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Weed management studies in onion (*Allium Cepa* L.) bulb crop

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Abstract

A field experiment was carried out during *rabi* 2023-24 at the All India Coordinated Research Project on Vegetable Crops, Department of Horticulture, MPKV, Rahuri, to evaluate the efficacy of different weed management practices in onion (*Allium Cepa* L.). The study was laid out with ten treatments including pre-emergence (PE) and post-emergence (PoE) applications of Oxyfluorfen and Pendimethalin alone and in combination with hand weeding, Propaquizafop based combinations, a weedy check, and a weed-free check, arranged in a randomized block design with three replications. The study showed that all weed management treatments significantly reduced weed population and dry weight in comparison with the weedy check. The highest weed control efficiency, minimum weed index, and lowest weed density were observed under weed-free treatment (T_{10}), followed by Pendimethalin 580 g a.i./ha (PE) + hand weeding at 45 DAP (T_4). Growth parameters including number of leaves per plant and plant height were maximum in weed-free plots, while T_4 was the most effective among herbicidal treatments. Similarly, bulb yield attributes including average bulb weight and total bulb yield were significantly higher in weed-free treatment, followed by T_4. Economic analysis showed that the highest net monetary returns (₹ 2,62,425.9 ha^{-1}) and B:C ratio (3.13) were recorded in weed-free treatment (T_{10}). Among herbicidal treatments, T_4 provided the highest net monetary returns (₹ 2,49,131.9 ha^{-1}) and the best B:C ratio (3.17). In contrast, the weedy check produced the lowest yield and economic returns. The study concluded that Pendimethalin 580 g a.i./ha (PE) combined with hand weeding at 45 DAP was the most effective herbicidal treatment for suppressing weeds, improving growth, and enhancing bulb yield in onion. However, further multi-season evaluation is necessary to confirm consistency of results.

Keywords: Onion, weed management, pendimethalin, bulb yield, weed control efficiency, economics

Introduction

Onion (*Allium Cepa L.*) is regarded as one of the crucial bulb crops cultivated worldwide as a vegetable and spice, popularly designated as the “Queen of the Kitchen Garden.” India ranks second in onion production after China, with Maharashtra contributing nearly 40% of the national output during 2022-23 (Anon., 2023) [2]. Despite the large area under cultivation, onion productivity in India remains considerably lower than in major producing countries such as China, USA, and the Netherlands. Weeds constitute a major constraint in onion cultivation, as the crop is inherently a poor competitor due to slow initial growth, short stature, sparse foliage, and shallow roots. Frequent irrigations and fertilizer use further aggravate weed incidence. Yield losses of 40-80 per cent have been reported under uncontrolled weed conditions (Channappagoudar and Biradar, 2007) [5], and in severe cases, a total failure of the crop can occur (Sahoo and Tripathy, 2017) [21]. Weeds not only reduce bulb yield and quality by competing for resources but also serve as alternative hosts for diseases and insect pests.

Manual weed control through hoeing and hand weeding, though effective, is labour-intensive, costly, and constrained by labour shortages during the critical crop-weed competition period (15-60 days after transplanting) (Singh and Singh, 1994). Rising wages and rural labour migration further limit its feasibility. In this context, chemical weed management offers a more practical, timely, and cost-effective alternative. Several pre- and post-emergence herbicides proved to be effective in reducing weed density and enhancing bulb yield in onion (Thakral *et al.*, 2003; Marwat *et al.*, 2005) [26, 14].

Combination of herbicides with hand weeding has been reported to further improve weed control efficiency and profitability (Ved Prakash *et al.*, 2002; Khokhar *et al.*, 2006) [28, 11]. Considering these aspects, the present investigation entitled *"*Weed management studies in onion *(Allium Cepa* L.) bulb crop*"* was undertaken during *rabi* 2023 at AICRP on Vegetable Crops, MPKV, Rahuri, to evaluate the efficacy of pre- and post-emergence herbicides on weed control efficiency, growth, and yield of onion.

Materials and Methods

The field investigation entitled *"*Weed management studies in onion (*Allium Cepa* L.) bulb crop*"* was conducted during *rabi* 2023-24 at the All India Coordinated Research Project on Vegetable Crops, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra. The experiment was laid out in a randomized block design (RBD) with three replications and ten treatments involving pre- and post-emergence applications of Oxyfluorfen, Pendimethalin, and Propaquizafop + Oxyfluorfen, along with hand weeding, a weedy check, and a weed-free check. Onion variety N-2-4-1 was transplanted on 22 December 2023 at a spacing of 15 × 10 cm in plots of 5.0 × 1.5 m size. The recommended package of practice was undertaken for conduct of experiment. The treatment details were as follows: T_1 - Oxyfluorfen 23.5% EC, 175 g a.i/ha (PE) and Oxyfluorfen 23.5% EC, 175 g a.i/ha (PoE), T_2 - Oxyfluorfen 23.5% EC, 175 g.a.i./ha (PE) and hand weeding at 45 DAP, T_3 - Pendimethalin 580 g.a.i./ha (PE) and Pendimethalin 580 g.a.i./ha (PoE), T_4 - Pendimethalin 580 g.a.i./ha (PE) and hand weeding at 45 DAP, T_5 - Propaquizafop 5% 43.75 g.a.i./ha + Oxyfluorfen 12% ww/EC 175 g.a.i./ha (PE) and Propaquizafop 5% 43.75 g.a.i./ha + Oxyfluorfen 12% ww/EC 175 g.a.i./ha (PoE), T_6 - Propaquizafop 5% 55.75 g.a.i./ha + Oxyfluorfen 12% ww/EC (PE) and Propaquizafop 5% 55.75 g.a.i./ha + Oxyfluorfen 12% ww/EC (PoE), T_7 - Propaquizafop 5% 43.75 g.a.i./ha + Oxyfluorfen 12% ww/EC 175 g.a.i./ha (PE) and hand weeding at 45 DAP, T_8 - Propaquizafop 5% 55.75 g.a.i./ha + Oxyfluorfen 12% ww/EC (PE) and hand weeding at 45 DAP, T_9 - Control (Weedy Check), T_{10} - Weed free check. Data on growth and yield parameters (plant height, number of leaves plant^{-1}, bulb weight, bulb diameter, marketable yield, and total yield) and weed parameters (species-wise count, weed dry weight, weed control efficiency, weed index, weed management index, and herbicide efficiency index) were recorded at regular intervals. The bulbs were harvested at full maturity stage. After proper curing and neck cutting the observations on plant morphological characters, yield and yield contributing characters and marketable bulb yield were recorded. Phytotoxicity symptoms (chlorosis, necrosis, hyponasty, epinasty, and yellowing) were observed at 3, 5, 7, and 10 days after spraying. Incidence of major pests (thrips) and diseases (Stemphylium blight and purple blotch) was also assessed. The data were analyzed using analysis of variance (ANOVA) for randomized block design as per Panse and Sukhatme (1985) [16]. Treatment means were compared using the critical difference (CD) at 5% level of probability.

Results and Discussion

Growth and Yield attributes

The growth was greatly impacted by weed management practices of onion. The maximum plant height and number of leaves per plant were recorded in the weed-free treatment (T_{10}), followed by Pendimethalin 580 g a.i. ha^{-1} (PE) + hand weeding at 45 DAP (T_4). The better growth in these treatments can be attributed to effective weed suppression, which reduced competition for nutrients, moisture, and light. In contrast, the weedy check (T_9) recorded the lowest values. Comparable results were documented by Channappagoudar and Biradar (2007) [5], who emphasized that unchecked weed growth severely hampers onion growth due to its poor competitive ability. Different weed control treatments significantly affected the average bulb weight. The maximum bulb weight was observed in T_{10} (weed free check, 74.60 g). Among herbicide treatments, T_4 (73.11 g) recorded the highest bulb weight, statistically at par with T_7 (72.67 g), T_6 (71.73 g), T_5 (70.40 g), T_8 (68.53 g), and T_3 (67.47 g). The lowest bulb weight was recorded in T_9 (weedy check, 59.80 g). Enhanced bulb weight under effective treatments may be due to reduced competition and better translocation of assimilates. Parallel findings were noted by Ghadage *et al.* (2006) [6], Patel *et al.* (2012) [18], and Kalhapure *et al.* (2013) [7]. Polar and equatorial diameters of bulbs were significantly influenced by weed management practices. The maximum polar diameter was recorded in T_{10} (4.84 cm), followed by T_4 (4.72 cm) and T_7 (4.57 cm). The lowest was observed in T_9 (3.88 cm). Similarly, equatorial diameter was highest in T_{10} (5.86 cm), which was at par with T_4 (5.64 cm) and T_7 (5.48 cm), while the lowest was observed in T_9 (4.42 cm). Larger bulb dimensions in effective treatments may be attributed to reduced competition and better crop vigor. The present results corroborate with Ved *et al.* (2000) [29], Atre (2001) [3], and Ghadage *et al.* (2006) [6].

Total bulb yield

Total bulb yield was significantly influenced by weed control treatments. The highest yield was recorded in T_{10} (weed free check, 331.64 q/ha), followed by T_4 (314.87 q/ha) and T_7 (300.62 q/ha). The lowest yield was obtained in T_9 (weedy check, 173.33 q/ha). Superior yields under effective treatments can be attributed to reduced competition during critical growth stages, ensuring efficient utilization of resources. The results correspond with Murthy *et al.* (2009) [15], Kathepuri *et al.* (2007) [9], Patel *et al.* (2012) [18], and Kalhapure & Shete (2013) [7]. The superior performance of these treatments may be due to reduced crop-weed competition during the critical growth stages, ensuring better translocation of photosynthates to bulbs. The weedy check recorded the lowest bulb yield, indicating heavy yield losses due to weed competition. The results validate the observations reported by Tripathy *et al.* (2013) [27].

Marketable Bulb Yield

Marketable bulb yield followed a similar trend. The maximum was recorded in T_{10} (321.40 q/ha), at par with T_4 (304.42 q/ha) and T_7 (292.03 q/ha). The lowest was in T_9 (157.64 q/ha). Higher marketable yield under effective weed management was due to improved bulb quality and reduced losses to inferior grades.

Weed parameters

Weed Flora and Species Composition

The trial field exhibited infestation of monocot weeds (*Cynodon dactylon, Echinochloa colona*), dicots (*Portulaca oleracea, Amaranthus viridis, Parthenium hysterophorus*), and sedge (*Cyperus rotundus*). Similar trends were reported by Patel *et al.* (2012) [18], Kalhapure *et al.* (2013) [7], and Khan *et al.* (2021) [10].

Weed Density

The total weed density was significantly reduced in weed free check (T_{10}) relative to all other treatments. Among herbicide treatments, T_4, T_7, T_6, and T_5 recorded lower densities, whereas T_9 (weedy check) showed the highest counts across all stages. Pre- and post-emergence herbicides suppressed both monocot and dicot weeds effectively, and supplementary hand weeding further minimized infestations. These results align with Kathepuri *et al.* (2007) [9], Chandrika *et al.* (2009) [4], Murthy *et al.* (2009) [15], and Priya *et al.* (2017) [19]. The improved control efficiency of Pendimethalin combined with hand weeding may be due to its ability to inhibit germination of weed seeds during the initial stages, whereas hand weeding minimized later flushes. The results concur with the observations of Kalhapure *et al.* (2014) [8].

Fresh and Dry Weed Weight

Weed fresh and dry weights were lowest in T_{10}, followed by T_4 and T_7. Maximum values were recorded in T_9. Reduced biomass under effective treatments reflects efficient weed suppression and less competition with the crop. These results corroborate findings of Kolhe (2001) [12], Sukhadia *et al.* (2002) [24], Chandrika *et al.* (2009) [4], and Kalhapure *et al.* (2013) [8].

Weed Control Efficiency (WCE)

WCE was highest in T_{10} (weed free check) across all stages. Among herbicides, T_4 consistently recorded the highest WCE, followed by T_7. The lowest WCE was in T_9. The effectiveness of T_4 can be credited to the combined impact of pre-emergence herbicide, post-emergence suppression, and timely hand weeding. The results agree with the observations of Ghadage *et al.* (2006) [6] and Kalhapure *et al.* (2013) [7].

Weed Management Index (WMI): WMI values were highest in T_{10} (1.85%), followed by T_4 (1.48%) and T_7 (1.31%), while the lowest was in T_9. Higher WMI reflects better efficiency of integrated weed management strategies.

Herbicide Efficiency Index (HEI): Among herbicide treatments, the highest HEI was recorded in T_4 (9.87%), followed by T_7 (6.23%). Effective herbicide combinations thus provided superior weed suppression and higher yields, as also noted by Ghadage *et al.* (2006) [6].

Weed Index (WI): WI was lowest in T_{10} (0%), followed by T_4 (6.18%) and T_7 (11.30%). The maximum was in T_9 (62.63%). Lower WI under effective treatments confirms their ability to minimize yield losses caused by weeds.

Agronomic Management Index (AMI)

The highest AMI was recorded in T_4 (6.77%), followed by T_7 (4.95%), while the lowest was in T_9. This indicates better agronomic performance of integrated treatments.

Phytotoxicity

No major phytotoxic symptoms such as chlorosis, necrosis, or epinasty were observed in any treatment at 3, 5, 7, and 10 days after herbicide application, confirming crop safety. Parallel findings were noted by Qasem (1996) [20], Tewari *et al.* (1999) [25], and Mahmood *et al.* (2002) [13] in garlic, and by Ahmed *et al.* (1994) [1] and Vishnu *et al.* (2014) [30] in onion.

Incidence of diseases and pests

Weed-free and effectively managed plots recorded lower incidence of thrips, Stemphylium blight, and purple blotch in comparison with the weedy check. This could be explained as a result of reduced weed flora that otherwise serve as alternate hosts for pests and pathogens. These observations are in conformity with the observations of Sahoo and Tripathy (2017) [21], who reported higher pest and disease incidence in poorly managed onion fields.

Economics

Economic evaluation indicated that the highest net returns and B:C ratio were obtained in weed-free plots (T_{10}). Among herbicidal treatments, T_4 provided the highest monetary benefits, closely comparable to the weed-free check. The maximum B:C ratio was recorded in treatment T4 (3.17), followed by T_{10} - weed free check (3.13). These were closely followed by T_7 (3.05), T_6 (3.04), and T_5 (3.01). The lowest B:C ratio was observed in T_9 - weedy check (1.75) owing to severe crop-weed competition and reduced bulb yield. Although the weed free check (T_{10}) recorded maximum gross returns, its B:C ratio was slightly lower than that of T_4 due to higher cost of repeated manual weeding. In contrast, herbicide treatments combined with hand weeding (particularly T_4) offered both high yield and lower cultivation costs, thereby maximizing profitability. This indicates that Pendimethalin (PE) + hand weeding at 45 DAP is not only agronomically effective but also economically viable. These outcomes are in accordance with the findings of Singh *et al.* (1986) [23], Ved Prakash *et al.* (2002) [28], Channappagoudar and Biradar (2007) [5], Kathepuri *et al.* (2007) [9], Patel *et al.* (2011) [17], and Priya *et al.* (2017) [19], who also reported higher benefit: cost ratios under integrated herbicide applications compared to weedy check and weed free treatments.

Table 1: Effect of different weed control treatments on growth parameters of onion bulb crop

Sr. No.	Treatments	Plant height at harvest (cm)	No. of leaves/plant (at harvest)	Equatorial diameter (cm)	Polar diameter (cm)	Average bulb weight (g)	Bulb yield (q/ha)	Marketable bulb yield (q/ha)
T_1	Oxyfluorfen 23.5% EC, 175 g a.i/ha (PE) and Oxyfluorfen 23.5% EC, 175 g a.i/ha (PoE)	46.83	10.20	4.67	4.00	65.27	242.68	222.51
T_2	Oxyfluorfen 23.5% EC, 175 g.a.i./ha (PE) and hand weeding at 45 DAP	47.22	10.32	4.71	4.11	67.13	255.33	236.03
T_3	Pendimethalin 580 g.a.i./ha (PE) and Pendimethalin 580 g.a.i./ha (PoE)	48.67	10.48	4.89	4.45	67.47	262.67	243.73
T_4	Pendimethalin 580 g.a.i./ha (PE) and hand	55.27	12.49	5.64	4.72	73.11	314.87	304.42

	weeding at 45 DAP.							
T5	Propaquizafop 5% 43.75 g.a.i./ha + Oxyfluorfen 12% ww/EC 175 g.a.i./ha (PE) and Propaquizafop 5% 43.75 g.a.i./ha + Oxyfluorfen 12% ww/EC 175 g.a.i./ha (PoE)	51.30	10.75	5.23	4.38	70.40	291.33	275.62
T6	Propaquizafop 5% 55.75 g.a.i./ha + Oxyfluorfen 12% ww/EC (PE) and Propaquizafop 5% 55.75 g.a.i./ha + Oxyfluorfen 12% ww/EC (PoE)	53.80	10.83	5.35	4.46	71.73	294.93	279.23
T7	Propaquizafop 5% 43.75 g.a.i./ha + Oxyfluorfen 12% ww/EC 175 g.a.i./ha (PE) and hand weeding at 45 DAP	54.55	10.90	5.48	4.57	72.67	300.62	292.03
T8	Propaquizafop 5% 55.75 g.a.i./ha + Oxyfluorfen 12% ww/EC (PE) and hand weeding at 45 DAP	49.90	10.62	5.07	4.26	68.53	272.04	254.54
T9	Control (Weedy Check)	43.30	9.08	4.42	3.88	59.80	173.33	157.64
T10	Weed free check	56.60	12.70	5.86	4.84	74.60	331.64	321.40
	S.E ±	2.45	0.47	0.15	0.11	2.75	5.65	5.73
	CD at 5%	7.28	1.38	0.46	0.33	8.16	16.80	17.04

Table 2: Effect of different weed control treatments on total weed density

Sr. No.	Treatments	30 DAP	60 DAP	90 DAP	At harvest
T1	Oxyfluorfen 23.5% EC, 175 g a.i/ha (PE) and Oxyfluorfen 23.5% EC, 175 g a.i/ha (PoE)	42.10 (6.52)	47.11 (6.90)	52.17 (7.25)	59.09 (7.72)
T2	Oxyfluorfen 23.5% EC, 175 g.a.i./ha (PE) and hand weeding at 45 DAP	39.24 (6.30)	44.28 (6.68)	49.24 (7.05)	56.27 (7.53)
T3	Pendimethalin 580 g.a.i./ha (PE) and Pendimethalin 580 g.a.i./ha (PoE)	35.42 (5.99)	40.52 (6.39)	45.47 (6.76)	52.39 (7.26)
T4	Pendimethalin 580 g.a.i./ha (PE) and hand weeding at 45 DAP.	15.66 (4.02)	17.74 (4.26)	19.69 (4.48)	21.56 (4.70)
T5	Propaquizafop 5% 43.75 g.a.i./ha + Oxyfluorfen 12% ww/EC 175 g.a.i./ha (PE) and Propaquizafop 5% 43.75 g.a.i./ha + Oxyfluorfen 12% ww/EC 175 g.a.i./ha (PoE)	27.38 (5.28)	32.42 (5.73)	37.42 (6.15)	44.27 (6.70)
T6	Propaquizafop 5% 55.75 g.a.i./ha + Oxyfluorfen 12% ww/EC (PE) and Propaquizafop 5% 55.75 g.a.i./ha + Oxyfluorfen 12% ww/EC (PoE)	24.33 (4.98)	29.36 (5.46)	34.38 (5.89)	41.39 (6.46)
T7	Propaquizafop 5% 43.75 g.a.i./ha + Oxyfluorfen 12% ww/EC 175 g.a.i./ha (PE) and hand weeding at 45 DAP	19.02 (4.41)	24.12 (4.95)	29.12 (5.43)	36.08 (6.04)
T8	Propaquizafop 5% 55.75 g.a.i./ha + Oxyfluorfen 12% ww/EC (PE) and hand weeding at 45 DAP	31.34 (5.64)	36.40 (6.07)	41.36 (6.47)	48.37 (6.99)
T9	Control (Weedy Check).	47.66 (6.94)	52.71 (7.29)	57.69 (7.62)	64.68 (8.07)
T10	Weed free check	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)
	S.E ±	0.12	0.16	0.17	0.18
	CD at 5%	0.39	0.49	0.51	0.54

Figures in the parenthesis are square root transformed ($\sqrt{x+0.5}$) values.

Table 3: Effect of different weed control treatments on weed indices and economics

Sr. No.	Treatments	Weed control efficiency (%) at harvest	WMI (%)	HEI (%)	WI (%)	AMI (%)	Gross monetary returns (Rs)	Net monetary returns (Rs)	B:C ratio
T1	Oxyfluorfen 23.5% EC, 175 g a.i/ha (PE) and Oxyfluorfen 23.5% EC, 175 g a.i/ha (PoE)	8.45 (16.87)	0.66	1.06	33.34	1.02	267012	156833.9	2.42
T2	Oxyfluorfen 23.5% EC, 175 g.a.i./ha (PE) and hand weeding at 45 DAP	13.10 (21.18)	0.84	2.92	32.88	1.71	283236	168019.9	2.46
T3	Pendimethalin 580 g.a.i./ha (PE) and Pendimethalin 580 g.a.i./ha (PoE)	18.93 (25.72)	0.90	3.34	31.82	2.17	292476	182793.9	2.67
T4	Pendimethalin 580 g.a.i./ha (PE) and hand weeding at 45 DAP.	66.52 (54.67)	1.48	9.87	6.18	6.77	364104	249131.9	3.17
T5	Propaquizafop 5% 43.75 g.a.i./ha + Oxyfluorfen 12% ww/EC 175 g.a.i./ha (PE) and Propaquizafop 5% 43.75 g.a.i./ha + Oxyfluorfen 12% ww/EC 175 g.a.i./ha (PoE)	31.34 (34.02)	1.13	4.77	15.65	2.77	330744	220963.9	3.01
T6	Propaquizafop 5% 55.75 g.a.i./ha + Oxyfluorfen 12% ww/EC (PE) and Propaquizafop 5% 55.75 g.a.i./ha + Oxyfluorfen 12% ww/EC (PoE)	36.08 (36.91)	1.24	5.72	13.39	3.60	335076	224721.9	3.04
T7	Propaquizafop 5% 43.75 g.a.i./ha + Oxyfluorfen 12% ww/EC 175 g.a.i./ha (PE) and hand weeding at 45 DAP	44.35 (41.75)	1.31	6.23	11.30	4.95	350436	235418.9	3.05
T8	Propaquizafop 5% 55.75 g.a.i./ha +	25.17 (30.10)	1.03	4.06	26.08	2.55	305448	190243.9	2.65

	Oxyfluorfen 12% ww/EC (PE) and hand weeding at 45 DAP								
T_9	Control (Weedy Check).	0.00 (0.00)	-	-	62.63	-	189168	80913.92	1.75
T_{10}	Weed free check	100.00 (89.77)	1.85	-	0.00	0.50	385680	262425.9	3.13
	S.E ±	1.06	0.07	0.23	1.44	0.45	-	-	-
	CD at 5%	3.15	0.21	0.70	4.28	1.34	-	-	-

Figures in the parenthesis are arc sine transformed.

Conclusion

The present study clearly demonstrated that weed management practices significantly influenced growth, yield, pest and disease incidence, weed indices, and economics of onion. Among the evaluated treatments, T_4 - application of Pendimethalin 580 g a.i./ha (PE) followed by hand weeding at 45 DAP proved to be the most effective and consistent performer. This treatment recorded superior growth attributes (plant height and number of leaves per plant) and yield parameters, including average bulb weight, bulb dimensions, total bulb yield, and marketable yield. With respect to weed indices, T_4 registered the highest weed control efficiency, weed management index, and herbicide efficiency index. Economically, it also provided the maximum benefit: cost ratio (3.17), closely followed by the weed free check (3.13) and T_7 (3.05). Therefore, integration of Pendimethalin (PE) with a single hand weeding at 45 DAP may be recommended as an effective and economical weed management strategy for onion bulb cultivation. Nevertheless, further multi-location trials across different seasons are suggested to validate these findings before large-scale adoption.

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