



## Research Article

## Efficacy of Herbicides on Weed Suppression and Yield Performance of Onion

Sabikunnahar<sup>1</sup>, Uttam Kumer Sarker<sup>2</sup>, Md. Yousuf Ali<sup>3</sup>, Mst. Hosne Ara<sup>4</sup>, Mohammad Muazzem Hossain Bhuiyan<sup>2</sup> and Md. Romij Uddin<sup>2</sup>, ✉

<sup>1</sup>Agronomy Division, Bangladesh Agricultural Research Institute, Gazipur

<sup>2</sup>Department of Agronomy, Bangladesh Agricultural University, Mymensingh- 2202, Bangladesh

<sup>3</sup>Maize Breeding Division, Bangladesh Wheat and Maize Research Institute, Dinajpur

<sup>4</sup>Agronomy Division, Bangladesh Wheat and Maize Research Institute, Dinajpur

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## Correspondence

Md. Romij Uddin

✉: [romijagron@bau.edu.bd](mailto:romijagron@bau.edu.bd)



Weed management is one of the significant challenges of vegetable tuber crops since weeds pose a remarkable threat to crop productivity in Bangladesh. A field experiment on efficacy of different herbicides for controlling weeds in onion field was conducted during the *rabi* season of 2024-25 at Regional Agricultural Research Station, Bangladesh Agricultural Research Institute (BARI), Cumilla, Bangladesh. The treatments included pendimethalin 33% EC @ 800 ml ha<sup>-1</sup> (T<sub>1</sub>) applied at the 2–4 leaf stage of weeds, pendimethalin 33% EC @ 1000 ml ha<sup>-1</sup> (T<sub>2</sub>) spraying on soil 1-2 days before transplanting, oxyfluorfen 23.5% EC @ 750 ml ha<sup>-1</sup> (T<sub>3</sub>) spraying at 3-4 day before transplanting, atrazine 50% + mesotrione 5% SC @ 1000 ml ha<sup>-1</sup> (T<sub>4</sub>) & @ 1500 ml ha<sup>-1</sup> (T<sub>5</sub>) spraying at 3-4 day before transplanting, two hand weeding at 25 and 50 days after transplanting (T<sub>6</sub>) and a control (T<sub>7</sub>) with three replications. Results revealed significant differences among treatments in terms of weed dry weight, seedling mortality, bulb yield and economic returns. Atrazine 50% + mesotrione 5% SC @ 1500 ml ha<sup>-1</sup> (T<sub>5</sub>) provided the highest weed control efficacy (up to 91%). Pendimethalin, hand weeding and control recorded 0% mortality of onion seedling. Pendimethalin was effective in controlling both broad leaf and narrow leaf weeds. Maximum bulb yield (18.25 t ha<sup>-1</sup>), the highest gross return (5,47,410 Tk. ha<sup>-1</sup>) and highest benefit–cost ratio (2.77) was obtained from pendimethalin 33% EC @ 1000 ml ha<sup>-1</sup> (T<sub>2</sub>). In contrast, atrazine and mesotrione based combinations (T<sub>4</sub> and T<sub>5</sub>) caused severe phytotoxicity with seedling mortality exceeding 75%, resulting in low yield (5.94–6.50 t ha<sup>-1</sup>), negative gross margins and poor BCR values (<1.0). The study concludes that pendimethalin @ 1000 ml ha<sup>-1</sup> before transplanting can be the effective and economically viable weed management practice in onion production.

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## Introduction

One of the most important vegetables and condiments that is regularly used in every home throughout the year is the onion (*Allium cepa* L.) (Gupta et al., 2020). Onion bulbs and green leaves are good providers of proteins, carbohydrates, and minerals like calcium, phosphorus, and vitamin C (Rahman et al., 2013). According to Sangha and Baring (2003), eating onions is also known to lower the risk of coronary heart disease and other ailments. In almost every area of Bangladesh, it is extensively grown in the winter. China, India, the United States, Turkey, Japan, Iran, Pakistan, Spain and Brazil are the major onion producing nations (Paikra et al., 2022). With an annual yield of 29,17,354.26 metric tons, it is cultivated on 5,13,526.97 acres in Bangladesh (BBS, 2024). In crop production, weeds provide a significant problem since they affect crop growth and

productivity, lower yields per unit area, and lower crop quality (Al-khazali et al., 2020). According to Minz et al. (2018) the main cause of low onion productivity is the long-duration cultivars (120–180 days), which are harmed by recurring weed flushes. Onions are a poor competitor with early-season weeds and are highly susceptible to weed interference. Because of their small size, poor leaf production, and long, narrow, and upright leaves that form a crop canopy that provides little to no shade, onion plants are known for having low soil cover. which fail to shade out emerging weeds. Because of its shallow root system, the onion crop is unable to effectively combat with weeds (Jat et al., 2018). Due to these factors, there is little competition, which permits weeds to germinate and grow at almost any stage of development (Dhananivetha et al., 2015).

## Cite This Article

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Since weeds compete with crop plants for resources like food, water, light and other growth-limiting elements, resulting in a reduction in both quantity and quality, weed management is a crucial variable in the definition of productivity (Al-khazali et al. 2020). Weeds grow alongside onion seedlings after they are transplanted. The crop and weed face intense competition as a result. The average bulb production can be reduced by 40–80% as a result of weed invasion (Ramalingam et al., 2013; Rathod et al., 2014; Vishnu et al., 2014), depending on the weed interference and cultural practices (Kaur et al. 2018). Weeds that appear later in ontogeny, notably after 20–25 days of transplanting are challenging to suppress because of the onion crop's lengthy duration and modest initial growth (Jat et al., 2018). According to estimates, weeds generate far more losses than insects, pests and diseases combined. Furthermore, a number of studies document a decline in bulb quality in the onion crop as a result of intense weed competition (Priya et al., 2017). According to several studies, weed competition during the growing season reduced onion yields by 49–86% and, in extreme cases, by 100%. If weed density and type are not controlled, commercial bulb output may also be lost (Jean-Simon et al., 2012).

Weed control involves various practices to reduce infestations and minimize crop competition while balancing control costs and yield loss. Effective management requires identifying weed flora and using suitable control methods—manual, mechanical, cultural, chemical, or biological. Farmers typically remove weeds early to prevent serious yield reduction. Mechanical weeding is more convenient in many vegetable crops due to their larger spacing. In onion cultivation, weeding by hand is a common practice in Bangladesh. Rahman et al. (2011) was reported that higher bulb weight and onion yield were obtained in the weed free (hand weeding) plots when compared with weedy plots. However, hand weeding is laborious, costly and time-consuming (Alkhazali and Shati, 2016). The scarcity of labor during critical growth stages further limits its practicality, often resulting in significant yield losses. Moreover, once bulb formation begins, mechanical or manual weeding can injure the bulbs, making these methods uneconomical for onion growers. On the flip side, because of its shallow roots system and closer inter-row spacing, onion crops pose serious obstacles to mechanical weeding, making weed control exceedingly challenging (Dhananivetha et al., 2017). Application of pre-emergence herbicides helps maintain a weed-free environment during the early growth stages of the crop. Nowadays, herbicides are extensively used as an effective tool for weed management (Stall and Gilreath, 2002). Patel et al. (2011) reported that herbicide application effectively reduced both the weed population and weed dry

weight per square meter. Similarly, Zubair et al. (2009) found that herbicide treatments increased onion bulb yield by 62.69% compared to unweeded plots. Ahuja and Sandhu (2003) also noted a significant decline in weed density and a corresponding increase in onion yield following herbicide use. Furthermore, several studies (Karimi et al., 2012; Dhananivetha et al., 2015; Gupta et al., 2020) have consistently recorded higher bulb yields under herbicide application.

In general, weeds are among the most aggressive and troublesome components of global vegetation, posing serious challenges to crop production. They not only reduce yield and quality but also exhaust soil nutrients, promote the spread of pests and diseases and compete with crops for essential resources such as water, nutrients, light, space and oxygen (Al-Khazali et al., 2020). Many farmers use different chemicals to control the weeds. Hence, the present study was undertaken to determine the efficiency of different herbicides in managing weed infestation in onion fields.

## **Materials and Methods**

### *Description of the experimental site and soil*

The research was conducted at the Regional Agricultural Research Station (RARS), Bangladesh Agricultural Research Institute (BARI), Cumilla during the *rabi* season of 2024-25. The experimental site was located at 23.27°N latitude and 91.10° E longitude at mean elevation of 15 m above the sea level. The area was a medium high land belonging to the non-calcareous grey floodplain soil type under the Middle Meghna River Floodplain (AEZ- 16). The reaction of the experimental soil was more or less neutral (pH value was 6.5) and the texture was silt loam. The land was fairly leveled with drainage facilities. The climate of the experimental site was tropical monsoon. It was characterized by high temperature, considerably high humidity and heavy precipitation with occasional gusty winds during *kharif* season (April to September) and heavy rainfall associated with moderately low temperature and plenty of sunshine during *rabi* season (October to March). The distribution of important weather variables such as minimum, maximum, average temperatures, rainfall and relative humidity during study period has been shown in Figure 1 and Figure 2, respectively.

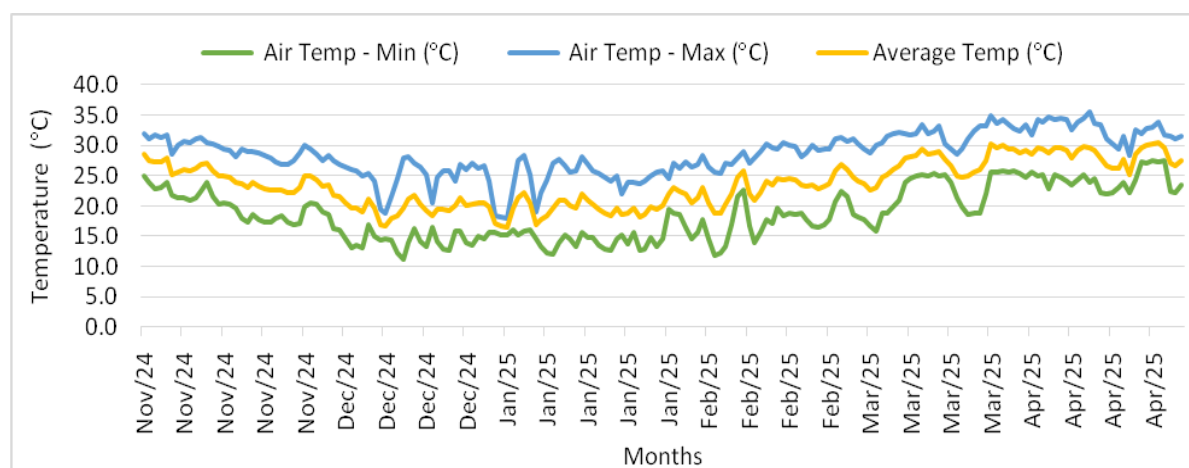


Figure 1: Maximum, minimum and average air temperature during the study period at RARS, Cumilla, BARI

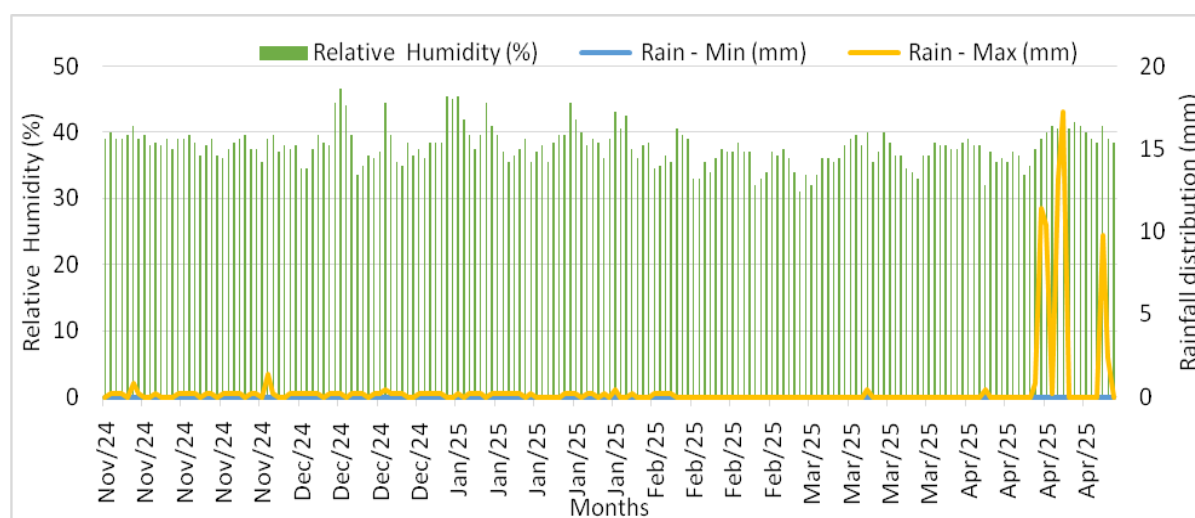


Figure 2: Relative humidity and rainfall pattern during the study period at RARS, Cumilla, BARI

#### Experimental Treatments and design

The experiment was organized in a randomized complete block design (RCBD) in three replications, Treatments were T<sub>1</sub> - Pendimethalin 33% EC @ 800 ml ha<sup>-1</sup> spraying at 2-4 leaf stage of weeds, T<sub>2</sub> - Pendimethalin 33% EC @ 1000 ml ha<sup>-1</sup> spraying on soil 1-2 days before transplanting, T<sub>3</sub> - Oxyfluorfen 23.5% EC @ 750 ml ha<sup>-1</sup> spraying at 3-4 days before onion seedling transplanting, T<sub>4</sub> - Atrazine 50% + Mesotrione 5% SC @ 1000 ml ha<sup>-1</sup> spraying at 3-4 days before onion seedling transplanting, T<sub>5</sub> - Atrazine 50% + Mesotrione 5% SC @ 1500 ml ha<sup>-1</sup> spraying at 3-4 days before onion seedling transplanting, T<sub>6</sub> - Two hand weeding at 25 & 50 DAT, T<sub>7</sub> - Control (No weeding and no herbicide). The unit plot size was 4.5 m × 2.1 m. BARI Pia-6 was used as variety.

#### Crop Husbandry

Spraying of herbicide was done by spray machine, as possible avoiding the contact with the onion seedling. Fertilizers were applied 105-45-90-30-3.0-1.5 kg/ha of N-P-K-S-Zn-B according to the standard recommendation for onion (FRG, 2018). All of P, S, Zn, B and ½ of N and K was applied as basal during final land preparation. Remaining N and K was applied in two equal splits at 25 and 50 DATs under moist soil condition and mixed thoroughly with soil as soon as possible for better utilization by plants. Forty days old onion seedlings were transplanted on 26 December 2024 maintaining the spacing of 15 cm × 5 cm. The crop was harvested on 19 April 2025.

#### Harvesting and Data collection

Weed samples were collected using 50 cm × 50 cm quadrates from randomly selected three places from

each plot at 25 and 45 DATs. The number of weeds within each quadrat was counted and then converted to a per square meter (m<sup>2</sup>) basis by multiplying the count by a factor of two. After recording the weed density, the weeds within each quadrat were carefully removed, cleaned and sorted species wise. The weed samples were then air-dried under sunlight before being baked at 80°C for 72 hours in an electric oven. The dry weight (DW) of each weed species was measured using an electronic balance and expressed in grams per square meter (g m<sup>-2</sup>) to record number of weeds, species of weeds and dry weight of weeds.

1. Relative Density

$$RD (\%) = \frac{A}{B} \times 100$$

where A- Number of individual weed species per m<sup>-2</sup> and B- Total number of weed species per m<sup>-2</sup>

2. Weed control efficiency (WCE)

$$WCE (\%) = \frac{A - B}{A} \times 100$$

where A- dry weight of weeds in no weeding plots and B- dry weight of weeds in treated plots.

3. % Weed control (WC)

$$(\%)WC = \frac{A - B}{A} \times 100$$

where A- number of weeds in no weeding plots and B- number of weeds in treated plots.

4. Economic analysis

The gross returns were calculated by converting the harvest into monetary terms at the current market rate throughout the course of the studies for each treatment. The gross margins were calculated by subtracting the cost of production from the gross returns. The cost ratio was calculated by dividing the gross returns by the production cost of the respective treatments.

$$BCR \text{ over TCP} = \frac{\text{Gross return}}{\text{Total cost of production}}$$

Here, BCR - Benefit-cost ratio, TCP- Total cost of production.

The benefit-cost ratio is a financial metric used to evaluate the economic feasibility and attractiveness of an investment and is commonly employed in cost-benefit analysis to assess whether the benefits derived from an investment are higher than the costs incurred. A benefit-cost ratio >1 indicates that the benefits outweigh the costs, suggesting that the study or project is economically viable. On the other hand, a ratio <1

may imply that the costs exceed the benefits, potentially signaling a less favorable investment.

#### Yield and yield contributing data

Pseudo stem height (cm), weight of single bulb (g), bulb diameter(cm), bulb count m<sup>-2</sup> (no.) were recorded. Total bulb yield of individual plot was recorded and subsequently converted to a ton per-hectare basis (t ha<sup>-1</sup>).

#### Statistical Analysis

The recorded data on various parameters under study were statistically analyzed according to the principles of experimental design to find out the variation resulting from experimental treatments. Analysis of variance was done following the randomized complete block design with the help of computer package R. The means of all the studied parameters were adjudged by Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

## Results

### Weed flora and weed density

Although there were many different types of monocot and dicot weeds at the chosen experimental location, monocot weeds predominated throughout the field. Among the listed weed species, several belong to the monocot group, which are typically characterized by narrow leaves with parallel venation and fibrous root systems. These include Durba (*Cynodon dactylon*), Mutha (*Cyperus rotundus*), Khude shama (*Echinochloa colona*), Anguli (*Digitaria sanguinalis*), Chapra (*Eleusine indica*), Gaicha (*Paspalum commersonii*), Kakpaya ghash (*Dactyloctenium aegyptium*) and Kanai bashi (*Commelina benghalensis*). Although Kanai bashi (*Commelina benghalensis*) is not a true grass, it is still a monocot due to its botanical characteristics.

On the other hand, the remaining species are dicots, typically having broad leaves with netted venation and a taproot system. These include Helencha (*Jussiaea repens*), Bathua (*Chenopodium album*), Hatisur (*Heliotropium indicum*), Shaknotey (*Amaranthus viridis*), Hazar dana (*Phyllanthus niruri*) and Nunia (*Portulaca oleracea*). These dicot weeds are common in many agricultural fields and pose a significant threat to crop productivity by competing for essential resources. The data on weed density (no. m<sup>-2</sup>) were recorded at 25 and 45 DASs (Table 1.)

Table 1. Weed infestation in onion field during the rabi season of 2024-25 at RARS, BARI, Cumilla.

Treatments	Weed species		At 25 DAT		At 45 DAT	
	Local Name	Scientific name	Weed density (no. m <sup>-2</sup> )	Relative density (%)	Weed density (no. m <sup>-2</sup> )	Relative density (%)
T <sub>1</sub>	Durba	<i>Cynodon dactylon</i>	2	3	-	-
	Mutha	<i>Cyperus rotundus</i>	0	-	1	1.5
	Khude shama	<i>Echinochloa colona</i>	54	83	44	57.2
	Anguli	<i>Digitaria sanguinalis</i>	3	4.5	-	-
	Kakpaya ghash	<i>Dactyloctenium aegyptium</i>	1	1.5	-	-
	Kanai bashi	<i>Commelina benghalensis</i>	1	1.5	-	-
	Shaknotey	<i>Amaranthus viridis</i>	4	6.15	17	22
	Bothua	<i>Chenopodium album</i>	0	-	15	19.5
		Total -	65	100	77	100
T <sub>2</sub>	Mutha	<i>Cyperus rotundus</i>	1	1.67	3	5.36
	Khude shama	<i>Echinochloa colona</i>	26	43.3	34	60.7
	Gaicha	<i>Paspalum commersonii</i>	-	-	0	-
	Bothua	<i>Chenopodium album</i>	15	25	7	12.5
	Hatisur	<i>Heliotropium indicum</i>	1	1.67	0	-
	Shaknotey	<i>Amaranthus viridis</i>	17	28.3	12	21.4
		Total -	60	100	56	100
T <sub>3</sub>	Durba	<i>Cynodon dactylon</i>	1	1.37	-	-
	Mutha	<i>Cyperus rotundus</i>	2	2.74	1	1.09
	Khude shama	<i>Echinochloa colona</i>	50	68.5	74	81.3
	Anguli	<i>Digitaria sanguinalis</i>	-	-	2	2.2
	Gaicha	<i>Paspalum commersonii</i>	2	2.74	-	-
	Kakpaya-ghash	<i>Dactyloctenium aegyptium</i>	1	1.37	2	2.2
	Kanai bashi	<i>Commelina benghalensis</i>	-	-	1	1.09
	Bathua	<i>Chenopodium album</i>	13	17.8	3	3.27
	Hatisur	<i>Heliotropium indicum</i>	1	1.37	1	1.09
	Shaknotey	<i>Amaranthus viridis</i>	2	2.74	7	7.63
	Hazar dana	<i>Phyllanthus niruri</i>	1	1.37	-	-
		Total -	73	100	91	100
T <sub>4</sub>	Durba	<i>Cynodon dactylon</i>	3	3.03	1	2.78
	Mutha	<i>Cyperus rotundus</i>	8	8.08	3	8.34
	Khude shama	<i>Echinochloa colona</i>	76	76.8	25	69.5
	Anguli	<i>Digitaria sanguinalis</i>	1	1.01	1	2.78
	Chapra	<i>Eleusine indica</i>	1	1.01	0	-
	Kanai bashi	<i>Commelina benghalensis</i>	-	-	1	2.78
	Helencha	<i>Jussiaea repens</i>	-	-	1	2.78
	Hatisur	<i>Heliotropium indicum</i>	1	1.01	1	2.78
	Shaknotey	<i>Amaranthus viridis</i>	7	7.07	2	5.56
	Hazar dana	<i>Phyllanthus niruri</i>	1	1.01	-	-
	Nunia	<i>Portulaca oleracea</i>	1	1.01	1	2.78
		Total -	99	100	36	100
	T <sub>5</sub>	Durba	<i>Cynodon dactylon</i>	3	5.16	-
Mutha		<i>Cyperus rotundus</i>	3	5.16	6	12
Khude shama		<i>Echinochloa colona</i>	41	70.5	37	74
Anguli		<i>Digitaria sanguinalis</i>	2	3.44	1	2
Chapra		<i>Eleusine indica</i>	2	3.44	-	-
Kanai bashi		<i>Commelina benghalensis</i>	-	-	1	2
Helencha		<i>Jussiaea repens</i>	-	-	1	2
Bothua		<i>Chenopodium album</i>	4	6.88	-	-
Hatisur		<i>Heliotropium indicum</i>	-	-	1	2
Shaknotey		<i>Amaranthus viridis</i>	-	-	2	4
Hazar dana		<i>Phyllanthus niruri</i>	2	3.44	-	-
Nunia		<i>Portulaca oleracea</i>	1	1.72	1	2
		Total -	58	100	50	100
T <sub>6</sub>	Mutha	<i>Cyperus rotundus</i>	1	0.84	1	1.27
	Khude shama	<i>Echinochloa colona</i>	78	65.52	61	77.47
	Anguli	<i>Digitaria sanguinalis</i>	1	0.84	-	-

	Kakpaya ghash	<i>Dactyloctenium aegyptium</i>	1	0.84	2	2.54
	Kanai bashi	<i>Commelina benghalensis</i>	1	0.84	1	1.27
	Helencha	<i>Jussiaea repens</i>	1	0.84	1	1.27
	Bothua	<i>Chenopodium album</i>	19	15.9	3	3.81
	Hatisur	<i>Heliotropium indicum</i>	2	1.68	1	1.27
	Shaknotey	<i>Amaranthus viridis</i>	13	10.9	8	10.16
	Hazar dana	<i>Phyllanthus niruri</i>	2	1.68	-	-
	Nunia	<i>Portulaca oleracea</i>	-	-	1	1.27
	Total -		119	100		100
T <sub>7</sub>	Durba	<i>Cynodon dactylon</i>	3	2.01	7	3.36
	Mutha	<i>Cyperus rotundus</i>	12	8.04	9	4.32
	Khude shama	<i>Echinochloa colona</i>	88	58.9	107	51.3
	Anguli	<i>Digitaria sanguinalis</i>	1	67	1	0.48
	Chapra	<i>Eleusine indica</i>	3	2.01		1.44
	Gaicha	<i>Paspalum commersonii</i>	1	1.34	3	0.96
	Kakpaya ghash	<i>Dactyloctenium aegyptium</i>	2	-	2	0.96
	Kanai bashi	<i>Commelina benghalensis</i>	-	1.34	2	0.96
	Bothua	<i>Chenopodium album</i>	17	11.39	2	11.04
	Hatisur	<i>Heliotropium indicum</i>	2	1.34	23	0.96
	Shaknotey	<i>Amaranthus viridis</i>	19	12.78	2	26.5
	Hazar dana	<i>Phyllanthus niruri</i>	2	1.34	49	1.44
	Total -		150	100	210	100

Among the weed species, Khude shama (*Echinochloa colona*), Mutha (*Cyperus rotundus*), Bothua (*Chenopodium album*) and Shaknotey (*Amaranthus viridis*) were dominant.

#### Weed biomass

The effects of different treatments on weed dry weight were evaluated at 25 and 45 DATs (Table 2). The results showed significant diversity among the treatments. At 25 DAT, the lowest weed dry weight (0.93 g m<sup>-2</sup>) was recorded in T<sub>5</sub>, followed by T<sub>4</sub> (1.2 g m<sup>-2</sup>) and T<sub>1</sub> (1.7 gm<sup>-2</sup>), whereas the highest dry weight (7.06 gm<sup>-2</sup>) was observed in the untreated control (T<sub>7</sub>). A similar trend was noticed at 45 DAT, where T<sub>5</sub> again showed the lowest weed dry weight (9.3 g m<sup>-2</sup>), followed by T<sub>1</sub> (12.7 gm<sup>-2</sup>), while the maximum was recorded in T<sub>7</sub> (104.7 gm<sup>-2</sup>).

#### Weed control efficiency

The trends of weed control were fluctuated due to environmental factors and responses of proper weeds management practices was positive (Table 2.). In terms of weed control efficiency, T<sub>5</sub> exhibited the highest values at both 25 DAT (86%) and 45 DAT (91%), indicating its superior performance in suppressing weed growth. Treatments T<sub>1</sub> and T<sub>4</sub> also showed good control efficiency, ranging from 76% to 87%. In contrast, T<sub>2</sub>, T<sub>3</sub> and T<sub>6</sub> demonstrated moderate effectiveness, while T<sub>7</sub> had no weed control measures applied, resulting in excessive weed infestation.

**Table 2. Effect of different treatments on total dry weight in onion field under different treatments during the rabi season of 2024-25 at RARS, BARI, Cumilla**

Treatments	Weed dry weight (gm <sup>-2</sup> )		Weed control efficiency (%)	
	25 DAT	45 DAT	25 DAT	45 DAT
T <sub>1</sub>	1.7c	12.7d	76	87
T <sub>2</sub>	3.2b	24.7b	55	76
T <sub>3</sub>	1.7c	26.7b	76	75
T <sub>4</sub>	1.2d	19.4c	83	81
T <sub>5</sub>	0.93e	9.3e	86	91
T <sub>6</sub>	3.05b	21.2c	57	79
T <sub>7</sub>	7.06a	104.7a	-	-
Level of Significance	**	**	NS	NS
LSD (0.05)	0.46	4.59	11.2	8.34
CV %	9.86	8.38	5.78	6.83

T<sub>1</sub> - Pendimethalin 33% EC @ 800 ml ha<sup>-1</sup> spraying at 2-4 leaf stage of weeds, T<sub>2</sub> - Pendimethalin 33% EC @ 1000 ml ha<sup>-1</sup> spraying on soil 1-2 days before transplanting, T<sub>3</sub>- Oxyfluorfen 23.5% EC @750 ml ha<sup>-1</sup> spraying at 3-4 days before onion seedling transplanting, T<sub>4</sub> - Atrazine 50% + Mesotrione 5% SC @ 1000 ml ha<sup>-1</sup> spraying at 3-4 days before onion seedling transplanting, T<sub>5</sub> - Atrazine 50% + Mesotrione 5% SC @ 1500 ml ha<sup>-1</sup> spraying at 3-4 days before onion seedling transplanting. T<sub>6</sub>- Two hand weeding at 25 & 50 DATs, T<sub>7</sub>- Control (No weeding and no herbicide)

#### Onion seedling survival

When evaluating seedling mortality, a contrasting trend emerged (Figure 3.). Treatments T<sub>1</sub> (Pendimethalin 33% @ 800 ml ha<sup>-1</sup> spraying at 2-4 leaf stage of weeds), T<sub>6</sub> (Two hand weedings at 25 & 50 DATs) and T<sub>7</sub> (Control) recorded 0% mortality, indicating their safety and compatibility with onion seedlings. T<sub>2</sub> (Pendimethalin

33% @ 1000 ml ha<sup>-1</sup> spraying on soil 1-2 days before transplanting) showed minimal mortality (1.06%), while T<sub>3</sub> (Oxyfluorfen 23.5% EC @750 ml ha<sup>-1</sup> spraying at 3-4 days before onion seedling transplanting) had a moderate mortality rate of 10%. Alarming high mortality rates were observed in T<sub>4</sub> (78%) and T<sub>5</sub> (76%).

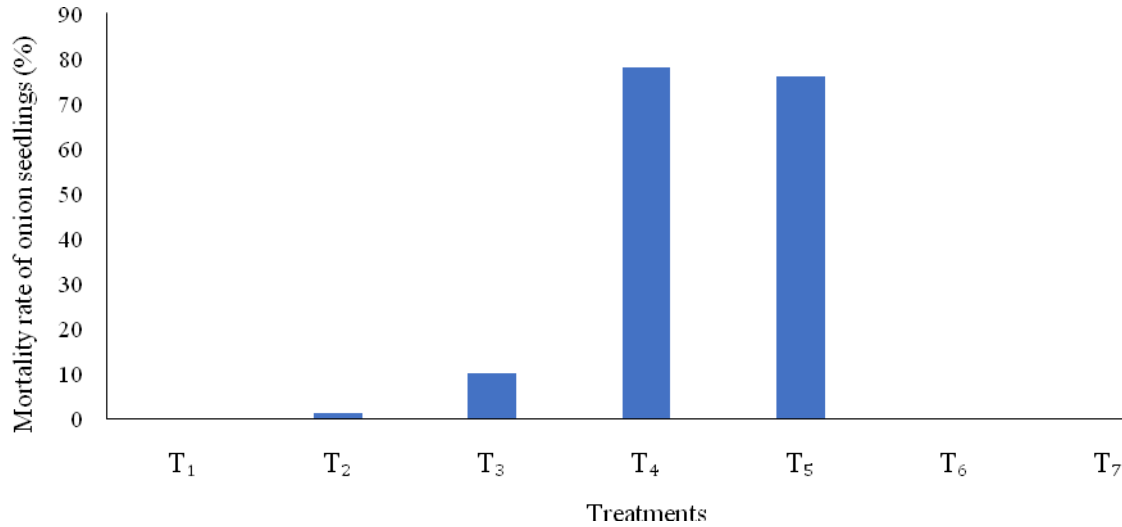


Figure 3: Onion seedling mortality across treatments during the study period at RARS, Cumilla, BARI

#### Weed species-specific control

The effectiveness of different weed management treatments (T<sub>1</sub> to T<sub>7</sub>) was assessed at 25 and 45 DATs against four predominant weed species: *Echinochloa colonum*, *Cyperus rotundus*, *Chenopodium album*, and *Amaranthus viridis* (Table 3.). The results showed considerable variation among treatments in terms of % weed control. For *Echinochloa colonum*, treatment T<sub>2</sub> provided the highest control at 25 DAT (70%), followed

by T<sub>5</sub> (53%) and T<sub>1</sub> (38%). At 45 DAT, T<sub>4</sub> exhibited the highest control (77%), while T<sub>2</sub> and T<sub>5</sub> also showed substantial effectiveness with 68% and 66% control, respectively. In the case of *Cyperus rotundus*, T<sub>1</sub> achieved complete control (100%) at 25 DAT and maintained 89% control at 45 DAT, making it the most effective treatment against this species. T<sub>6</sub> and T<sub>2</sub> also showed high efficacy with 91% control at 25 DAT and 89% and 67% control at 45 DAT, respectively.

Table 3. % Weed control (species-specific) in onion field under different treatments during the rabi season of 2024-25 at RARS, BARI, Cumilla.

Treatments	<i>Echinochloa colonum</i> (L.)		<i>Cyperus rotundus</i>		<i>Chenopodium album</i>		<i>Amaranthus viridis</i> L.	
	25 DAT	45 DAT	25 DAT	45 DAT	25 DAT	45 DAT	25 DAT	45 DAT
T <sub>1</sub>	54 (38)	44 (59)	0 (100)	1 (89)	0 (100)	0 (100)	4 (79)	5 (90)
T <sub>2</sub>	26 (70)	34 (68)	1 (91)	3 (67)	15 (12)	7 (70)	17 (11)	12 (76)
T <sub>3</sub>	50 (43)	74 (31)	2 (83)	1 (89)	13 (23)	3 (87)	2 (89)	7 (63)
T <sub>4</sub>	76 (13.4)	25 (77)	8 (33)	3 (67)	0 (100)	0 (100)	7 (63)	2 (96)
T <sub>5</sub>	41	37	3	6	4	0	0	2

## Performance of Herbicides on Onion

	(53)	(66)	(75)	(33)	(76)	(100)	(100)	(96)
T <sub>6</sub>	78	61	1	1	19	3	13	8
	(11)	(43)	(91)	(89)	(-12)	(87)	(32)	(84)
T <sub>7</sub>	88	107	12	9	17	23	19	49

Figure in parenthesis is the percent reduction value over control

T<sub>1</sub> - Pendimethalin 33% EC @ 800 ml ha<sup>-1</sup> spraying at 2-4 leaf stage of weeds, T<sub>2</sub> - Pendimethalin 33% EC @ 1000 ml ha<sup>-1</sup> spraying on soil 1-2 days before transplanting, T<sub>3</sub>- Oxyfluorfen 23.5% EC @750 ml ha<sup>-1</sup> spraying at 3-4 days before onion seedling transplanting, T<sub>4</sub> - Atrazine 50% + Mesotrione 5% SC @ 1000 ml ha<sup>-1</sup> spraying at 3-4 days before onion seedling transplanting, T<sub>5</sub> - Atrazine 50% + Mesotrione 5% SC @ 1500 ml ha<sup>-1</sup> spraying at 3-4 days before onion seedling transplanting. T<sub>6</sub>- Two hand weeding at 25 and 50 DATs, T<sub>7</sub>- Control (No weeding and no herbicide)

*Chenopodium album* was highly susceptible to several treatments. T<sub>1</sub>, T<sub>4</sub> and T<sub>5</sub> each achieved complete control (100%) at both 25 and 45 DAT. T<sub>3</sub> and T<sub>6</sub> also performed well, with more than 85% control at both stages. For *Amaranthus viridis*, the most effective treatments at 25 DAT were T<sub>3</sub> (89%) and T<sub>1</sub> (79%), followed closely by T<sub>4</sub> (63%) and T<sub>5</sub> (100%). By 45 DAT, T<sub>4</sub> and T<sub>5</sub> showed excellent control (96% each) followed by T<sub>1</sub> (90%). In contrast, the untreated control (T<sub>7</sub>) exhibited the highest weed infestation, highlighting the effectiveness of the applied weed management strategies.

### Effect on yield and yield attributes of onion

The growth and yield parameters of onion were significantly influenced by different weed management practices. The data was presented in Table 4. Pseudo

stem height ranged from 29.9 cm in hand weeding (T<sub>6</sub>) to 36.7 cm in mesotrione + atrazine (T<sub>5</sub>), although differences were not statistically significant. In terms of bulb number per unit area, two hand weeding at 25 and 50 DAT (T<sub>6</sub>) produced the maximum (93 bulbs m<sup>-2</sup>), followed by pendimethalin 800 ml ha<sup>-1</sup> at 2-4 leaf stage of weeds (T<sub>1</sub>, 89 bulbs m<sup>-2</sup>), while atrazine 50% + mesotrione 5% (T<sub>4</sub> and T<sub>5</sub>) recorded the lowest (32.3 bulbs m<sup>-2</sup>). Bulb weight was significantly affected, with the highest values recorded in pendimethalin 33% @ 1000 ml applied before transplanting (T<sub>2</sub>, 20.9 g) and atrazine + mesotrione (T<sub>4</sub>, 20.1 g), while the lowest was in the untreated control (T<sub>7</sub>, 14.2 g). Bulb yield was also significantly affected, where T<sub>2</sub> (18.25 t ha<sup>-1</sup>) and T<sub>6</sub> (18.08 t ha<sup>-1</sup>) were statistically similar and superior, while T<sub>5</sub> recorded the lowest yield (5.94 t ha<sup>-1</sup>).

**Table 4. Yield and yield attributes as influenced by different treatments during the rabi season of 2024-25 at RARS, BARI, Cumilla.**

Treatments	Pseudo stem height (cm)	Weight of single bulb (g)	Bulb diameter (cm)	Bulb count m <sup>-2</sup> (no.)	Bulb yield (t ha <sup>-1</sup> )
T <sub>1</sub>	31.5	18.1b	3.3	89.0ab	16.13b
T <sub>2</sub>	33.5	20.9a	3.5	87.3ab	18.25a
T <sub>3</sub>	33.4	19.3ab	3.2	76.3c	14.75b
T <sub>4</sub>	30.1	20.1a	3.4	32.3d	6.50d
T <sub>5</sub>	36.7	18.3b	3.6	32.3d	5.94d
T <sub>6</sub>	29.9	19.4ab	3.4	93.0a	18.08a
T <sub>7</sub>	33.4	14.2c	3.1	86.0b	12.24c
Level of significance	NS	**	NS	**	**
LSD (0.05)	8.3	1.67	0.39	6.86	1.75
CV %	14.30	5.06	6.59	5.44	7.49

Means with the same letters within the same column do not differ significantly

\*\* - Significant at 1 % level of probability, \* - Significant at 5 % level of probability, NS-Not significant

T<sub>1</sub> - Pendimethalin 33% EC @ 800 ml ha<sup>-1</sup> spraying at 2-4 leaf stage of weeds, T<sub>2</sub> - Pendimethalin 33% EC @ 1000 ml ha<sup>-1</sup> spraying on soil 1-2 days before transplanting, T<sub>3</sub>- Oxyfluorfen 23.5% EC @750 ml ha<sup>-1</sup> spraying at 3-4 days before onion seedling transplanting, T<sub>4</sub> - Atrazine 50% + Mesotrione 5% SC @ 1000 ml ha<sup>-1</sup> spraying at 3-4 days before onion seedling transplanting, T<sub>5</sub> - Atrazine 50% + Mesotrione 5% SC @ 1500 ml ha<sup>-1</sup> spraying at 3-4 days before onion seedling transplanting. T<sub>6</sub>- Two hand weeding at 25 & 50 DAT, T<sub>7</sub>- Control (No weeding and no herbicide)

### Economic analysis

Economics analysis of onion in different treatments is presented in Table 5. The highest gross monetary returns (5,47,410 Tk. ha<sup>-1</sup>) and highest gross monetary

margin (3,49,563 Tk. ha<sup>-1</sup>) was obtained in T<sub>2</sub> where Pendimethalin was sprayed on soil 1-2 days before transplanting. The gross monetary returns (5,42,310 Tk. ha<sup>-1</sup>) of T<sub>6</sub> (two hand weeding at 25 & 50) DAT was

comparatively close to T<sub>2</sub>. But ultimately T<sub>2</sub> was recorded highest benefit cost ratio (2.77). The reason behind it the labor wages are higher now-a-days. Both T<sub>4</sub> and T<sub>5</sub> consists of atrazine 50% + mesotrione 5% performed poorly in terms of yield and profitability. Although production costs were similar across

treatments ( $\approx 1,97,847$  Tk. ha<sup>-1</sup>), the low yields led to gross returns of Tk. 1,95,000/ha in T<sub>4</sub> and Tk. 1,78,290/ha in T<sub>5</sub>, resulting in negative gross margins (2,847 Tk. ha<sup>-1</sup> and 19,557 Tk. ha<sup>-1</sup>, respectively). The corresponding BCR values were below 1.0 (0.99 and 0.90), indicating economic losses.

**Table 5. Effect of herbicides on Economics**

Treatments	Yield (t ha <sup>-1</sup> )	Gross return (Tk. ha <sup>-1</sup> )	Cost of production (Tk. ha <sup>-1</sup> )	Gross margin (Tk. ha <sup>-1</sup> )	BCR
T <sub>1</sub>	16.13	4,83,900	1,97,847	2,86,053	2.45
T <sub>2</sub>	18.25	5,47,410	1,97,847	3,49,563	2.77
T <sub>3</sub>	14.75	4,42,410	1,97,847	2,44,563	2.24
T <sub>4</sub>	6.50	1,95,000	1,97,847	-2847	0.99
T <sub>5</sub>	5.94	1,78,290	1,97,847	-19557	0.90
T <sub>6</sub>	18.08	5,42,310	2,86,978	2,55,332	1.89
T <sub>7</sub>	12.24	3,67,110	1,67,985	1,99,125	2.18

Labor 750 Tk. /person/day, Onion seedling - 30 Tk/kg, Herbicide - 100 Tk/100 ml bottle T<sub>1</sub> - Pendimethalin 33% EC @ 800 ml ha<sup>-1</sup> spraying at 2-4 leaf stage of weeds, T<sub>2</sub> - Pendimethalin 33% EC @ 1000 ml ha<sup>-1</sup> spraying on soil 1-2 days before transplanting, T<sub>3</sub>- Oxyfluorfen 23.5% EC @750 ml ha<sup>-1</sup> spraying at 3-4 days before onion seedling transplanting, T<sub>4</sub> - Atrazine 50% + Mesotrione 5% SC @ 1000 ml ha<sup>-1</sup> spraying at 3-4 days before onion seedling transplanting, T<sub>5</sub> - Atrazine 50% + Mesotrione 5% SC @ 1500 ml ha<sup>-1</sup> spraying at 3-4 days before onion seedling transplanting. T<sub>6</sub>- Two hand weeding at 25 & 50 DAT, T<sub>7</sub>- Control (No weeding and no herbicide).

## Discussion

### Weed flora and weed density

The predominance of monocot weeds over dicots in the present study indicates favorable conditions for their growth in the onion field, likely due to their efficient vegetative propagation and adaptability to the soil and moisture conditions. Similar weed compositions have been reported in onion fields by Bhutia et al. (2005) and Patel et al. (2012), where monocot weeds such as *Echinochloa colona* and *Cyperus rotundus* were dominant. The dominance of *Echinochloa colona* and *Cyperus rotundus* may be attributed to their rapid multiplication through seeds and underground tubers, as well as their strong competitive ability for resources. On the other hand, dicot weeds like *Amaranthus viridis* and *Chenopodium album* persisted in smaller proportions but still contributed significantly to overall weed pressure due to their high seed production potential. Consistent findings were also reported by Kumar et al. (2022), who observed that monocot weeds predominated in onion fields despite the coexistence of diverse dicot species. Moreover, Al-Khaz'Ali et al. (2023) identified similar weed compositions, reporting nine different weed types in winter crop fields. These observations collectively suggest that the weed flora in onion ecosystems is largely dominated by resilient monocot species capable of thriving under a wide range of field conditions.

### Weed biomass

The significant reduction in weed dry weight observed in herbicide-treated plots compared to the untreated control demonstrates the efficiency of the applied herbicides in minimizing weed infestation. The superior performance of T<sub>5</sub> in both observations suggests that this treatment provided prolonged weed control, effectively suppressing weed emergence and growth during the critical early growth stages of the crop. The untreated control (T<sub>7</sub>) recorded the highest weed dry weight due to the absence of any weed management practice, which allowed maximum weed proliferation. The uncontrolled weed growth created severe competition with the crop for essential growth factors such as light, nutrients, moisture, and space. This competition favored weed dominance and resulted in higher weed biomass accumulation. The reduction in weed dry weight in treated plots also indicates the physiological and biochemical impacts of herbicides on weed plants. Herbicidal action typically destroys chlorophyll-bearing tissues, impairs photosynthesis and disrupts normal metabolic processes. The inhibition of anabolic activities and the enhancement of catabolic processes ultimately reduce dry matter accumulation and weaken the weed's ability to regenerate. Al-Khaz'Ali et al. (2023) also reported that the reduction in weed dry weight clearly indicated the herbicides' effectiveness in disrupting photosynthetic activity and metabolic processes, leading to decreased biomass accumulation. Rahman et al. (2011) reported minimum dry weed biomass was recorded in plots sprayed with

pendimethalin while, maximum dry weed biomass was noticed in weedy check. These findings are consistent with the results reported by Bawazir and Bin Shuaib (2013), Kumar et al. (2014), Al-Khazali and Shati (2016), and Al-Khazali et al. (2020), who also observed a significant decline in weed dry weight due to effective herbicide application in various cropping systems. Such consistency across studies confirms the reliability of herbicidal treatments in managing weed populations and improving crop-weed balance in the field.

#### Weed control efficiency

The observed variations in weed control efficiency (WCE) among treatments highlight the interplay between herbicide efficacy, weed biomass reduction and crop safety. T<sub>5</sub> (Atrazine 50% + Mesotrione 5% SC @ 1500 ml ha<sup>-1</sup>) consistently exhibited the highest WCE at 25 DAT (86%) and 45 DAT (91%), reflecting its superior capacity to suppress both grassy and broadleaf weeds. The high weed control efficiency under T<sub>5</sub> is strongly associated with the significant reduction in weed dry biomass, as recorded in the same treatment. By inhibiting photosynthesis and disrupting metabolic processes in weed tissues, T<sub>5</sub> limited dry matter accumulation, confirming the close relationship between biomass reduction and effective weed suppression (Bawazir and Bin Shuaib, 2013; Kumar et al., 2014; Al-Khazali et al., 2020). Treatments T<sub>1</sub> (Pendimethalin 33% @ 800 ml ha<sup>-1</sup>) and T<sub>4</sub> also maintained good weed control efficiency (76–87%), which corresponded with moderate reductions in weed dry weight. This indicates that early-stage pre-emergence or post-emergence herbicide application can effectively manage weed growth while minimizing competition for essential resources such as light, water, and nutrients. However, the high WCE observed in T<sub>5</sub> came at a cost: significant onion seedling mortality (76–78%) was recorded under this treatment. The phytotoxic effects likely arose from the residual activity of atrazine and mesotrione on young seedlings, which can interfere with chlorophyll synthesis, photosynthetic activity, and overall growth (Barchanska et al., 2014; Wang et al., 2015; Wang et al., 2018). In contrast, T<sub>1</sub> and T<sub>2</sub> caused minimal seedling mortality (0–1%), indicating a safer balance between weed suppression and crop tolerance. This demonstrates that while T<sub>5</sub> is highly effective in controlling weeds, its application requires careful consideration to avoid crop damage. The untreated control (T<sub>7</sub>) recorded the lowest weed control efficiency (0%) and the highest weed biomass, which, combined with intense competition, suppressed seedling growth and could indirectly increase seedling mortality due to resource limitation (Al-Khazali et al., 2020). These findings suggest a trade-off between maximum weed control and crop safety. Optimal weed

management in onions should target effective suppression of dominant weed species while minimizing herbicide-induced phytotoxicity. Treatments like pendimethalin-based pre-emergence applications or integrated approaches combining moderate herbicides with hand weeding provide a practical solution, achieving reasonable weed control without compromising seedling survival. Similar observations were reported by Sinare et al. (2014), who emphasized that careful selection of herbicide type, dose, and timing is crucial for sustaining crop growth alongside weed management.

#### Onion seedling survival

The results clearly indicate that while some herbicides were effective in weed suppression, their impact on crop safety varied greatly. The complete absence of seedling mortality in T<sub>1</sub>, T<sub>6</sub>, and T<sub>7</sub> confirms their compatibility and non-toxic nature to onion seedlings. The safety of pendimethalin at lower doses (T<sub>1</sub>) aligns with its known selectivity and limited residual activity when applied post-emergence. Similarly, hand weeding (T<sub>6</sub>) and the untreated control (T<sub>7</sub>) naturally posed no phytotoxic risk. In contrast, the high mortality observed in T<sub>4</sub> and T<sub>5</sub> can be attributed to the phytotoxic properties of atrazine and mesotrione. These herbicides, though effective against weeds, can damage crop tissues through oxidative stress and pigment degradation. Barchanska et al. (2014) and Wang et al. (2015) reported that atrazine and mesotrione can induce oxidative damage and disrupt photosynthetic pigments, leading to chlorosis and necrosis in sensitive plants. Furthermore, Wang et al. (2018) found that the combined application of atrazine and mesotrione intensified phototoxic effects in *Cynodon dactylon* by increasing lipid peroxidation and altering antioxidant enzyme activity.

These findings suggest that T<sub>5</sub>, despite being the most efficient in weed suppression, was also among the most damaging to crop survival. For post-emergence herbicide applications, phytotoxicity remains a major limitation, as noted by Uygur et al. (2010). In winter onions, such risks are further compounded by low-temperature stress and potential carryover effects on subsequent crops.

#### Weed control (species-specific)

The findings demonstrate clear differences in herbicide efficacy depending on the weed species and application timing. For *Echinochloa colona*, the superior control achieved by T<sub>2</sub> (Pendimethalin 33% @ 1000 ml ha<sup>-1</sup> applied before transplanting) indicates its strong pre-emergence activity. Mahajan and Chauhan (2022) similarly reported that pendimethalin, even when

applied at crop emergence, provides effective control of *E. colona* without harming the crop. The enhanced control at 45 DAT under T<sub>4</sub> and T<sub>5</sub> suggests that atrazine and mesotrione based combinations possess prolonged residual effects, aligning with the observations of Chhokar et al. (2012) that herbicide performance can vary by species and timing. For *Cyperus rotundus*, T<sub>1</sub> (Pendimethalin @ 800 ml ha<sup>-1</sup> at 2–4 leaf stage) proved most effective, achieving nearly complete control. This result corroborates the findings of Minz et al. (2018), who reported maximum weed control efficiency of pendimethalin against sedges and grasses in field crops. *Chenopodium album* exhibited high susceptibility to several treatments, with complete control under T<sub>1</sub>, T<sub>4</sub>, and T<sub>5</sub>, and substantial suppression under T<sub>3</sub> and T<sub>6</sub>. The effectiveness of both chemical and manual interventions aligns with Hooda and Yadav (2020), who noted that selective herbicides or hand weeding can efficiently eliminate *C. album* due to its sensitivity to herbicidal action. For *Amaranthus viridis*, high control rates under T<sub>3</sub>, T<sub>4</sub>, and T<sub>5</sub> indicate that timely application of pre or post emergence herbicides can successfully suppress fast-growing broadleaf weeds. This observation is consistent with Woodyard et al. (2009), who emphasized that early application of post-emergence herbicides is crucial for managing vigorous species like *Amaranthus*. Overall, the absence of weed control in the untreated control (T<sub>7</sub>) highlights the necessity of implementing effective weed management strategies. The results reinforce the importance of species-specific approaches in integrated weed management systems, as recommended by Bhutia et al. (2005) and Jat et al. (2018) to achieve sustainable weed suppression while ensuring crop safety.

#### Effect on yield and yield attributes of onion

The results of this study demonstrate that weed management practices had a significant influence on onion growth, yield attributes and final bulb yield. Although pseudo stem height did not differ significantly among treatments, the tallest pseudostems were observed in T<sub>5</sub> (Atrazine 50% + Mesotrione 5%), likely reflecting vigorous vegetative growth under reduced competition from weeds. However, this increase in pseudo stem height did not correspond to higher bulb yield, highlighting that vegetative growth alone is not always indicative of productive performance. Similar observations were reported by Rahman et al. (2012), Chopra et al. (2014) and Mawalia et al. (2016) who noted that some herbicides or intensive weed control treatments may promote vegetative growth without proportionally increasing yield.

Bulb number per unit area was highest under T<sub>6</sub> (two hand weeding at 25 and 50 DATS), followed by T<sub>1</sub>

(Pendimethalin 33% @ 800 ml ha<sup>-1</sup>), reflecting that early-season weed removal allows maximum crop establishment and reduces competition for resources such as light, nutrients, and moisture. In contrast, T<sub>4</sub> and T<sub>5</sub> showed the lowest bulb numbers, despite effective weed suppression, likely due to the high onion seedling mortality observed under these herbicide treatments. These findings support earlier reports by Marwat et al. (2003), who emphasized that pre-emergence herbicides like pendimethalin maintain crop safety while effectively controlling weeds, resulting in higher stand density and bulb counts.

Bulb weight and yield were also closely associated with weed management and crop survival. Treatments T<sub>2</sub> (Pendimethalin 33% @ 1000 ml ha<sup>-1</sup> applied before transplanting) and T<sub>6</sub> recorded the highest bulb weight and yield, indicating a combination of effective weed suppression and high seedling survival. Conversely, T<sub>5</sub>, despite producing tall pseudo stems and achieving the highest weed control efficiency, resulted in the lowest bulb yield due to severe reduction in bulb number per unit area, reflecting the impact of herbicide-induced seedling mortality. The results align with findings from Hussain et al. (2008), Jat et al. (2018) and Minz et al. (2018) who reported that phytotoxic effects can reduce yield despite effective weed control.

#### Conclusions

Weeds are typically common, hardy species with rapid growth and widespread rooting that can effectively compete with farmed crops for resources, negatively impacting crop productivity and growth. In order to get the highest possible crop output, it is imperative that weed competition be eliminated or reduced. The present study clearly demonstrate that weed management practices exert a profound influence on the growth, yield and profitability of onion. Among the tested options, pendimethalin 33% at 1000 ml ha<sup>-1</sup> applied before transplanting (T<sub>2</sub>) was found to be the most effective. In contrast, treatments involving mesotrione and atrazine-based combinations (T<sub>4</sub> and T<sub>5</sub>) caused severe seedling mortality, poor yield and negative gross margins, indicating their unsuitability for onion cultivation. Although manual weeding (T<sub>6</sub>) performed well, it is labor-intensive and costly whereas pendimethalin (T<sub>2</sub>) proved to be a more practical and economically viable alternative.

The relationship between the timing of herbicide applications and agronomic activities including residue assimilation, transplanting, irrigation and nutrient management could be the subject of future research. Researchers can determine the most efficient and long-lasting methods for controlling weeds and optimizing the production and quality of onion crops by analyzing

various combinations of herbicides and agronomic techniques.

### Authors contribution

S and MUA developed the concept and designed the experiments. MHA collected the data and wrote the manuscript. S, MUA and MHA evaluated the result, analyzed data statistically and contributed to writing the manuscript. UKS, MMHB and MRU contributed to revising manuscript critically for important intellectual content. All authors read the article and approved the final version to be published.

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### Competing interests

The authors have declared that no competing interests exist

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