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Effect of integrated weed management practices on weed dynamics and economic performance of potato crop in northern plains

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Abstract
Acknowledging that effective weed management is essential for ensuring healthy crop growth and maximizing yields, a field experiment was undertaken during the Rabi season of 2022 at the Research Farm of the Department of Vegetable Science, CCSHAU, Hisar, Haryana. The study aimed to evaluate the performance of the potato variety 'Kufri Bahar' under thirteen different weed control treatment combinations. The analysis of collected data demonstrated that the choice of weed management strategy had a significant influence on multiple yield and weed-related parameters, underscoring the importance of integrated weed control practices in optimizing potato production. The results obtained were recorded and observed that at 25 DAP highest weed density and maximum dry matter accumulation of weeds were recorded in the treatments T_{13}, T_{11} and T_{8}. The weed control efficiency among different weed control treatments was found maximum in T_6 followed by T_3. Weed index was found minimum in T_{12} which was followed by T_{11}, T_6 and T_3. The highest net returns was recorded under treatment T_{12}, followed by T_{11}, T_6 and T_3.

Keywords: Tuber, weed population, weed index, net return

Introduction
Potato (*Solanum tuberosum* L.), a member of the Solanaceae family, ranks as the fourth most significant food crop globally, following wheat, maize, and rice, in terms of its contribution to food and nutritional security (Singh *et al*., 2018) [19]. This autotetraploid species possesses a chromosome number of 2n = 4x = 48, which is characteristic of cultivated potatoes. Potato thrive in cool climates, with optimal growth occurring at day temperatures between 15°C and 25 °C and night temperatures around 15 °C. Tuberization is most efficient when temperatures are below 20 °C. High temperatures, particularly those exceeding 30 °C during the day, can reduce tuber formation by decreasing photosynthetic efficiency and increasing the production of gibberellic acid in the buds, leading to early senescence (Menzel, 1983; Menzel, 1985; Struik *et al*., 1989; Prange *et al*., 1990; Lafta and Lorenzen, 1995) [13, 14, 20, 18, 9]. In regions like China, a 1 °C increase in temperature has been associated with a decrease in potato yield by approximately 583 kg ha^{-1} (Li and Zhang, 2020) [11]. Potatoes are best cultivated in well-drained loamy or sandy loam soils rich in organic matter, which provide optimal aeration and moisture retention. The ideal soil pH ranges from 5.0 to 6.5, with slightly acidic soils being preferable to mitigate the risk of scab disease (Kar and Kumar, 2007) [6].

The critical period for crop-weed competition in potato is reported to be between 20 and 66 days after planting (Monteiro *et al*., 2011) [16]. Weeds emerging during this window can significantly affect crop performance by competing for vital resources such as light, moisture, and nutrients. This competition is particularly harmful around 40-50 days after planting, when the crop is still in its early vegetative phase (Channappagoudar *et al*., 2007; Lal and Gupta, 1984) [2, 10]. Effective weed management during the critical period is essential for maintaining crop health and maximizing yield (Hutchinson, 2020) [5]. Integrated Weed Management (IWM) approaches which combine cultural, mechanical, and chemical methods have shown promise in achieving long-term control. Early weeding, crop rotation, mulching, timely herbicide application, and the

use of competitive cultivars are all part of a sustainable weed control strategy (Singh *et al*. 2018) [19]. Given these challenges, the present study was designed to evaluate and compare the efficacy of chemical and non-chemical methods of weed management in potato, with the aim of identifying practical solutions to reduce yield losses and improve resource use efficiency.

Materials and Methods

The experiment was carried out at the Research Farm of the Department of Vegetable Science, CCSHAU, Hisar, Haryana during the Rabi season of 2022-23. The study evaluated the potato variety *Kufri Bahar* under thirteen different weed control treatment combinations. The treatments were arranged in a Randomized Block Design (RBD). Weed density, by species, was recorded at 25 days after planting (DAP) using a 0.5 m × 0.5 m quadrant placed at two randomly selected locations within each plot. The weeds within each quadrat were counted, and the average of the two quadrats was converted to number of weeds per square meter for all treatments, excluding the weed-free control. To determine the dry matter accumulation of weeds, the collected samples were first shade-dried for 24 hours, followed by oven-drying at 65 °C until a constant weight was achieved. The average values from two quadrats were then converted to weed density per square meter and expressed as grams per square meter (g m^{-2}). To assess the effectiveness of the weed control treatments, weed control efficiency (WCE) was calculated at the specified observation intervals using the formula proposed by Mani *et al*. (1973) [12]. The weed index measures the reduction in tuber yield caused by competition from weeds, relative to a weed-free condition. It is inversely related to the effectiveness of weed control. Net return was calculated by deducting the total cost of cultivation for each specific treatment from its corresponding gross return, providing a clear measure of the economic benefit derived from that treatment.

Statistical analysis

The data pertaining to various parameters were subjected to statistical analysis by using ANOVA method of Panse and Sukhatme (1987) [17]. To assess significant difference between two treatment means, the critical difference (CD) was computed at 5% level of significance.

Results and Discussion

In experimental crop field, *Cyperus rotundus*, *Coronopus didymus* and *Fumaria parviflora* were the main weed flora, and the remaining weeds with a restricted population in the field were classified as others. A comparable weed flora in potato crops was also reported by Kumar *et al*. (2017) [8] and Mohaniya *et al*. (2022) [15].

The data on the impact of weed control treatments on weed density at 25 days after planting (DAP) for the year 2022-23 are presented in Table 1. The highest weed density at 25 days after planting (DAP) was recorded in treatments treatments T_{13}: Weedy check, T_{11}: Earthing up and T_8: Metribuzin 70% WP of 0.525 kg ha^{-1} as PoE, because no weed control measures had been applied in these plots up to that point. In contrast, the remaining treatments showed reduced weed populations compared to these three. Among all treatments, T_{12}: Weed free, consistently recorded the lowest weed density. Apart from T_{12} the most effective weed control at 25 DAP was observed in T_6: Metribuzin 70% WP of 0.525 kg ha^{-1} + rice straw of 6 t ha^{-1}, with a weed density of 80.0/m^2. This was statistically comparable to T_3: Metribuzin 70% WP of 0.525 kg ha^{-1} (85.3/m^2) and T_7: Oxyfluorfen 23.5% EC of 0.150 kg ha^{-1} + rice straw of 6 t ha^{-1} (89.3/m^2). Comparable results were observed by According to Hoogar *et al*. (2017) [4], among the vari Kebede *et al*. (2016) [7] and Azadbakht *et al*. (2017) [1]. ous herbicide treatments evaluated, the application of metribuzin at 500 g a.i. ha^{-1} as a pre-emergence herbicide was most effective in reducing both the density and dry weight of monocot weeds.

The data on dry matter accumulation of weeds is illustrated in Table 2. In the weed-free treatment, no weed dry matter accumulation was recorded, as these plots were kept free of weeds throughout the crop season. The treatment T_6: Metribuzin 70% WP of 0.525 kg ha^{-1} + rice straw of 6 t ha^{-1} had the lowest total weed dry matter accumulation at 25 days after planting (DAP), with 4.0 g/m^2. This was statistically similar to treatment T_3: Metribuzin 70% WP of 0.525 kg ha^{-1}, which recorded 4.5 g/m^2. On the other hand, the highest weed dry matter accumulation was noted in treatments T_{13}: Weedy check, T_{11}: Earthing up and T_8: Metribuzin 70% WP of 0.525 kg ha^{-1} as PoE, as no weed control measures had been applied in these plots up to 25 DAP. Similar findings were also reported by Yadav *et al*. (2015) [23] and Kebede *et al*. (2016) [7].

The data on weed control efficiency of different treatments measured at 25 days after planting (DAP) is displayed in Table 2. Among all treatments, T_6: Metribuzin 70% WP of 0.525 kg ha^{-1} + rice straw of 6 t ha^{-1} exhibited the highest weed control efficiency at 80.1%, closely followed by T_3: Metribuzin 70% WP of 0.525 kg ha^{-1} at 77.6% and T_7: Oxyfluorfen 23.5% EC (0.150 kg ha^{-1}) + rice straw (6 t ha^{-1}) at 68.7%. Conversely, the lowest efficiencies were recorded in treatments T_{13}: Weedy check, T_{11}: Earthing up and T_8: Metribuzin 70% WP of 0.525 kg ha^{-1} as PoE, which can be attributed to the absence of any weed control interventions in these plots up to 25 DAP. These findings are in agreement with the results reported by Yadav *et al*. (2013) [24] and Kebede *et al*. (2016) [7]. In a separate study, Yadav *et al*. (2015) [23] observed that weed control efficiency varied across different management practices, ranging from 22.8% to 100%. The highest efficiency was achieved in the weed-free treatment, followed by the use of metribuzin in combination with a single hand weeding.

The weed index reflects the effectiveness of a weed control treatment in comparison to a completely weed-free condition. It was calculated using data on total tuber yield for each treatment. As shown in Table 3 for the 2022-23 season, the weed index varied significantly across treatments, ranging from 0.0% to 49.7%. The lowest weed index (0.0%) was observed in treatment T_{12}: Weed free, indicating its high effectiveness. This was followed by T_{11}: Earthing up (6.4%), T_6: Metribuzin 70% WP of 0.525 kg ha^{-1} + rice straw of 6 t ha^{-1} (7.9%), and T_3: Metribuzin 70% WP of 0.525 kg ha^{-1} (12.2%). In contrast, the highest weed index was recorded in treatment T_{13}: Weedy check, (49.7%). These findings are consistent with those reported by Yadav *et al*. (2015) [24] and Hoogar *et al*. (2017) [4].

The data pertaining to net returns is presented in Table 4, among the various weed control treatments, the highest net returns of Rs. 177,634/ha was recorded under treatment T_{12}: Weed free. This was followed by T_{11}: Earthing up (Rs. 171,314 /ha), T_6: Metribuzin 70% WP of 0.525 kg ha^{-1} + rice straw of 6 t ha^{-1} (Rs. 159,494/ha) and T_3: Metribuzin 70% WP of 0.525 kg ha^{-1} (Rs. 161,774/ha). According to Yadav *et al*. (2021) [21], the highest net return achieved was Rs. 176,100 per hectare. In a separate study, Mohaniya *et al*. (2022) [15] reported that two rounds of hand weeding at 20 and 40 days after planting yielded the maximum net return of Rs. 245,677 per hectare among all weed management treatments. These outcomes are further supported by the findings of Yadav *et al*. (2014) [22] and Gupta *et al*. (2019) [3].

Table 1: Effect of weed control treatments on weed density at 25 days (number/m^2) in potato during 2022-23

Treatments	Time of application	*Cyperus rotundus*	*Coronopus didymus*	*Fumaria parviflora*	Others	Total
T_1: Rice straw (6 t ha^{-1})	PE	118.0 (10.9)	142.7 (11.7)	8.2 (2.9)	4.0 (1.9)	272.9 (16.5)
T_2: Pendimethalin 30% EC (1 kg ha^{-1})	PE	115.0 (10.7)	13.3 (2.8)	0.0 (1.0)	2.7 (1.7)	127.0 (11.3)
T_3: Metribuzin 70% W P (0.525 kg ha^{-1})	PE	81.3 (9.1)	2.7 (1.7)	0.0 (1.0)	1.3 (1.4)	85.3 (9.3)
T_4: Oxyfluorfen 23.5% EC (0.150 kg ha^{-1})	PE	99.3 (10.0)	10.7 (3.3)	0.0 (1.0)	4.0 (2.1)	114.0 (10.7)
T_5: Pendimethalin 30% EC (1 kg ha^{-1}) + rice straw (6 t ha^{-1})	PE	102.7 (10.2)	0.0 (1.0)	0.0 (1.0)	1.3 (1.4)	103.9 (10.2)
T_6: Metribuzin 70% WP (0.525 kg ha^{-1}) + rice straw (6 t ha^{-1})	PE	80.0 (9.0)	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)	80.0 (9.1)
T_7: Oxyfluorfen 23.5% EC (0.150 kg ha^{-1}) + rice straw (6 t ha^{-1})	PE	87.3 (9.4)	0.0 (1.0)	0.0 (1.0)	2.0 (1.4)	89.3 (9.5)
T_8: Metribuzin 70% WP (0.525 kg ha^{-1})	PoE	128.0 (11.3)	232.0 (15.2)	13.0 (3.6)	18.7 (4.3)	391.7 (19.8)
T_9: Pendimethalin 30% EC (1 kg ha^{-1}) *fb* metribuzin 70% WP (0.525 kg ha^{-1})	PE *fb* PoE	111.2 (10.5)	14.7 (3.5)	0.0 (1.0)	1.9 (1.5)	127.8 (11.3)
T_{10}: Oxyfluorfen 23.5% EC (0.150 kg ha^{-1}) *fb* metribuzin 70% WP (0.525 kg ha^{-1})	PE *fb* PoE	98.7 (10.0)	12.0 (3.6)	0.0 (1.0)	2.7 (1.7)	113.4 (10.7)
T_{11}: Earthing up	30 DAP	100.7 (10.0)	256.0 (16.0)	14.3 (3.9)	16.3 (4.0)	398.3 (20.0)
T_{12}: Weed free		0.0 (1.0)	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)
T_{13}: Weedy check		118.0 (10.8)	252.0 (15.9)	12.0 (3.5)	17.3 (4.1)	399.3 (20.0)
CD at 5% level of significance		1.5	1.9	1.3	0.5	1.0

* PE- Pre-emergence, PoE- Post-emergence, DAP- Days after planting; The values in parentheses are square root (x+1) transformed values.

Table 2: Effect of weed control treatments on weed dry matter accumulation (g/m^2) at 25 DAP in potato during 2022-23

Treatments	Time of Application	Weed dry matter accumulation (g/m^2)
T_1: Rice straw (6 t ha^{-1})	PE	19.9 (4.6)
T_2: Pendimethalin 30% EC (1 kg ha^{-1})	PE	13.9 (3.9)
T_3: Metribuzin 70% W P (0.525 kg ha^{-1})	PE	7.4 (2.9)
T_4: Oxyfluorfen 23.5% EC (0.150 kg ha^{-1})	PE	13.1 (3.8)
T_5: Pendimethalin 30% EC (1 kg ha^{-1}) + rice straw (6 t ha^{-1})	PE	12.9 (3.7)
T_6: Metribuzin 70% WP (0.525 kg ha^{-1}) + rice straw (6 t ha^{-1})	PE	6.6 (2.8)
T_7: Oxyfluorfen 23.5% EC (0.150 kg ha^{-1}) + rice straw (6 t ha^{-1})	PE	11.2 (3.5)
T_8: Metribuzin 70% WP (0.525 kg ha^{-1})	PoE	18.0 (4.4)
T_9: Pendimethalin 30% EC (1 kg ha^{-1}) *fb* metribuzin 70% WP (0.525 kg ha^{-1})	PE *fb* PoE	10.8 (3.4)
T_{10}: Oxyfluorfen 23.5% EC (0.150 kg ha^{-1}) *fb* metribuzin 70% WP (0.525 kg ha^{-1})	PE *fb* PoE	9.6 (3.3)
T_{11}: Earthing up	30 DAP	5.1 (2.4)
T_{12}: Weed free		0.0 (1.0)
T_{13}: Weedy check		23.7 (5.0)
CD at 5%		0.4

*The values in parentheses are square root (x+1) transformed values

Table 3: Effect of weed control treatments on weed control efficiency (%) and weed index (%)

Treatments	Time of Application	Weed control efficiency (%)	Weed index (%)
T_1: Rice straw (6 t ha^{-1})	PE	43.8	31.8
T_2: Pendimethalin 30% EC (1 kg ha^{-1})	PE	55.2	29.1
T_3: Metribuzin 70% W P (0.525 kg ha^{-1})	PE	73.1	12.2
T_4: Oxyfluorfen 23.5% EC (0.150 kg ha^{-1})	PE	57.9	25.7
T_5: Pendimethalin 30% EC (1 kg ha^{-1}) + rice straw (6 t ha^{-1})	PE	58.6	23.5
T_6: Metribuzin 70% WP (0.525 kg ha^{-1}) + rice straw (6 t ha^{-1})	PE	76.1	7.9
T_7: Oxyfluorfen 23.5% EC (0.150 kg ha^{-1}) + rice straw (6 t ha^{-1})	PE	62.3	15.2
T_8: Metribuzin 70% WP (0.525 kg ha^{-1})	PoE	48.4	44.1
T_9: Pendimethalin 30% EC (1 kg ha^{-1}) *fb* metribuzin 70% WP (0.525 kg ha^{-1})	PE *fb* PoE	66.6	38.9
T_{10}: Oxyfluorfen 23.5% EC (0.150 kg ha^{-1}) *fb* metribuzin 70% WP (0.525 kg ha^{-1})	PE *fb* PoE	74.7	34.0
T_{11}: Earthing up	30 DAP	82.8	6.4
T_{12}: Weed free		100.0	0.0
T_{13}: Weedy check		0.0	49.7

*PE- Pre-emergence, PoE- Post-emergence, DAP- Days after planting

Table 4: Effect of weed control treatments on net returns (Rs./ha)

Treatments	Time of Application	Net returns (Rs./ha)
T_1: Rice straw (6 t ha^{-1})	PE	88554
T_2: Pendimethalin 30% EC (1 kg ha^{-1})	PE	105014
T_3: Metribuzin 70% W P (0.525 kg ha^{-1})	PE	161774
T_4: Oxyfluorfen 23.5% EC (0.150 kg ha^{-1})	PE	116218
T_5: Pendimethalin 30% EC (1 kg ha^{-1}) + rice straw (6 t ha^{-1})	PE	125234
T_6: Metribuzin 70% WP (0.525 kg ha^{-1}) + rice straw (6 t ha^{-1})	PE	159494
T_7: Oxyfluorfen 23.5% EC (0.150 kg ha^{-1}) + rice straw (6 t ha^{-1})	PE	137968
T_8: Metribuzin 70% WP (0.525 kg ha^{-1})	PoE	59534
T_9: Pendimethalin 30% EC (1 kg ha^{-1}) *fb* metribuzin 70% WP (0.525 kg ha^{-1})	PE *fb* PoE	72544
T_{10}: Oxyfluorfen 23.5% EC (0.150 kg ha^{-1}) *fb*metribuzin 70% WP (0.525 kg ha^{-1})	PE *fb* PoE	88428
T_{11}: Earthing up	30 DAP	171314
T_{12}: Weed free		177634
T_{13}: Weedy check		44124

*PE- Pre-emergence, PoE- Post-emergence, DAP- Days after planting

Conclusion

Based on the findings of the study, it can be concluded that weed management practices play a crucial role in influencing the growth performance and yield potential of potato crops. Among the various treatments evaluated, treatment T_{11}, which includes earthing up at 30 days after planting (DAP) in combination with standard agronomic practices. It proved to be one of the most effective in enhancing productivity and profitability. This approach not only minimized weed competition during critical growth stages but also contributed to better tuber development. Therefore, for maximizing both yield and economic returns in potato cultivation, adopting treatment T_{11} as part of an integrated crop management strategy is strongly recommended.

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