Impact of weed control practices on weed suppression and crop performance in boro rice

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ABSTRACT

Weed control is important to prevent yield loss and production costs, and to preserve quality grain. Therefore, a study was conducted during December 2016 to May 2017 to find out appropriate weed management practices in boro rice. Two boro rice varieties namely, BRRI dhan28 and BRRI dhan29 were included in the study. Twelve different combinations of herbicidal weed managements viz., No weeding, Amchlor 5G or Talon 52WP as pre-emergence, Supermix 18WP or Clean master 18WP as post-emergence, Amchlor 5G followed by Supermix 18WP or Clean master 18WP, Talon 52WP followed by Clean master 18WP or Supermix 18WP, Amchlor 5G + Supermix 18WP + Hand weeding at 35 DAT, Talon 52WP + Clean master 18WP + Hand weeding at 42 DAT, and Two hand weeding were included in this experiment following single factor randomized complete block design with three replications. The maximum weed density (74.0 m⁻² in BRRI dhan28 and 65.0 m⁻² in BRRI dhan29) and biomass (38.2 g m⁻² in BRRI dhan28 and 31.25 g m⁻² in BRRI dhan29) were found in no weeding treatment and that of the lowest was obtained from Talon 52WP + Clean master 18WP + one hand weeding at 42 DAT. The highest grain yield (5.5 t ha⁻¹ in BRRI dhan28 and 6.23 t ha⁻¹ in BRRI dhan29), net return (58050 Tk ha⁻¹ in BRRI dhan28 and 61229 Tk ha⁻¹ in BRRI dhan29) were recorded when Talon 52WP + Clean master 18WP + one hand weeding and that of the lowest was obtained from the unweeded plots of both varieties. Based on this results Talon 52WP + Clean master 18WP + one hand weeding at 42 DAT was the best weed management practice in terms of efficacy and economics for both boro rice varieties.

Keywords: Weed management, herbicide, Importance Value, net return, Benefit Cost Ratio

1 Introduction

Economic losses in agricultural production due to weed are of utmost importance in modern day input intensive agricultural systems. Globally, the highest potential loss (approximately 34%) produced by weed in comparison to animal pests (18%) and pathogens (16%) (Oerke, 2005). In rice, about 40-60% average yield loss because of weed competition was estimated and it may increase up to 94-96% under season long weedy condition (Chauhan and Johnson, 2011; Ramana et al., 2007; Islam et al., 2017). However, the degree of yield reduction resulting from crop-weed competition varies from country to country. In China, every year about 10 million tons of rice is lost owing to weed infestation (Zhang, 2003). And, in Sri Lanka, the estimated yield reduction in rice due to weeds was around 30-40% (Abeysekera, 2001). On the other side, it was reported that in Bangladesh, weeds decrease the grain yield by 70-80%, 30-40% and 22-36% in aus, transplanted aman and modern boro rice, respectively (BRRI, 2008). The climatic as well as the edaphic condition of these countries are congenial for vigorous growth of many noxious weeds and it provides a severe competition with rice crop. Ashiq
and Aslam (2014) reported that weeds compete with crop for different growth promoting resources such as light, air, water, space as well as nutrients and adversely affect the crop growth, grain yield and quality as well. Therefore, weed management is very crucial for increasing the rice yield.

Now a days, herbicidal weed control is gaining popularity in Bangladesh because of its miraculous results such as rapid effect on weed, easier to application and more cost effective compared to commonly used conventional methods of weed control. As stated by Anwar et al. (2012), weed management using herbicide has considered as the smartest and most viable alternative in large-scale farming due to the unavailability and rising wages of labor. It motivates the farmers more on using herbicides to manage the weeds effectively. But from sustainability point of view the single use of chemical method is not feasible. Repeated application of herbicides for a long time is very congenial for producing herbicide resistant weed species and causes shifting of weed flora (Chauhan and Opeña, 2013). So, this problem can be minimized by combining hand weeding with herbicide or combination of different pre-emergence or post-emergence herbicides to enhance their efficacy (Dhakal et al., 2019; Popy et al., 2017). In addition, the maximum weed biomass reduction and maximum yield increase were observed with the successive application of pre-emergence herbicide (pendimethalin) and post-emergence herbicide (bispyribac-sodium bazzimsulfuron) (Singh et al., 2016). However, efficiency of an herbicide is mostly determined by their ability to develop the desired effects on the target pests. While, it is expected for herbicides to kill weeds but not expected for them to sustain and retard the subsequent growth and development of crop. Besides, the suitability of an herbicide not only determined by its efficacy but also determined by its cost effectiveness. The application time as well as appropriate management of herbicide should be considered before selecting herbicide. Moreover, integration of herbicides along with other weed control practices is the fundamental requirement of Integrated Weed Management (IWM) strategies. Hence, the study was conducted with a view to evaluate the weed control efficiency as well as the cost-effectiveness of different herbicidal weed management practices in *boro* rice varieties.

2 Materials and Methods

2.1 Experimental site and soil

The study was carried out at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh (24°43′9″N, 90°25′43.8″E) during the period from December 2016 to May 2017. The monthly average maximum and minimum temperature, and relative humidity were 23.5–35.1 °C, 12.3–23.0 °C and 75.3–86.2%, respectively, while monthly total precipitation and sunshine hours were 0-445.3 mm and 132.5-225.4 h, respectively.

2.2 Experimental treatment and design

This experiment included single factor. In this experiment 12 different combinations of herbicidal weed managements viz., No weeding (W0), Amchlor 5G as pre-emergence (W1), Talon 52WP as pre-emergence (W2), Supermix 18WP as post-emergence (W3), Clean master 18WP as post-emergence (W4), Amchlor 5G + Supermix 18WP (W5), Amchlor 5G + Supermix 18WP + Hand weeding at 35 days after transplanting (DAT) (W6), Amchlor 5G + Clean master 18WP (W7), Talon 52WP + Clean master 18WP (W8), Talon 52WP + Supermix 18WP (W9), Talon 52WP + Clean master 18WP + Hand weeding at 42 DAT (W10), Two hand weeding at 21 and at 42 DAT (W11) were included as treatments. Two *boro* rice varieties such as, BRRI dhan28 and BRRI dhan29, were selected to observe the effect of abovementioned treatments. The experiment was laid out according to randomized complete block design with three replications. An overview about the herbicides used in this experiment is provided in Table 1.

2.3 Plant materials

BRRI dhan28 and BRRI dhan29, modern high yielding varieties of rice, were used as plant materials. These two varieties were released by the Bangladesh Rice Research Institute (BRRI) in 1994 and suggested to cultivate in *boro* season. The potential yield of BRRI dhan28 and BRRI dhan29 are 6.0 t ha$^{-1}$ and 7.5 t ha$^{-1}$, respectively (BRRI, 2016).

2.4 Agronomic management

Rice seeds were collected from Agronomy Field Laboratory, Bangladesh Agricultural University. The pregerminated seeds were sown in nursery bed on 9 December 2016 and seedlings were raised with proper care. The experiment was set up in puddled condition on 18 January 2017. Rice varieties were fertilized with 300, 100, 120, 110 and 10 kg ha$^{-1}$ urea, triple super phosphate, muriate of potash, gypsum and zinc sulphate, respectively (BRRI 2016). The entire amount of all fertilizers except urea was applied during the final land preparation. And, urea was applied in three equal installments following top dressing method at 15 days interval after transplanting. Seedlings were transplanted in the experimental plots as per lay out with two seedlings hill$^{-1}$ following 25 cm × 15 cm spacing. The experimental plots were irrigated for six times. BRRI dhan28 and BRRI dhan29 were harvested on 29 April and 18 May 2017, respectively.
2.5 Data collection and analysis

The weed species were collected from the experimental area at 45 DAT and weed density and dry weight were estimated. The dominant weed flora was determined based on the Importance Value ($IV$) which was calculated by following formula:

$$ IV = \frac{n}{N} \times 100 \quad (1) $$

where, $IV = \text{Importance Value}$ ($\%$), $n$ and $N$ designate number of an individual species in a community and total number of species in a community.

Weed control efficiency was measured based on weed dry weight and calculated using the formula developed by Sawant and Jadav (1985):

$$ WCE = \frac{DWC - DWT}{DWC} \times 100 \quad (2) $$

where, $WCE = \text{Weed control efficiency}$, $DWC = \text{Dry weight of weeds in weedy check}$, and $DWT = \text{Dry weight of weeds in each treatment}$.

Susceptibility of different weed species owing to different weed management practices were graded based on weed control efficiency as suggested by Mian and Gaffer (1968) (Table 2).

Five randomly selected hills (excluding border rows) from each plot were uprooted prior to harvest to record the data of yield contributing attributes. Besides, the harvested crops of central one square meter area from each plot were threshed manually to record yield data. The grains were properly cleaned after sun drying. Finally, the grain weight was adjusted to 14% moisture content ($MC$) by following formula:

$$ MC(\%) = \frac{W_F - W_O}{W_F} \times 100 \quad (3) $$

$$ Y_A = \frac{W_F \times (100 - \%MC)}{100 - 14} \times 100 \quad (4) $$

where, $MC(\%) = \text{Moisture content (} \%, W_F = \text{fresh weight (} g), W_O = \text{oven dry weight (} g),$ and $Y_A = \text{Adjusted yield at 14\% moisture content}$.

Analysis of variance (ANOVA) was done with the aid of computer package MSTAT-C. Duncan’s Multiple Range Test was used to compare the treatment means (Gomez and K, 1984). Cultivation cost was based on weed control efficiency scale as suggested by Mian and Gaffer (1968), moderately susceptible weeds were found in aforementioned pre-emergence followed by post-emergence herbicide performed better over two hand weeding and single application of herbicides.

3 Results

3.1 Weed infestation in rice field

Nineteen weed species belonging to nine families were found in the experimental field. Among 19 weed species, six were grasses, five were sedges and eight were broad leaves. Local, english, scientific and family names of the weeds that found in the experimental plots along their morphological type and life cycle have been shown in Table 3. Results showed that grasses, sedges and broad leaves constituted about 45.38%, 36.41% and 18.21% of total density, respectively at 45 DAT. Perennial and annual weeds constituted 57.89% and 42.11% of the weed population, respectively (data not shown). Based on importance value, the five most dominant weed species of the experimental plots were Echinochloa crus-galli (20.55%), Panicum repens (14.40%), Leersia hexandra (9.75%), Fimbristylos miliaea (8.54%) and Scirpus juncoides (8.12%). Whereas, the least dominant weed flora was sedge weed Cyperus difformis (0.57%) followed by sedge weed species Cyperus iria (1.02%) (Table 3).

3.2 Weed density and total dry weight

Weed management practices exerted significant impact on weed density and dry weight at 45 DAT (Table 4). The highest weed density (74.0 m$^{-2}$ in BRRI dhan28 and 65.0 m$^{-2}$ in BRRI dhan29) and dry weight (38.20 g m$^{-2}$ in BRRI dhan28 and 31.25 g m$^{-2}$ in BRRI dhan29) were found in control (no weeding). On the contrary, the lowest weed density (5.67 m$^{-2}$ in BRRI dhan28 and 6.20 m$^{-2}$ in BRRI dhan29) and dry weight (2.76 g m$^{-2}$ in BRRI dhan28 and 2.77 g m$^{-2}$ in BRRI dhan29) were found in Talon 52WP+Clean master 18WP along with hand weeding at 42 DAT (W10) followed by Amchlor 5G + Supermix 18WP along with hand weeding at 35 DAT(W6). For both rice varieties, application of pre-emergence followed by post-emergence herbicide performed better over two hand weeding and single application of herbicides.

3.3 Weed control efficiency

Weed control efficiency (%) of different weed control practices along with grades of weed control and degrees of weed susceptibility are presented in the Table 5. The results showed that pre–followed by post-emergence herbicide along with hand weeding, like Talon 52WP + Clean master18WP along with one hand weeding (W10) provided “excellent control” over weeds. Whereas, Amchlor 5G + Supermix 18WP along with a hand weeding (W6) showed “good control”. Treatments like Amchlor 5G + Supermix 18WP (W5), Amchlor 5G + Clean master18WP (W7), Talon 52WP + Clean master18WP (W8), Talon 52WP + Supermix 18WP (W9) and Two hand weeding (W11) produced “fair control”. According to weed control efficiency scale as suggested by Mian and Gaffer (1968), moderately susceptible weeds were found in aforementioned pre-emergence followed by post-emergence herbicidal treatments. On the other hand, one additional hand weeding with Talon 52WP + Clean master 18WP performed the best where weeds were very highly susceptible.
Table 1. Description of the herbicides used in the experiment

| Common name † | Trade name | Target weed | Dose | Mode of action |
|---------------|------------|-------------|------|---------------|
| Amchlor 5G    | Butachlor  | Selective for annual grasses, sedges and broadleaves | 25 kg ha$^{-1}$ | Pre-emergence |
| Talon 52WP    | Pretilachlor + Triasulfuron | Selective for annual and perennial grasses, sedges and broadleaves | 741 g ha$^{-1}$ | Pre-emergence |
| Supermix 18WP | Benzosulfuran methyl | Selective for shama, panikachu, and other annual sedges | 750 g ha$^{-1}$ | Post-emergence |
| Clean master 18WP | Acetachlor + Bensulfuron | Selective for grasses, sedges and broad leaf and | 500 g ha$^{-1}$ | Post-emergence |

† Require 4-6 cm standing water in the filed for these herbicides to work.

Table 2. Weed susceptibility grading based on weed control efficiency as suggested by Mian and Gaffer (1968)

| Degrees of weed susceptibility | Weed control efficiency | Grades of weed control |
|-------------------------------|------------------------|------------------------|
| Completely susceptible (CS)   | 100                    | Completely control (CC) |
| Very highly susceptible (VHS) | 90-99                  | Excellent control (EC)  |
| Highly susceptible (HS)       | 70-89                  | Good control (GC)       |
| Moderately susceptible (MS)   | 40-69                  | Fair control (FC)       |
| Poorly susceptible (PS)       | 20-39                  | Poor control (PC)       |
| Slightly susceptible (SS)     | 1-19                   | Slightly control (SC)   |
| Completely resistant (CR)     | 0                      | No control (NC)         |

Table 3. Infesting weed species found in the experimental plots of boro rice

| Sl. | Common name | English name         | Scientific name | Family    | Type † | IV (%) |
|-----|-------------|----------------------|-----------------|-----------|--------|--------|
| 1   | Shama       | Burnyard grass       | Echinochloa crusgalli | Poaceae   | G, A   | 20.55  |
| 2   | Khudeshama  | Echinochloa colonum  | Poaceae         | G, A      | 3.05   |
| 3   | Durba       | Cynodon dactylon     | Poaceae         | G, P      | 3.85   |
| 4   | Angta       | Panicum repens       | Poaceae         | G, P      | 14.4   |
| 5   | Areal       | Leersia hexandra     | Poaceae         | G, P      | 9.75   |
| 6   | Angulighash | Digitaria sanguinalis | Poaceae     | G, P      | 6.04   |
| 7   | Sobujnakful | Small flower umbrella | Cyperus diiformis | Cyperaceae | S, P | 0.57    |
| 8   | Joina       | Fimbristylis miliacea | Cyperaceae       | S, P      | 8.54   |
| 9   | Bara chucha | Cyperus iria         | Cyperaceae      | S, P      | 1.02   |
| 10  | Mutha       | Cyperus rotundus     | Cyperaceae      | S, P      | 1.79   |
| 11  | Chechra     | Scirpus juncoides    | Cyperaceae      | S, P      | 8.12   |
| 12  | Kochu       | Calocasia esculenta  | Araceae         | B, P      | 1.58   |
| 13  | Kanainala   | Cygnatis axillaris   | Commelinaceae   | B, A      | 1.70   |
| 14  | Monayna     | Commelina diffusa    | Commelinaceae   | B, A      | 2.01   |
| 15  | Kesuti      | Eclipta alba         | Compositae      | B, A      | 3.90   |
| 16  | Panilong    | Ludwigia hyssopfolia | Onagraceae      | B, A      | 2.03   |
| 17  | Amrulshak   | Oxalis corniculata   | Oxalidaceae     | B, A      | 3.43   |
| 18  | Panikochu   | Monochoria vaginalis | Pontederiaceae  | B, P      | 5.57   |
| 19  | Biskatali   | Polygonum hydropiper | Polygonaceae    | B, A      | 2.10   |

† Morphology (G = grass, S = sedge, B = Broadleaf) and life cycle (A = annual, P = perennial); IV = importance value.
Table 4. Influence of weed control practices on weed density and total dry weight in BRRI dhan28 and BRRI dhan29 plots

| Treatment | BRRI dhan28 | BRRI dhan29 | BRRI dhan29 | BRRI dhan29 |
|-----------|-------------|-------------|-------------|-------------|
|           | Weed density and dry weight at 45 DAT |           |
| Density (no. m$^{-2}$) | Dry weight (g m$^{-2}$) | Density (no. m$^{-2}$) | Dry weight (g m$^{-2}$) |
| W0        | 74.00a      | 38.20a      | 65.00a      | 31.25a      |
| W1        | 43.00c      | 26.33b      | 42.24bc     | 20.88bc     |
| W2        | 38.67d      | 24.22d      | 41.41c      | 19.58d      |
| W3        | 49.00b      | 24.97c      | 45.06b      | 21.50b      |
| W4        | 37.00d      | 23.15e      | 34.96d      | 19.83cd     |
| W5        | 25.33ef     | 14.37g      | 27.67f      | 14.02fg     |
| W6        | 9.33i       | 4.50j       | 11.33h      | 4.267i      |
| W7        | 23.67fg     | 13.53h      | 25.33f      | 13.29g      |
| W8        | 20.67gh     | 11.70i      | 16.43g      | 11.17h      |
| W9        | 27.67e      | 13.10h      | 28.67ef     | 15.40e      |
| W10       | 5.67j       | 2.76k       | 6.20i       | 2.77j       |
| W11       | 18.67h      | 16.47f      | 31.16e      | 14.83ef     |
| S$\bar{x}$ | 1.029      | 0.2049      | 1.138       | 0.4167      |
| Sig. lev. | **         | **          | **          | **          |
| CV (%)    | 5.74       | 2.03        | 6.3         | 4.59        |

Table 5. Weed control efficiency of different weed control practices in BRRI dhan28 and BRRI dhan29 fields

| Treatment | BRRI dhan28 | BRRI dhan29 | BRRI dhan29 |
|-----------|-------------|-------------|-------------|
|           | WCE (%)     | Grade       | Susceptibility | WCE (%)     | Grade       | Susceptibility |
| W0        | 0           | NC          | CR           | 0           | NC          | CR           |
| W1        | 31.07       | PC          | PS           | 33.18       | PC          | PS           |
| W2        | 36.60       | PC          | PS           | 37.34       | PC          | PS           |
| W3        | 34.63       | PC          | PS           | 31.20       | PC          | PS           |
| W4        | 39.00       | PC          | PS           | 36.54       | PC          | PS           |
| W5        | 62.38       | FC          | MS           | 55.14       | FC          | MS           |
| W6        | 88.22       | GC          | HS           | 86.34       | GC          | HS           |
| W7        | 64.58       | FC          | MS           | 57.47       | FC          | MS           |
| W8        | 69.00       | FC          | HS           | 64.26       | FC          | MS           |
| W9        | 65.71       | FC          | MS           | 50.72       | FC          | MS           |
| W10       | 92.77       | EC          | VHS          | 91.14       | EC          | VHS          |
| W11       | 56.88       | FC          | MS           | 52.54       | FC          | MS           |

WCE = weed control efficiency (%), Grade = grade of weed control, and Susceptibility = degree of weed susceptibility; No weeding (W0), Amchlor 5G as pre-emergence (W1), Talon 52WP as pre-emergence (W2), Supermix 18WP as post-emergence (W3), Clean master 18WP as pre-emergence (W4), Amchlor 5G + Supermix 18WP (W5), Amchlor 5G + Supermix 18WP + Hand weeding at 35 DAT (W6), Amchlor 5G + Clean master 18 WP (W7), Talon 52WP + Clean master 18WP (W8), Talon 52WP + Supermix 18WP (W9); Talon 52WP + Clean master 18WP + Hand weeding at 42 DAT (W10), two hand weeding at 21 and at 42 DAT (W11); CC= Complete control (100%), EC= Excellent control (90-99%), GC= Good control (70-89%), FC= Fair control (40-69%), PS= Poor control (20-39%), SC= Slightly control (1-19%), NC= No control (0%), CS = Completely susceptible (100%), VHS = Very highly susceptible (90-99%), HS = Highly susceptible (70-89%), MS = Moderately susceptible (40-69%), PS = Poorly susceptible (20-39%), SS = Slightly susceptible (1-19%), CR = Completely resistant (0%)
3.4 Yield contributing characters of rice

Significant influence of weed control practices was observed on the yield contributing characters and yield of BRRI dhan28 and BRRI dhan29 and shown in Table 6 and Table 7, respectively. In case of BRRI dhan28, the highest number of total tillers hill$^{-1}$ (17.67), effective tillers hill$^{-1}$ (15.33), number of grains panicle$^{-1}$ (93), 1000 grain weight (23.62 g), grain yield (5.5 t ha$^{-1}$), straw yield (5.87 t ha$^{-1}$) and biological yield (11.37 t ha$^{-1}$) were recorded in Talon 52WP + Clean master 18WP along with hand weeding at 42 DAT (W10) followed by Amchlor 5G + Supermix 18WP along with hand weeding at 35 DAT (W6) (Table 6). In BRRI dhan29, number of total tillers hill$^{-1}$ (19.10), effective tillers hill$^{-1}$ (15.33), number of grains panicle$^{-1}$ (96.75), 1000-grain weight (24.1 g), grain yield (6.23 t ha$^{-1}$), straw yield (6.73 t ha$^{-1}$) and biological yield (12.96 t ha$^{-1}$) were found maximum in Talon 52WP + Clean master 18WP along with hand weeding at 42 DAT (W10) followed by Amchlor 5G + Super mix 18WP along with hand weeding at 35 DAT (W6) (Table 7). Irrespective of rice varieties, treatments like pre-emergence herbicide followed by post-emergence herbicide and two hand weeding produced statistically similar number of effective tillers hill$^{-1}$ and 1000-grain weight. But, pre-emergence herbicide followed by post-emergence herbicide was statistically superior to two hand weeding in terms of producing number of grains panicle$^{-1}$, grain yield and straw yield. The lowest value of yield contributing parameters and yield was observed in unweeded condition.

3.5 Economics of the weed management regimes

The budget analysis of different weed management practices is provided in the Table 8. Partial budget analysis revealed that, the highest net income (58050 Tk ha$^{-1}$ in BRRI dhan28 and 61229 Tk ha$^{-1}$ in BRRI dhan29) and B:C ratio (1.81 in BRRI dhan28 and 1.86 in BRRI dhan29) were recorded in Talon 52WP + Clean master 18WP along with hand weeding at 42 DAT (W10). Whereas, Amchlor 5G + Supermix 18WP along with hand weeding at 35 DAT (W6) produced the second highest net return (56480 Tk ha$^{-1}$ in BRRI dhan28 and 58806 Tk ha$^{-1}$ in BRRI dhan29) as well as B:C ratio (1.78 in BRRI dhan28 and 1.82 in BRRI dhan29). Besides, higher net profit was also obtained from pre-emergence herbicide followed by post-emergence herbicide than two hand weeding (W11). The lowest profit was achieved from the control (W0) treatment.

4 Discussion

The present study showed that *Echinochloa crusgalli*, *Panicum repens*, *Leersia hexandra*, *Fimbristylis miliacea*, and *Scirpus juncoides* appeared as the most dominant weed species in the study area. *Echinochloa crusgalli* dominated weed species in rice were also reported by others (Afroz et al., 2019; Islam et al., 2018; Popy et al., 2017) at the same location. Weed competes with crop aggressively due to their high growth rate, high potential to acclimatize changing environment and more efficient seed production (Swanton et al., 2015). Most of the studies showed that crop-weed competition at early growth stage (from 15 to 45 DAS) had significant effect on yield of wet seeded rice (Moody, 1993; Ladu and Singh, 2006; Saneeetha et al., 2009). Generally, farmers practice 2-3 hand weeding to control weeds. But scarcity of labor during the peak period has currently become a serious problem led to delaying in weeding, which results in drastic yield reduction because of high crop-weed competition (Hasanuzzaman et al., 2009; Rashid et al., 2012). To prevail over this problem, researchers stand in using herbicides as potential weed control practice to reduce labor inputs (Ahmed et al., 2001). The weed seedbank in the soil acts as the prime source of weed infestations (Cavers, 1983). This phenomenon favors continuous emergence of weed throughout crop growing season and speed-up crop-weed competition. Mahajan and Chauhan (2015) reported that the time frame of pre-emergence herbicide application is very short and often, farmers fail to take the advantage of optimum time application. Hence, successive application of pre-emergence and post-emergence herbicides suppressed the early and late flushes of weeds more efficiently compared to sole application of herbicide (Mahajan and Chauhan, 2013). And, one additional hand weeding helps in the reduction of weed pressure throughout the critical period resulting the highest weed control efficiency (Dhakal et al., 2019).

In this experiment, Talon 52WP followed by post-emergence herbicide; Clean master 18WP along with hand weeding at 42 DAT revealed excellent weed control efficiency over Amchlor 5G followed by Supermix 18WP along with hand weeding at 35 DAT. This might be due to broad spectrum effect of Talon 18WP and Clean master 18WP on both annual and perennial grass, sedge and broadleaf at early stage of crop growth. This result is corroborated with that reported by other researchers (Lin, 2000; Banerjee et al., 2008; Saha and Rao, 2009; Ahmed and Chauhan, 2014). On the other hand, Amchlor 5G and Supermix 18WP are mostly selective to annual grasses, sedges and few broadleaves. The study also revealed that treatments like Amchlor 5G + Supermix 18WP, Amchlor 5G + Clean master 18WP, Talon 52WP + Clean master 18WP and Talon 52WP + Super mix 18WP showed higher weed control efficiency over two hand weeding treatment. While others reported the minimum weed pressure and the maximum weed control efficiency under two hand weeding treatment (Kumar et al., 2017; Rekha et al., 2002; Singh and Deo, 2004).
Table 6. Influence of weed control practices on yield contributing characters and yield of BRRI dhan28

| Treatment | Total tillers hill⁻¹ | Eff. tillers hill⁻¹ | Non-eff. tillers hill⁻¹ | Panicle length (cm) | Grains pan⁻¹ (no) |
|-----------|----------------------|--------------------|------------------------|---------------------|------------------|
| W0        | 12.67e               | 10.33 e            | 2.33abc               | 17.73c              | 72.67f           |
| W1        | 13.67 de             | 11.67 de           | 2.00bc                | 20.37 b             | 80.00e           |
| W2        | 14.00de              | 10.67e             | 3.33ab                | 21.49ab             | 80.00e           |
| W3        | 15.00cd              | 11.00de            | 4.00a                 | 21.51ab             | 81.67de          |
| W4        | 14.67cd              | 11.33de            | 3.33abc               | 21.48ab             | 82.33d           |
| W5        | 16.00bc              | 13.67bc            | 2.33abc               | 22.55a              | 85.00c           |
| W6        | 16.67ab              | 14.33ab            | 2.33abc               | 21.84ab             | 87.67b           |
| W7        | 15.67bc              | 13.33bc            | 2.33abc               | 22.85a              | 85.33c           |
| W8        | 16.33bc              | 13.33bc            | 3.00abc               | 22.11ab             | 87.00b           |
| W9        | 16.33bc              | 13.00bc            | 3.33ab                | 22.88a              | 85.67c           |
| W10       | 17.67a               | 15.33a             | 2.33abc               | 22.59a              | 93.00a           |
| W11       | 15.67bc              | 13.33bc            | 2.33abc               | 22.78a              | 81.00de          |
| S x       | 0.512                | 0.643              | 0.509                 | 0.579               | 0.649            |
| Sig. lev. | **                   | **                 | **                    | *                   | **               |
| CV (%)    | 5.77                 | 8.75               | 7.38                  | 4.63                | 4.35             |

| Treatment | WTS (g) | Grain yield (t ha⁻¹) | Straw yield (t ha⁻¹) | BY (t ha⁻¹) | HI (%) |
|-----------|---------|----------------------|----------------------|-------------|-------|
| W0        | 20.81c  | 3.17j                | 4.22h                | 7.40j       | 42.82e |
| W1        | 21.13c  | 3.55h                | 3.97i                | 7.52j       | 47.24c |
| W2        | 21.42c  | 3.76f                | 4.47g                | 8.23h       | 45.70d |
| W3        | 21.73bc | 3.32i                | 4.56g                | 7.87i       | 42.13e |
| W4        | 21.92bc | 3.66g                | 5.02e                | 8.67g       | 42.16e |
| W5        | 22.00bc | 4.70d                | 5.12e                | 9.82e       | 47.84bc|
| W6        | 22.23abc| 5.26b                | 5.62b                | 10.88b      | 48.36ab|
| W7        | 22.12abc| 4.78d                | 5.32d                | 10.10d      | 47.31c |
| W8        | 22.24abc| 5.20bc               | 5.45c                | 10.66c      | 48.86a |
| W9        | 22.20abc| 5.15c                | 5.37cd               | 10.52c      | 48.95a |
| W10       | 23.62a  | 5.50a                | 5.87a                | 11.37a      | 48.38ab|
| W11       | 23.04ab | 3.983e               | 4.85f                | 8.83f       | 45.11d |
| S x       | 0.464   | 0.0316               | 0.107                | 0.048       | 0.258  |
| Sig. lev. | *       | **                   | **                   | **          | *     |
| CV (%)    | 3.64    | 3.2                  | 2.27                 | 3.9         | 3.96  |

In column, figures with similar letter (s) do not differ significantly while figures with dissimilar letter differ significantly (according to DMRT), ** = Significant at 1% level of probability, * = Significant at 5% level of probability, CV = Co-efficient of variance; No weeding (W0), Amchlor 5G as pre-emergence (W1), Talon 52WP as pre-emergence (W2), Supermix 18WP as post-emergence (W3), Clean master 18 WP as post-emergence (W4), Amchlor 5G + Supermix 18WP (W5), Amchlor 5G + Supermix 18WP + Hand weeding at 35 DAT (W6), Amchlor 5G + Clean master 18WP (W7), Talon 52WP + Clean master 18WP (W8), Talon 52WP + Supermix 18WP (W9); Talon 52WP + Clean master 18WP + Hand weeding at 42 DAT (W10), two hand weeding at 21 and at 42 DAT (W11)
Table 7. Influence of weed control practices on yield contributing characters and yield of BRRI dhan29

| Treatment | Total tillers hill\(^{-1}\) | Eff. tillers hill\(^{-1}\) | Non-eff. hill\(^{-1}\) | Panicle length (cm) | Grains pan\(^{-1}\) (no) |
|-----------|-----------------|-----------------|-----------------|-------------------|-------------------|
| W0        | 13.47g          | 11.10g          | 2.370b          | 19.97ab           | 80.65g            |
| W1        | 14.13g          | 12.49f          | 2.647b          | 20.61b            | 84.24f            |
| W2        | 15.90f          | 12.47f          | 3.43a           | 22.19ab           | 85.11ef           |
| W3        | 15.80f          | 12.64f          | 3.46a           | 23.15a            | 86.32ef           |
| W4        | 15.83f          | 13.00ef         | 3.29a           | 20.66b            | 87.65de           |
| W5        | 16.53cde        | 13.10cde        | 3.43a           | 22.03ab           | 89.73cd           |
| W6        | 17.17b          | 13.87b          | 3.29a           | 21.89ab           | 92.38bc           |
| W7        | 16.74cde        | 13.39cde        | 3.35a           | 21.55ab           | 90.56cd           |
| W8        | 17.03c          | 13.74c          | 3.30a           | 21.88ab           | 91.76c            |
| W9        | 16.85cde        | 13.40cde        | 3.45a           | 20.58b            | 91.37c            |
| W10       | 19.10a          | 15.53a          | 3.56a           | 21.20b            | 96.75a            |
| W11       | 16.14cd         | 13.77cd         | 3.37a           | 21.95ab           | 90.02cd           |

\(\bar{S}\) \(x\) \(0.253\) \(0.245\) \(0.097\) \(0.537\) \(1.07\)

Sig. lev. ** ** ** * **

CV (%) 3.64 4.68 7.38 6.09 2.92 2.92

| Treatment | WTS (g) | Grain yield (t ha\(^{-1}\)) | Straw yield (t ha\(^{-1}\)) | BY (%) | HI (%) |
|-----------|---------|-----------------|-----------------|--------|-------|
| W0        | 20.12bc | 3.27h           | 4.31h           | 7.58i  | 43.14d |
| W1        | 21.12bc | 4.45g           | 5.04g           | 9.497h | 46.82bc|
| W2        | 21.37bc | 4.74f           | 5.40f           | 10.14gh| 46.64c |
| W3        | 21.68bc | 5.08e           | 5.43f           | 10.52fg| 48.47a |
| W4        | 21.76bc | 5.06e           | 5.73e           | 10.79f | 48.42a |
| W5        | 22.19ab | 5.43d           | 5.85e           | 11.31de| 48.27ab|
| W6        | 22.23ab | 5.92b           | 6.37bc          | 12.30abc| 48.18ab|
| W7        | 22.22ab | 5.54d           | 5.99de          | 11.54cde| 47.96bc|
| W8        | 22.20ab | 5.84c           | 6.17cd          | 12.02bcd| 48.63a |
| W9        | 22.21ab | 5.79c           | 6.02de          | 11.81bcd| 49.01a |
| W10       | 24.14a  | 6.23a           | 6.73a           | 12.96a | 48.11bc|
| W11       | 22.18ab | 4.25gh          | 4.54ab          | 8.79 gh | 48.02bc|

\(\bar{S}\) \(0.64\) 0.068 0.102 0.275 0.474

Sig. lev. * ** ** ** *

CV (%) 7.14 3.12 4.32 6.01 2.42 2.42

In column, figures with similar letter (s) do not differ significantly while figures with dissimilar letter differ significantly (according to DMRT), ** = Significant at 1% level of probability, * = Significant at 5% level of probability, CV = Co-efficient of variance; No weeding (W0), Amchlor 5G as pre-emergence (W1), Talon 52WP as pre-emergence (W2), Supermix 18 WP as post-emergence (W3), Clean master 18 WP as post-emergence (W4), Amchlor 5G + Supermix 18WP (W5), Amchlor 5G + Supermix 18WP + Hand weeding at 35 DAT (W6), Amchlor 5G + Clean master 18 WP (W7), Talon 52WP + Clean master 18 WP (W8), Talon 52WP + Supermix 18WP (W9), Talon 52WP + Clean master 18 WP + Hand weeding at 42 DAT (W10), two hand weeding at 21 and at 42 DAT (W11).
Table 8. Partial budget-analysis of different weed control practices (BDT ha$^{-1}$) in boro rice

| Treatment | Vc  | Hc  | Lc  | TC     | GI   | NR    | BCR  | GI   | NR    | BCR  |
|-----------|-----|-----|-----|--------|------|-------|------|------|-------|------|
| W0        | 55950 | 0  | 0   | 55950  | 64125| 8175  | 1.15 | 65253| 9303  | 1.17 |
| W1        | 55950 | 1125| 520 | 57955  | 73835| 16240 | 1.28 | 74853| 17258 | 1.3  |
| W2        | 55950 | 629 | 520 | 57099  | 75866| 18767 | 1.33 | 77030| 19931 | 1.35 |
| W3        | 55950 | 675 | 520 | 57145  | 72666| 15521 | 1.27 | 74440| 17295 | 1.3  |
| W4        | 55950 | 400 | 520 | 56870  | 73650| 16780 | 1.3  | 75257| 18387 | 1.32 |
| W5        | 55950 | 1800| 1040| 58790  | 99680| 40890 | 1.7  | 101117| 42327 | 1.72 |
| W6        | 55950 | 16100| 14300| 72050  | 127530| 56480 | 1.78 | 130856| 58806 | 1.82 |
| W7        | 55950 | 1525| 1040| 58515  | 104255| 44740 | 1.76 | 104533| 46018 | 1.79 |
| W8        | 55950 | 1029| 1040| 58019  | 99309| 41290 | 1.71 | 101141| 43122 | 1.74 |
| W9        | 55950 | 1374| 1040| 58364  | 101954| 43590 | 1.75 | 104239| 45875 | 1.79 |
| W10       | 55950 | 15329| 14300| 71250  | 129300| 58050 | 1.81 | 132479| 61229 | 1.86 |
| W11       | 55950 | 0   | 28600| 84550  | 127100| 42550 | 1.57 | 129904| 45354 | 1.54 |

Vc = variable cost, Hc = herbicide cost, Lc = labour cost, TC = total cost, GI = gross income, NR = net return, BCR = benefit-cost ratio; One man-day labourer was valued at 260 Tk; Amchlor 5G = 1125 Tk @ 45 Tk kg$^{-1}$, Talon 52WP = 629 Tk @ 85 Tk 100 g$^{-1}$, Supermix 18WP = 7385 Tk @ 90 Tk 100 g$^{-1}$, Clean master 18WP = 104255 Tk @ 80 Tk 100 g$^{-1}$; No weeding (W0), Amchlor 5G as pre-emergence (W1), Talon 52WP as pre-emergence (W2), Supermix 18WP as post-emergence (W3), Clean master 18WP as post-emergence (W4), Amchlor 5G + Supermix 18WP (W5), Amchlor 5G + Supermix 18WP + Hand weeding at 35 DAT (W6), Amchlor 5G + Clean master 18WP (W7), Talon 52WP + Clean master 18WP (W8), Talon 52WP + Supermix 18WP (W9); Talon 52WP + Clean master 18WP + Hand weeding at 42 DAT (W10), two hand weeding at 21 and at 42 DAT (W11).

The probable cause of the present finding was mimic nature of weed, which help them to escape at the early crop growth stage and compete with crop. Rao and Moody (1988) reported that identical growth of grasses like *Echinochloa crusgalli* and rice seedlings increases the difficulty of manual weeding. On the contrary, the highest weed pressure was observed in unweeded plots owing to unchecked growth of weeds, which provide unlimited competition to crop. The highest grain yield, biological yield were recorded in Talon 52WP + Clean master 18WP along with hand weeding at 42 DAT followed by Amchlor 5G + Supermix 18WP along with hand weeding at 35DAT. The possible reason of higher yield of rice was the effect of herbicides on weeds so rice plants received more water, air, light, space and nutrients for their optimum growth and development and this favored in developing higher number of yield contributing attributes. Moreover, the growing number of foliage might have promoted the photosynthesis owing to low crop-weed competition, which acts as source of higher yield under this treatment. Dhakal et al. (2019) also reported the similar result. Besides, economic study of different weed management practices revealed that the highest profit was obtained from Talon 52WP + Clean master 18WP along with hand weeding at 42 DAT. Moreover, Amchlor 5G + Supermix 18WP along with hand weeding at 35 DAT also produced higher profit over two hand weeding. This is due to less labor cost involvement compared to two hand weeding. Sathyamoorthy et al. (2004) and Parvez et al. (2013) also reported that herbicides (pre-emergence and post-emergence) with hand weeding would help to achieve the maximum crop yield with less efforts and cost. On the other hand, treatments like pre-emergence herbicide followed by post emergence herbicide (Amchlor 5G + Supermix 18WP, Amchlor 5G + Clean master 18WP, and Talon 52WP + Supermix 18WP) seemed to be more valuable than two hand weeding owing to its ability to control only a portion of the weed population at the earlier growth stage and minimum labor charge involvement.

5 Conclusions

The present study showed that Talon 52WP + Clean master 18WP + Hand weeding at 42 DAT, Amchlor 5G + Supermix 18WP along with hand weeding at 35 DAT, Amchlor 5G + Supermix 18WP, Amchlor 5G + Clean master 18WP, Talon 52WP + Clean master 18WP and Talon 52WP + Supermix 18WP were more remunerative than two hand weeding. Considering available resources such as labor, farmers’ can proceed with any one of the aforementioned herbicidal weed management practices. But based on the present findings Talon 52WP + Clean master 18WP + Hand weeding at 42 DAT appeared as the most promising practice regarding weed control and yield.
with the highest net profit and B:C ratio for BRRI dhan28 and BRRI dhan29. However, as herbicide application has been expanding quickly in Bangladesh, effects of repeated use of herbicide for a long time on soil health has become a burning issue and demand attention for subsequent investigation before arriving at any exact decision.

Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

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