rajvir Sharma and H.M. Mehta. 1994. Chemical weed control in onion. Indian J. Weed Sci., 26 (1&2): 44-45.
[53] Shah, S.N., N.P. Agnihotri and V.T. Gajbhiye. 1996. Field evaluation of pendimethalin for weed control in onion and pesticides in plant and soil. Ann. Plant Prot. Sci., 4 (1): 71-75.
[54] Melander, B. and P. Hartvig. 1997. Yield responses of weed free seeded onions (Allium cepa L.) to hoeing close to the row. Crop Prot., 16 (7): 687-691.
[55] Amrutkar, S.D., B.M. Patil, A.P. Karunakar, H.N. Sethi and D.J. Jiotode. 1998. Efficacy of herbicides for control of weeds and their effects on yield of onion (Allium cepa L.) Crop Res., 16 (3): 372-374.
[56] Tewari, A.N., K.S. Rathi, K. Hussian, S.K. Singh and B. Singh. 1999. Integrated weed management in onion (Allium cepa L.). Indian J. Weed Sci., 31 (1&2): 53-55.
[57] Ishwar Singh, H.S., Dungarwal and I. Singh. 2000. Management of wild onion (Asphodelus tenuipholius) in irrigated mustard. Indian J. Agrl. Sci., 70 (11): 799-800.
[58] Arya, D.R., R.D. Kapoor and Dhiraj Pant. 2008. Herbicide tolerant crops: A Boon to Indian Agriculture. In: Biennial conference on weed management in modern agriculture: Emerging challenges and opportunities. 27-28 February. Organised by ISWS, NRCWS, Jabalpur (M.P) and Rajendra Agricultural University, Pusa (Bihar). pp 23-27.
[59] Davies, D.H.K. and J.P. Welsh. 2002. Weed control in organic cereals and pulses in Younie, D., Taylor, B.R., Welch, J.M and Wilkinson, J.M. Eds. Organic cereals and pulses. Papers presented at conferences held at the

Heriot-Watt University, Edinburgh and at Cranfield university silsoe campus, Bedfordshire, 6 and 9 November 2001, chapter 5, pp. 77- 114. Chalcombe publications.
[60] Pandita, M.L., R.D. Bhutani and G.P. Singh. 1978. Chemical weed control in onion (Allium cepa L.). Indian J. Weed Sci., 15: 7-11.
[61] Singh, R., A.P. Sinha and S.P. Singh. 1986. Comparative efficacy of herbicides and handweeding for the control of weeds in onion. Haryana. J. Hort. Sci., 15: 76-82.
[62] Rodriguez, A.M., A. Soto and C.J. Gamboa. 1988. Chemical control of weeds in onions (Allium cepa L.) under irrigation in Alajuela. Agronomia Costarricense, 12 (1): 99-105.
[63] Saraf, R.K., J.P. Tiwari and S.K. Yadav. 1994. Productivity and Economic viability of kharif onion as influenced by herbicidal weed control in satpura plateau of Madhya Pradesh. World Weeds, 1: 89-94.
[64] Mc Intyre, G. and C. Barbe. 1995. Weed control in direct seeded and transplanted onion. Revue agricole et sucriere de i'Ile-Maurice., 74 (3): 32-36.
[65] Porwal, M.K. 1995. Integrated weed management in garlic (Allium sativum L.) under vertisols. Indian J. Weed. Sci., 27 (1&2): 16-18.
[66] Balraj Singh, 1996. Studies on weed control in onion. Veg. Sci., 23 (1): 30-35.
[67] El-naggar, H.M.M., K.E. El-Habbak and S.A.A. Shams. 1996. Effect of intercropping onion with cotton and chemical weed control on growth, yield and associated weeds in both crops. Ann. Agrl. Sci., 34 (3): 839-857.
[68] Singh, R., U.K. Kohli and T.R. Nandal. 1997. Efficacy of selected weedicides against onion weeds in Himachal Pradesh. J. Hill Res., 10 (2): 200-201.
[69] Ravinder Singh, T.R. Nandal and U.K. Kohli. 1998. Efficacy and economics of some herbicides for weed control in onion (Allium cepa L.). Ann. Agric. Res., 19 (2): 153-157.
[70] Balraj Singh, B.D., Yadav and Yogesh Kumar. 1998. A note on economics of weed control with herbicides in rabi onion (Allium cepa L.). Haryana J. Hort. Sci., 27 (1): 59-60.
[71] Shimi, P. and J. Maillet. 1998. Oxyfluorfen as a general herbicides in onion fields. Comptes rendus 6 eme symposium mediteranean EWRS, Montpillier, France, 13-15 Mai, 1998. 1998, 340.
[72] Tewari, A.N., K.S. Rathi, K. Hussian, S.K. Singh and B. Singh. 1999. Integrated weed management in onion (Allium cepa L.). Indian J. Weed Sci., 31 (1&2): 53-55.
[73] Ramachandra Prasad, T.V. 2000. Integrated weed management in vegetables (transplanted onion), All India Coordinated Research Project on Weed Control, Bangalore Centre (ICAR), 22nd. Annual Progress Report, pp. 27-40.
[74] Yadav, S.P.S., K.K. Thakral, Ashok Yadav and S.K. Sanwal. 2000. Economics of weed control with herbicides in onion. Haryana J. Agron., 16 (1&2): 113-116.
[75] Vedprakash, A., K. Pandey, R.D. Singh and V.P. Mani. 2000. Integrated weed management in winter onion (Allium cepa L.) under mid hill conditions of north-western Himalayas. Indian J. Agron., 45 (4): 816-821.
[76] Ranpise, S.A. and B.T. Patil. 2001. Effect of herbicides on weed intensity and yield of summer onion cv. N-2-4-1. Pestol., 25 (1): 59-60.
[77] Kolhe, S.S. 2001. Integrated weed management in onion (Allium cepa L.). Indian J. Weed Sci., 33 (1&2): 26-29.
[78] Stall, W.O. and J.P. Gilreath. 2002. Estimation effectiveness of recommended herbicides on selected common weeds in Florida vegetables. In: W.M. Stall (ed.), Weed Management in Florida Fruits and Vegetables, 2002-2003. Gainesville, FL: IFAS, 59-64.
[79] Sathya Priya, R. and C. Chinnusamy. 2013. Evaluation of new formulation of oxyfluorfen on weed control practices on weed dry weight, nutrient removal and yield of onion. Green Fmg. 4 (1): 72-75.
[80] Ghoshen. 2004. Single herbicide treatments for control of broad leaved weeds in onion (Allium cepa). Crop Prot., 23: 539-542.
[81] Schumacher, C.E., M. Harlene and M. Hatterman valenti. 2007. Effect of dose and spray volume on early-season broad leaved weed control in Allium using herbicides. Crop Prot., 26: 1178-1185.
[82] Janaki, P., R. Sathya Priya and C. Chinnusamy. 2013. Field dissipation of oxyfluorfen in onion and its dynamics in soil under Indian Tropical Conditions. J. Environ. Sci. and Health, Part B: Pesticide, Food Contaminants and Agricultural Waste. 48:11, 941-947.
[83] Chivinge, O.A. 1990. Weed science technological needs for the communal areas of Zimbabwe. Zambezia, 17 (2):133-143.
[84] Tajuddin, A. 2006. Design, development and testing of engine operated weeder. Agric. Engg. Today, 30 (5&6): 15-17.

[85] Yadav, R. and S. Pond. 2007. Development and ergonomic evaluation of manual weeder. Agrl. Engineering International: CIGRE journal. Manuscript PM 07022. Vol 9.
[86] Rajakumar, D. 2008. Study on the effect of nitrogen fertililzation, green manure intercropping and weed management in aerobic rice. Ph.D. Thesis, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India.
[87] Gore, A.K., G.D. Gadade and J.K. Jadhav. 2010. Performance of mechanical weeders on vertisols of marathwada region in soybean. In: Biennial conference of Indian society of weed science on Recent Advances in Weed Science Research-2010, 25-26 February. IGKV, Raipur, Chhattisgarh. P. 106
[88] Gowsalya, S., K.R. Latha, N.K. Prabhakaran and D. Asokan. 2010. Mechanical weed control in rainfed pigeonpea. M.Sc. Thesis, Tamil Nadu Agric. Univ., Coimbatore, Tamil Nadu, India.
[89] Ravinder Singh, T.R. Nandal and U.K. Kohli. 1998. Efficacy and economics of some herbicides for weed control in onion (Allium cepa L.). Ann. Agric. Res., 19 (2): 153-157.
[90] Yadav, S.P.S., K.K. Thakral, Ashok Yadav and S.K. Sanwal. 2000. Economics of weed control with herbicides in onion. Haryana J. Agron., 16 (1&2): 113-116.
[91] Rameshwar, G.S. Chadha, D. Sharma and Surinder Rana. 2002. Evaluation of herbicides for weed control and economics in onion (Allium cepa L.) under cold desert Region of Himachal Pradesh. Indian J. Weed Sci., 34 (1&2): 68-71.
[92] Ranpise, S.A. and B.T. Patil. 2001. Effect of herbicides on weed intensity and yield of summer onion cv. N-2-4-1. Pestol., 25 (1): 59-60.
[93] Ravinder Singh, T.R. Nandal and Y.R. Shukla. 2001. Weed intensity and onion bulb yield as influenced by different weed management practices. Crop Res., 22 (1): 32-37.
[94] Kolhe, S.S. 2001. Integrated weed management in onion (Allium cepa L.). Indian J. Weed Sci., 33 (1&2): 26-29.
[95] Nandal, T.R. and R. Ravinder Singh. 2002. Integrated weed management in onion (Allium cepa L.) under Himachal Pradesh conditions. Indian J. Weed Sci., 34 (1&2): 72-75.
[96] Mondal, D.C., A. Hossiain and B. Duary. 2005. Chemical weed control in onion (Allium cepa L.) under lateritic belt of West Bengal. Indian J. Weed Sci. 37 (3-4): 281-282.
[97] Channappagoudar, B.B. and N.R. Biradar. 2007. Physiological studies on weed control efficiency in direct sown onion. Karnataka J. Agric. Sci., 20 (2): 375-376.

Publication History
Received 05th Apr 2017
Revised 15th Apr 2017
Accepted 17th Apr 2017
Online 30th Apr 2017