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Integrated weed management studies in onion (*Allium cepa* L.) During Rabi and Kharif season

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Abstract
Onion is one of the most important commercial vegetable crops grown all over the world. In India onion occupies about 1.23 million hectare area having 19.40 million metric tonnes of production and average productivity of 16.10 metric tonnes ha^{-1} (Anonymous 2013-14). Onion has culinary, dietary and medicinal importance in daily life of Indian people and due to its export trade, it is also a major vegetable crop to gain foreign currency. Onion crop is slow growing, shallow rooted, narrow, upright leaves and non branching habit. Due to this type of growing habit, onion crop cannot compete well with weeds. In addition to this, frequent irrigation water and fertilizer application allows for successive flushes of weeds in onion. The reduction in crop yield has direct correlation with weed competition. Onion exhibits greater susceptibility to weed competition as compared to other crops due to its inherent characteristics such as their slow growth, small stature, shallow roots and lack of dense foliage. The effective weed control involves identification of weed flora, method of weed control and judicious combination of effective weed control methods. Hand weeding in onion is a common practice in India, but it is a tedious, expensive and time consuming task due to closer spacing and shallow root system. Non-availability of labourers during critical period of crop makes hand weeding difficult leading to heavy yield losses. Spraying of pre-emergence herbicides keeps the crop in weed free conditions during the early stages. At later stage, second flush of weeds will affect the bulb formation. Hand weeding helps to keep the weed population below economic threshold level throughout the crop growth period. Pre-emergence combined with hand weeding may be costly because of the reduced labour availability and higher labour cost. After bulb formation manual or mechanical methods of weed control will damage the bulb. Application of early post emergence may be helpful to reduce damage to the bulb, weed competition and cost of weeding. Hence a brief review was presented to find out the effect of different weed management method in onion.

Keywords: Growth, onion, weed management, yield attributes

Introduction
Onion (*Allium cepa* L.) is a biennial or perennial herb belongs to family Alliaceae. It is one of the most important cash crops. It can be transported to a long distance without much transit injury losses. The significance of crop further enhances due to its multiple uses. Onion is rich in protein, calcium, phosphorus and carbohydrates (Bose *et al.*, 1989) [4]. It gives a distinctive and pungent odour, when tissues are crushed due to presence of a colourless, odourless volatile oil known as allyl propyl disulphide. Among many causes of low productivity, onion exhibits greater susceptibility to weed competition as compared to other crops due to its inherent characteristics such as slow germination, extremely slow growth in the initial stages, non-branching habit, sparse foliage and shallow root system. This favours quick and fast growth of weeds in the initial stages and competition thus tends to be severe. Moreover, use of liberal dose of FYM, fertilizers and frequent irrigations creates favourable conditions for weed growth (Singh *et al.* 1986) [49]. In onion, weeds emerge with transplanting of seedlings and grow along with them. This causes severe competition between the crop and weed. If the weeds are present throughout the crop growth period, there may be complete loss of marketable yield. The reduction in bulb yield varies to the extent of 48 to 80 per cent depending upon the duration, intensity of weed growth and weed competition (Patel *et al.* 1983) [26]. Hand weeding in onion is a common practice in India, but it is a tedious, expensive and time consuming task due to closer spacing and shallow root system. Nonavailability of labourers during critical period of crop makes hand weeding difficult leading to heavy yield losses. The critical period of crop-weed competition in onion lies between 15-60 days after transplanting (Singh and Singh, 1994) [48].

Hence, managing the weeds meticulously in early stages is an imperative task to get higher weed control efficiency and bulb yield.

Common weed flora in onion field

The major weeds flora in onion (*Allium cepa* L.,) field were *Chenopodium album* L., *Chenopodium morale* L., *Spergula arvensis* L. *Anagallis arvensis* L., *Convolvulus arvensis* L., *Cyperus rotundus* L. and *Cynodon dactylon* (L.) in dharwad (Porwal and Singh 1993) [30]. Sharma and Mehta (1994) [45] observed that the predominant weed flora in onion fields of Gujarat were *Cyperus rotundus* L., *Dactyloctenium aegyptium* L., *Cynodon dactylon Pers*. and *Phyllanthus niruri* L. The weed flora of experimental field at Varanasi were found to be *Eragrostis tenella* (Raem) *schutt*, *Cyperus rotundus* L., *Trianthema portulacastrum* L., *Echinocloa crusgulli* (L.)*Beauv*., *Ageratum conyzoides* L., *Portulaca oleracea* L., *Partulaca quadrifeda* L., *Cleomeviscosa* L., *Euphorbia hirta* L., and *Desmodium trifolium* L., during *kharif* seasons (Singh and Singh, 1994) [48]. They found that the monocotyledon weeds were generally found to be more numerous than dicotyledon weeds. The monocotyledon weed population was found to increase up to 60 days after transplanting and decreased in subsequent stages, while dicotyledon weed was found to be increase with advancement in crop age. The predominant weeds noticed in onion fields at Faizabad (U.P) during rainy season were *Echinochloa colonum Echinochloa crus-galli* L., Beauv., *Cyperus rotundus* L., *Cynodon dactylon* pers., *Saccharum spontaneum* L., *Trianthema monogyna* L., *Solanum nigrum* L., *Eclipta alba* Hassk., *Phyllanthus simplex* Retz and *Euphorbia microphylla* Verma and Singh (1997). Balraj Singh *et al*. (1998) [3] reported that *Chenopodium album, Portulaca oleraceae, Echinochloa crusgalli and Cyperus spp*., were the dominant weeds in onion during *rabi* season. 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.

Effect of weeds on crop growth and yield

Growth Components

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) [54] Singh and Singh (1994) [48] reported that unweeded onion plots recorded reduced plant height, number of leaves, which in turn reduced the bulb diameter and bulb yield due to increased weed competition. Maximum number of leaves 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) [40]. Taller plants, higher bulb diameter and bulb weight were recorded under weed-free condition, followed by alachlor 2.0 kg ha^{-1}+ Hand Weeding on 45 days after transplanting and pendimethalin at 1.5 kg ha^{-1} followed by Hand Weeding on 45 DAT (Ved Prakash *et al.*, 2000) [53]. Plant height, number of leaves, fresh and dry weight were found to be higher under weed free condition and pendimethalin treated plots as reported by Sharma and Khandwe (2008) [46]. Taller plants, neck thickness and dry matter accumulation was observed under pendimethalin applied plots by Patel *et al*. (2011) [28].

Yield and yield components

They found that the highest average onion bulb yield was obtained in the plots treated with Stomp 33%. The bulb yield was 62.69 % higher than the un-weeded treatment. Similar results were also demonstrated by Jilani *et al.* (2003) [15], Ghaffoor (2004) [4] and Manisha *et al.* (2005) [19]. They reported that the highest bulb yield was obtained in plots sprayed with Stomp 33%. James and Harlen (2010) [14] reported that uncontrolled weed growth caused 49-86 per cent reduction in bulb yield compared with the best herbicidal treatment. The higher onion bulb yield of 38.3 t ha^{-1} due to lesser weed population and weed growth from initial crop growth as compared to weedy check was obtained by Patel *et al.* (2011) [28]. Higher fresh bulb weight (135.4 g) was obtained in the plots where hand weeding was done after every 15 days while lesser fresh bulb weight (65.75 g) was recorded in control plots where no weeding was done throughout the season. Bulb diameter, bulb height, bulb volume, bulb weight and bulb yield were found to be high in weed free plots followed by pendimethalin (Rahman *et al.*, 2011) [34]. Saini and Walia (2012) [41] confirmed that oxyfluorfen treated plots recorded higher fresh bulb weight and diameter of the bulb. Karimi *et al.* (2012) [16] recorded higher bulb yield of 15.3 t ha^{-1} in pendimethalin treated plots while lesser yield of 4.2 t ha^{-1} in weedy control plots. Rahman *et al.* (2012) reported lower bulb yield of onion in weedy check to the fact that weeds appeared immediately after sowing and competed with onion crop until harvest. Higher bulb yield was recorded under early post emergence application of quizalofop-ethyl under grass dominated field as recorded by Dhananivetha *et al.* (2015) [7].

Integrated weed management in onion

Singh *et al*. (1985) reported that the supplementary weeding at 45 DAT over the application of alachlor @ 2.0 kg ha^{-1} resulted in significant increase in bulb yield but oxadiazon @ 1.0 kg ha^{-1} was more effective than other herbicides applied. Application of alachlor @ 1.0 kg ha^{-1} + HW at 45 DAT resulted in reduced dry weight of weeds and increased the bulb yield of onion next to repeated hand weeding (Prasad and Singh, 1998). Application of pendimethalin @ 1.0 and 1.25 kg ha^{-1} with HW at 60 DAT was more effective against weeds as reported by Sharma and Mehta (1994) [45]. While, pendimethalin @ 1.0 kg ha^{-1} coupled with HW at 45 DAT was found effective in controlling weeds and increased the direct drill sown onion bulb yield (Nadagouda, 1995) [23]. The pre-emergence application of alachlor at 2.0 kg ha^{-1} + HW at 40 DAS increased WCE as compared to lower rate of its application (Porwal, 1995) [29]. Application of pendimethalin @ 1.0 kg ha^{-1} + HW at 60 DAT resulted in the lowest population of weeds per 0.5 m^2 (Nekar 1997) [25]. Tiwari *et al*., 1998, reported that pendimethalin at 1.0 kg per hectare followed by hand weeding 65 days after transplanting gave the best results in terms of weed control followed by linuron and oxadiazon applied at 1.0 kg per hectare along with hand weeding 65 days after transplanting Field experiments conducted at GAU, Junagadh, showed that application of fluchloralin @ 0.90 kg ha^{-1}, alachlor @ 1.0 kg ha^{-1}, butachlor @ 1.0 kg ha^{-1}, oxadiazone @ 0.50 kg ha^{-1} and 18 oxyfluorfen @ 0.18 kg ha^{-1} alone did not control weeds effectively. Herbicide application coupled with HW at 40 DAT gave higher bulb yields and monetary returns than herbicide alone (Vora and Mehta, 1998) [55]. Kolhe (2001) [18] reported that the pre-emergence application of pendimethalin and oxyfluorfen at 1.0 kg a.i ha^{-1} and 0.15 kg a.i ha^{-1} respectively and each

supplemented with one HW at 35 DAT was significantly superior over the single application of herbicide at higher rates reducing weed dry matter and enhancing bulb yield of onion. Rameshwar *et al*. (2002) [38] reported that the lowest weed density and dry matter were noticed in plots treated with pendimethalin @ 1.5 kg ha-¹ + HW at 60 DAT. This treatment combination also recorded maximum net returns. The minimum N, P and K uptake by weeds was obtained when oxyfluorfen at 0.25 kg ha^{-1} was supplemented with hand weeding at 40 DAT followed by oxyfluorfen at 0.37 kg ha-¹. Maximum N, P and K uptake by onion bulbs was obtained due to oxyfluorfen at 0.25 kg ha-1 + HW at 40 DAT followed by oxyfluorfen at 0.37 kg ha^{-1} (Nandal and Singh, 2002)[24]. Yumnam *et al.* (2009) conducted a field experiment during the winter season of 2006 in West Bengal, India, to provide economically acceptable and eco-friendly weed control in onion and reported that hand weeding at 40 DAT along with application of quizolofop-ethyl 5% EC at 2.5 ml L^{-1} of water at 20 DAP, HW at 20 and 40 DAT significantly reduced weed density (25.5) and dry weight (55.3 g) of weed compared to other treatments.

Nutrient uptake by weeds and onion

Kathepuri *et al.* (2007) conducted a field experiment at College of Agriculture, Pune, and reported that, the weed control methods showed significant difference in N removal by weeds. Nitrogen uptake through weeds was minimum under weed free condition i.e. 2 HW at 20 and 40 DAT followed by pendimethalin 1.0 kg + HW at 40 days after transplanting. Weedy check removed the highest amount of nitrogen. The onion crop removed the highest amount of nitrogen under 2 HW at 20 and 40 DAT followed by pendimethalin 1 kg ha^{-1} + HW at 40 DAT and oxyfluorfen 0.2 kg ha^{-1} + HW at 40 DAT. Chandrika *et al*. (2009) [5] from experimentation at S. V. Agricultural College, Tirupati observed that, HW twice resulted in the highest yield attributes and the highest bulb yield, which was at par with weed management practices i.e. pre-emergence application of oxyfluorfen @ 0.24 kg ha^{-1} + HW at 40 DAT and pre emergence application of pendimethalin @ 0.75 kg ha^{-1}+ HW at 40 DAT. Rajkumara *et al.* (2010) reported that, weeds removed significantly higher nitrogen in weedy check (141.5 kg ha^{-1}) compared to rest of the treatments. Nitrogen uptake by weeds was significantly lower and zero in weed free check and weed free upto 120 DAS with which it was on par. The nitrogen uptake was recorded significantly higher in onion in weed free check (115.2 kg ha^{-1}) compared to the rest of treatments except weed free up to 100 DAS (89.3 kg ha^{-1}) and 120 DAS (93.8 kg ha^{-1}) which was on par. Nitrogen uptake was significantly low in weedy check (0.62 kg ha^{-1}) in onion over rest of the treatments.

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

Hand weeding was significantly better in increasing the bulb diameter, bulb weight, bulb yield and loss of bulb weight when compared with the control. Saraf *et al.*, (1994) [42] reported that Hand weeding on 45 DAP gave more yield due to minimum crop weed competition for resources. Higher bulb yield was obtained with three Hand Weeding (HW) 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 (Sharma and Mehta, 1994) [45]. Shah *et al*. (1996) [44] reported that hand weeding was significantly better in increasing the bulb diameter, bulb weight, bulb yield and loss of bulb weight when compared with unweeded control. According to Melander and Hartvig (1997) [21], 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 higher bulb and weed control efficiency were recorded in the weed free treatment followed by three HW on 20, 40 and 60 days after transplanting (Amrutkar *et al*., 1998) [1]. Prasad and Singh (1998) 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. 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 per cent) or Metolachlor 1.25 kg ha^{-1} + hand weeding (77 per cent) or oxyfluorfen 0.07 kg ha^{-1} + hand weeding (74.0 per cent) (Tewari *et al*., 1999) [52]. Weed management by hoeing gave higher yield closely followed by the application of oxadiazon and pendimethalin (Ishwar Singh *et al*., 2000) [13]. Priyadharshini and Anburani (2004) [32] reported that dry biomass of weeds was significantly reduced by the application of herbicides and through hand weeding practices. Higher weed control was obtained with manual weeding throughout the crop season (Zubiar *et al.*, 2009) [58]. Maximum bulb size and yield of onion were recorded in hand weeded plots followed by pendimethalin as compared to weedy check as noticed by Hussain *et al.* (2008) [12]. Rahman *et al.* (2011) [34] reported that hand weeding throughout the growing season controlled all weeds and resulted in higher onion bulb yield.

Chemical

Mc Intyre and Barbe (1995) [20] indicated that chemical weed control with oxyfluorfen or oxadiazon was superior to hand weeding. Porwal (1995) [29] 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). Ramachandra Prasad (2000) [37] reported that pendimethalin and oxyfluorfen were most effective in lowering dry weight of grassy weeds as compared to alachlor and metalachlor. Ranpise and Patil (2001) [39] observed that preemergence application of oxyfluorfen at 0.4 kg ha^{-1} in onion recorded maximum yield (242.2 q ha^{-1}) followed by oxyfluorfen 0.2 kg ha-1 (233.3 q ha^{-1}) as compared to the lower yield under control (50 q ha^{-1}) due to maximum weed intensity. Kolhe (2001) [18] 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 in onion. Presently herbicides are widely applied for weed destruction and oxyfluorfen is a very effective herbicide suitable for weed

destruction in onion and cabbage (Stall and Gilreath, 2002) [50]. Ghoshen (2004) conducted experiments to evaluate the efficacy of herbicides for control of broad leaved weeds which were applied only once in irrigated onion. Sharma and Khandwe (2008) [46] observed lesser weed population and dry weight of weeds m-2 with pendimethalin at 1.25 kg ha^{-1}. An increase in the bulb yield of onion by 62.69 per cent with pendimethalin at 2.5 l ha^{-1} than the unweeded plots was recorded by Zubiar *et al*. (2009)[58]. Patel *et al*. (2009) [27] revealed that application of quizalofop-ethyl at 200 g ha^{-1} on 30 days after sowing was effective in controlling weeds in groundnut. In onion, pendimethalin at 1.0 kg ha^{-1} + hand weeding and oxyfluorfen at 0.24 kg ha^{-1} recorded higher weed control efficiency of 80.6 and 73.4 per cent (Patel *et al.*, 2011) [28]. Pre-emergence application of oxyfluorfen (23.5per cent EC) at 200 g ha^{-1} recorded lesser weed density and dry weight in onion (Sathya Priya *et al.*, 2013) [43]. Early post emergence application of quizalofop-ethyl at 75 g ha^{-1} recorded lower weed density and dry weight which resulted in increased yield of onion under grass dominated field conditions (Dhananivetha *et al*. 2015) [7].

Mechanical

Yadav and Pond (2007) [56] reported that 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. 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 one cm depth is effective for controlling weeds followed by cutting at the soil surface as noticed by Rajakumar (2008). Gore *et al*. (2010) [10] reported that cycle hoe weeder produced significantly higher grain yield and found to be effective in controlling grass as well as broad leaved weeds (69 and 44per cent) and (63 and 67per cent) at 30 and 60 DAS in soybean. Gowsalya *et al*. (2010) [11] observed that 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. According to Sathya Priya *et al.* (2013) [43] pre-emergence application of pendimethalin at 0.75 kg ha^{-1} + Rotary weeding on 45 DAS recorded lower gross and net returns.

Economics of weed management

Nandal and Ravinder Singh (2002) [24] observed higher net return when oxyfluorfen at 0.25 kg ha^{-1} was supplemented with hand weeding at 40 DAT (60,196 ha^{-1}) followed by oxyfluorfen at 0.75 kg ha^{-1} (54,978 ha^{-1}) and pendimethalin at 1.00 kg ha^{-1} + hand weeding at 40 DAT (51,162 ha^{-1} and net loss of 2,624 ha^{-1} where weeds were not controlled under weedy check in onion. According to Mondal *et al*. (2005) higher net monetary returns were obtained with pre-emergence application of oxyfluorfen at 100 g ha^{-1} supplemented with one hand weeding on 25 DAT (33,650 ha^{-1}) followed by fluchloralin at 750 g ha^{-1} + hand weeding (31,983 ha^{-1}), pendimethalin at 750 g ha^{-1} + hand weeding (31,450 ha^{-1}) and oxyfluorfen at 200 g ha^{-1} (31,400 ha^{-1}). There was net loss of 3,900 ha^{-1} under weedy check. Pre-emergence application of pendimethalin at 1.00 kg ha^{-1} supplemented with one hand weeding in onion gave the higher net return of 51,296 ha^{-1} with maximum benefit cost ratio of 8.77 (Channappagoudar and Biradar, 2007) [6]. Economic analysis by Patel *et al.* (2011) [28] revealed that higher net profit (2,69,422 ha^{-1}) in onion crop was obtained with application of pendimethalin at 1.0 kg ha^{-1} + HW on 40 DAT with the B:C ratio of 7.85 followed by oxyfluorfen at 1.0 kg ha^{-1} + HW on 40 DAT (2,51,910) and weed free control. In onion higher net return (1,85,600) with B:C ratio of 7.63 was registered with the application of oxyfluorfen (Saini and Walia, 2012) [41].

Conclusion

The conventional method of weed control is effective but due to labour scarcity and high cost of human labour weeding during the critical stage of the crop is a problem. As an alternate chemical method of weed control can be adopted. Numerous herbicides with varying mode of action are available in the market with wide spectrum of weed control. Hence, selection of method of weed control should be based on the nature of the crop and mode of action of the herbicide that should control weeds effectively and increase the yield of the crop. 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.

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