

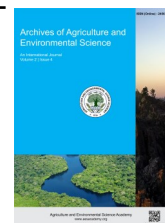


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ORIGINAL RESEARCH ARTICLE



Effect of integrated weed management practices on the growth, yield, quality and economic of onion (*Allium cepa* L.)

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ABSTRACT

A field study was conducted at research field of Spices Research Sub-Centre (SRSC), Faridpur, Bangladesh to find out the efficacy of weed management practices on the growth, yield, quality and economics of onion with the variety BARI Piaz-6. Thirteen treatments such as: T₁- control as check (no weeding), T₂-weed free, T₃-one hand weeding (HW) at 45 days after transplanting (DAT), T₄-two HW at 25 and 45 DAT, T₅-three HW at 25, 45 and 65 DAT, T₆- pre-emergence (PE) spray of pendimethalin 33 EC @ 330g a.i./litre + one HW at 45 DAT, T₇- PE spray of pendimethalin 33 EC @ 330g a.i./litre + two HW at 45 and 65 DAT, T₈- post emergence (POE) spray of pendimethalin 33 EC @ 330g a.i./litre at 25 DAT + one HW at 65 DAT, T₉- PE spray of oxyfluorfen 23.5 EC @ 235g a.i./litre + one HW at 45 DAT, T₁₀- PE spray of oxyfluorfen 23.5 EC @ 235g a.i./litre + two HW at 45 & 65 DAT, T₁₁- POE spray of oxyfluorfen 23.5 EC @ 235g a.i./litre at 25 DAT + one HW at 65 DAT, T₁₂- PE spray of pendimethalin 33 EC @ 330g a.i./litre + POE spray of oxyfluorfen 23.5 EC @ 235g a.i./litre at 45 DAT + one HW at 65 DAT and T₁₃- PE spray of oxyfluorfen 23.5 EC @ 235g a.i./litre + POE spray of pendimethalin 33 EC @ 330g a.i./litre at 45 DAT + one HW at 65 DAT were compared by randomized complete block design with three replications. The study revealed that the weed management treatments under the study significantly influenced all parameters except total soluble solid content of onion bulb. Weed density had reverse effect on growth, development and yield of onion. Among the weed's infestation, *Cyperus rotundus* (55-60%), *Echinochloa crusgalli* (10-15%) and *Chenopodium album* (8-10%) were predominant. The highest weed density (137.25 weeds/m²) were recorded from the T₁. The lowest weed density (15.24 weeds/m²) were observed from T₁₃. The T₃ had the least weed control efficacy (23.56%). The maximum fresh yield (19.49 t/ha) of onion bulb were obtained from T₂ followed by T₁₃ (19.31 t/ha). The highest benefit-cost ratio (2.19) was calculated from the T₁₃ closely followed by T₁₂ (2.18). From this study it was concluded that Pre-emergence application (PE) application of oxyfluorfen or pendimethalin + post-emergence (POE) application of oxyfluorfen or pendimethalin at 45 DAT (days after transplanting) + once HW (hand weeding) at 65 DAT and also PE of oxyfluorfen or pendimethalin + twice HW at 45 & 65 DAT exhibited good performance to control weeds in onion field.

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INTRODUCTION

Onion (*Allium cepa* L.) belongs to the Alliaceae family and can form bulbs which consumed by people "in nature" or processed food or as spice. Onion is a critical crop which produced 78 million tons per year by the top 20 countries (FAO, 2018). Among the spice crops, onion stands first place in Bangladesh based on the daily intake (35g/day/person) and production as well (Khan et al., 2020). Onion is produced 19.51 lakh metric tonnes per annum and the average yield is 9.71 t/ha in Bangladesh (BBS, 2020).

Weed is one of the most important yield reducing factors all over the world. It is called a silent killer of crop (Priya et al., 2017). Onion exhibits greater susceptibility to weed competition as compared to the other crops due to its inherent characteristics such as their slow growth, small nature, shallow roots and lack of dense foliage (Dhananivetha et al., 2017). Weeds constitute one of the serious problems in agriculture that not only reduce the yield and quality of onion but also utilize essential nutrients, space, soil moisture and light (Ramalingam et al., 2013). Uncontrolled weed growth reduces the bulb yield up to 40-80% depending upon the nature of intensity and duration of weed competition in onion field (Ramalingam et al., 2013). However, Vijayvergiya et al. (2018) found 30-60%, 42.3%, 94.7% yield reduction in onion, respectively due to crop-weed competition. Besides, weeds harbor insects, plant pathogens and serve as hosts for parasitic weeds adding more complications to the control of these important pests (Qasem and Foy, 2008). Weeds also increased the production and harvesting cost Bangladesh faces serious problem for getting higher quality and quantity productivity of onion due to infestation of weeds. Removing weeds throughout the growing season may not be economical. Therefore, onion crop must be kept weed free during its critical period, 55 DAT (Khan et al., 2013); 20-60 DAT (Chopra and Chopra, 2006); 50 DAT (Qasem, 2005) and 60 DAT (Rameshwar et al., 2001) to avoid yield reduction and to gain economic return. The effective weed control involves identification of weed flora, method of weed control and judicious combination of effective weed control methods (Dhananivetha et al., 2017). Weeds could be controlled by different weed control methods such as manual, cultural, chemical, mechanical and biological (Dhananivetha et al., 2017). Weed management methods best suited for an individual grower will depend on several factors such as present weed species, crop variety, crop growth stage, weed species, labour cost and availability (Bell and Boutwell, 2001). Hand weeding (4 or 3 HW) gave better results on weed density and yield contributing characters than chemical control (Waseem-ul-Hassan and Malik, 2001) but they did not compute economics aspect under their study. Critically viewing, the conventional method of weed control with only hand/hoes is extremely laborious, time consuming, expensive, less effective (Dhananivetha et al., 2017 and Sanker et al., 2015) and needed to be repeated at frequent intervals as well. This situation makes it necessary to use herbicides for effective and timely control of weeds in this crop (Sanker et al., 2015). It is thus highly imperative to schedule

suitable method of weed control by application of different herbicides for enhancing profits to the onion growers (Sanker et al., 2015). On the other hand, continuous and imbalanced use of herbicides adversely affects the sustainability of agricultural production besides causing environmental pollution (Gyani et al., 2020). In addition, only application of herbicide called weedicide does not give the effective control. Chemical weed control is an option in integrated weed management that refers to the integrated use of cultural, manual, mechanical and/or chemical control method. The common worldwide weed management practice in onion is pre-emergence/post emergence application of selective herbicides like pendimethalin, oxyfluorfen, oxadiazon, quizalofop ethyl, alachlor, butachlor and metolachlor followed by one hand weeding (Gyani et al., 2020; Jangre et al., 2019; Angmo et al., 2018 and Dhananivetha et al., 2017) which are used alone or in different combinations. The most effective herbicide suitable for weed destruction presently in onion is oxyfluorfen as reported by Stall and Gilreath (2002). The pre-emergence herbicides offer the most practical, effective and economical method of weed control for increasing bulb yield of onion (Ramalingam et al., 2013). Weedicide application time is more important to control weeds effectively. Several researchers in the world found benefits applying different weedicide in onion crop. No single weed control method may provide effective control of weeds (Jat et al., 2018).

Kumar (2014) stated that effective weed control was recorded under application of oxyfluorfen 23.5 EC @ 2 ml/litre (before planting) + one HW at 40 DAT or combined spray of pendimethalin 30 EC @ 2.5 ml/litre + quizalofop ethyl 5 EC @ 1.75 ml/litre (at the time of planting) and at 30 DAT. Priya et al. (2017) reported that pre-emergence of application of oxyfluorfen at 200 g/ha or pendimethalin 750 g/ha followed by one HW at 40 DAT kept the weed density and dry weight of weeds reasonably at lower level and enhanced the productivity of onion resulting in higher economic returns. Spraying oxyfluorfen 23.5% EC @ 100-150 g a.i./ha at 15-20 DAT and one HW at 45DAT had the maximum weed control efficiency, yield, net return and benefit-cost ratio in onion followed by pre-planting spray of oxyfluorfen 23.5% EC @ 100-150 g a.i./ha and one HW at 45DAT (Gaharwar et al., 2017). The pre-emergence herbicides offer the most practical, effective and economical method of weed control for increasing onion bulb yield (Uygur et al., 2010). A good integrated weed management program is needed for getting optimum productivity of quality onion bulb. Integrated weed management is a more recent strategy that combines two or more methods of weed management to give results that are superior to those obtained when a single method is used (Das, 2019). In addition, numerous alternative techniques proved that herbicides application and cultural practices have been effectively used to control weeds in onion field, as indicated by Dhananivetha et al. (2017). Based on the aforesaid reasons a research finding on integrated weed management practices including new weedicide (oxyfluorfen) is necessary for growing onion in the country. Hence, it is necessary to judge different weed management practices alone and in combination with

integrated approach at proper stage of crop growth.

The present experiment objective was to study the efficacy of weed management practices on controlling weeds and growth, yield & quality of onion and to find out the suitable integrated weed management practice on the basis of economics of onion.

MATERIALS AND METHODS

The present study was carried out at Spices Research Sub-Centre (SRSC), Bangladesh Agricultural Research Institute (BARI), Faridpur, Bangladesh during winter season of 2020-2021 to find out the efficacy of weed management practices on the growth, yield, quality and economics of onion with the variety BARI Pia-6.

Experimental design

The study was designed in a randomized complete block design (RCBD) with three replications. In the study thirteen treatments such as: T₁-control as check (no weeding), T₂-weed free, T₃-one hand weeding (HW) at 45 days after transplanting (DAT), T₄-two HW at 25 and 45 DAT, T₅-three HW at 25, 45 and 65 DAT, T₆-pre-emergence (PE) spray of pendimethalin 33 EC @ 330g a.i./litre + one HW at 45 DAT, T₇- PE spray of pendimethalin 33 EC @ 330g a.i./litre + two HW at 45 and 65 DAT, T₈- post emergence (POE) spray of pendimethalin 33 EC @ 330g a.i./litre at 25 DAT + one HW at 65 DAT, T₉- PE spray of oxyfluorfen 23.5 EC @ 235g a.i./litre + one HW at 45 DAT, T₁₀- PE spray of oxyfluorfen 23.5 EC @ 235g a.i./litre + two HW at 45 & 65 DAT, T₁₁- POE spray of oxyfluorfen 23.5 EC @ 235g a.i./litre at 25 DAT + one HW at 65 DAT, T₁₂- PE spray of pendimethalin 33 EC @ 330g a.i./litre + POE spray of oxyfluorfen 23.5 EC @ 235g a.i./litre at 45 DAT + one HW at 65 DAT and T₁₃- PE spray of oxyfluorfen 23.5 EC @ 235g a.i./litre + POE spray of pendimethalin 33 EC @ 330g a.i./litre at 45 DAT + one HW at 65 DAT were compared. Weed free: weeds were continuously removed by hand until harvest and weedy check: weeds were left until

harvest. Weeds were allowed to compete with onion plants as per treatment designed. Pendimethalin and oxyfluorfen were sprayed @ 2.00 l/ha and 1.00 l/ha, respectively with a Hi-Sprite Pressure Sprayer while pre-emergence (PE) herbicides were applied at 3 days before transplanting of seedling and post emergence (POE) herbicides was applied as per treatment. Weeds were removed by using hand hoe for manual hand weeding (HW).

Management practices

Onion seedlings were raised in the nursery beds from 10 November to 20 December 2020 using nursery management practices. The 40-day old uniform and healthy seedlings were transplanted on 20 December 2020 in the experimental plots maintaining 15 cm x 10 cm spacing. Khan et al. (2020) reported that, the optimum date of onion seedlings transplanting is from 15-30 December for getting maximum productivity and quality of onion bulbs. Before transplanting, roots of the seedlings were soaked in Rovral (Iprodione) solution for 5 minutes and about 5 cm of seedling tops were trimmed out. The unit plot size was 3.00 m x 1.50 m. The experimental field was fertilized with 3 tones well-decomposed cowdung, 100 kg N, 45 kg P, 75 kg K and 20 kg S per hectare. Nitrogen, phosphate, potash and sulphur were supplied in the form of Urea, TSP, MP and Gypsum, respectively. The fungicide mancozeb/iprodione @ 3 g/1 litre of water was sprayed at fortnightly interval commencing from one month after transplanting of seedlings. All other recommended management practices were followed for each treatment. The experimental site is belonging to Agro Ecological Zone (AEZ) no. 12 (Low Ganges River Floodplain). The geographic coordinates of the trial site are 23°11'N and 89°09'E. While its elevation is about 12 meters above sea level. Among the crops grown in the area, onion is predominantly cultivated as irrigated crop. Monthly average air temperature, average relative humidity and total rainfall for the trial location during 2020-2021 are illustrated in Figure 1.

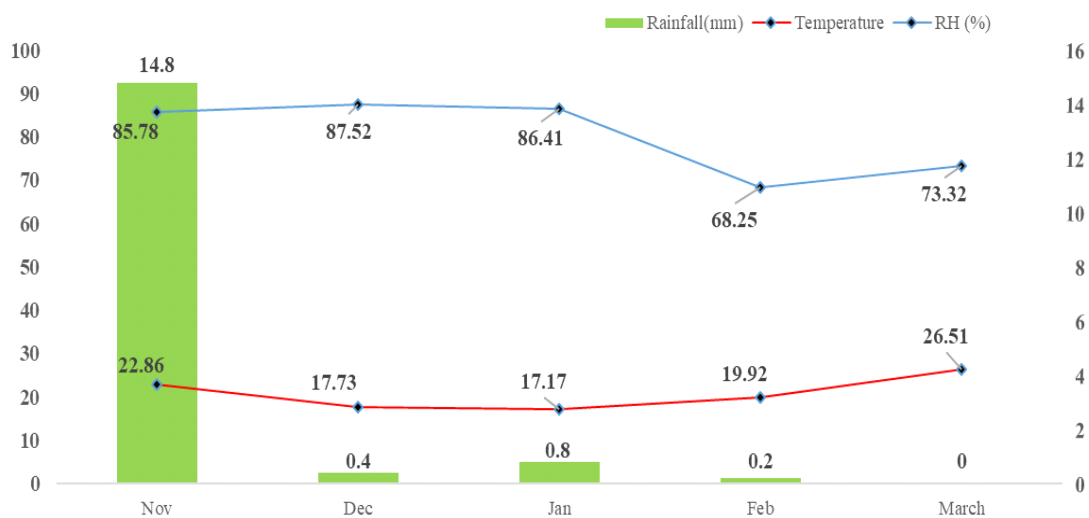


Figure 1. Monthly average air temperature (°C), average relative humidity (%) and total rainfall (mm) at SRSC, BARI, Faridpur during November/2020-March/2021 (SRSC, 2021).

Data recorded

The data recorded were: Plant height (cm), number of leaves/plant (no.), neck size (cm), incidence of bolting (%), bulb diameter (cm), individual bulb weight (g), dry matter of bulbs (%), dry matter of leaves (%), total soluble solid (°brix), bulbs weight per plot (kg/ha) then calculated as yield per hectare (t), types of flora, weed density (number/m²), weed index (%), dry weight of weed (g/m²), weed control efficiency (%), economic analysis (Tk.). Ten plants were randomly selected from each plot for data recording and averaging it. Plant height and number of leaves were recorded at 75 days after seedling transplanting. But average plant height and number of leaves were presented in the paper. Each experimental plot was examined regularly. The number of bolting plants (flowering stalk) was visually counted in each plot, recorded and expressed in percent in relation to the total number of plants. Bulbs were harvested at maturity when the pseudo stem becomes flaccid and unable to support the leaf blades (Brewster, 1990^a). Onions were harvested on 20 March, 2021. The leaves of harvested onion were removed at seven days after curing by cutting 8-10 cm above the bulb (Brewster, 1990^b). After curing, the total bulb fresh weight was measured for each plot. The number of bolter bulb was visually counted in each plot, recorded and expressed in percent in relation to the total number of plants. The percent dry matter content of bulbs was calculated by dry weight basis as per procedure of Walle et al. (2018) as: (dry weight of bulbs/fresh weight of bulb) x 100 and expressed in %. The dry matter content of leaves was also calculated similarly as to the dry matter of bulb. The total soluble solids (TSS) content of bulbs was recorded by hand refractometer (ATAGO, Master-53M, Japan) with a range of 0-53 °brix. Bulb diameter (equatorial diameter) is the maximum width of the onion in plane perpendicular to the polar diameter. Weed density was recorded at 75 DAT of onion seedlings by placing a "Quadrat" of 0.5 m x 0.5 m randomly from three places in each plot. The weed population falling within the frames of the "Quadrat" was recorded species-wise and expressed as number per m². The weeds falling within frames of the "Quadrat" were collected and categorized into species. The weeds from each category were dried in hot-air oven at 80°C for 72 hr (Ramalingam et al., 2013). The dry weight of weeds was expressed in g/m². Weed index (WI) is the measure of the efficiency of a particular treatment when compared with a weed free treatment. It was calculated as following method of Ramalingam et al. (2013) and expressed in %. $WI (\%) = \{(X-Y)/X\} \times 100$, where WI- weed index (%), X- bulb yield (kg/ha) from minimum weed competition plot and Y- bulb yield (kg/ha) from the treatment plot for which WI to be worked out. Weed control efficiency (WCE) which indicates the comparative magnitude of reduction in weed dry matter was highly influenced by different weed control treatments. It was calculated as per the procedure of Ramalingam et al. (2013) and expressed in % as follows. $WCE (\%) = \{(WD_c - WD_t)/ WD_c\} \times 100$, where WCE- weed control efficiency (%), WD_c - weed biomass (g/m²) in control plot and WD_t - weed biomass (g/m²) in treated plot For the economic analysis, based on the market price of all the applied inputs and

wholesale prices of the produce; cost, return and BCR were estimated.

Statistical analysis

The Analysis of variance was done with the help of statistical package 'R', the mean difference among the treatments were adjusted by Duncan's Multiple Range Test (DMRT) and Principle Component Analysis (PCA) done by statistical software "MINITAB".

RESULTS AND DISCUSSION

Effect of weed management practices on the weeds weed flora

The experimental field was infested with different types of weed flora (Table 1). Among them, *Cyperus rotundus* (55-60%), *Echinochloa crusgalli* (10-15%) and *Chenopodium album* (8-10%) were predominant. Islam et al. (2020) also recorded the highest percent weed infestation with *Cyperus rotundus* in onion field. However, *Chenopodium album* was the most predominant weed flora in onion field, as found by Khan et al. (2013). The results of the study (Figure 2) depicted that weed management practices had significant variation on weed density (WD), weed dry weight (WDW), weed index (WI) and weed control efficiency (WCE). All the treatments imposed for weed management under the study clearly reduced the WD, WDW & WI and increased the WCE.

The un-weeded treatment (control) plot (T₁) exhibited the highest weed density (137 weeds/m²), maximum weed dry weight (120.31 g), highest weed index (52.74%) and lowest weed control efficiency (0.00%) significantly followed (108.81 weeds/m² WD, 91.96 g/m² WDW, 32.33% WI and 23.56% WCE) by the treatment T₃. Treatment T₈, being 93.00 weeds/m² WD, 78.99 g/m² WDW, 28.19% WI, 34.34% WCE; the T₁₁, being 80.13 weeds/m² WD, 67.29 g/m² WDW, 23.08% WI, 44.07% WCE; and the treatment T₄ being 74.02 weeds/m² WD, 62.38 g/m² WDW, 21.59% WI, 48.15% WCE. The least infested plot by weeds 15.24 weeds/m² was found in the treatment T₁₃ with 13.05 g/m² WDW, 0.90% WI, 89.15% WCE; which was insignificantly followed by the treatment T₁₁. The weed infestation of T₇ and T₁₀ was statistically similar. The zero-weed infestation found in Treatment T₂ (Weed free plot). The variation found among the weed management practices due to variant weed management practices. The lowest variation under the treatment T₁₃ and T₁₂ might be due to twice checking of weed growth by oxyflourfen or pendimethalin at initial stage of onion growth and at the critical period of weed control (45 DAT). Chattopadhyay et al. (2016) opined that application of pendimethalin at pre-plant and at 30 DAT showed better management of weed flora indicating the ability of the treatment pendimethalin to suppress the growth of all types of weed flora through its higher persistence in the soil.

The maximum dry weight from T₁ (weedy check) might be attributed due to increased weed density & continuous weed growth and due to the higher amount of nutrient uptake (Gaharwar et al., 2017; Chattopadhyay et al., 2016; Vishnu et al.,

Table 1. Infesting weed species found in onion experimental plots.


S. N.	Common Name	Scientific Name	Family	Picture
1	Lambs quarters (Bathua)	<i>Chenopodium album</i>	Amaranthaceae	
2	Prostrate spurge	<i>Euphorbia prostrata</i>	Euphorbiaceae	
3	Snake-needle grass	<i>Hedyotis diffusa</i>	Rubiaceae	
4	Water Spinach	<i>Ipomoea aquatica</i>	Convolvulaceae	
5	Dwarf copper leaf	<i>Alternanthera sessilis</i>	Amaranthaceae	
6	Bitter leaf	<i>Glinus oppositifolius</i>	Molluginaceae	
7	Cutleaf ground cherry	<i>Physalis angulata</i>	Solanaceae	
8	Helencha	<i>Enhydra fluctuans</i>	Asteraceae	
9	Durva Grass	<i>Cynodon dactylon</i>	Poaceae	
10	Asthma plant	<i>Euphorbia hirta</i>	Euphorbiaceae	
11	Carpet grass	<i>Artraxon spp.</i>	Poaceae	
12	Purple amaranth	<i>Amaranthus blitum</i>	Amaranthaceae	
13	Para grass	<i>Brachiaria mutica</i>	Poaceae	

Table 1. Contd.....

14	Mutha grass	<i>Cyperus rotundus</i>	Poaceae	
15	Couch grass	<i>Elymus repens</i>	Poaceae	
16	Duck weed	<i>Portulaca oleracea</i>	Portulacaceae	
17	False Daisy	<i>Eclipta prostrata</i>	Asteraceae	
18	Four-leaf clover	<i>Trifolium repens</i>	Fabaceae	
19	Slender amaranth	<i>Amaranthus viridis L.</i>	Amaranthaceae	
20	Umbrella grass	<i>Panicum decompositum</i>	Poaceae	
21	Barnyard grass (Shyma)	<i>Echionochloa crusgalli</i>	Poaceae	

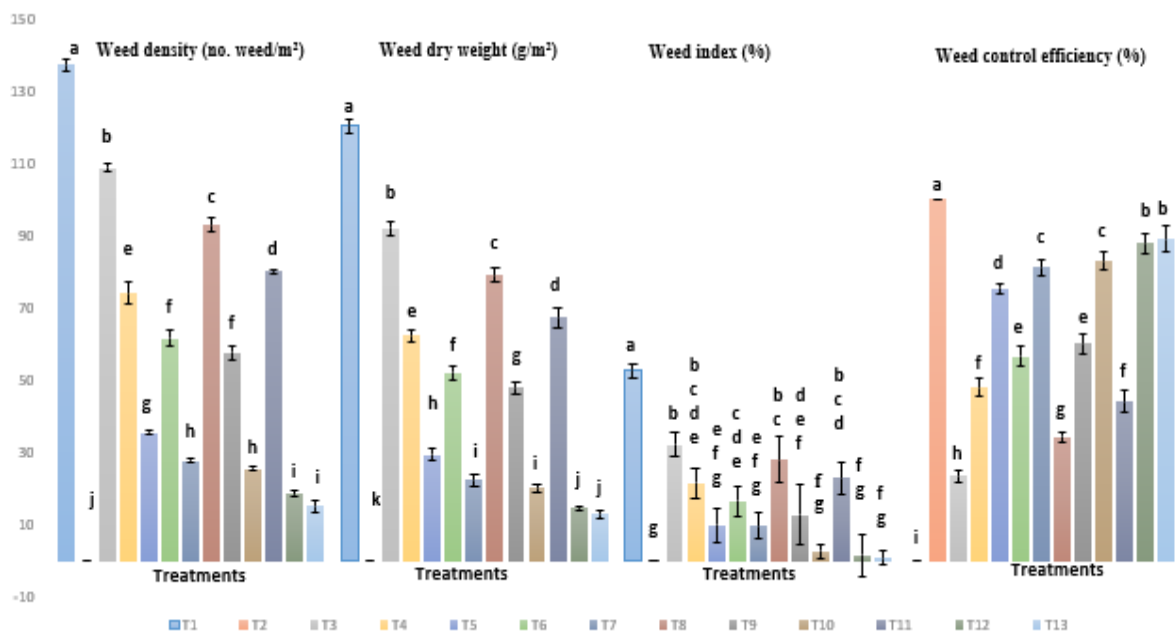


Figure 2. Effects of weed management practices on the weed density (%), weed dry weight (g/m²), weed index (%) and weed control efficiency (%) in onion field at SRSC, BARI, Faridpur during 2020-2021. Letters denote differences. Vertical bars indicate standard error of means. T₁: no weeding (check); T₂: weed free; T₃:1HW at 45 DAT; T₄: 2HW at 25 & 45 DAT; T₅: 3HW at 25, 45 & 65 DAT; T₆: PE Pend. + 1HW at 45 DAT; T₇:PE Pend. + 2HW at 45 &65 DAT; T₈: POE Pend. at 25DAT+1HW at 65 DAT; T₉: PE Oxyf. + 1HW at 45 DAT; T₁₀:PE Oxyf. + 2HW at 45 &65 DAT; T₁₁: POE Oxyf. at 25 DAT + 1HW at 65 DAT; T₁₂:PE Pend. + POE Oxyf. at 45 DAT + 1HW at 65 DAT and T₁₃: PE Oxyf. + POE Pend. at 45 DAT + 1HW at 65 DAT.

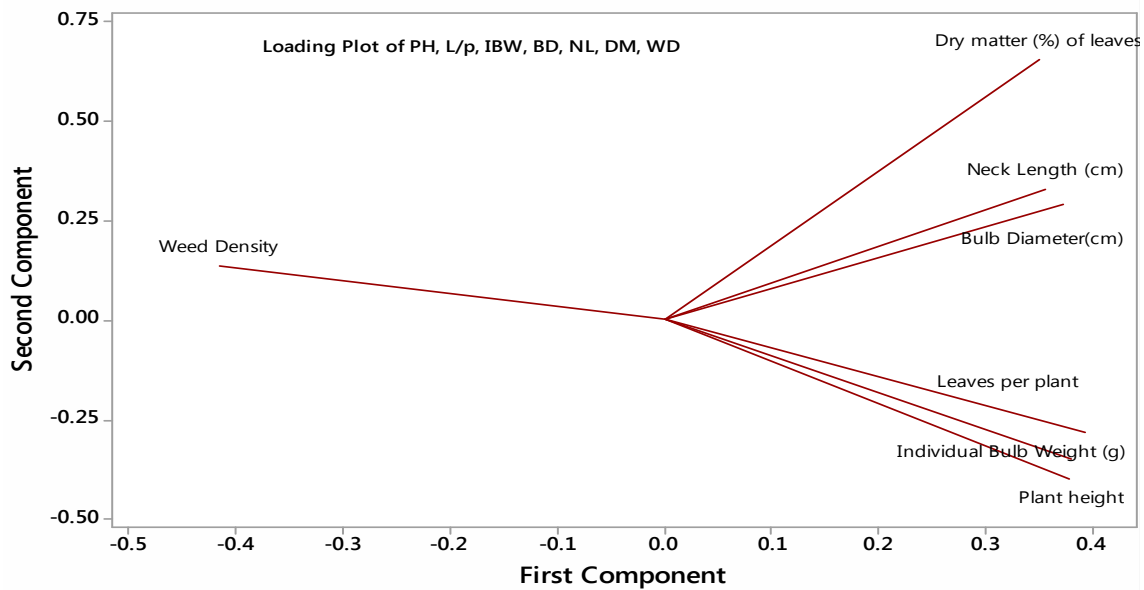


Figure 3. Loading plot shows relation between weed density and Plant height, individual bulb weight, leaves per plant, bulb diameter, neck length and dry matter percent of leaves.

2015 and Patel et al., 2012) The lowest dry weight with applying twice applications of herbicide as PE and POE also published by Vishnu et al. (2015). They found lower dry weight by applying PE pendimethalin + POE imazethapyr at 45 DAT. They further mentioned this treatment as effective weed control method, which reflected on a smaller number of weeds and ultimately lower weed biomass. Sahoo et al. (2017) and Ramalingam et al. (2013) found higher weed index from un-weeded control treatment due to heavy competition of weeds for nutrients, space and light. Sahoo et al. (2017) found zero (0) percent weed control index in weed free check which is similar to the present result.

The current finding of WCE corroborates the finding of several researchers. Significantly higher WCE was observed under weed free check (Vishnu et al., 2015). The PE application of oxyfluorfen + POE application quizaofop ethyl at 40 DAT were found effective after weed free plots (Angmo et al., 2018; Kalhapure et al., 2013). The chemical weed control in onion is a better practice supplemented to conventional methods and forms and integral part of the modern crop production practices, as states by Angmo et al. (2018). The combine application of pre- and post-emergence herbicide is one of the options left with the farmers to eliminate crop weed competition at early and later stages of the crop and to achieve higher weed control efficiency (Angmo et al., 2018). Pre-emergence herbicides like oxyfluorfen 23.5 EC or pendamithalin 30 EC before planting or at the time of planting effectively and economically control the weed population during the critical stages of crop growth (Sahoo and Tripathy, 2019).

Effect of weed management practices on the growth and development of onion

Here the Principal Component Analysis (PCA) of weed management practices (Figure 3) showed the relation between weed density and Plant height, individual bulb weight, leaves per plant, bulb diameter, neck length and dry matter percent of leaves. Weed density had reverse effect on Plant height, individual bulb weight, leaves per plant, bulb diameter, neck length and dry

matter percent of leaves. When weed density increase then others growth parameter showed lowest results and weed free or minimum infested plot show positive results on growth and development parameters. Because under weedy condition lack of optimum environment, all the growth parameters reduced and the crop and weed compete with each other for survival (Uygun et al., 2010).

The plant height ranged from 35.88 to 50.66 cm with the shortest in the treatment T₁ (no weeding) and the tallest in the T₂ (weed free for whole season). The 2nd (48.00 cm), 3rd (47.30 cm) 4th (46.83 cm) and 5th (45.66 cm) tallest plant heights were noted in the T₁₃, T₁₂, T₁₀ and T₇, respectively. In addition, these values of the corresponding treatment were not statistically differed with each other. The T₁ was insignificantly followed by T₃ (39.10 cm) and significantly followed by T₈ (41.11 cm), T₁₁ (42.05 cm). Shortest plant height from weedy check might be due to heavy weed population increased the weed crop competition and stress on onion crop (Gaharwar et al., 2017). In contrast, opposite observation was made by Waiganji et al. (2009), who stated that onion plants from the un-weeded plots grew much taller probably in search of sunlight as a result of shading by weeds, although not significantly taller than plants from all other treatments.

The maximum number of leaves/plants was recorded in the T₂ (8.21) insignificantly followed by T₁₃ (7.88) and significantly followed T₁₂ (7.25), T₁₀ (7.10) and T₇ (7.00). While the T₁₃ was significantly differed with T₁₂ but not differed with T₁₀ and T₇. The T₁ produced the minimum number of leaves/plant (5.55) significantly followed by T₃ (5.86), T₁₁ (6.00), T₈ (6.10) and T₄ (6.12). The variation might be due to the same reason as cited earlier in case of plant height. It was clearly observed by Sahoo and Tripathy (2019) and Gupta et al. (2020) that the application of weedicide before planting significantly created an effective security mechanism and reduced the crop and weed competition by promoting an optimum vegetative plant growth in onion.

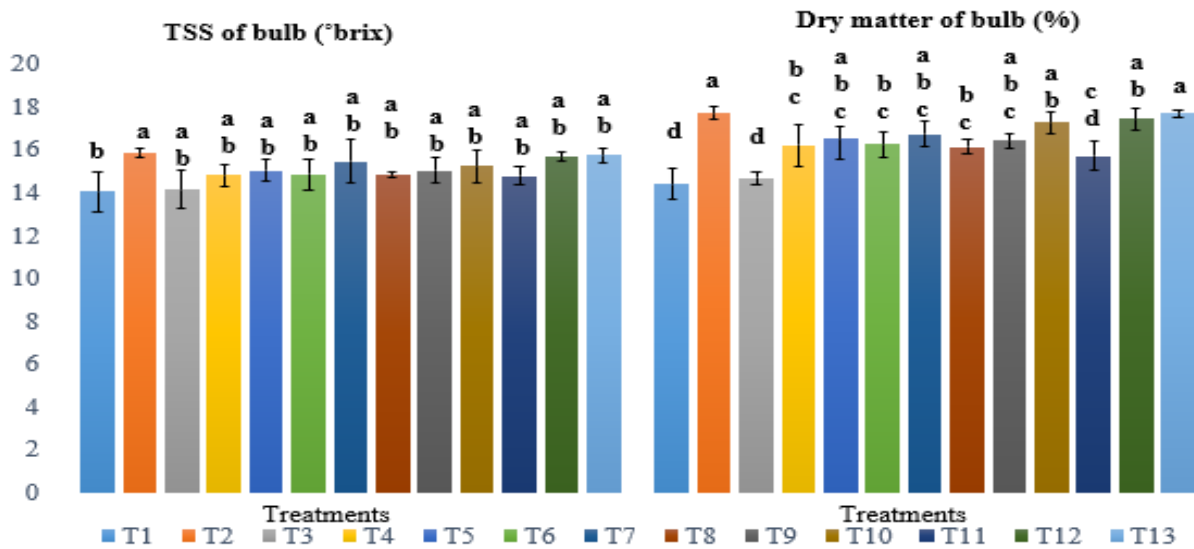


Figure 4. Effect of treatments on TSS of bulb (°brix), dry matter of bulb. Letters denote differences. Vertical bars indicate standard error of means. T₁: no weeding (check); T₂: weed free; T₃: 1HW at 45 DAT; T₄: 2HW at 25 & 45 DAT; T₅: 3HW at 25, 45 & 65 DAT; T₆: PE Pend. + 1HW at 45 DAT; T₇: PE Pend. + 2HW at 45 & 65 DAT; T₈: POE Pend. at 25DAT+1HW at 65 DAT; T₉: PE Oxyf. + 1HW at 45 DAT; T₁₀: PE Oxyf. + 2HW at 45 & 65 DAT; T₁₁: POE Oxyf. at 25 DAT + 1HW at 65 DAT; T₁₂: PE Pend. + POE Oxyf. at 45 DAT + 1HW at 65 DAT and T₁₃: PE Oxyf. + POE Pend. at 45 DAT + 1HW at 65 DAT.

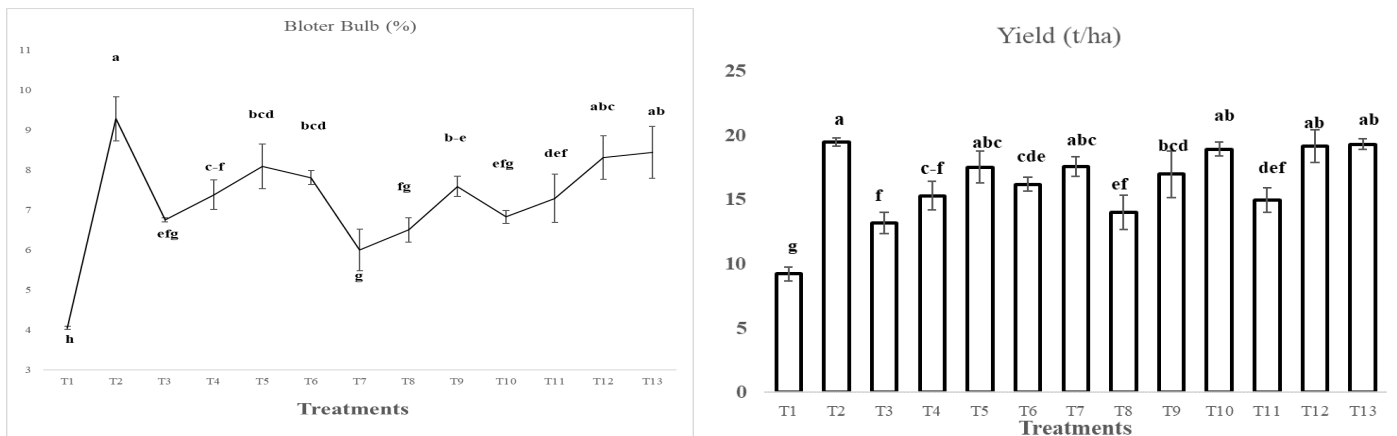


Figure 5. Effect of treatments on Bolter Bulb (%) and Yield (t/ha). Letters denote differences. Vertical bars indicate standard error of means. T₁: no weeding (check); T₂: weed free; T₃: 1HW at 45 DAT; T₄: 2HW at 25 & 45 DAT; T₅: 3HW at 25, 45 & 65 DAT; T₆: PE Pend. + 1HW at 45 DAT; T₇: PE Pend. + 2HW at 45 & 65 DAT; T₈: POE Pend. at 25DAT+1HW at 65 DAT; T₉: PE Oxyf. + 1HW at 45 DAT; T₁₀: PE Oxyf. + 2HW at 45 & 65 DAT; T₁₁: POE Oxyf. at 25 DAT + 1HW at 65 DAT; T₁₂: PE Pend. + POE Oxyf. at 45 DAT + 1HW at 65 DAT and T₁₃: PE Oxyf. + POE Pend. at 45 DAT + 1HW at 65 DAT.

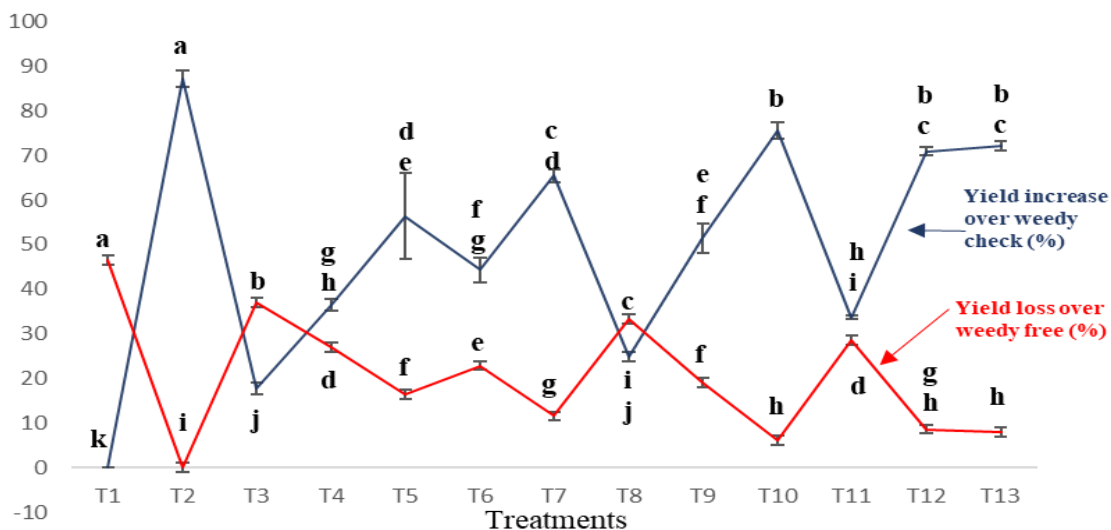


Figure 6. Effect of treatments on Yield loss over weed free (%) and Yield increase over weedy check (%). Letters denote differences. Vertical bars indicate standard error of means. T₁: no weeding (check); T₂: weed free; T₃: 1HW at 45 DAT; T₄: 2HW at 25 & 45 DAT; T₅: 3HW at 25, 45 & 65 DAT; T₆: PE Pend. + 1HW at 45 DAT; T₇: PE Pend. + 2HW at 45 & 65 DAT; T₈: POE Pend. at 25DAT+1HW at 65 DAT; T₉: PE Oxyf. + 1HW at 45 DAT; T₁₀: PE Oxyf. + 2HW at 45 & 65 DAT; T₁₁: POE Oxyf. at 25 DAT + 1HW at 65 DAT; T₁₂: PE Pend. + POE Oxyf. at 45 DAT + 1HW at 65 DAT and T₁₃: PE Oxyf. + POE Pend. at 45 DAT + 1HW at 65 DAT.

The thickest neck length was recorded from the treatment T₂ (1.13 cm) insignificantly followed by T₁₃ (1.09 cm), T₁₂ (1.07 cm), T₇ (1.04 cm) and T₁₀ (1.04 cm) but significantly followed by T₅ (0.97 cm). Moreover, the thinnest size of neck was observed from the treatment T₁ (0.80 cm) insignificantly followed by T₃ (0.84 cm), T₈ (0.85 cm), T₄ (0.91 cm), T₁₁ (0.91 cm), T₆ (0.92 cm) and T₉ (0.94 cm). The present finding concurs the finding of Kalhapure and Shete (2013), Vishnu et al. (2015), Kumar et al. (2014). They found that weed free plot or less weed density plot showed significantly highest neck length because there was less weed crop competition throughout crop growth period.

The treatment T₂ yielded the highest dry matter content (DMC) of leaves (13.22%). The highest value is not consistent with the values of T₁₃ (13.12%), T₁₂ (13.00%), T₁₀ (12.87%), T₈ (12.79%), T₇ (12.70%), T₅ (12.621%), T₉ (12.42%) but consistent with the value of T₆ (12.29%). The treatment T₁ gave the lowest DMC of leaves (10.85%) insignificantly followed by T₃ (11.35%) and significantly followed by T₈ (11.79%). Increased crop growth by all weed management treatments over weedy check might be due to providing comparatively favourable environment for crop growth, thus hastened the crop growth and ultimately the quality of produce (Gaharwar et al., 2017).

The diameter of bulb ranged from 3.01 to 4.18 cm under the trial of weed management practices. The greatest diameter of bulb was provided by the treatment T₂ (4.18 cm). Nonetheless, the T₂ was not significantly varied with the T₁₃ (4.13 cm), T₁₂ (4.09 cm), T₁₀ (4.08 cm), T₆ (4.0 cm), T₇ (3.98 cm), T₅ (3.91 cm), T₉ (3.83 cm) but significantly varied with the T₄ (3.74 cm). However, the smallest bulb diameter was registered from the T₁ (3.01 cm) insignificantly followed by T₃ (3.39 cm) but significantly followed by T₈ (3.49 cm). The reduced crop-weed competition provides proper development of crop growth characters (plant height, number of leaves per plant and dry matter accumulation), which enhanced the diameter of bulb (Patel et al., 2011). The weed free plot for the whole season (T₂) resulted in the heaviest bulb (30.31 g) insignificantly followed by T₁₃ (29.55 g), T₁₂ (28.40 g), T₁₀ (27.86 g). On the other hand, the T₁ caused to the lightest bulb (17.99 g) which was statistically differed with all other treatments.

Effect of weed management practices on the quality and yield of onion

There was a significant variation among the weed management practices on the characters of quality and yield of onion except total soluble solid content of bulb (Figures 4-6).

Total soluble solid content of bulb

Total soluble solid (TSS) content ranged from 14.01 to 15.82 °brix. The maximum TSS content was realized from the T₂ (15.82 °brix) which was statistically similar to the other treatments studied in the present experiment. However, the minimum TSS content was calculated from the T₁ (14.01 °brix) (Figure 4). The higher tendency of increasing total soluble solid content of bulb from all the weed management treatments over weedy check might happen due to same causes as mentioned in case of dry matter content of bulb.

Dry matter content of bulb

The T₂ attained the utmost DMC of bulb (17.70%) which was

statistically close the DMC of T₁₃ (17.67%), T₁₂ (17.41%), T₁₀ (17.26%), T₇ (16.71%), T₅ (16.49%), T₉ (16.42%) but distant to the T₆ (16.23%). Nonetheless, the least DMC of bulb was noticed from the T₁ (14.39%) insignificantly followed by T₃ (14.65%), T₈ (15.69%) but significantly followed by T₁₁ (16.10%) (Figure 4). The variation might be due to the effects as highlighted above in case of diameter of bulb. The increase in dry matter content by all the weed management treatments over weedy check was because of the fact that the weed population and weed growth remained low during the crop growth period, which markedly improved the dry matter content of bulb (Patel et al., 2011).

Bolter bulb

The topmost incidence of bolting was occurred in the treatment T₂ (9.28%) which was statically at par with the T₁₃ (8.44%), T₁₂ (8.31%) but unequal with T₅ (8.09%). The T₁₃ was statistically equal to the T₁₂, T₅, T₉ (7.81), T₆ (7.59%) but unequal to the T₄ (7.38%). The least incidence of bolting was counted in T₁ (4.05%) significantly followed by T₇ (6.00%) and T₈ (6.50%). The T₇, T₈, T₃ and T₁₀ were statistically similar with one another (Figure 5).

Fresh bulb yield

The weed free plot for whole season (T₂) gave rise to the highest fresh yield of onion bulb (19.49 t/ha) which was statistically similar to the yield of T₁₃ (19.31 t/ha), T₁₂ (19.18 t/ha), T₁₀ (18.95 t/ha), T₇ (17.56 t/ha) and T₅ (17.55 t/ha). Nevertheless, the un-weeded plot for whole season (T₁) produced the lowest fresh yield of onion bulb (9.22 t/ha) significantly followed by T₃ (13.21 t/ha) and T₈ (14.01 t/ha) (Figure 5).

Yield loss over weed free and yield increase over weedy check

The yield loss over weed free (%) and yield increase over weedy check (%) presented in the figure 6. The maximum yield loss (46.55%) over weed free plot (T₂) was recorded in un-weeded control plot (T₁) significantly followed by T₃ (37.07%), T₈ (33.25%). However, the minimum yield loss (8.00%) was obtained from T₁₃ insignificantly followed by T₁₂ (8.62%), T₁₀ (6.19%) but significantly followed by other treatments. Contrastingly, the highest yield increase (87.08%) over weedy control plot (T₁) was computed with the T₂ (weed free plot). The 2nd, 3rd and 4th highest yield increase were calculated from the T₁₀ (75.49%), T₁₃ (72.10%) and T₁₂ (70.94%). Additionally, the T₃ offered the lowest yield increase (17.73%) over un-weeded control plot insignificantly followed by T₈ (24.87%) and significantly followed by T₁₁ (33.69%). The lowest yield was recorded in weedy check plots owing to low chlorophyll content and photosynthetic rate due to un-checked weed growth there by reducing the availability of moisture, light and nutrients to the crop thus resulting in loss of yield. The maximum yield was recorded in weed free plot followed by other manual/herbicidal treatments due to the favorable environmental conditions created by the clean crop culture resulted in more absorption of solar radiation and plant nutrients which ultimately resulting in more photosynthetic rates and dry matter accumulation (Angmo et al., 2018). The similar results are also published by Khan et al. (2013).

Table 2. Effect of weed management practices on the economics of onion at SRSC, BARI, Faridpur during 2020-2021 (Tk./ha).

Treatments	A. Variable cost (Tk.)							Sub-total (A)
	Cost of land preparation (1 ha = 247 decimal @ 20.00/decimal)	Cost of seeds (price @ 2500.00/kg) (Seed rate: @ 6 kg/ha)	Cost of manures and fertilizers (@ Tk. 8.00, 16.00, 22.00, 15.00 and 7.00/kg of 3000 kg cowdung, 220 kg urea, 220 kg TSP, 150 kg MOP and 110 kg gypsum, respectively)	Cost of herbicides (Oxyflourfen: @ 1.00 l/ha & price- @ Tk. 175.00/25 ml, Pendimethalin: @ 2.00 l/ha & price-@ Tk. 438.00/500 ml)	Cost of plant protection (fungicide/insecticide) (LS)	Cost of labours (seedling raising, transplanting, spreading manure & fertilizers, spraying herbicides, irrigation, hand weeding, earthing up, harvesting, post harvest processing etc.)	Interest on investment @ 14% per year for 6 months	
T ₁	4940.00	15000.00	35380.00	00.00	15000.00	52000.00	8562.00	130882.00
T ₂	4940.00	15000.00	35380.00	00.00	15000.00	102000.00	12062.00	184382.00
T ₃	4940.00	15000.00	35380.00	00.00	15000.00	62000.00	9262.00	141582.00
T ₄	4940.00	15000.00	35380.00	00.00	15000.00	72000.00	9962.00	152282.00
T ₅	4940.00	15000.00	35380.00	00.00	15000.00	82000.00	10662.00	162982.00
T ₆	4940.00	15000.00	35380.00	1752.00	15000.00	62000.00	9385.00	143457.00
T ₇	4940.00	15000.00	35380.00	1752.00	15000.00	72000.00	10085.00	154157.00
T ₈	4940.00	15000.00	35380.00	1752.00	15000.00	62000.00	9385.00	143457.00
T ₉	4940.00	15000.00	35380.00	7000.00	15000.00	62000.00	9752.00	149072.00
T ₁₀	4940.00	15000.00	35380.00	7000.00	15000.00	72000.00	10452.00	159772.00
T ₁₁	4940.00	15000.00	35380.00	7000.00	15000.00	62000.00	9752.00	149072.00
T ₁₂	4940.00	15000.00	35380.00	8752.00	15000.00	62000.00	9875.00	150947.00
T ₁₃	4940.00	15000.00	35380.00	8752.00	15000.00	62000.00	9875.00	150947.00

T₁: no weeding (check); T₂: weed free; T₃: 1HW at 45 DAT; T₄: 2HW at 25 & 45 DAT; T₅: 3HW at 25, 45 & 65 DAT; T₆: PE Pend. + 1HW at 45 DAT; T₇: PE Pend. + 2HW at 45 & 65 DAT; T₈: POE Pend. at 65 DAT; T₉: PE Oxyf. + 1HW at 45 DAT; T₁₀: PE Oxyf. + 2HW at 45 & 65 DAT; T₁₁: POE Oxyf. at 25 DAT + 1HW at 45 & 65 DAT; T₁₂: PE Pend. + POE Oxyf. at 45 DAT + 1HW at 65 DAT and T₁₃: PE Oxyf. + POE Pend. at 45 DAT + 1HW at 65 DAT.

Table 2. Contd

Treatment	B. Fixed cost (Tk.)			Total cost (A + B) = C	Gross return (D)	Net return (D - C)	Gross margin (D-A)	Benefit-cost ratio (D/C)
	Land rent (1 ha = 7.5 bigha @ 6000.00 /bigha/year)	Land management charge for 6 months (LS)	Sub-total (B)					
T ₁	22500	2500	25000	155882.00	184466.67	28584.67	53584.67	1.18
T ₂	22500	2500	25000	209382.00	389800.00	180418.00	205418.00	1.86
T ₃	22500	2500	25000	166582.00	264200.00	97618.00	122618.00	1.59
T ₄	22500	2500	25000	177282.00	306200.00	128918.00	153918.00	1.73
T ₅	22500	2500	25000	187982.00	351000.00	163018.00	188018.00	1.87
T ₆	22500	2500	25000	168457.00	323800.00	155343.00	180343.00	1.92
T ₇	22500	2500	25000	179157.00	351200.00	172043.00	197043.00	1.96
T ₈	22500	2500	25000	168457.00	280200.00	111743.00	136743.00	1.66
T ₉	22500	2500	25000	174072.00	339800.00	165728.00	190728.00	1.95
T ₁₀	22500	2500	25000	184772.00	379000.00	194228.00	219228.00	2.05
T ₁₁	22500	2500	25000	174072.00	300000.00	125928.00	150928.00	1.72
T ₁₂	22500	2500	25000	175947.00	383600.00	207653.00	232653.00	2.18
T ₁₃	22500	2500	25000	175947.00	386200.00	210253.00	235253.00	2.19

T₁: no weeding (check); T₂: weed free; T₃: 1HW at 45 DAT; T₄: 2HW at 25 & 45 DAT; T₅: 3HW at 25, 45 & 65 DAT; T₆: PE Pend. + 1HW at 45 DAT; T₇: PE Pend. + 2HW at 45 & 65 DAT; T₈: POE Pend. at 25DAT+1HW at 65 DAT; T₉: PE Oxyf. + 1HW at 45 DAT; T₁₀: PE Oxyf. + 2HW at 45 & 65 DAT; T₁₁: POE Oxyf. at 25 DAT + 1HW at 65 DAT; T₁₂: PE Pend. + POE Oxyf. at 45 DAT + 1HW at 65 DAT and T₁₃: PE Oxyf. + POE Pend. at 45 DAT + 1HW at 65 DAT.

Effect of weed management practices on the economic analysis of onion

The economics of onion crops imposing different weed management practices were worked out in respect of the net return, the gross margin and finally the benefit-cost ratio (BCR), are shown in Table 2. The economic analysis data depicted that weed free plot for whole season (T₂) incurred the highest total cost of onion bulb production (Tk. 209382.00) followed (Tk. 187982.00) by growing onion with thrice HW at 25, 45 & 65 DAT (T₅). The T₁ (un-weeded check plot) had the lowest total cost of production (Tk. 155882.00). The maximum gross return was estimated from the T₂ (Tk. 389800.00) followed by T₁₃ (Tk. 386200.00), T₁₂ (Tk. 383600.00), T₁₀ (Tk. 379000.00). However, the minimum gross return was accounted from the T₁ (Tk. 184466.67) followed (Tk. 264200.00) by T₃ (once HW at 45 DAT). The highest net return (Tk. 210253.00) was calculated in the T₁₃ followed by T₁₂ (Tk. 207653.00), T₁₀ (Tk. 194228.00), T₇ (Tk. 172043.00). While, the least net return was scored in the T₁ (Tk. 28584.00) followed by T₃ (Tk. 97618.00). The treatment T₁₃ showed the topmost gross margin (Tk. 235253.00) closely followed by T₁₂ (Tk. 232653.00), T₁₀ (Tk. 219228.00). In contrast, the lowermost gross margin was noted from the T₁ (Tk. 53588.00) followed by T₃ (Tk. 122618.00). The highest benefit-cost ratio (BCR) was computed from the T₁₃ (12.19) closely followed by T₁₂ (2.18), T₁₀ (2.05), T₇ (1.96). On the other hand, the lowest BCR (1.18) was received from the T₁ and the 2nd lowest BCR was recorded from the T₃ (1.59). The maximum gross return from weed free plot by manual weeding was due to obtaining the highest yield from weed free plot. But the weed free plot did not give the maximum gross margin, net return and BCR due to higher and expensive labor consumption. Gupta *et al.* (2020) stated that though weeds were controlled more efficiently and bulb yield production was highest in weed free treatment but engaged more human labor and cost of cultivation was more resulted in lower benefit-cost ratio. The weedy check plot had the minimum gross return, gross margin, net return and BCR due to producing the least yield by the weedy check plot. The lowest total cost of production was also calculated from the weedy check plot which was due to no manual or chemical weed management practice in the weedy check plot. Weedy check plot and one hand weeding at 20 DAT recorded minus benefit-cost ratio due to poor yield as compared to cost of cultivation (Gaharwar *et al.*, 2017). The lowest BCR was also found with weedy check plot over rest of treatments due to lower bulb yield. The yield T₂, T₁₃, T₁₂, T₁₀ and T₇ was statistically similar with each other. On the other hand, monetary returns and BCR from T₁₃, T₁₂, T₁₀ and T₇ each were higher than those of T₂ due to involving lower number of labour. The maximum gross margin, net return and BCR under the integrated weed management practice (T₁₃ and T₁₂) are agree with findings of Patel *et al.* (2011).

Conclusion

- Pre-emergence application (PE) application of oxyflourfen or pendimethalin + post-emergence (POE) application of

oxyflourfen or pendimethalin at 45 DAT (days after transplanting) + once HW (hand weeding) at 65 DAT and also PE of oxyflourfen or pendimethalin + twice HW at 45 & 65 DAT exhibited good performance to control weeds in onion field.

- From the yield point of view, weed free plot with hand weeding for whole season produced the highest yield which was very closely followed by PE application of oxyflourfen or pendimethalin + POE application of oxyflourfen or pendimethalin at 45 DAT + once HW at 65 DAT and also PE spray of oxyflourfen or pendimethalin + two HW at 45 & 65 DAT.
- The weed free plot incurred the maximum total cost of onion production due to more and expensive human labors.
- The highest gross margin, net return and benefit-cost (B:C) ration were estimated from PE application of oxyflourfen 23.5 EC @ 235g a.i./litre or pendimethalin 33 EC @ 330g a.i./litre + POE application of oxyflourfen 23.5 EC @ 235g a.i./litre or pendimethalin 33 EC @ 330g a.i./litre at 45 DAT + once HW at 65 DAT.

From the economic point of view, integrated weed management practice with twice applications of oxyflourfen or pendimethalin as pre and post-emergence (45 DAT) + once HW at 65 DAT proved the best for growing onion over the other practices.

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