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Investigating the Effectiveness of Various Weed Control Methods to Reduce Narrow and Broad Leaf Populations in the Oat (*Avena sativa* L.) Crop

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: It is aim to investigating the effectiveness of various weed control methods to reduce narrow and broad leaf populations in oat (*Avena sativa* L.) crop.
Study Design: The experiment was designed using a Randomized Block design method.

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Place and Duration of Study: Department of agronomy, School of Agriculture, Abhilashi university, Chail Chowk, Mandi, India (H.P.) during the *Rabi* season of 2022.
Methodology: The field trail was conducted with seven treatments and replicated thrice. The investigation included seven different weed control techniques *i.e.* T_1 - weedy check (control), T_2 - weed free, T_3 - one hand weeding at 25 DAS, T_4 - two hand weeding at 25 DAS and 45 DAS, T_5 - pre-emergence application of Pendimethalin @ 0.75 kg a.i. ha^{-1} + one hand weeding at 25 DAS, T_6 - post emergence application of atrazine @ 0.75 kg a.i. ha^{-1} at 35 DAS + one hand weeding at 25 DAS, T_7 - post emergence metsulfuron methyl @ 0.004 kg a.i. ha^{-1} at 35 DAS + one hand weeding at 25 DAS.
Results: The investigation found that the most effective ways to control weeds are by keeping the area completely weed-free or by using two-hand weeding at 25 DAS and 45 DAS. T_2 (weed-free), which involved keeping the area weed-free, was found to be the most successful in terms of achieving the lowest weed density and highest weed control efficiency. Two-hand weeding at 25 DAS and 45 DAS was found to be better than using herbicides to reduce weed infestation in oat crops.
Conclusion: Based on the results, it can be concluded that integrated weed management practices weed-free treatment is the most effective option for managing weeds in oats.

Keywords: Oat crop; green forage yield; weed index; weed control efficiency and weed control.

1. INTRODUCTION

"The oat (*Avena sativa* L.), also known as the common oat, is a variety of cereal grain grown for its seeds, which are known locally as javi, jai, or jodar. Oats are a domesticated cereal grass (family Gramineae/Poaceae) primarily grown for their edible starchy grains. Oats are the 6th most produced cereal crop in the world. Oats were grown in Southeast Europe or Asia Minor. Oats are self-pollinating crops. In the Rabi season, oats are the major cereal forage crop in India because they are quick-growing, palatable, and nutritious for livestock. The cultivation of oat for fodder may be more profitable than grain, cash or commercial crops" [1]. Green fodder typically contains 10-12 % protein and 30-35% dry matter. The nutritive value of forage oats is high, with a dry matter digestibility of over 75% when fed to dairy cattle [2].

"India has the largest livestock population of 535.78 in the world" [3]. But the country has only 9.13 million hectares of cultivated area (4.4% of gross cropped area) under fodder crop, and 10.26 million hectares are used for pasture and grazing. This is not enough to meet the existing demand for fodder. Currently, India has a 35.6% deficiency in green fodder, a 10.95% deficiency in dry fodder, and a 44% deficiency in concentrate feed materials [4]. "In Himachal Pradesh, 9,451 hectares of cultivated fodder crops and 1508 thousand hectares of pastures and grasslands are only able to meet a partial requirement of the 4.41 million large livestock population. The annual requirement of green and dry fodder in Himachal Pradesh is about 62 and 198 lakhs tonnes, respectively, while the total availability of green and dry fodder in the state is 31 and 52 lakhs tonnes, respectively" [3].

"Weed management is not common in fodder crops because farmers often consider weeds to be animal feed. However, weeds can reduce fodder yield by up to 40%. Yield loss due to weed competition is thought to be one of the main causes of lower productivity in many agricultural crops" [5]. "Integrated weed management (IWM) is a science-based decision-making procedure that coordinates the use of environmental information. IWM is a multi-disciplinary approach that involves chemical and cultural methods of weed management" [6]. "IWM reduces the weed burden by depleting the weed seed bank, minimizing weed germination, and reducing the competitiveness of weeds. can be controlled manually by physical removal or pulling out of weeds by hand. Implements called khurpi, which resemble sickles, can also be used. Physical removal of weeds by disturbing the soil is one of the oldest methods of weed control in crops" [7]. Tillage, harrowing, hoeing, and hand weeding are the main mechanical weed control techniques used.

"Mechanical weed control is a method that involves using tillage and cultivation to control weeds in three different ways. Firstly, it uproots and buries both growing weeds and dormant structures. Secondly, it inhibits the germination of weed seeds. Thirdly, it redistributes weed seeds vertically and horizontally, thereby reducing the likelihood of seedling emergence and survival" [7]. "Currently, the use of mechanical weed control is limited in modern agriculture because herbicides are more popular among farmers. However, with growing awareness of organic farming and the environmental impacts of herbicides, mechanical weed control is becoming more popular" [8].

"Chemical weed control (herbicide) is a quick, effective, time-saving, and labour-saving method. The chemicals used for weed control, which suppress or destroy the growth of weeds, are called herbicides. Herbicides that can prevent weed infestation during the first six weeks are particularly useful in oat crops. Herbicides are replacing manual weeding because they are cost-effective and easy to use. Using a pre-emergence herbicide (pendimethalin) and post-emergence herbicides (atrazine and metsulfuron methyl) in combination with mechanical and cultural methods is the best way to manage weeds. All these herbicides are used to control annual grasses and certain broadleaf weeds that interfere with growth, development, yield, and quality of agricultural crops by competing for nutrients, water, and light. The oat is a Rabi irrigated and long-duration crop that is massively infested with various species of annual and perennial weeds, some of which are not preferred by animals" [9].

"Wild oat (*Avena fatua*) is the most serious weed concern for oat growers. An increasing number of wild oats reduces oat yield loss. Wild oat does not emerge early in the spring, making pre-seeding applications of glyphosate less effective, and it continues to emerge over 4-6 weeks. The earlier the emergence of wild oat relative to the oat crop, the higher the yield loss. Wild oat can be a difficult weed to handle in oat cultivation, with densities of 60 to 180 plants per m^2 causing a reduction in productivity by 3 to 22%" [10]. "In the past, oat growers used late planting to control wild oat, which allowed them to control emerging weeds by chemical and mechanical means before sowing oat but resulted in reduced grain yield and grain quality" [11]. An alternative to late planting is to use herbicide-resistant oat cultivars that would allow the use of herbicides to control wild oat. The other weeds that grow in oat crops include bathua (*Chenopodium album*), canary grass (*Phalaris minor*), wild raddish (*Raphanus raphanistrum*), nut grass (*Cyperus rotandus*), blue pimpernel (*Anagallis arvensis* L.), hariyali (*Cynodon dactylon*), and wild hollyhock (*Althaea ludwigri*).

2. MATERIALS AND METHODS

A research project was conducted during the *Rabi* season of 2022-2023 at the Research Farm of the School of Agriculture, Abhilashi University Mandi (H.P.), India. The experimental farm is located at 30º32'N latitude and 74º53'E longitude, with an elevation of 1391 m above mean sea level. The soil has a slightly acidic reaction with a pH of 5.65, an electrical conductivity of 0.29, and organic carbon of 0.73. The available nitrogen is low (234.98), while the available phosphorus (13.67) and potassium (203.31) are medium. The net plot size was 3.4 m × 1.2 m, and the gross plot size was 3.7 m × 1.5 m. The observation was recorded at 30, 60, and 90 DAS and at harvest on weed parameters [*viz*., narrow and broadleaf weeds, including the number of weeds (No. m^2), weed dry matter accumulation (g/m^2), weed control efficiency (%), and weed index]. The oat cultivar variety Kent was sown manually in rows with a spacing of 20 cm and a seed rate of 100 kg ha^{-1}. The experimental design was a randomised block design (RBD) with seven treatments and three replications. The treatments, viz., weedy check (control), weed free, one hand weeding at 25 DAS, two hand weeding at 25 DAS and 45 DAS, pre-emergence application of Pendimethalin @ 0.75 kg a.i. ha^{-1} + one hand weeding at 25 DAS, post-emergence application of atrazine @ 0.75 kg a.i. ha^{-1} at 35 DAS + one hand weeding at 25 DAS, post-emergence metsulfuron methyl @ 0.004 kg a.i. ha^{-1} at 35 DAS + one hand weeding at 25 DAS. In each experimental plot, an area of 1 m^2 was fixed, and the number of weeds was recorded at 30, 60, and 90 DAS. The weed samples were sun-dried for three days and then oven-dried at 70 °C to ensure a consistent weight. Pendimethalin, atrazine, and metsulfuron methyl were applied according to their respective treatments. No weed management was performed in the T_1 treatment (weedy check).

3. RESULTS AND DISCUSSION

3.1 Weed Studies

The weed flora observed in the experimental field was collected, identified, and categorised into narrow-leaf and broad-leaf weeds. During the investigation of the experimental plots, several major weed species were observed, including narrow-leaf weeds such as *Avena fatua, Phalaris minor, Cynodon dactylon, and Cyprus rotandus,* and broad-leaf weeds such as *Chenopodium album L., Anagallis arvensis L., Rumex spp.,* and *Raphanus raphanistrum.*

3.2 Narrow Leaf Weed Density

Density of narrow leaf weeds were observed at 30, 60. 90 DAS and at harvest of crop period and had been presented in Table 1 and illustrated in Fig. 1. As per result indicated that the density of narrow leaf weeds was significantly affected by weed control methods at all the stages of crop growth.

The density of narrow leaf weeds at 30, 60, and 90 DAS and at harvest was recorded to show that there were no weeds in treatment T_2 (weed-free) since the weeds were being removed every time they appeared. This treatment was kept weed-free throughout the growing period; hence, it recorded zero weed density over the other treatments. Among the treatments, T_2 (weed-free) recorded the lowest weed density, followed by T_4 at 24.83, 16.88, 7.35, and 2.23 m^2 (two hand weeding at 25 DAS and 45 DAS). It was observed that the weed density was decreasing continuously with the ageing of the crop. The highest weed density at 30, 60, and 90 DAS and at harvest (52.61, 47.37, 28.94, and 12.69 m^2) was found in treatment T_1 (weedy check), in which no control measures were taken. Among the herbicidal applications, treatment T_7 (post-emergence application of metsulfuron methyl @0.004 kg a.i. ha^{-1} at 35 DAS + one hand weeding at 25 DAS) was found to be more effective in controlling weed population density compared to treatment T_6 (post-emergence application of atrazine @0.75 kg a.i. ha^{-1} at 35 DAS + one hand weeding at 25 DAS) and T_5 (pre-emergence application of pendimethalin @0.75 kg a.i. ha^{-1} + one hand weeding at 25 DAS). This indicates that the weed density tends to increase with the advancement of crop age up to 30 DAS and then decreases.

The reduction in weed density in hand weeding is due to periodic disturbances of the soil by removing the weeds with the help of hand tools. The application of herbicides also substantially reduces weed density [12,13]. This could to be due to the broad-spectrum activity of herbicides, which works effectively on both narrow and broad-leaf weeds. A similar finding was reported by Singh et al. [14].

3.3 Broad Leaf Weed Density

The density of broad leaf weeds was measured at different crop growth stages, specifically at 30, 60, and 90 DAS and at the time of harvest. The results have been presented in Table 2 and illustrated in Fig. 2. The outcome showed that weed control methods had a significant impact on the density of broad leaf weeds throughout all stages of crop growth.

Table 1. Effect of integrated weed management practices on narrow leaf weed density (m^{-2}) of oat crop

Sr. No.	Treatments	At 30 DAS	At 60 DAS	At 90 DAS	At harvest
T_1	Weedy check (control)	7.31 (52.61)	6.95 (47.37)	5.47 (28.94)	3.69 (12.69)
T_2	Weed free	1.0 (0.00)	1.0 (0.00)	1.0 (0.00)	1.0 (0.00)
T_3	One hand weeding at 25 DAS	5.21 (26.22)	4.77 (21.87)	3.50 (11.26)	2.60 (5.81)
T_4	Two hand weeding at 25 DAS and 45 DAS	5.07 (24.83)	4.22 (16.88)	2.88 (7.35)	1.79 (2.23)
T_5	Pre-emergence application of pendimethalin @ 0.75 kg a.i. ha^{-1} + one hand weeding at 25 DAS	5.15 (25.63)	4.68 (20.99)	3.46 (11.01)	2.52 (5.38)
T_6	Post emergence application of atrazine @ 0.75 kg a.i. ha^{-1} at 35 DAS + one hand weeding at 25 DAS	5.12 (25.31)	4.60 (20.23)	3.20 (9.34)	2.45 (5.05)
T_7	Post emergence application of metsulfuron methyl @ 0.004 kg a.i. ha^{-1} at 35 DAS + one hand weeding at 25 DAS	5.10 (25.06)	4.53 (19.60)	3.09 (8.62)	2.35 (4.55)
SE (m)±		0.15	0.13	0.10	0.07
CD (P= .05)		0.48	0.43	0.33	0.24

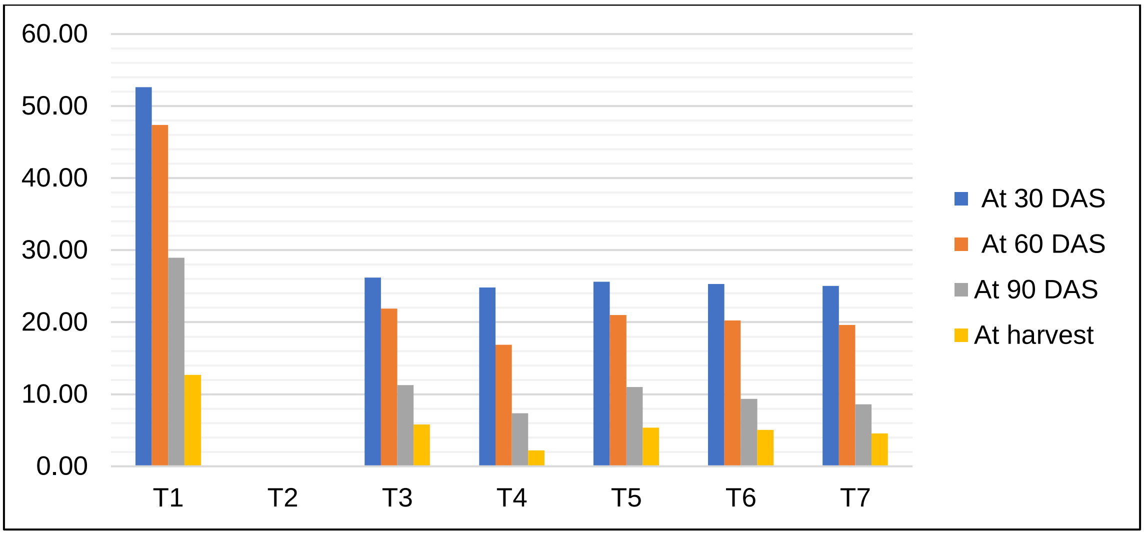

Fig. 1. Effect of integrated weed management practices on narrow leaf weed density (m^{-2}) of oat crop

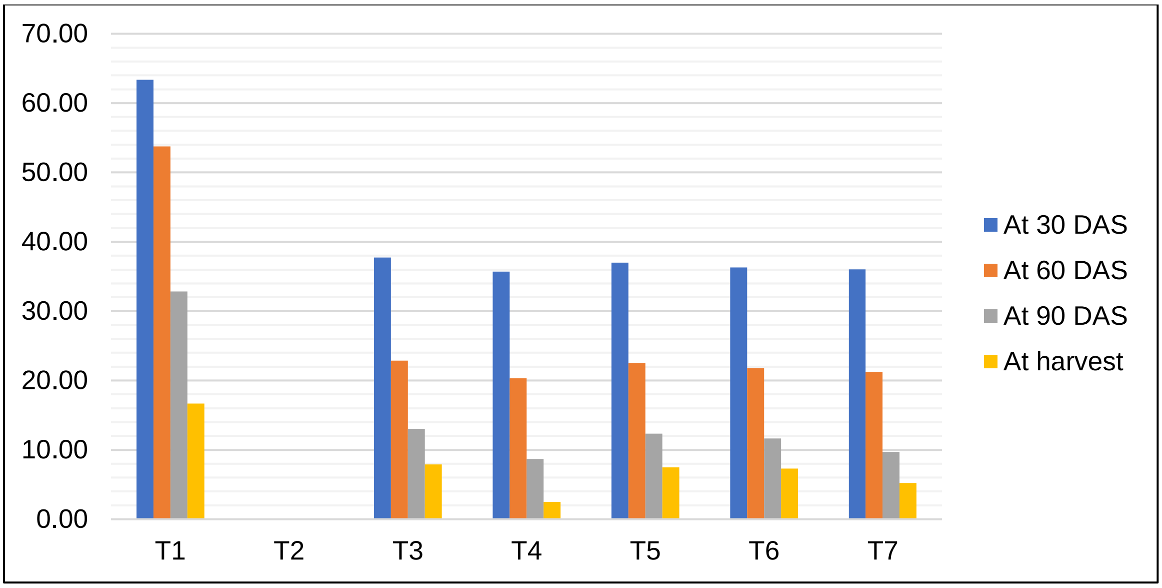

Fig. 2. Effect of integrated weed management practices on broad leaf weed density (m^{-2}) of oat crop

During the study, the density of broad leaf weeds was observed at 30, 60, and 90 DAS and at the time of harvest. It was recorded that there was no weed population under treatment T_2 (weed-free), in which the weeds were managed throughout the growing period. As a result, treatment T_2 recorded zero weed density as compared to the other treatments. Out of all the treatments, T_2 (weed-free) had the lowest weed density, followed by treatments T4 (35.72, 20.30, 8.70, and 2.47 m2) (two hand weedings of 25 DAS and 45 DAS). The treatment T_1 (weedy check) had the highest weed density during the investigation (63.38, 53.77, 32.84, 16.68 m2). Treatment T_7 (post-emergence application of metsulfuron methyl @0.004 kg a.i. ha^{-1} at 35 DAS + one hand weeding at 25 DAS) was found to be more effective than T_6 (post-emergence application of atrazine @0.75 kg a.i. ha^{-1} at 35 DAS + one hand weeding at 25 DAS) and Treatment T_5 (pre-emergence application of pendimethalin @0.75 kg a.i. ha^{-1} + one hand weeding at 25 DAS) in controlling weed population density among herbicidal applications. On average, it was observed during the investigation that at all the crop stages, the weed density peaks at 30 DAS and then decreases with further crop age.

There are various effective herbicides (among which we have used atrazine, pendimethalin, and metsulfuron methyl) available to manage broadleaf weeds in oats. Although some weeds may die as a result of tall weeds and the crop canopy's shade impact, herbicides should only be used as an additional tool, never as a cure. However, the regular application of any kind of control method, chemical or mechanical, often results in a change in the weed population towards a species that is more challenging to eradicate. This finding has been reported by Bisiwasi et al. [15] and Singh et al. [14]. The use of herbicides significantly decreases weed density. Similar findings were reported by Pandey et al. [12].

3.4 Total Weed Density (m^{-2})

The total weed density was measured at 30, 60, and 90 DAS and at harvest. The results have been presented in Table 3 and illustrated in Fig. 3. The findings indicate that weed control methods significantly affect the total weed density at all stages of crop growth. Treatment T2 (weed-free), which was kept weed-free during the growth season, showed negligible weed density compared to the other treatments. This was because the weeds were being pulled out whenever they appeared, resulting in a weed-free treatment. Among the treatments, T2 (weed-free) recorded the lowest weed density, followed by two-hand weeding at 25 DAS and 45 DAS (60.54, 37.18, 16.05, and 4.70 m2). As the crop matured, the weed density consistently decreased. The weed density was highest (115.99, 101.14, 61.78, and 29.37 m2) in treatment T1 (weedy check) at 30, 60, and 90 DAS and at harvest.

The density of total weeds (narrow and broad leaf weeds) was significantly reduced by adopting weed management treatments instead of relying on weedy checks. Among various integrated weed management practices, weed-free treatment was the most effective in reducing weed density as it did not allow the growth of weeds in the oat field compared to other weed management methods, as reported by Naik et al. [16]. The application of herbicides has been reported to significantly reduce weed density. Several authors have observed a decrease in weed density due to the use of pendimethalin: Pandey et al. [12], Singh et al. [13], and Chopra et al. [17]. Pendimethalin works by inhibiting cell division and elongation in the root and shoot meristem, resulting in the inhibition of growth. It is absorbed through the hypocotyls or shoot growth and can cause the death of the germinated seedling Gupta et al. [18]. However, weed density data may not always provide realistic and meaningful information, and it is necessary to assess the weed dry weight.

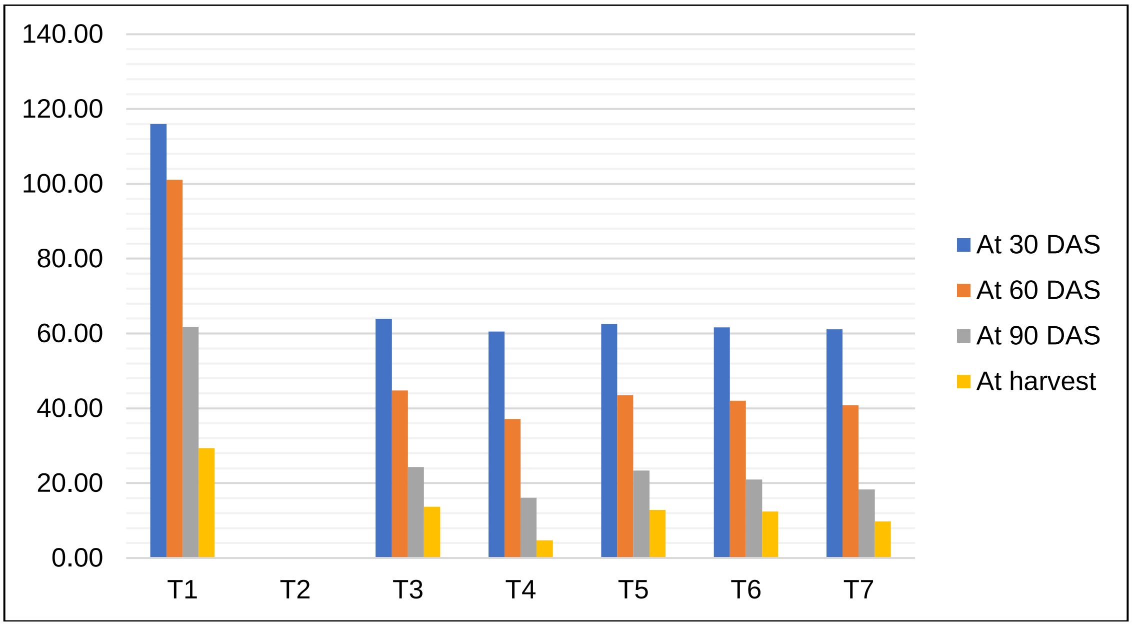

Fig. 3. Effect of integrated weed management practices on total weed density (m^2) of oat crop

Table 2. Effect of integrated weed management practices on broad leaf weed density (m^{-2}) of oat crop

Sr. No.	Treatments	At 30 DAS	At 60 DAS	At 90 DAS	At harvest
T_1	Weedy check (control)	8.02 (63.38)	7.40 (53.77)	5.81 (32.84)	4.20 (16.68)
T_2	Weed free	1.0 (0.00)	1.0 (0.00)	1.0 (0.00)	1.0 (0.00)
T_3	One hand weeding at 25 DAS	6.21 (37.75)	4.88 (22.87)	3.73 (13.04)	2.98 (7.92)
T_4	Two hand weeding at 25 DAS and 45 DAS	6.05 (35.72)	4.61 (20.30)	3.11 (8.70)	1.85 (2.47)
T_5	Pre-emergence application of pendimethalin @ 0.75 kg a.i. ha^{-1} +one hand weeding at 25 DAS	6.16 (36.98)	4.84 (22.52)	3.65 (12.35)	2.91 (7.49)
T_6	Post emergence application of atrazine @ 0.75 kg a.i. ha^{-1} at 35 DAS + one hand weeding at 25 DAS	6.10 (36.29)	4.76 (21.81)	3.55 (11.63)	2.88 (7.32)
T_7	Post emergence application of methasulfuron methyl @ 0.004 kg a.i. ha^{-1} at 35 DAS + one hand weeding at 25 DAS	6.08 (36.04)	4.71 (21.23)	3.26 (9.70)	2.48 (5.22)
SE (m)±		0.15	0.14	0.11	0.08
CD (*P*= .05)		0.46	0.43	0.35	0.27

Table 3. Effect of integrated weed management treatment on total weed density (m^{-2}) of oat crop

Sr. No.	Treatments	At 30 DAS	At 60 DAS	At 90 DAS	At harvest
T_1	Weedy check (control)	10.81 (115.99)	10.10 (101.14)	7.92 (61.78)	5.50 (29.37)
T_2	Weed free	1.0 (0.00)	1.0 (0.00)	1.0 (0.00)	1.0 (0.00)
T_3	One hand weeding at 25 DAS	8.05 (63.96)	6.75 (44.74)	5.02 (24.30)	3.83 (13.73)
T_4	Two hand weeding at 25 DAS and 45 DAS	7.83 (60.54)	6.17 (37.18)	4.12 (16.05)	2.38 (4.70)
T_5	Pre- emergence application of pendimethalin @ 0.75 kg a.i./ha + one hand weeding at 25 DAS	7.96 (62.60)	6.67 (43.52)	4.93 (23.36)	3.72 (12.87)
T_6	Post emergence application of atrazine @ 0.75kg a.i./ha at 35 DAS + one hand weeding 25 DAS	7.90 (61.60)	6.55 (42.04)	4.68 (20.97)	3.65 (12.37)
T_7	Post emergence application of metsulfuron methyl @ 0.004 kg a.i./ha at 35 DAS + one hand weeding at 25 DAS	7.87 (61.11)	6.46 (40.84)	4.37 (18.32)	3.27 (9.77)
SE (m)±		0.20	0.18	0.13	0.10
CD (*P*= .05)		0.62	0.56	0.41	0.33

3.5 Weed Dry Matter Accumulation (gm^{-2})

The dry matter accumulation of total weed density (narrow and broad-leaved weeds) was recorded throughout the growing period and is represented in Table 4 and illustrated in Fig. 4. The perusal of the data revealed that the various weed management treatments significantly influenced the weed dry matter of the crop at all growth stages of the oat crop. The observations on total weed dry matter recorded in gm^{-2} were reported during the experiment. At all stages of growth, treatment T_1 (weedy check) had the highest weed dry matter (37.62, 68.27, 152.89, and 272.51 gm^{-2}), closely followed by treatment T_3 (one hand weeding at 25 DAS). Whereas, the minimum weed density and weed dry matter were noted under treatment T_2 (weed-free). However, all the herbicidal treatments as well as other treatments were significantly superior in reducing the total dry matter of weed over weedy.

The reduction in total weed dry matter in these treatments was primarily due to the effective control of all monocots, dicots, and sedges at the early stages, which, as a consequence, recorded lower total weed density at all growth stages. The results conform with the findings of Sanjoy Saha [19]. This could be attributed to the re-emergence and accumulation of biomass in the weeds as they grew bigger with time. As the density of weeds decreases, their dry weight also decreases. Similar results were found by Pandey and Singh [20], Naik et al. [16], and Singh et al. [14].

3.6 Weed Control Efficiency (%)

The WCE on the basis of dry matter accumulation of weeds was worked out in different treatments at the time of harvest. The data regarding WCE have been present in Table 5 and illustrated in Fig. 5. As per result indicated that the weed control methods were significantly affected on weed control efficiency.

Table 4. Effect of integrated weed management practices on weed dry matter accumulation (gm^{-2}) of oat crop

Sr. No.	Treatments	At 30 DAS	At 60 DAS	At 90 DAS	At harvest
T_1	Weedy check (control)	6.21 (37.62)	8.32 (68.27)	12.40 (152.89)	16.53 (272.51)
T_2	Weed free	1.0 (0.00)	1.0 (0.00)	1.0 (0.00)	1.0 (0.00)
T_3	One hand weeding at 25 DAS	5.85 (33.32)	6.87 (46.23)	7.83 (60.42)	8.54 (71.95)
T_4	Two hand weeding at 25 DAS and 45 DAS	4.51 (19.42)	5.20 (26.15)	5.68 (31.27)	6.10 (36.31)
T_5	Pre-emergence application of pendimethalin @ 0.75 kg a.i. ha^{-1} + 25 DAS	5.76 (32.26)	6.76 (44.76)	7.74 (58.92)	8.38 (69.31)
T_6	Post emergence application of atrazine @ 0.75 kg a.i. ha^{-1} at 35 DAS + one hand weeding at 25 DAS	5.49 (29.21)	6.36 (39.51)	7.32 (52.69)	8.21 (66.43)
T_7	Post emergence application of metsulfuron methyl @ 0.004 kg a.i. ha^{-1} at 35 DAS + one hand weeding at 25 DAS	4.93 (23.37)	5.79 (32.65)	6.23 (37.83)	7.20 (50.97)
SE (m)±		0.04	0.05	0.07	0.08
CD (*P*= .05)		0.13	0.17	0.22	0.26

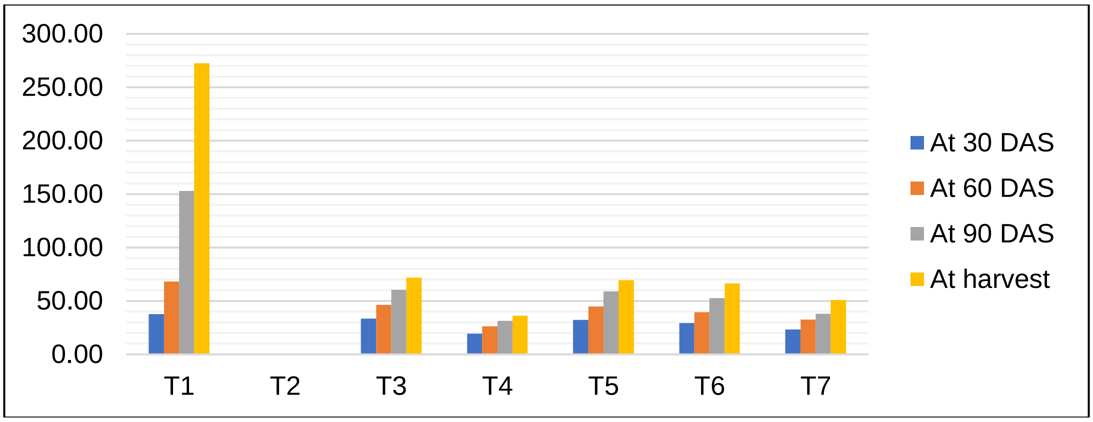

Fig. 4. Effect of integrated weed management treatment on weed dry matter accumulation (gm^{-2}) of oat crop

Table 5. Effect of integrated weed management practices on weed control efficiency (%) and weed index (%) of oat crop

Sr. No.	Treatments	Weed control efficiency (%)	Weed index (%)
T_1	Weedy check (control)	0.00	41.13
T_2	Weed free	100.00	0.00
T_3	One hand weeding at 25 DAS	73.59	20.47
T_4	Two hand weeding at 25 DAS and 45 DAS	86.67	4.03
T_5	Pre-emergence application of pendimethalin@ 0.75 kg a.i. ha^{-1} + one hand weeding at 25 DAS	74.56	15.78
T_6	Post emergence application of atrazine@ 0.75 kg a.i. ha^{-1} at 35 DAS + one hand weeding at 25 DAS	75.62	11.88
T_7	Post emergence application of metsulfuron methyl@ 0.004 kg a.i. ha^{-1} at 35 DAS + one hand weeding at 25 DAS	81.29	9.14
SE (m)±		0.92	0.82
CD (P= 0.05)		2.87	2.57

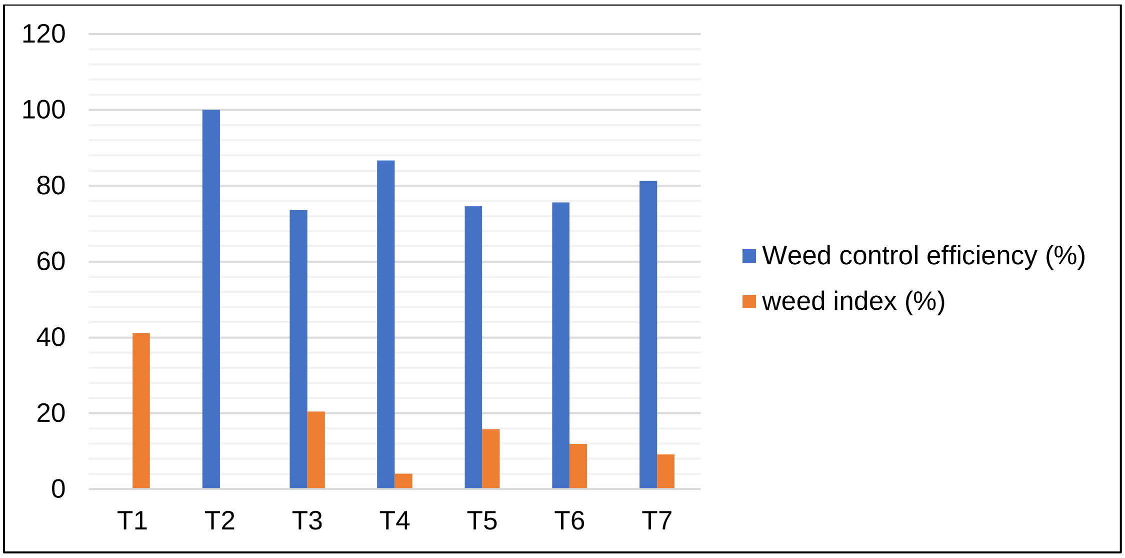

Fig. 5. Effect of integrated weed management practices on weed control efficiency (%) and weed index (%) of oat crop

For both narrow and broad leaf weed, the maximum WCE was recorded with treatment T_2 (weed free) 100% along with treatment T_4 (Two hand weeding at 25 DAS and 45 DAS) which gave the next best next value ranged 86.67%. The lowest weed control efficiency was observed under treatment T_1 (weedy check) because no measure has been taken to control weed during the experiment. Other treatments such as Post emergence application of metsulfuron methyl @0.004 kg a.i. ha^{-1} at 35 DAS + one hand weeding at 25 DAS, post emergence application of atrazine @0.75kg a.i. ha^{-1} at 35 DAS + one hand weeding at 25 DAS, pre-emergence application of pendimethalin @0.75 kg a.i. ha^{-1} + one hand weeding at 25 DAS and one hand weeding at 25 DAS gave WCE varying from 73.59 to 81.29 % at different crop growth.

The best WCE (weed control efficiency) was observed when the field was kept weed-free. This is because the weeds were manually removed on a weekly basis, resulting in fewer weeds and less dry matter accumulation, which is directly related to effective weed control. This is mainly due to the lowest amount of weed dry matter under the above treatment. Similar results were also reported by Tiwari et al. [21], Naik et al. [16] and Singh et al. [14]. This is possible due to depletion of weed dry weight resulted in increase in WCE. Similar favourable effect due to application of pendimethalin was observed by different worker [22].

3.7 Weed Index (%)

The weed index data have been presented in Table 5 and illustrated in Fig. 5. The results indicated that weed control methods significantly affect the weed index. The weed index was significantly influenced by the different weed control treatments. The mean weed index was varying the range (0.0, 4.03, 9.14, 11.88, 15.78, 20.57 and 41.13%) at different crop growth stages. The maximum weed index was recorded with treatment T_1 (weedy check) 41.13% and treatment T_3 (one hand weeding at 25 DAS) gave the next value ranged 20.47%. treatment T_2 (weed free) recorded the minimum weed index (0%) indicating that there was no reduction in crop yield of this treatment due to weed infestation [23-26].

The crops faced increased stress as a result of uncontrolled weed growth, leading to lower yields. Chemical treatments that reduced the weed index were found more effective in suppressing weeds, providing better conditions for crop growth and ultimately increasing grain yields compared to weedy check treatments. Pandey et al. [27] who also stated that broad leaf weeds were effectively controlled when metsulfuron methyl was used alone. Similar results were found by Sharma et al. [28] and Choudhary et al. [29].

4. CONCLUSIONS

On the basis of the results, it could be concluded that weed-free (pre-emergence application of pendimethalin, post-emergence application of atrazine, post-emergence application of metsulfuron methyl, and three hand weeding) treatment is the best option that should be adopted for effective weed management in oats. Treatments T_4 (two hand weeding at 25 DAS and 45 DAS) and T_7 (post-emergence application of metsulfuron methyl at 0.004 kg a.i./ha+, one hand weeding at 25 DAS) are also recommended to the farmer because they are cost-effective. It was observed that both treatments (T_2 and T_4) resulted in significantly lower weed density, including narrow and broad leaf weed, and reduced weed dry matter accumulation compared to other treatments. The weed-free treatment showed a remarkable increase in weed control efficiency by reducing the weed index. It is recommended to conduct further experiments to confirm these findings.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declares that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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COMPETING INTERESTS

The authors have stated that they have no competing interests.

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