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Studies on comparative bioefficacy of pre and post emergence herbicide on Onion (*Allium cepa* L.) bulb crop

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Abstract
A field experiment was conducted during the *rabi* season of 2023-24 at MPKV, Rahuri, to assess the effectiveness of various weed management practices in onion (*Allium cepa* L.). The trial comprised ten treatments involving pre- and post-emergence applications of Oxyfluorfen and Pendimethalin, alone or in combination with hand weeding, along with Propaquizafop-based treatments, a weedy check, and a weed-free check, arranged in a randomized block design with three replications. All weed control treatments significantly reduced weed population and dry matter over the weedy check. The weed-free treatment recorded the highest weed control efficiency, lowest weed density, and superior growth attributes, followed closely by Pendimethalin 580 g a.i./ha (PE) plus hand weeding at 45 DAP. Yield parameters such as average bulb weight and total bulb yield were also highest under weed-free conditions, with T_4 emerging as the best among herbicidal treatments. Economic analysis revealed maximum net returns and benefit-cost ratio in the weed-free treatment, while T_4 provided the highest economic gains among herbicides. The study concludes that Pendimethalin 580 g a.i./ha (PE) combined with hand weeding at 45 DAP is the most effective herbicidal strategy for weed suppression, improved growth, and enhanced bulb yield in onion. Multi-season validation is recommended for broader applicability.

Keywords: Onion, pendimethalin, weed management, growth and yield, weed control efficiency

Introduction
Onion (*Allium cepa* L.) is a major bulb crop cultivated worldwide as both a vegetable and spice, commonly known as the "Queen of the Kitchen Garden." India is the second-largest global producer after China, with Maharashtra contributing around 40% of national production in 2022-23 (Anon., 2023) [1]. Despite widespread cultivation, the country's productivity remains comparatively low relative to leading producers such as China, the USA, and the Netherlands. Weed infestation is one of the most serious constraints in onion production. Owing to its slow initial growth, small plant stature, sparse canopy, and shallow roots, onion competes poorly with weeds. Frequent irrigation and fertilizer use further encourage weed emergence. Yield reductions of 40-80% under unmanaged weed conditions have been documented, and complete crop failure has been reported in severe infestations (Sahoo & Tripathy, 2017) [15]. Weeds additionally harbour pests and pathogens, thereby deteriorating bulb yield and quality. While manual weeding is effective, its practical use is increasingly limited by labour scarcity, high wages, and the need for timely operations during the critical weed competition period of 15-60 days after transplanting (Singh & Singh, 1994) [16]. Chemical weed management thus presents a more feasible and economical alternative. Numerous studies have shown the effectiveness of pre- and post-emergence herbicides in suppressing weeds and improving onion yield (Thakral *et al*., 2003; Marwat *et al*., 2005) [17, 10]. Combining herbicides with a single hand weeding has also proven beneficial for enhancing weed control and profitability (Ved Prakash *et al*., 2002; Khokhar *et al*., 2006) [18, 9]. In this context, the present study entitled "Studies on comparative bioefficacy of pre and post emergence herbicide on Onion (*Allium cepa* L.) bulb crop" was conducted during *rabi* 2023 at AICRP on Vegetable Crops, MPKV, Rahuri, to evaluate the influence of selected herbicides on weed control efficiency, crop growth, and bulb yield.

Materials and Methods

A field experiment titled "Studies on comparative bioefficacy of pre and post emergence herbicide on Onion (*Allium cepa* L.) bulb crop" was carried out during the rabi season of 2023-24 at the All India Coordinated Research Project on Vegetable Crops, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra. The study was arranged in a randomized block design (RBD) comprising ten treatments replicated three times. Treatments included pre- and post-emergence applications of Oxyfluorfen, Pendimethalin, and Propaquizafop + Oxyfluorfen, along with hand weeding, a weedy check, and a weed-free check. Onion cultivar N-2-4-1 was transplanted on 22 December 2023 at a spacing of 15×10 cm in plots measuring 5.0 × 1.5 m. All recommended agronomic practices were followed throughout the cropping period. The treatments 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 attributes—such as plant height, number of leaves per plant, bulb weight, bulb diameter, marketable yield, and total yield—were recorded at appropriate crop stages. Weed-related observations, including species composition, weed control efficiency, weed index, weed management index, and herbicide efficiency index, were also collected. Bulbs were harvested at full maturity, and after proper curing and neck removal, measurements on morphological and yield-contributing traits were documented. The experimental data were analyzed using analysis of variance (ANOVA) for RBD as outlined by Panse and Sukhatme (1985) [12], and treatment means were separated using the critical difference (CD) at the 5% probability level.

Results and Discussion

Growth Parameters

Plant height was significantly highest in the weed-free check (T_{10}) at 56.60 cm, which was statistically on par with T_4 (Pendimethalin 580 g a.i./ha + hand weeding at 45 DAP, 55.27 cm), T_7 (Propaquizafop 5% 43.75 g + Oxyfluorfen 12% 175 g a.i./ha PE + hand weeding, 54.55 cm), T_6 (Propaquizafop 5% 55.75 g + Oxyfluorfen 12% PE and PoE, 53.80 cm), T_5 (Propaquizafop 5% 43.75 g + Oxyfluorfen 12% 175 g PE and PoE, 51.30 cm), and T_8 (Propaquizafop 5% 55.75 g + Oxyfluorfen 12% PE + hand weeding, 49.90 cm). The lowest height (43.30 cm) was observed in the weedy check (T_9). The maximum number of leaves per plant was recorded in the weed-free check (T_{10}), with 12.70 leaves, which was statistically comparable to T_4 (Pendimethalin 580 g a.i./ha PE + hand weeding at 45 DAP) with 12.49 leaves. The minimum number of leaves (9.08) occurred in the weedy check (T_9). These findings are in agreement with the observations reported by Patel *et al*. (2011) [13]. The highest average bulb weight was recorded in the weed-free check (T_{10}) at 74.60 g. Among the herbicidal treatments, T_4 (Pendimethalin 580 g a.i./ha PE + hand weeding at 45 DAP) produced the maximum bulb weight (73.11 g), which was statistically comparable 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 (59.80 g) occurred in the weedy check (T_9). These results align with earlier findings reported by Ghadage *et al*. (2006) [5], Patel *et al*. (2012) [14], and Kalhapure *et al*. (2013) [7] in onion. The maximum polar diameter of bulbs was recorded in the weed-free check (T_{10}) at 4.84 cm. Among the herbicide treatments, T_4 (Pendimethalin 580 g a.i./ha PE + hand weeding at 45 DAP) produced the highest polar diameter (4.72 cm), which was statistically comparable to T_7 (4.57 cm). The smallest polar diameter (3.88 cm) occurred in the weedy check (T_9). Similarly, equatorial diameter was significantly highest in T_{10} (5.86 cm). Among weed-management treatments, T_4 again recorded the maximum equatorial diameter (5.64 cm), followed by T_7 (5.48 cm), both statistically at par. The lowest equatorial diameter (4.42 cm) was noted in T_9. These findings corroborate earlier reports by Ved *et al*. (2000) [18], Atre (2001) [2], and Ghadage *et al*. (2006) [5].

Grade Bulb (%)

Significant differences were observed among treatments for the proportion of 'A' grade bulbs. The highest percentage was recorded in the weed-free check (T_{10}) at 63.57%, which was statistically comparable to T_4 (61.72%), T_7 (60.85%), T_6 (58.91%), T_5 (57.97%), and T_8 (55.24%). The lowest share of 'A' grade bulbs was obtained in the weedy check (T_9), with only 10.23%. The percentage of 'B' grade bulbs was highest in the weedy check (T_9) at 41.42%, which was statistically comparable with T_1 (39.56%), T_2 (37.85%), and T_3 (36.26%). In contrast, the lowest proportion of 'B' grade bulbs was recorded in the weed-free check (T_{10}), with only 26.47%. The highest proportion of 'C' grade bulbs was observed in the weedy check (T_9), accounting for 39.23%, while the lowest percentage was recorded in the weed-free check (T_{10}) at 6.87%.

Total bulb yield (q/ha)

Total bulb yield was significantly highest in the weed-free check (T_{10}), producing 331.64 q/ha, while the lowest yield was recorded in the weedy check (T_9) at 173.33 q/ha. Among herbicidal treatments, T_4 (Pendimethalin 580 g a.i./ha PE + hand weeding at 45 DAP) achieved the highest yield (314.87 q/ha), which was statistically comparable to T_7 (300.62 q/ha). The superior yields in effectively managed plots may be attributed to reduced weed competition, enabling better utilization of nutrients, moisture, and sunlight—crucial for vigorous growth and bulb formation. These findings align with earlier reports by Murthy *et al*. (2009) [11], Kathepuri *et al*. (2007) [8], Patel *et al*. (2012) [14], and Kalhapure & Shete (2012) [6].

Marketable bulb yield (q/ha)

Marketable bulb yield was significantly highest in the weed-free check (T_{10}) at 321.40 q/ha, which was statistically comparable to T_4 (Pendimethalin 580 g a.i./ha PE + hand weeding at 45 DAP) yielding 304.42 q/ha. The lowest marketable yield was recorded in the weedy check (T_9) at 157.64 q/ha. Among herbicide treatments, T_4 produced the highest marketable yield, closely followed by T_7 (292.03 q/ha). These results corroborate earlier findings by Murthy *et al*. (2009) [11], Kathepuri *et al*. (2007) [8], Patel *et al*. (2012) [14], and Kalhapure and Shete (2012) [6].

Weed Control Efficiency (%)

Weed control efficiency (WCE) differed significantly among treatments. The weed-free check (T_{10}) consistently recorded the

highest WCE at all observation stages. Among herbicidal treatments, T_4 (Pendimethalin 580 g a.i./ha PE + hand weeding at 45 DAP) achieved the highest WCE at 30 DAP (66.94%), 60 DAP (66.25%), 90 DAP (65.69%), and at harvest (66.52%), followed by T_7, which recorded 60.09%, 54.38%, 49.67%, and 44.35%, respectively. The lowest efficiency was observed in the weedy check (T_9). The superior performance of these treatments may be attributed to the broad-spectrum action of pre-emergence herbicides in suppressing early weed germination, complemented by post-emergence applications and hand weeding, which collectively reduced weed density. These findings align with earlier reports by Ghadage *et al*. (2006) [5], Chandrika *et al*. (2009) [3], and Kalhapure *et al*. (2013) [7].

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 weeding at 45 DAP.	55.27	12.49	5.64	4.72	73.11	314.87	304.42
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)	51.30	10.75	5.23	4.38	70.40	291.33	275.62
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)	53.80	10.83	5.35	4.46	71.73	294.93	279.23
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	54.55	10.90	5.48	4.57	72.67	300.62	292.03
T_8	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
T_9	Control (Weedy Check)	43.30	9.08	4.42	3.88	59.80	173.33	157.64
T_{10}	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 grade-wise percentage distribution of onion bulbs

Sr. No.	Treatments	Grade (%)		
		A	B	C
T_1	Oxyfluorfen 23.5% EC, 175 g a.i/ha (PE) and Oxyfluorfen 23.5% EC, 175 g a.i/ha (PoE)	41.23	39.56	10.90
T_2	Oxyfluorfen 23.5% EC, 175 g.a.i./ha (PE) and hand weeding at 45 DAP	44.76	37.85	9.84
T_3	Pendimethalin 580 g.a.i./ha (PE) and Pendimethalin 580 g.a.i./ha (PoE)	47.75	36.26	8.78
T_4	Pendimethalin 580 g.a.i./ha (PE) and hand weeding at 45 DAP.	61.72	27.89	6.81
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)	57.97	29.78	6.85
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)	58.91	29.12	6.98
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	60.85	27.68	6.95
T_8	Propaquizafop 5% 55.75 g.a.i./ha + Oxyfluorfen 12% ww/EC (PE) and hand weeding at 45 DAP	55.24	30.18	8.16
T_9	Control (Weedy Check)	10.23	41.42	39.23
T_{10}	Weed free check	63.57	26.47	6.87
	S.E ±	3.19	2.14	0.73
	CD at 5%	9.49	6.35	2.17

Table 3: Effect of different weed control treatments on weed control efficiency in onion bulb crop

Sr. No.	Treatments	Weed control efficiency (%)			
		30 DAP	60 DAP	90 DAP	At harvest
T_1	Oxyfluorfen 23.5% EC, 175 g a.i/ha (PE) and Oxyfluorfen 23.5% EC, 175 g a.i/ha (PoE)	11.63 (19.86)	10.01 (17.94)	9.20 (17.49)	8.45 (16.87)
T_2	Oxyfluorfen 23.5% EC, 175 g.a.i./ha (PE) and hand weeding at 45 DAP	17.73 (24.72)	16.04 (23.39)	14.67 (22.26)	13.10 (21.18)
T_3	Pendimethalin 580 g.a.i./ha (PE) and Pendimethalin 580 g.a.i./ha (PoE)	25.20 (30.02)	22.57 (28.27)	20.55 (26.82)	18.93 (25.72)
T_4	Pendimethalin 580 g.a.i./ha (PE) and hand weeding at 45 DAP.	66.94 (54.95)	66.25 (54.53)	65.69 (54.19)	66.52 (54.67)

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)	42.27 (40.53)	38.20 (38.13)	34.86 (36.15)	31.34 (34.02)
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)	49.07 (44.47)	44.43 (41.80)	40.60 (39.57)	36.08 (36.91)
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	60.09 (50.83)	54.38 (47.52)	49.67 (44.81)	44.35 (41.75)
T_8	Propaquizafop 5% 55.75 g.a.i./ha + Oxyfluorfen 12% ww/EC (PE) and hand weeding at 45 DAP	34.13 (35.72)	30.87 (33.71)	28.19 (32.01)	25.17 (30.10)
T_9	Control (Weedy Check).	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
T_{10}	Weed free check	100.00 (89.74)	100.00 (89.75)	100.00 (89.76)	100.00 (89.77)
	S.E ±	1.51	1.88	1.63	1.06
	CD at 5%	4.52	5.61	4.87	3.15

Figures in the parenthesis are arc sine transformed.

Conclusion

The analysis of variance (ANOVA) revealed that weed management practices had a significant influence on the growth and yield performance of onion. Among all treatments, T_4 Pendimethalin 580 g a.i./ha applied as a pre-emergence followed by hand weeding at 45 DAP—consistently outperformed others. This treatment produced the tallest plants, the highest number of leaves, and superior yield-attributing traits, including maximum bulb weight, polar diameter, and equatorial diameter. Consequently, T_4 also recorded the highest total and marketable bulb yields per hectare. Overall, the results demonstrate that integrating Pendimethalin with timely hand weeding is an effective and efficient weed management strategy for maximizing onion productivity

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