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Research article

Effectiveness of Different Herbicides on Growth, Yield and Weed Flora Control Indices of Onion

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Abstract

The effects of various herbicides on the economic performance, yield, and growth of onions were determined during the winter season of 2019-2020. Two field experiments were carried out at the Regional Agricultural Research Station (RARS), Jashore, and the Agronomy research field of the Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. Various herbicides were evaluated through both pre- and post-planting applications. The findings demonstrated that the application of Full clear at 1125 g.a.i./ha (T_1) resulted in lower weed index and greater herbicide efficiency index, BCR, and weed control efficiency. This was followed by Pellet at 660 g.a.i./ha applied before transplanting (T_5), Bullet at 525 g.a.i./ha applied at the 2-3 leaf stage of weeds (T_4) and Penlin at 330 g.a.i./ha applied at the 2-3 leaf stage of weeds (T_2) at both locations. It was also found that hand weeding (T_6) was the best option for getting the maximum yield of onion, weed persistence index, weed management index, and agronomic management index across both sites. The study also found significant correlation matrix of the yield contributing traits and weed indices. Therefore, the study concludes that herbicide treatments T_1, T_5, T_4, and T_2 were effective in weed control and enhancement of the onion bulb yield.

Keywords: effectiveness; herbicides; weed indices; correlation matrix; onion

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1. Introduction

Onion (*Allium cepa* L.), a major bulbous crop in the family of Alliaceae, is used as a vegetable, spice, or medicinal plant. Globally, more than 61 million metric tons of onions are produced annually (Teshika et al., 2019; Jayakumar et al., 2021). Onion guards against some major chronic diseases such as cataracts, cardiovascular disease, and cancer (Kumar et al., 2010, Tsuboki et al., 2016). It is cultivated commercially in many countries of the world. It is an essential element of daily life and has a growing consumer demand throughout the year. In Bangladesh, it is one of the most popular spices, ranking first among the spice crops. The country produces 1.7 million metric tons of onion, and the average yield is 10.05 t/ha. This is a low yield compared to the worldwide average which is due to several factors such as the use of poor-quality seeds, unexpected rainy weather, lack of knowledge on appropriate crop management practices, and farmers giving low priority to onion cultivation over rice in Bangladesh (BBS, 2015). Bangladesh imports large amounts of onions from neighboring countries every year to meet local demand. However, using an advanced varieties with sustainable technology can enhance onion production in Bangladesh (Ashrafuzzaman et al., 2009).

One of the major problems in onion cultivation is the control of weeds in the field. Weeds compete with onions for sunlight, nutrients, moisture, and space (Khan et al., 2023). They also serve as a reservoir for a number of harmful pests. Many research studies indicate that onion plants do not compete effectively with weeds (Uygur et al., 2010; Siddhu et al., 2018), because of certain characteristics such as lower leaf area, shallow rooting depth, lower canopy, concise stature, and slow development process (Singh et al., 1992; Bell & Boutwell, 2001). Weed infestation can reduce the bulb yield of onions by 40 to 80% (Channapagoudar & Biradar, 2007). Moreover, it is quite difficult to perform intercultural operations and physical means of weed control. Hand weeding, in particular, can damage the crop at the initial stage of establishment (Siddhu et al., 2018). Hand weeding is a traditional and effective means of weed control, but it is also laborious, time-consuming, and cost-ineffective (Dhananivetha et al., 2017). Hand weeding or mechanical weeding activities are sometimes postponed or abandoned entirely due to labor shortages and unpredictable rainfall.

In this era, a wide range of environmentally safe and powerful herbicides are becoming available for efficiently controlling weeds in crop production. Herbicides are a cornerstone of modern onion cultivation, providing a reliable method for weed control. The common worldwide weed management practice for onion is pre-emergence and post-emergence application of selective herbicides followed by one hand weeding (Khan et al., 2023). Research shows that applying pre-emergence herbicides, often followed by hand weeding, is a highly effective weed control strategy that significantly boosts onion yield and profitability (Islam et al., 2020; Khan et al., 2021). However, post-emergence herbicides are often used as a follow-up to pre-emergence treatments to manage later-season weeds. In pre-emergence application, weed seedlings rarely emerge from the soil (Khan et al., 2023). Metolachlor, metribuzin, and pendimethalin are effective when applied as pre-emergence herbicides for weed control of onions (Norsworthy et al., 2007; Olescowicz et al., 2021). However, application of these herbicides specifically pendimethalin after emergence of weed specifically at the 2-3 leaf stage, is also effective in weed control. While pendimethalin is primarily a pre-emergence herbicide, some studies have explored its use at the 2-3 leaf stage of weeds (Khan et al., 2021; Bajagain et al., 2024). These studies suggest that pendimethalin can be effective at this growth stage, especially when applied in a direct manner to minimize crop injury. Therefore,

pendimethalin is traditionally pre-emerged. However, with problems such as weed resistance, labor shortages, and limited safe herbicides in onion, its potential for post-emergence application at the 2-3 leaf stage is both novel and practical, and worthy or research.

In Bangladesh, the use of chemicals to control weeds has received little attention. Continuous and imbalanced use of herbicides could adversely affect the sustainability of agricultural production besides causing environmental pollution. Under these circumstances, the purpose of this study was to determine an appropriate herbicide for reducing weed growth and enhancing the yield of onion bulbs.

2. Materials and Methods

2.1 Experimental details and treatments

2.1.1 Experimental material

The experiments were executed in the agronomy research field, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur and at the Regional Agricultural Research Station (RARS) of BARI, Jashore, during winter season in the year 2019-2020. The pH and texture of the soil of Joydebpur was 6.3 and silty clay loam under the Agro-Ecological Zone (AEZ) - 28. The soil at RARS Jashore was silty clay loam in texture with pH of 8.3 belonging to AEZ - 11. The investigation was laid out in randomized complete block design. Bangladesh Agricultural Research Institute (BARI) developed an onion variety named BARI Piaj-4 which is a high yielding winter season variety used in this experiment. Uniform and healthy seed were transplanted in 20 cm x 10 cm spacing. The unit plot size was 3m x 3m. Quadrat sampling technique was applied to count weeds per square meter from five replications.

During the land preparation process, 10 t/ha of cowdung was incorporated into the soil, and chemical fertilizers were applied at the recommended doses (120-39-75-20 kg/ha N-P-K-S). Following irrigation, the remaining nitrogen (N) and potassium (K) were added at 25 and 50 DAP (days after planting). Half of the N and K, along with full dosages of phosphorus (P) and sulfur (S), were applied in the final steps in the field. The research fields were irrigated as needed, and proper drainage was maintained to keep the field surface suitable for the growth and development of onions. During the growing season of the crops, in order to improve growth of the crops, the suggested cultural techniques were taken to manage pests and diseases. To control diseases and insect infestations, healthy, uniform, and disease-free seedlings were collected. For controlling thrips and aphids, blue and yellow sticky traps were installed in the research fields at both locations. Neem-based bio-pesticide azadirachtin was applied at 0.035% (30 mL per 15 L of water) three times at 10-day intervals in cases of severe thrip infestations and iris yellow spot of onion, which is transmitted by thrips. To control fungal diseases such as purple blotch and bulb rot, the dicarboximide-group fungicide Rovral was applied at 2 g/L three times at 10-day intervals. Different herbicides were evaluated according to the treatments on the onion field. The crop was harvested on 7 April 2020. Furthermore, there was no control over weather parameters. The weather was favorable for onion cultivation in both locations as depicted in Figures 1 and 2.

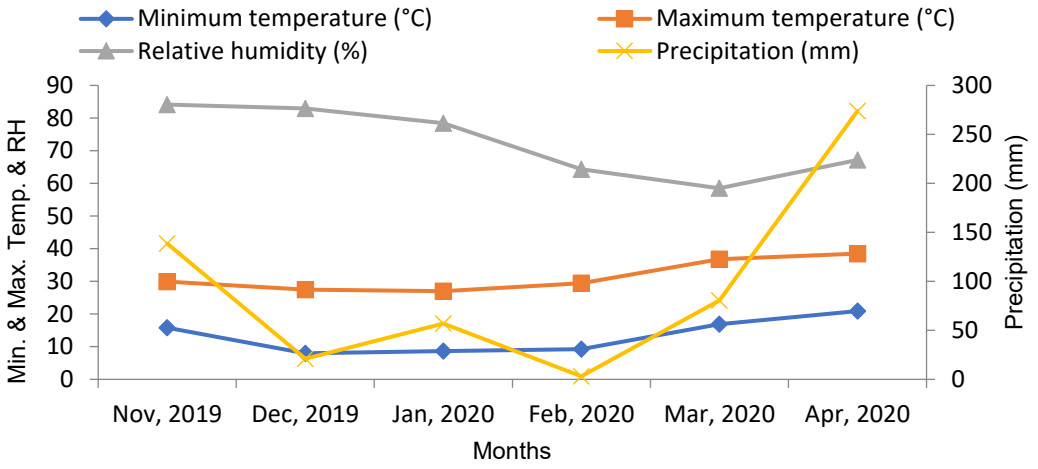


Figure 1. Weather parameter at Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur from November 2019 to April 2020

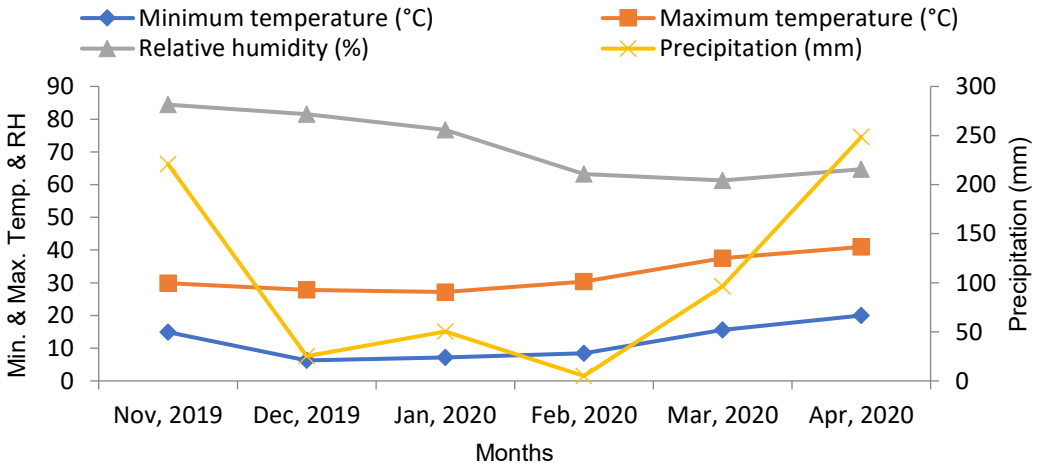


Figure 2. Weather parameter at Regional Agricultural Research Station (RARS), BARI, Jashore from November 2019 to April 2020

2.1.2 Treatments

For selecting the best herbicides to suppress weed growth and increase onion bulb yield, the treatments were: T_1 = Full clear at 1125 g.a.i./ha (Metolachlor + Pendimethalin) (at pre-emergence of weed), T_2 = Penlin at 330 g.a.i./ha (Pendimethalin) spraying at weed leaf stage 2-3, T_3 = Stomp extra at 796 g.a.i./ha (Pendimethalin) spraying at weed leaf stage 2-3, T_4 = Bullet at 525 g.a.i./ha (Metribuzin) spraying at weed leaf stage 2-3, T_5 = Pellet at 660 g.a.i./ha (Pendimethalin) spraying before transplanting of onion, T_6 = Hand

weeding two times at 20-25 and 35-40 (DAP), T_7 = Control (No hand weeding and herbicide).

A hand operated knapsack sprayer (16 L capacity) was used to apply herbicides with a flat-fan nozzle to ensure uniform coverage of the soil and weed canopy. Before application, the sprayer was calibrated to deliver the recommended spray volume (typically 500-600 L of water/ha) at a constant pressure of 2-3 kg/cm².

2.2 Assessment of weed management indices

At 25 DAP and 50 DAP, dry weight and number of weeds were meticulously recorded. Weed population (no/m^2), and weed density were recorded. Characters related to yield and yield contributions were recorded. The data were analyzed following standard statistical procedures. The following is how the various weed indices were calculated.

2.2.1 Weed control efficiency (WCE)

The formula below was used to calculate WCE.

$$WCE\ (\%) = \left(\frac{W_{dwc} - W_{dwt}}{W_{dwc}}\right) \times 100$$

Where, W_{dwc} = Dry weight of weed (control plot) and W_{dwt} = Dry weight of weed (treated plot).

2.2.2 Weed control index (WCI)

The formula below was used to calculate the WCI, which indicate the % difference in the weed population of the treated plots and the untreated plot.

$$WCI\ (\%) = \left(\frac{W_{pc} - W_{pt}}{W_{pc}}\right) \times 100$$

Where, W_{pc} = Population of weed (control plot) and W_{pt}= Population of weed (treated plot).

2.2.3 Weed index (WI)

The effectiveness of a certain treatment in comparison to a weed-free treatment is assessed by the weed index. The yield potential under weed-free conditions is shown as a percentage. The weed index, more conveniently, is the percentage of yield loss attributed to weeds as opposed to un-weeded (hand weeded). Greater loss is associated with a higher weed index. The calculation involves deducting the yield of the treated plot from the yield of the weed-free plot, then dividing the result by 100.

$$WI\ (\%) = \left(\frac{Y_{wf} - Y_t}{Y_{wf}}\right) \times 100$$

Where, Y_{wf} = Yield (hand weeded plot) and Y_t = Yield (treated plot).

2.2.4 Weed persistence index (WPI)

The formula below was used to calculate WPI.

$$WPI = \left(\frac{W_{dwt}}{W_{dwc}}\right) \times \left(\frac{W_{pc}}{W_{pt}}\right)$$

2.2.5 Weed management index (WMI)

The WMI was calculated according to the following formula.

$$WMI = \left(\frac{\frac{Y_t - Y_c}{Y_c}}{\frac{W_{dwc} - W_{dwt}}{W_{dwc}}}\right)$$

Where, Y_c = Yield of control plot.

2.2.6 Agronomic management index (AMI)

The AMI was calculated according to the following formula.

$$AMI = \left(\frac{Y_{oc} - C_w}{C_w}\right) \times 100$$

Where, Y_{oc} = Percent yield over control and C_w = Percent control of the weed.

2.2.7 Herbicide efficiency index (HEI)

The HEI was calculated according to the following formula.

$$HEI = \left(\frac{\frac{Y_t - Y_c}{Y_c}}{\frac{W_{dwt}}{W_{dwc}}}\right)$$

2.2.8 Statistical analysis

Data were recorded for various traits including weed growth, population, yield, and other related attributes of onion. Recorded data for the studied traits were assigned to analysis of variance (ANOVA) following the procedure by Steel & Torrie (1980) to calculate the significant variation among the treatments using Statistix 10 software. Furthermore, Pearson correlation analysis was performed to reveal significant associations between various traits, shedding light on their interrelationships, and potential influence (Pearson, 1920). The recorded data were subjected to statistical analysis as suggested by Gomez

& Gomez (1984) and the means of significant treatment were compared using the least significant difference (LSD).

3. Results and Discussion

3.1 Weed density, dry matter and weed control efficiency

The distribution of weed population across major weed types in both experimental sites is summarized in Table 1. The recorded weeds were categories into grasses, broadleaf, and sedges. The results revealed that broadleaf weeds were the most prevalent in both locations. The highest weed population was observed in Joydebpur for Bathua (*Chenopodium album*) (32 weeds/m²), while in Jashore, the maximum population was recorded for Helencha (*Enhydra fluctuans*) (38 weeds/m²). In addition to these, other dominant and frequently occurring species identified in both locations included Shama (*Echinochloa crus-galli*), Malancho (*Enhydra fluctuans*), Shetlomi (*Gnaphalium affine*), Durba (*Cynodon dactylon*), Mutha (*Cyperus rotundus*), Bon mashur (*Vicia sativa*), Bon mula (*Raphanus raphanistrum*), and Bon palong (*Rumex maritimus*) (Table 1).

Table 1. Weed population according to major types in both experimental sites

Major type	Joydebpur		Jashore	
	Common Name (Scientific Name)	**Weed Population (no/m²)**	**Common Name (Scientific Name)**	**Weed Population (no/m²)**
Grasses (Monocots, narrow leaves, parallel venation)	Shama (*Echinochloa crus-galli*)	28	Shama (*Echinochloa crus-galli*)	36
	Durba (*Cynodon dactylon*)	22	Durba (*Cynodon dactylon*)	28
Broadleaves (Dicots, broad leaves, net venation)	Bathua (*Chenopodium album*)	32	Bathua (*Chenopodium album*)	37
	Malancho (*Enhydra fluctuans*)	10	Malancho (*Enhydra fluctuans*)	16
	Shetlomi (*Gnaphalium affine*)	11	Shetlomi (*Gnaphalium affine*)	19
	Helencha (*Enhydra fluctuans*)	23	Helencha (*Enhydra fluctuans*)	38
	Bon mashur *(Vicia sativa*)	08	Bon Mula (*Raphanus raphanistrum*)	15
			Bon palong (*Rumex maritimus*)	16
Sedges (Grass-like, triangular stems)	Mutha (*Cyperus rotundus*)	19	Mutha (*Cyperus rotundus*)	23

The weed density as a function of various weed management techniques is shown in Table 2. The mean total weed density varied significantly due to several weed management techniques. Weed populations (no/m²) differed across treatments, ranging from 10 to 65 and 12 to 84 at Joydebpur, and from 16 to 81 and 22 to 120 at Jashore at

25 DAP and 50 DAP, respectively. The highest weed population (no/m^2) was recorded for T_7 (control plots) (65 and 84 at Joydebpur and 81 and 120 at Jashore at 25 and 50 DAP, respectively). In contrast, the lowest weed population (no/m^2) was found in T_1 treatment (Table 2). Table 3 reports the weed dry weight (g/m^2) and weed control efficiency (%). The maximum weed dry weight was found in T_7 (control), with 12.22 and 46.12 at Joydebpur and 11.7 and 20.0 at Jashore at 25 DAP and 50 DAP, respectively. In the treated plots, the minimum weed dry weight was found in T_1 (1.80 and 4.72 at Joydebpur and 1.30 and 2.50 at Jashore at 25 DAP and 50 DAP, respectively). This was followed by T_5, T_4, and T_2. The T6 (hand weeding) treatment also resulted in minimum weed dry weight at both locations (Table 3). Different herbicides showed varying weed control efficiency (WCE). Among the treated plots, T_1 application showed the highest WCE (85.27% and 89.76% at Joydebpur and 88.88% and 87.50% at Jashore at 25 DAP and 50 DAP, respectively) followed by T_6, T_5, T_4 and T_2. The herbicide methods of weed control worked well because the maximum quantity of weeds was found in the control treatment and smaller weed populations were found in the herbicide treatments. Mehmood et al. (2007) and Mohite et al. (2015) found similar findings in garlic. Comparable findings were also reported in onion by Sable et al. (2013) and Shinde et al. (2013). They observed that pre-emergence application of herbicides, particularly pendimethalin-based treatments, markedly reduced weed density and dry matter accumulation compared with untreated plots. The authors explained that early suppression of weed germination during the critical crop-weed competition period allowed better crop establishment and vegetative growth. The results of weed control efficiency showing better performance of T_1 treatment in onion, which was also found in weed control experiment by Sraw et al. (2016). The weed control efficiency showed similar results in both locations, Joydebpur and Jashore.

3.2 Plant height, bulb diameter, single bulb weight and yield

Plant height, bulb diameter, single bulb weight and yield of onions were significantly influenced by the different weed management methods presented in Table 4. An important yield attribute of onions is plant height, which is directly correlated with the yield of onion bulbs. The current experiment's findings showed that the treatments in Joydebpur and Jashore significantly differed in terms of plant height. Both the diameter and weight of bulbs were found to be higher in the case of herbicide applied plots as compared to non-herbicide applied plots or control (no hand weeding and herbicide) but the hand weeding (T_6) recorded the maximum diameters (3.97 cm at Joydebpur and 4.53 cm at Jashore) followed by T_1 treatment. The single bulb weight significantly varied with the different weed management methods at Joydebpur and Jashore. The highest single bulb weights (39.10 gm at Joydebpur and 38.63 gm at Jashore) were recorded for T_6 (Two hand weeding) which was followed by T_1. The lowest single bulb weights (21.17 g at Joydebpur and 17.40 g at Jeshore) were recorded from T_7 (control). Accordingly, the highest bulb yields (11.30 t/ha at Joydebpur and 11.9 t/ha at Jeshore) were obtained from T_6 (hand weeding). Due to efficient weed control at critical growth phases, the T_6 treatment provided the best results, creating an environment that was conducive to improved growth and development and increased weight of single bulb. Bulbs obtained from control plots were small, inferior and under-developed bulbs than the herbicides-treated cases. This result is in accordance with the results of Verma and Singh (1996).

Effective weed management reduced crop–weed competition, improving the availability of light, soil moisture, nutrients, and growing space for onion plants. This

enhanced resource utilization increased photosynthetic activity, dry matter accumulation, and ultimately bulb yield. Similar observations were reported by Mishra et al. (1986) and Singh (1996), who found that timely weed control improved crop growth and yield by reducing competition and facilitating more efficient use of resources.

Table 2. Periodical total weed density at different days after planting (DAP) for onions as influenced by different weed management treatments

Treatments	Joydebpur				Jashore			
	25 DAP		50 DAP		25 DAP		50 DAP	
	Weed population (WP) (no/m^2)	Weed density (WD)	Weed population (WP) (no/m^2)	Weed density (WD)	Weed population (WP) (no/m^2)	Weed density (WD)	Weed population (WP) (no/m^2)	Weed density (WD)
T_1	10	3.33	12	3.60	24	5.00	31	5.65
T_2	13	3.74	23	4.89	29	7.74	27	5.29
T_3	25	5.05	25	5.09	32	9.48	36	6.08
T_4	16	4.12	23	4.89	21	7.28	22	4.69
T_5	14	3.87	20	4.58	25	7.07	27	5.19
T_6	10	3.22	14	3.87	16	4.12	22	4.79
T_7	65	8.12	84	9.21	81	9.05	120	11.00
CV (%)	3.40	2.12	6.24	3.12	4.62	2.05	5.65	3.20
LSD (0.05)	2.23	3.40	3.23	2.50	3.20	3.21	2.45	2.11

Weed density is square root transform $\sqrt{(X+1)}$ values. The weed/m^2 is original values.

T_1 = Full clear at 1125 g.a.i./ha (Metolachlor + Pendimethalin) (at pre-emergence of weed), T_2 = Penlin at 330 g.a.i./ha (Pendimethalin) spraying at weed leaf stage 2-3, T_3 = Stomp extra at 796 g.a.i./ha (Pendimethalin) spraying at weed leaf stage 2-3, T_4 = Bullet at 525 g.a.i./ha (Metribuzin) spraying at weed leaf stage 2-3, T_5 = Pellet at 660 g.a.i./ha (Pendimethalin) spraying before transplanting of onion, T_6 = Hand weeding two times at 20-25 and 35-40 (DAP), T_7 = Control (No hand weeding and herbicide).

Table 3. Weed dry weight and weed control efficiency influenced by different doses of herbicide for controlling weeds in onion field

Treatments	Weed Dry Weight (WDW) (g/m^2)				Weed Control Efficiency (WCE) (%)			
	Joydebpur		Jashore		Joydebpur		Jashore	
	25 DAP	50 DAP	25 DAP	50 DAP	25 DAP	50 DAP	25 DAP	50 DAP
T_1	1.80	4.72	1.30	2.50	85.27	89.76	88.88	87.50
T_2	2.40	5.50	2.30	3.20	80.36	82.07	80.34	81.50
T_3	4.40	16.72	4.20	7.00	63.99	63.74	62.50	65.00
T_4	2.35	6.93	2.30	3.50	80.76	84.97	82.34	82.50
T_5	2.20	6.23	2.10	3.40	81.99	86.49	82.50	83.00
T_6	2.00	5.15	2.00	3.20	83.36	88.88	82.90	84.00
T_7	12.22	46.12	11.70	20.00	-	-	-	-
CV (%)	5.36	8.03	3.25	7.89				
LSD	3.83	6.68	7.36	4.43				

T_1 = Full clear at 1125 g.a.i./ha (Metolachlor + Pendimethalin) (at pre-emergence of weed), T_2 = Penlin at 330 g.a.i./ha (Pendimethalin) spraying at weed leaf stage 2-3, T_3 = Stomp extra at 796 g.a.i./ha (Pendimethalin) spraying at weed leaf stage 2-3, T_4 = Bullet at 525 g.a.i./ha (Metribuzin) spraying at weed leaf stage 2-3, T_5 = Pellet at 660 g.a.i./ha (Pendimethalin) spraying before transplanting of onion, T_6 = Hand weeding two times at 20-25 and 35-40 (DAP), T_7 = Control (No hand weeding and herbicide).

Table 4. Effect of different doses of herbicides on yield components and yield of onion

Treatments	Plant Height (PH) (cm)		Bulb Diameter (BD) (cm)		Single Bulb Weight (SBW) (gm)		Bulb Yield (BY) (t/ha)	
	Joydebpur	Jashore	Joydebpur	Jashore	Joydebpur	Jashore	Joydebpur	Jashore
T_1	43.00	39.10	3.93	4.34	38.79	36.14	9.96	10.20
T_2	42.20	38.47	3.47	3.64	26.70	24.64	8.36	7.90
T_3	39.27	34.57	3.38	3.41	27.78	25.41	6.25	6.00
T_4	38.33	37.37	3.39	3.81	33.39	21.81	8.04	8.90
T_5	43.60	36.93	3.87	2.61	35.84	24.61	9.85	9.20
T_6	38.80	37.17	3.97	4.53	39.10	38.63	11.30	11.90
T_7	41.53	29.77	2.76	3.40	21.17	17.40	2.85	3.20
CV (%)	2.66	4.04	7.29	4.51	3.85	3.54	3.96	3.20
LSD	2.17	2.60	0.46	0.29	3.62	6.3	2.60	4.69

T_1 = Full clear at 1125 g.a.i./ha (Metolachlor + Pendimethalin) (at pre-emergence of weed), T_2 = Penlin at 330 g.a.i./ha (Pendimethalin) spraying at weed leaf stage 2-3, T_3 = Stomp extra at 796 g.a.i./ha (Pendimethalin) spraying at weed leaf stage 2-3, T_4 = Bullet at 525 g.a.i./ha (Metribuzin) spraying at weed leaf stage 2-3, T_5 = Pellet at 660 g.a.i./ha (Pendimethalin) spraying

before transplanting of onion, T_6 = Hand weeding two times at 20-25 and 35-40 (DAP), T_7 = Control (No hand weeding and herbicide).

The yield loss in the control plots was seen as a result of low chlorophyll content and photosynthetic rates brought on by uncontrolled weed growth that limited the crop's access to nutrients, light, and moisture (McKenzie-Gopsill et al., 2020; Choudhary et al., 2025). These findings match up with Ramani and Khanpara (2010), Kumar (2014), and Sahoo & Tripathy (2019) for garlic whereas onions were recorded by Verma and Singh (1996) and Anarase (2014).

3.3 Weed indices

The results of different weed indices like weed control index (WCI), weed index (WI), weed persistence index (WPI), weed management index (WMI), agronomic management index (AMI) and herbicide efficiency index (HEI) are presented in Tables 5 and 6. Table 5 shows that the highest weed control index (%) was observed in T_1 (84.61 and 85.71 at Joydebpur and 81.37 and 82.16 at Jeshore at 25 DAP and 50 DAP, respectively) followed by T_6, T_5, T_4 and T_2. Different weed control treatments showed significant variation in terms of weed index. The highest weed index was recorded for T_7 (74.77 at Joydebpur and 73.10 at Jessore) followed by T_3. However, among the treatments, the lowest weed index (%) was found in T_1 (11.85 at Joydebpur and 14.28 at Jashore) followed by T_5 (Table 5). The relative dry matter formation of weeds per count in comparison to control was indicated by the weed persistence index (Table 5). It was indicated that the two hand weeding treatment (T_6) resulted in higher persistence indices (1.06 and 0.86 at Joydebpur and 0.85 and 0.80 at Jashore at 25 and 50 DAP, respectively) followed by T_1, T_4 and T_2, indicating the resistance of escaped weeds to control measures (Table 5). Treated plots had the lowest weed infestation, which led to a better weed control index. Tewari et al. (1999) found similar outcomes in onion. Due to significant weed competition, crop plant suppression by emergent weeds, and increased weed canopy utilizing nutrients and moisture, T_7 (control) had the highest weed index and the lowest yield. In the respective treatments, a lower weed index led to a better bulb production, and vice versa (Ghadge et al., 2012; Rahman et al., 2012). The ability of weeds to resist or persist despite management techniques is expressed by the weed persistence index. The higher agronomic management index (AMI) observed in T_6 and T_1 was associated with enhanced crop growth and vigor due to effective weed suppression, which improved resource availability for the onion plants. These findings are consistent with Kumar et al. (2017), who reported that effective weed control in garlic increased nutrient uptake, photosynthetic efficiency, and overall crop performance. In this study, T_1 (pre-emergence Metolachlor + Pendimethalin) and T_6 (hand weeding) showed the highest herbicide efficiency index (HEI), indicating their superior ability to suppress weed emergence while maintaining the safety and normal growth of the onion crop. High HEI in these treatments reflects both effective weed control and minimal phytotoxic effects on the crop. These findings are consistent with the study of Sraw et al. (2016), who reported that pre-emergence and early post-emergence herbicide applications in onion effectively reduced weed density and biomass, resulting in improved crop growth and yield. The weed management index (WMI) was observed to be highest in T_6 treatment (3.52 and 3.32 at Joydebpur and 3.42 and 3.37 at Jashore at 25 DAP and 50 DAP, respectively). However, among the herbicide treatments, T_1 showed higher WMI (2.98 and 2.89 at Jeydebpur and 3.01 and 3.22 at Jashore at 25 DAP and 50 DAP, respectively) than T_5 and T_4. Additionally, the lowest WMI was recorded in T_3 treatment (Table 6). The agronomic management index (AMI), which reflects the overall crop performance under the given weed management practices, was highest in T_6 (hand weeding) at both

locations

Table 5. Effects of different weed control treatments on weed control index, weed index and weed persistence index in onion field

Treatments	Weed Control Index (WCI) (%)				Weed index (WI) (%)		Weed Persistence Index (WPI)			
	Joydepur		Jashore				Joydebpur		Jashore	
	25 DAP	50 DAP	25 DAP	50 DAP	Joy.	Jash.	25 DAP	50 DAP	25 DAP	50 DAP
T_1	84.61	85.71	81.37	82.16	11.85	14.28	0.95	0.71	0.65	0.74
T_2	70.00	72.61	74.19	74.50	26.01	33.61	0.63	0.53	0.52	0.50
T_3	61.53	60.23	60.49	60.00	44.69	49.57	0.41	0.31	0.45	0.42
T_4	75.38	72.61	74.07	75.66	28.84	25.21	0.78	0.64	0.56	0.53
T_5	78.46	76.19	79.13	77.50	12.83	17.68	0.83	0.84	0.78	0.75
T_6	83.07	83.33	80.24	81.66	00	00	1.06	0.86	0.85	0.80
T_7	-	-	-	-	74.77	73.10	-	-	-	-

T_1 = Full clear at 1125 g.a.i./ha (Metolachlor + Pendimethalin) (at pre-emergence of weed), T_2 = Penlin at 330 g.a.i./ha (Pendimethlin) spraying at weed leaf stage 2-3, T_3 = Stomp extra at 796 g.a.i./ha (Pendimethlin) spraying at weed leaf stage 2-3, T_4 = Bullet at 525 g.a.i./ha (Metribuzin) spraying at weed leaf stage 2-3, T_5 = Pellet at 660 g.a.i./ha (Pendimethlin) spraying before transplanting of onion, T_6 = Hand weeding two times at 20-25 and 35-40 (DAP), T_7 = Control (No hand weeding and herbicide).

Table 6. Effects of different weed control treatments on weed management index, agronomic management index and herbicide efficiency index in onion field

Treatments	Weed Management Index (WMI)				Agronomic Management Index (AMI)				Herbicide Efficiency Index (HEI)			
	Joydepur		Jashore		Joydebpur		Jashore		Joydebpur		Jashore	
	25 DAP	50 DAP	25 DAP	50 DAP	25 DAP	50 DAP	25 DAP	50 DAP	25 DAP	50 DAP	25 DAP	50 DAP
T_1	2.98	2.89	3.01	3.22	1.98	1.84	2.01	2.23	18.08	26.50	22.50	20.00
T_2	2.41	2.19	1.75	1.75	1.41	1.14	0.83	0.75	7.80	9.18	7.47	9.18
T_3	1.89	1.86	1.35	1.35	0.89	0.86	0.37	0.35	3.30	3.28	2.45	2.28
T_4	2.49	2.14	2.22	2.14	1.42	1.19	1.22	1.15	9.83	12.11	9.05	10.17
T_5	2.93	2.84	2.80	2.84	1.93	1.79	1.80	1.84	13.83	18.13	15.60	16.47
T_6	3.52	3.32	3.42	3.37	2.52	2.32	2.41	2.37	16.90	20.33	16.85	16.93
T_7	-	-	-	-	-	-	-	-	-	-	-	-

T_1 = Full clear at 1125 g.a.i./ha (Metolachlor + Pendimethalin) (at pre-emergence of weed), T_2 = Penlin at 330 g.a.i./ha (Pendimethlin) spraying at weed leaf stage 2-3, T_3 = Stomp extra at 796 g.a.i./ha (Pendimethlin) spraying at weed leaf stage 2-3, T_4 = Bullet at 525 g.a.i./ha (Metribuzin) spraying at weed leaf stage 2-3, T_5 = Pellet at 660 g.a.i./ha (Pendimethlin) spraying before transplanting of onion, T_6 = Hand weeding two times at 20-25 and 35-40 (DAP), T_7 = Control (No hand weeding and herbicide).

(2.52 and 2.32 at Joydebpur; 2.41 and 2.37 at Jashore at 25 and 50 DAP), followed by T_1,
T_5, and T_4. These results suggest that while pre-emergence herbicide (T_1) effectively controlled weeds, hand weeding (T_6) provided the best overall agronomic performance, likely due to complete removal of weeds and minimal crop stress (Table 6). Weed control treatments influenced herbicide efficiency index significantly (Table 6). Among the treatments, application of T_1 produced the highest herbicide efficiency index (18.08 and 26.50 at Joydebpur and 22.50 and 20.00 at Jashore at 25 DAP and 50 DAP, respectively) followed by T_6, T_5 and T_4.

3.5 Economic performance

The highest gross margin (BDT/ha) was obtained from T_6 (BDT 156000 (US$ 1300 at Joydebpur and BDT 168000 (US$ 1400 at Jashore). However, the lowest gross margin came from T_7, BDT 11000 (US$ 91.67) at Joydebpur and BDT 18000 (US$ 150) at Jashore. Due to different costs of weeding among the treatments, the production costs varied (Table 6). Additionally, among the herbicidal treatments, T_1 showed higher benefit cost ratios (BCR) (2.90 at Joydebpur and 3.00 at Jashore) followed by T_5 (2.86 at Joydebpur and 2.60 at Jashore) and T_4 (2.35 at Joydebpur and 2.49 at Jashore) (Table 7). The highest production costs were recorded for hand weeding (T_6), due to its labor-intensive nature, and for Pendimethalin-based herbicide applications, particularly T_2 and T_5, due to the cost of the herbicide and its application. Despite the higher costs, hand weeding (T_6) provided the highest gross margin in onion cultivation, indicating that effective weed management can increase profitability (Table 7).

Reduced cultivation costs in these herbicide treatments in comparison to the weed-free treatment were the rationale given for the economic performance of the various treatments. Treatment T_6 (hand weeding) failed to produce the highest BCR although it had the highest grain yield and gross return due to increased expense associated with more manual weeding. It raised the expense of manually weeding, which in turn raised the overall cost of the entire yield. The costs associated with the treatment also suggests that hand weeding is costly and therefore it reduces the benefit cost ratio of onion. On the other hand, the moderate cost of T_1 treatment showed highest BCR. Our findings are fairly similar to other previous studies in herbicidal control of onion field weeds in which BCR ranged from 1.638 and 2.11, respectively (Kumar et al., 2014; Gupta et al., 2020).

3.6 Correlation matrix

The Pearson correlation analysis of the fourteen agro-morphological traits for the two areas (Joydebpur and Jashore) revealed significant associations between various traits, shedding light on their interrelationships and potential influence (Figure 3). The results for Joydebpur showed that bulb diameter (BD) was positively influenced by AMI, bulb yield (BY) and WMI. In contrast, BD showed a significant negative relationship with weed index. Furthermore, weed persistence index showed significant positive relationship with AMI, BY and WMI whereas negatively with WI. The study also ensured that there was a significant positive relationship among AMI, BY and WMI. In contrast, significant negative interaction was observed between AMI and WI. The most interesting results related to yield and showed that BY significantly deteriorated by weeds and improved by WMI. Moreover, WMI and WCI showed significant positive relations. However, weed

management of onions

Table 7. Economic performance of different herbicides treatment on onion field

Treatments	Gross Return (BDT/ha) (US$/ha)		Cost of Treatments (BDT/ha) (US$/ha)		Total Cost of Production (BDT/ha) (US$/ha)		Gross Margin (BDT/ha) (US$/ha)		BCR	
	Joydepur	Jashore	Joydepur	Jashore	Joydepur	Jashore	Joydepur	Jashore	Joydepur	Jashore
T_1	199200 (1660.00)	204000 (1700.00)	4675 (38.95)	4675 (38.95)	51000 (425.00)	51000 (425.00)	148200 (1235.00)	153000 (1275.00)	2.90	3.00
T_2	167200 (1393.33)	158000 (1316.67)	5200 (43.33)	5200 (43.33)	51000 (425.00)	51000 (425.00)	116200 (968.33)	107000 (891.67)	2.27	2.09
T_3	125000 (1041.67)	120000 (1000.00)	3300 (27.50)	3300 (27.50)	51000 (425.00)	51000 (425.00)	74000 (616.67)	46000 (383.33)	1.45	0.90
T_4	160800 (1340.00)	178000 (1483.33)	3720 (31.00)	3720 (31.00)	51000 (425.00)	51000 (425.00)	109800 (915.00)	127000 (1058.33)	2.35	2.49
T_5	197000 (1641.67)	184000 (1533.33)	4720 (39.33)	4720 (39.33)	51000 (425.00)	51000 (425.00)	146000 (1216.67)	133000 (1108.33)	2.86	2.60
T_6	226000 (1883.33)	238000 (1983.33)	10000 (83.33)	10000 (83.33)	70000 (583.33)	70000 (583.33)	156000 (1300.00)	168000 (1400.00)	2.22	2.40
T_7	57000 (475.00)	64000 (53.33)	-	-	46000 (383.33)	46000 (383.33)	11000 (91.67)	18000 (150.00)	0.23	0.39

Onion Price = BDT 20/kg.; 1 US$ = 120 BDT

T_1 = Full clear at 1125 g.a.i./ha (Metolachlor + Pendimethalin) (at pre-emergence of weed), T_2 = Penlin at 330 g.a.i./ha (Pendimethalin) spraying at weed leaf stage 2-3, T_3 = Stomp extra at 796 g.a.i./ha (Pendimethalin) spraying at weed leaf stage 2-3, T_4 = Bullet at 525 g.a.i./ha (Metribuzin) spraying at weed leaf stage 2-3, T_5 = Pellet at 660 g.a.i./ha (Pendimethalin) spraying before transplanting of onion, T_6 = Hand weeding two times at 20-25 and 35-40 (DAP), T_7 = Control (No hand weeding and herbicide).

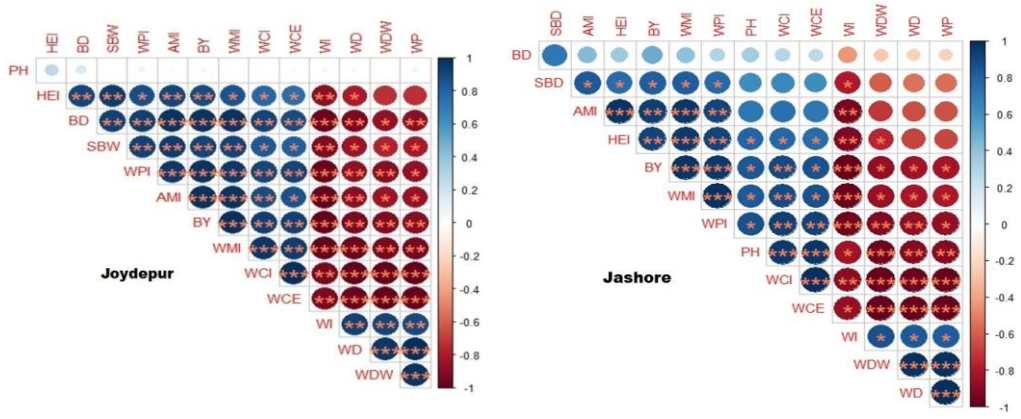


Figure 3. Correlation of yield contributing traits and weed indices of onion (PH= Plant height (cm), BD= Bulb diameter (cm), SBW= Single bulb weight (g), BY= Bulb yield (t/ha), WP= Weed population (weed/m^2), WD= Weed density, WI= Weed index (%), WDW= Weed dry weight (g/m^2), WCE= Weed control efficiency (%),WCI= Weed control index (%), WPI= Weed persistence index, WMI= Weed management index, AMI= Agronomic management index, HEI= Herbicide efficiency index)

might be disturbed by weed density. WD and WP influenced the WCI negatively. Moreover, WP significantly increases WD, WI and WDW.

In Jashore, the result showed that there was a significant positive relationship among AMI, HEI and WMI. Furthermore, BY was positively influenced by weed management and negatively by WI in Jashore. WP, WD and WDW significantly reduced the plant height (PH) whereas efficient control of weeds (WCE) increases it. In contrast, efficiency of control of weeds (WCI) significantly was reduced by the increases of WP and WD. Finally, the results highlighted that WP increased the WD and this both increases the WDW.

Different correlation matrix showed the relationship of the traits used in this study. The results highlighted that proper agronomic and weed management practice increase the bulb diameter of onions. Further, BY increases with the positive performance of agronomic and weed management. Proper management and control of weeds can increase the bulb yield of onion.

3.7 Relationship between bulb yield and weed control efficiency

The relationship between bulb yield (t/ha) and weed control efficiency (WCE) at 50 DAP of onion is shown in Figure 4 where bulb yield was plotted against weed control efficiency. Bulb yields in both areas (Joydebpur and Jashore) were highly linearly correlated with WCE (R^2 of Joydebpur = 0.851 and R^2 of Jashore = 0.752). The slope was evident for the significant linear regression between these two variables. The slope coefficients for Joydebpur and Jashore (0.080 and 0.079, respectively) indicated that 1% increase of weed control efficiency could increase the bulb yield by 0.08 and 0.079 ton per hectare of onions, respectively. Therefore, the study confirmed that proper weed control efficiency increased the bulb yield of onions.

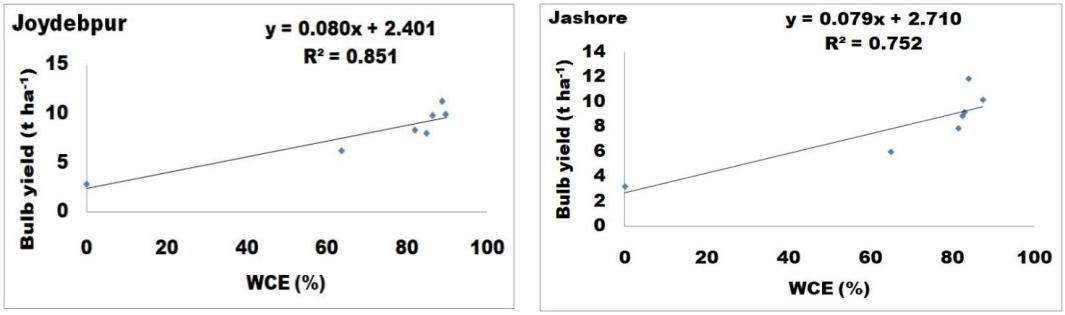


Figure 4. Relationship between bulb yield and weed control efficiency (WCE) at 50 DAP of onion

4. Conclusions

The results revealed that hand weeding might be the ideal choice to get the highest yield of onions and the best gross margin. Considering the impact of herbicides on the environment, the application of hand weeding should be suggested. However, hand weeding tends to be laborious and therefore herbicide application is needed. In this case, the study recommends the application of full clear at 1125 g.a.i./ha (T_1) as a pre-emergence herbicide. In case of post-emergence, the application of Bullet at 525 g.a.i./ha spraying at weed leaf stage 2-3 is recommended when considering economic profitability and reduction of weed persistency in the onion fields.

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6. Authors' Contributions

Md. Shaheenuzzamn: planned, designed, and performed the experiment, collected data and wrote the manuscript. Anjuman Ara Begum: performed the experiment and wrote the manuscript. Md. Rasheduzzaman: analyzed experimental results, drafted, and wrote the manuscript. Md. Sarwar Jahan Shaun: drafted and wrote the manuscript. Md. Foysal Ibne Siraj: drafted and wrote the manuscript. Md. Ahasan Habib: drafted and wrote the manuscript. Md. Sarowar Alam: analyzed experimental results, drafted, and wrote the manuscript. A. K. M. Zonayed-Ull-Noor: read and edited the manuscript. Md. Abu Hena Sorwar Jahan: supervised and edited the manuscript.

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7. Conflicts of Interest

All authors declare no conflict of interest.

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