EFFECT OF HERBICIDES DOSES AND DATES OF APPLICATION ON WEED, AND WEED INDICES IN WHEAT

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ABSTRACT

Weeds pose a serious threat to wheat productivity. A study was undertaken during the winter season of 2019/20 in the experimental field, of the National Agronomy Research Centre, NARC, Khumaltar to assess various doses and application dates for controlling mixed weed flora in wheat. The experiment was laid out in a Randomized Complete Block Design with ten treatments replicated thrice with net a plot size of 6 sq. m. The treatments included metribuzin @ 250 g/ha at 25 DAS and 45 DAS, metribuzin @ 500 g/ha at 25 DAS and 45 DAS, carfentrazone @ 20 g/ha and @ 40 g/ha at 25 DAS, metribuzin+carfentrazone (@ 250 g/ha+ @ 20 g/ha) at 25 DAS, metribuzin+carfentrazone (@ 500 g/ha + @ 40 g/ha) at 45 DAS, pendimethalin @ 1000 g/ha at 2 DAS and weedy check. Data regarding the weed density and weed biomass were recorded following the standard procedures. The result revealed pendimethalin @ 1000 g/ha applied at 2 DAS, metribuzin @ 250 g/ha applied at 25 DAS, and metribuzin+carfentrazone (@ 250 g/ha + @ 20 g/ha) applied at 25 DAS, respectively, 24 %, 33%, and 26% lower total weed density in comparison to the weedy check. The use of pendimethalin @ 1000 g/ha at 2 DAS showed the maximum herbicide efficiency index, 2.17%, closely followed by metribuzin @ 250 g/ha applied at 25 DAS (1.92%).

Key words : Density, efficiency indices, emergence, herbicides, metribuzin

INTRODUCTION

Wheat (*Triticum* spp.) is the most important grain crop both in regarding to its antiquity and its use as a source of human food. Wheat is the third most important cereal crop after rice and maize in Nepal. It is cultivated on 711,067 ha with a production of 2,127,276 tons (MoALD, 2021). Although wheat is the major food grain crop of Nepal, its yield is low. Weed infestation is one of the significant biotic factors limiting wheat production and productivity. The losses caused by weeds depend on their types, abundance, and environmental factor (Chhokar *et al.*, 2012). Wheat fields are generally infested with both grassy as well as broad leaf weeds and cause yield loss of 7 to 50 % depending upon the type of weed flora and their intensity (Singh *et al.*, 2004).

Again, weeds tend to shift with the change in tillage, agronomic management, and cropping system although other environmental and biotic factors govern the changes in the weed flora. Farmers are unaware of the herbicidal weed control method which offers an advantage to save labor and money. Information regarding the efficacy to arrest diverse weed flora in wheat is still scanty in the Nepalese context. The present research eventually helps in identifying the best ways of managing the diverse weed problem and evaluating the performance of herbicides.

MATERIALS AND METHODS

The experiment was carried out in the winter season of 2019-2020 at the National Agronomy Research Centre, Nepal Agriculture Research Council, Khumaltar, Lalitpur located at 27^0 39′ 24″ N latitude, 85^0 19′ 35″ E longitude. The soil, on which the experiment was carried out, was silty clay loam in texture having a pH of 5.98 with 2.01 organic C, 0.019% total nitrogen content, 478.6 kg/ha available phosphorous, and 160.5 kg/ha available potassium. The experiment was laid out in a randomized complete block design (RCBD) replicated thrice. Herbicidal treatments were randomly allotted to each replication. The size of each experimental plot was 3 m × 2 m. The treatments included metribuzin @ 250 g/ha at 25 DAS and 45 DAS, metribuzin @ 500 g/ha at 25 DAS and 45 DAS, carfentrazone @ 20 g/ha and 40 g/ha at 25 DAS, metribuzin+carfentrazone @ (250 g/ha + 20 g/ha) at 25 DAS, metribuzin+carfentrazone @ (500 g/ha + 40 g/ha) at 45 DAS, pendimethalin @ 1000 g/ha at 2 DAS and weedy check. The variety used in the experiment was Dhaulagiri, an irrigated, highly tillering variety for the mid-hill conditions of Nepal. Seeds were sown in lines 25 cm apart with a seed rate of 120 kg/ha. The field was fertilized using common inorganic fertilizer for improved wheat i.e. nitrogen, phosphorus, and potash @ 100:50:25 kg NPK/ha was applied through Urea (46%N), DAP (18% N and 46% P_2O_5), and MOP (60% K_2O). Herbicides were applied with the use of a knapsack sprayer fitted with a flat-fan nozzle and water as a carrier at 375 lit/ha for spray. A three nozzles boom with flat fan nozzle tip was used for spraying. For tank mix herbicides, herbicides were properly mixed in-stock solution prior to adding to the spray tank avoiding mixing the herbicides directly in a spray tank. Quadrates (1 m x 1 m) were established in each plot after pre-emergence applications, 1-2 days after seeding. Initial weed count was taken from quadrates before the application of early-post and post-emergence herbicides. For weed density and weed biomass at 2, 25, and 45 days after herbicide application, the count was taken from quadrates and weed biomass from random quadrates. Weeds were cut at ground level, washed with tap water, sun-dried, oven-dried at 72 ^{0}C for 48 hr, and then weighed. Weed control efficiency (WCE) was calculated based on weed biomass. Herbicides Efficiency Index (HEI), indicating the weed-killing potential of different herbicide treatments and their phyto-toxicity related to the crop, was calculated using the following formula (Krishnamurthy *et al.,* 1975).

$$\text{HEI} = \frac{(\text{Yield in the treated plot} - \text{Yield in the control plot})}{\text{Yield in control plot}} \times 100$$

Data on weed density and dry weight were subjected to log transformation to normalize the distribution. Mean separations for different treatments under different parameters were performed using Least Significance Difference (LSD). Statistical analysis was carried out using R-Studio software (version 4.2.0). Graphical analysis was done by using Minitab Software.

RESULTS AND DISCUSSION

Weed Flora

The weed flora of the experiment site was comprised of 16 weed species belonging to 10 families. Among 16 weed species, 2 were narrow-leaf weeds that belonged to the Poaceae family, and the rest of the 14 weed species fell under broad leaf weed categories (Table 1). The species-wise density of weeds recorded at various stages of crop growth revealed that the wheat crop was infested with grassy as well as non-grassy weeds. *Phalaris minor* was the important monocot weed, which remained throughout the growing season. *Chenopodium album* L., *Yongia japonica* L., *Capsella bursa-pastoris* L., *Fumaria parviflora* Wt & Ait., *Rumex nepalensis* L., *Polygonum hydropiper* L., *Bidens pilosa* L., *Capsella impatiens* L., *Ranunculus diffuses* DC., *Spergula arvensis* L., *Euphorbia hirta* L., *Polygonum aviculareae* L. and *Rorripa dubia* (Pers) Hara. were found in the experimental field.

Table 1. Description of weeds recorded in wheat field, Khumaltar, 2019/20

Scientific name	Local name	Common name	Family	Class	Habit
Phalaris minor Retz.	Raga	Canary grass	Poaceae	Monocot	Annual herb
Polypogon spp		Beard grass	Poaceae	Monocot	Annual herb
Chenopodium album L.	Bethe	White goosefoot	Amaranthaceae	Dicot	Annual dicot
Yongia japonica L.	Chaulaane	Oriental false hawks-beard	Asteraceae	Dicot	Annual dicot
Capsella bursa-pastoris L	Chamsuro	Lady Purse	Brassicaceae	Dicot	Annual flowering
Fumaria parviflora Wt & Ait	Jangali Gajar	Fumitory	Papavaraceae	Dicot	Annual dicot
Anagalis arvensis L.	Krishnanil	Red Chickweed	Primulaceae	Dicot	Annual flowering
Rumex nepalensis L.	Halhale	Toothed dock	Polygonaceae	Dicot	Annual herb
Polygonum hydropiper L.	Pire	Water pepper	Polygonaceae	Dicot	Annual herb
Bidens pilosa L.	Aakuro	Blackjack	Asteraceae	Dicot	Annual herb
Capsella impatiens L.	Gaathe-chamsuro	Pink Shepherds purse	Brassicaceae	Dicot	Annual herb
Ranunculus diffuses DC.	Naakuro	Buttercup	Rananculaceae	Dicot	Perennial herb
Spergula arvensis L.	Thangne	Corn Spurry	Caryophyllaceae	Dicot	Annual herb
Euphorbia hirta L.	Dudhe	Asthma plant	Euphorbiaceae	Dicot	Annual herb
Polygonum aviculareae L.		Common knotweed	Polygonaceae	Dicot	Annual herb
Rorripa dubia (Pers) Hara.	Mulajari	Yellow cress	Brassicaceae	Dicot	Annual herb

Effect of different herbicidal treatments on weed density and dry weight

Pre-emergence (2 DAS), early post-emergence (25 DAS) and post-emergence (45 DAS) application of pendimethalin, metribuzin and carfentrazone differed widely on their effect on density and dry weight of narrow and broad leaf compared to weedy check plot that was most severely infested with weeds. Metribuzin 500 g/ha at 25 DAS was found superior among others treatments to reduce narrow leaf weed density by 49% which was closely followed by metribuzin+ carfentrazone (250 g + 20 g) at 25 DAS and metribuzin 250 g at 25 DAS having 42% and 36% lower weed density as compared to weedy check plot (Table 2).

After the application of early post-emergence herbicides at 25 DAS, the lowest broad leaf weed density ($7/m^2$) was found in carfentrazone 20 g/ha at 25 DAS followed by carfentrazone 40 g/ha at 25 DAS with $12/m^2$ broad leaf weed density which was 61% and 51% lower than weedy check plot (Table 3). Under different herbicidal treatments higher broad leaf weed density was found in weedy check plot ($151/m^2$) which was statistically similar with the remaining non-treated plot at 40 DAS. Pendimethalin 1000 g/ha at 2 DAS recorded with 0.48 g/m^2 narrow leaf weed biomass which was 95% lower than weedy check as compared to their real value (Table 4). Before application of early post-emergence herbicidal treatments at 20 DAS, minimum broad leaf weed density ($1.9/m^2$) was recorded under carfentrazone 20 g/ha at 25 DAS which was statistically at par with carfentrazone 40 g/ha at 25 DAS which was found 88% and 67% lower dry weight as compared to weedy check plot (Table 5). After application of post emergence herbicides at 45 DAS, broad leaf weed dry weight (52.48 g/m^2) found in weedy check plot which was statistically at par with rest of the post-emergence herbicides applied at 45 DAS (Table 5). Pendimethalin 1000 g/ha at 2 DAS, metribuzin 250 g/ha at 25 DAS and metribuzin+carfentrazone (250 g/ha + 20 g/ha) at 25 DAS was found to have 24%, 33% and 26% lower total weed density than weedy check (Table 6). Total weed dry weight ranged from 3 g/m^2 to 41.7 g/m^2 and 13.5 g/m^2 to 87.1 g/m^2 at 45 DAS and 60 DAS.

Pendimethalin showed the dual character to controlling both grass and broad-leaf weed at the early stages of crop growth which drastically suppressed the density and dry weight of weed during the critical period of weed-crop competition. The earlier literature also reported the potential of pendimethalin in the management of mixed weed flora especially *P. minor* and improvement of the productivity of wheat (Yadav *et al.,* 1995; Yaduraju *et al.,* 2000; Chhokar and Sharma, 2008; Dhawan *et al.,* 2012).

Carfentrazone alone provided excellent control of broad-leaf weeds. This might be due to the fact that carfentrazone as contact and broad-spectrum herbicide is quite effective against common broad-leaf weeds as reported by Brar *et al.* (2005) and Punia *et al.* (2005). The weed population remaining in these treatments was large of narrow leaf weeds. Conversely, carfentrazone did not effect on grassy weeds while giving excellent control of broad-leaf weeds (Table 4). Mixtures of metribuzin and carfentrazone at 25 DAS were quite effective against both grass and broad-leaf weeds but the application of these combinations at 45 DAS had no advantage on control of mixed weed flora in wheat. It was noted that when metribuzin and carfentrazone herbicides were sprayed alone, the weed control ability was much lesser than their combination with carfentrazone. It was evident that early post-emergence application of metribuzin and carfentrazone combination at 25 DAS had a better narrow and broad-leaf killing ability as reflected from the value over carfentrazone. Naeem *et al.* (2003) also reported that all the herbicides decreased the weed population and significantly increased the yield and yield components as compared to the control. Population and dry matter accumulation of grassy and broad-leaf weeds were reduced drastically with the use of herbicides (Sharma *et al.,* 2018).

Table 2. Narrow-leaf weed density as influenced by herbicidal treatment in different stages

Treatment	Dose g/ha	Time of application	Weed density (no./m^2) Before spray	Weed density (no./m^2) After spray	Weed density (no./m^2) Before spray	Weed density (no./m^2) After spray
			20 DAS	40 DAS	45 DAS	60 DAS
Metribuzin	250	25 DAS	2.04(110)	1.30(20)^{cd}	1.34(21.88)^{c}	1.42(26.30)^{b}
Metribuzin	250	45 DAS	2.19(155)	2.19(159)^{a}	2.12(131.83)^{a}	2.08(120.23)^{a}
Metribuzin	500	25 DAS	1.89(79)	1.05(11)^{e}	1.18(15.14)^{c}	1.40(25.12)^{b}
Metribuzin	500	45 DAS	2.09(126)	2.10(126)^{ab}	2.16(144.54)^{a}	2.06(114.82)^{a}
Carfentrazone	20	25 DAS	1.99(99)	2.01(103)^{b}	1.99(97.72)^{ab}	1.98(95.50)^{a}
Carfentrazone	40	25 DAS	2.15(144)	2.15(141)^{ab}	2.14(138.04)^{a}	2.14(138)^{a}
Metribuzin + Carfentrazone	250+20	25 DAS	2.07(119)	1.19(15.48)^{de}	1.69(48.98)^{abc}	1.47(29.51)^{b}
Metribuzin + Carfentrazone	500+40	45 DAS	1.97(94)	2.01(105)^{b}	2.14(138.05)^{a}	2.08(120.23)^{a}
Pendimethalin	1000	3 DAS	0.72(5)	1.45(28)^{c}	1.47(29.51)^{bc}	1.51(32.36)^{b}
Weedy check	-	-	2.06(115)	2.06(114.8)^{ab}	2.04(109.65)^{ab}	2.06(114.82)^{a}

Figures in the parentheses are original values. Data subjected to log transformation; DAS- Days after sowing

Table 3. Broad-leaf weed density as influenced by herbicidal treatment in different stages

Treatment	Dose g/ha	Time of application	Weed density (no./m^2) Before spray	Weed density (no./m^2) After spray	Weed density (no./m^2) Before spray	Weed density (no./m^2) After spray
			20 DAS	40 DAS	45 DAS	60 DAS
Metribuzin	250	25 DAS	2.07(118)	1.53(33.8)^{b}	1.01(10.23)^{c}	1.02(10.5)^{de}
Metribuzin	250	45 DAS	2.08(121)	2.06(114.8)^{a}	1.87(74.13)^{a}	1.73(53.7)^{ab}
Metribuzin	500	25 DAS	2.03(109)	1.15(14)^{c}	1.00(10)^{c}	0.76(5.8)^{e}
Metribuzin	500	45 DAS	2.13(136)	2.12(133)^{a}	2.07(117.49)^{a}	1.93(85.1)^{a}
Carfentrazone	20	25 DAS	1.99(98)	0.83(7)^{d}	0.93(8.51)^{c}	0.90(7.9)^{de}
Carfentrazone	40	25 DAS	1.98(96)	1.06(12)^{c}	1.0511.2)^{c}	0.98(9.5)^{de}
Metribuzin+ Carfentrazone	250+20	25 DAS	2.09(126)	1.42(27)^{b}	1.06(11.4)^{c}	1.19(15.5)^{cd}
Metribuzin + Carfentrazone	500+40	45 DAS	2.02(106)	2.15(143)^{a}	2.06(114.8)^{a}	1.99(97.7)^{a}
Pendimethalin	1000	3 DAS	0.66(4.67)	1.51(33)^{b}	1.37(23.4)^{b}	1.43(26.9)^{bc}
Weedy check	-	-	2.15(141)	2.18(151)^{a}	2.11(128.8)^{a}	2.07(117.5)^{a}

Figures in the parentheses are original values. Data subjected to log transformation; DAS- Days after sowing

Table 4. Narrow-leaf weed biomass as influenced by herbicidal treatment in different stages

Treatment	Dose g/ha	Time of application	Weed dry weight (g/m^2) Before spray	Weed dry weight (g/m^2) After spray	Weed dry weight (g/m^2) Before spray	Weed dry weight (g/m^2) After spray
			20 DAS	40 DAS	45 DAS	60 DAS
Metribuzin	250	25 DAS	0.99(9.93)	0.30(2.03)^{cd}	0.64(4.37)^{cd}	1.08(12.02)^{bc}
Metribuzin	250	45 DAS	1.44(13.95)	1.20(15.93)^{ab}	1.43(26.92)^{a}	1.74(54.95)^{a}
Metribuzin	500	25 DAS	0.81(6.6)	0.08(1.20)^{e}	0.48(3.02)^{d}	1.06(11.48)^{c}
Metribuzin	500	45 DAS	1.05(11.3)	1.09(12.63)^{ab}	1.46(28.84)^{a}	1.72(52.48)^{a}
Carfentrazone	20	25 DAS	0.95(9.01)	1.01(10.4)^{ab}	1.12(13.18)^{abc}	1.2(15.85)^{bc}
Carfentrazone	40	25 DAS	1.13(13.68)	1.16(14.63)^{ab}	1.20(15.85)^{abc}	1.3(19.95)^{b}
Metribuzin + Carfentrazone	250+20	25 DAS	1.03(10.91)	0.19(1.54)^{de}	0.98(9.55)^{abcd}	1.13(13.49)^{bc}
Metribuzin + Carfentrazone	500+40	45 DAS	0.93(8.49)	0.99(9.77)^{b}	1.44(27.54)^{a}	1.74(54.95)^{a}
Pendimethalin	1000	3 DAS	0.31(0.48)	2.83(0.45)^{c}	0.77(5.89)^{bcd}	1.17(14.79)^{bc}
Weedy check	-	-	0.99(9.81)	11.5(1.05)^{ab}	1.34(21.88)^{ab}	1.72(52.48)^{a}

Figures in the parentheses are original values. Data subjected to log transformation; DAS- Days after sowing

Table 5. Broad-leaf weed biomass as influenced by herbicidal treatment in different stages

Treatment	Dose g/ha	Time of application	Weed dry weight (g/m^2) Before spray	Weed dry weight (g/m^2) After spray	Weed dry weight (g/m^2) Before spray	Weed dry weight (g/m^2) After spray
			20 DAS	40 DAS	45 DAS	60 DAS
Metribuzin	250	25 DAS	0.85(7.1)	1.43(31.46)^{bc}	0.54(3.5)^{b}	0.50(3.2)^{de}
Metribuzin	250	45 DAS	0.86(7.2)	1.97(97.33)^{ab}	1.04(10.9)^{a}	1.21(16.2)^{ab}
Metribuzin	500	25 DAS	0.81(6.6)	1.05(11.48)^{cd}	0.42(2.6)^{b}	0.24(1.7)^{e}
Metribuzin	500	45 DAS	0.90(7.99)	2.03(106.2)^{a}	1.24(17.4)^{a}	1.41(25.7)^{a}
Carfentrazone	20	25 DAS	0.81(6.49)	0.23(1.9)^{e}	0.54(3.4)^{b}	0.46(2.9)^{de}
Carfentrazone	40	25 DAS	0.92(8.42)	0.67(4.73)^{de}	0.39(2.5)^{b}	0.48(3.0)^{de}
Metribuzin + Carfentrazone	250+20	25 DAS	1.03(10.91)	1.32(21.3)^{c}	0.51(3.2)^{b}	0.67(4.9)^{cd}
Metribuzin + Carfentrazone	500+40	45 DAS	0.88(7.54)	2.05(114.7)^{a}	1.23(16.9)^{a}	1.46(28.8)^{a}
Pendimethalin	1000	3 DAS	0.55(0.28)	1.42(26.4)^{c}	0.54(3.4)^{b}	0.91(8.1)^{bc}
Weedy check	-	-	0.93(8.46)	2.08(121)^{ab}	1.29(19.5)^{ab}	1.55(35.5)^{a}

Figures in the parentheses are original values. Data subjected to log transformation; DAS- Days after sowing

Table 6. Total weed density and dry weight as influenced by various herbicides in wheat at different growth stages

Treatment	Dose g/ha	Time of application	Total weed density (no./m^2) Before spray 45 DAS	Total weed density (no./m^2) After spray 60 DAS	Total dry weight (g/m^2) Before spray 45 DAS	Total dry weight (g/m^2) After spray 60 DAS
Metribuzin	250	25 DAS	$1.52(33.1)^{e}$	$1.57(37.1)^{ef}$	$0.78(6)^{d}$	$1.19(15.5)^{cd}$
Metribuzin	250	45 DAS	$2.34(218.8)^{ab}$	$2.27(186.2)^{ab}$	$1.6(39.8)^{a}$	$1.88(75.8)^{a}$
Metribuzin	500	25 DAS	$1.18(15.1)^{f}$	$1.51(32.5)^{f}$	$0.48(3)^{e}$	$1.13(13.5)^{a}$
Metribuzin	500	45 DAS	$2.42(263)^{a}$	$2.30(199.5)^{ab}$	$1.67(46.7)^{a}$	$1.89(77.6)^{a}$
Carfentrazone	20	25 DAS	$2.03(107.1)^{c}$	$2.01(102.3)^{c}$	$1.22(16.6)^{b}$	$1.27(18.6)^{bcd}$
Carfentrazone	40	25 DAS	$2.18(151.36)^{bc}$	$2.17(147.9)^{bc}$	$1.26(18.2)^{b}$	$1.36(22.9)^{bc}$
Metribuzin+ Carfentrazone	250+20	25 DAS	$1.76(57.5)^{d}$	$1.75(56.2)^{de}$	$1.05(11.2)^{c}$	$1.35(22.4)^{bc}$
Metribuzin + Carfentrazone	500+40	45 DAS	$2.40(251.2)^{a}$	$2.34(218.8)^{ab}$	$1.65(44.6)^{a}$	$1.93(85.1)^{a}$
Pendimethalin	1000	3 DAS	$1.74(54.9)^{d}$	$1.79(61.6)^{d}$	$0.99(9.7)^{c}$	$1.38(23.9)^{b}$
Weedy check	-	-	$2.38(239.8)^{a}$	$2.37(234.4)^{a}$	$1.62(41.7)^{a}$	$1.94(87.1)^{a}$
Grand mean			1.99(139.21)	2.00(127.66)	1.23(23.78)	1.53(44.26)
LSD(0.05)			0.16	0.18	0.165	0.176
CV			4.78	5.24	7.82	6.71

Figures in the parentheses are original values. Data subjected to log transformation; DAS- Days after sowing. LSD-Least significant differences, CV- Co-efficient of Variation

Effect of Different Herbicidal Treatments on Weed Indices

Among the herbicidal treatments, the highest weed control efficiency 36.4% at 40 DAS and 60 DAS was achieved with metribuzin 250g/ha at 25 DAS whereas pendimethalin 1000 g/ha at 2 DAS recorded 24.2% at both 40 and 60 DAS (Fig. 1). Carfentrazone applied at early post-emergence stage noted with lower weed control efficiency 15.76% & 9.74% at 40 and 60 DAS, respectively (Fig. 1). Pendimethalin 1000 g/ha at 2 DAS recorded the maximum herbicide efficiency index (2.17%) closely followed by metribuzin 250 g/ha at 25 DAS (1.92%) (Fig. 2). As far as the herbicide efficiency was concerned, higher values were reflected with pre-emergence and early post-emergence application of herbicides compared to post-emergence application. It was reflected from the study that application of herbicides at the post-emergence stage in low-land winter wheat either sole or in the form of mixtures had a poor weed-controlling ability than the application of pendimethalin, metribuzin, and its combination with carfentrazone at pre-emergence and early post-emergence application respectively. Metribuzin 500 g/ha at 45 DAS was noted with higher weed control efficiency at 40 and 60 DAS but toxicity exhibited by metribuzin inhibits PSII on plants leading to a reduction in growth parameters though toxicity rankings were not observed in our experimentation. This finding is corroborated by the results of Kostopoulou *et al.,* 2020).

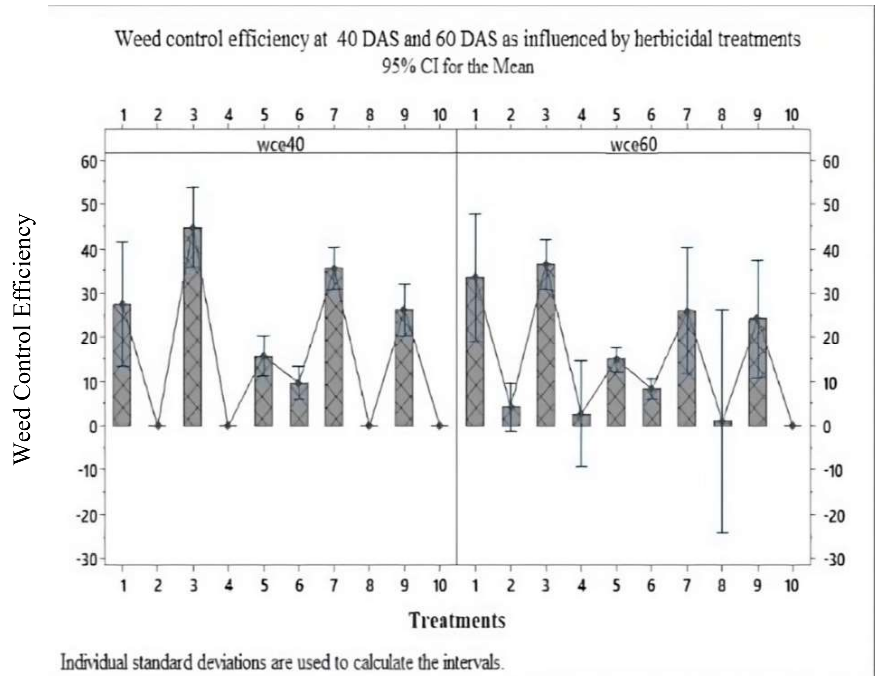

Fig. 1. Weed control efficiency influenced by herbicidal treatments at 40 DAS and 60 DAS.

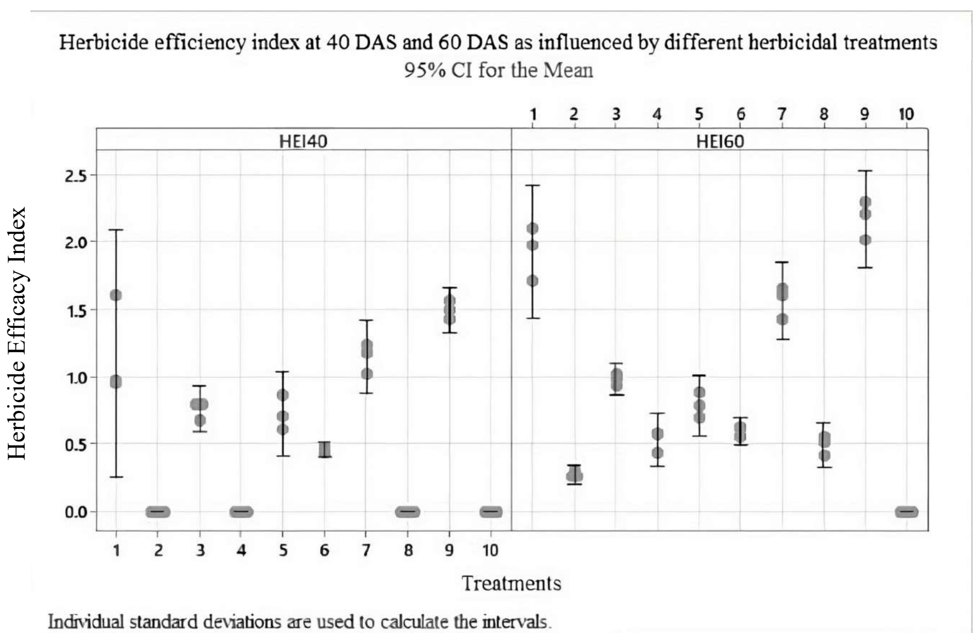

Fig. 2. Herbicide efficiency index influenced by herbicidal treatments at 40 DAS and 60 DAS.

CONCLUSIONS

Based on one season research experiment, it was concluded that among all the herbicides applied at various doses and times, the application of pendimethalin 1000 g/ha at 2 DAS was found most effective against mixed weed flora in wheat and it was also recorded with a lower weed density and dry matter accumulation at a critical period of crop-weed competition, higher herbicide efficiency index (2.17).

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