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RESEARCH PAPER

Weed dynamics and yield of wheat under stale seedbed technology with an additional tillage

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Key Message: In this study, the targeting weed seed bank was removed through stale seedbed formation in wheat after sowing, particularly early growing season (first 60 days). This will aid in reducing weeds infestation and improve yield attributes to enhance wheat productivity.

Abstract: A field study was undertaken to investigate the influence of stale seedbed on weed dynamics and yield performance of wheat at farm area, MNS-University of Agriculture Multan. Current study was carried out under RCBD with three replications. This experiment have eight treatments viz: one till + no herbicide, one till + glyphosate 48% SL at 711 a.i mL/ha, one till + paraquat 20% SL at 494 a.i mL/ha, one till + atlantis (mesosulfuron-methyl and iodosulfuron-methyl sodium) 6% WG at 15 a.i g/ha, one till + glyphosate at 48% SL 356 a.i mL/ha + paraquat 20% SL at 247 a.i mL/ha, one till + glyphosate 48% SL at 356 a.i mL/ha followed by atlantis 6% WG at 7.5 a.i g/ha, one till + paraquat 20% SL at 247 a.i mL/ha followed by atlantis 6% WG at 7.5 a.i g/ha, one till + glyphosate 48% SL at 237 a.i mL/ha + paraquat 20% SL at 165 a.i mL/ha followed by atlantis 6% WG at 5 a.i g/ha. *Cronopus didymus* and *Chenopodium album* density was maximum in one till + no herbicide while, minimum was observed in one till + glyphosate + paraquat followed by atlantis treatment at 45 DAS and 60 DAS, respectively. While maximum dry weight of weeds was recorded at harvest. Maximum thousand grain weight (31.88 g) and grain yield (4.65 tons/ha) were recorded in one till + glyphosate + paraquat followed by atlantis. It can be concluded that adoption of stale seedbed technology and post emergence application showed a check on weeds growth till 60 DAS to maximize the economical wheat yield. There is a need to explore weed management by combining chemical and mechanical weed control under stale seedbed, sole and in combination along with varying cropping systems under climate change scenario to reduce the reliance on herbicides.

Keywords: Wheat productivity, Weeds, Weed dynamics, Yield

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Introduction

Wheat is the most significant cereal crop covering an area of 8,740 thousand ha contributing 25.492 million tons towards food grain production with the grain yield 2,883 kg/ha during 2018-2019 (Government of Pakistan, 2019). Wheat covers 40% cultivated area of Pakistan that shows its importance in the country (Prikhodko & Zrilyi, 2013). Wheat crop contribution in gross domestic product in Pakistan is 0.8 percent and value addition in agriculture is 4.5 percent (Government of Pakistan, 2019).

In Pakistan, average wheat yield is 70% lower than average wheat yield obtained by the international grower due to several constraints (Aslam, 2016). Which included: poor management, pest and disease attack, natural hazards (hailstorm), lodging, non-judicious use of herbicides, non-judicious use of fertilizer, weed infestation, competition period and weeds allelopathic effects (Abbas et al., 2005; Mubeen et al., 2009; Mubeen et al., 2011; Aslam, 2016; The Express Tribune, 2019). Infestation of weed is one of the leading causes of low wheat productivity in Pakistan (Qureshi & Bhatti, 2001; Oad et al., 2007; Waheed et al., 2009; Usman et al., 2020). Weeds have potential to reduce yield up to 50% (Khan & Haq, 2002; Waheed et al., 2009; Fahad et al., 2015).

Various approaches have been used now a day to control the weed infestation (Kahramanoglu & Uygur, 2010). Traditionally farmers use various tactics (non-chemical) to control weeds, which included: crop rotation, cover crops, tillage, and stale seedbed etc. (Bond & Grundy, 2001; Abouziena & Haggag, 2016). In recent times herbicides are extensively used for weed control (Sindhu et al., 2010). Anyhow, unwise use of herbicides resulted in some environmental hazards, such as herbicide resistance in weeds, shifting of minor weed population from one area to another where suitable crops were sown (Heap, 2007; Sindhu et al., 2010). Weed management by using an integrated approach can provide environmentally safe and a long lasting weed control (Harker & O'Donovan, 2013). Integrated weed management (IWM) method uses herbicide as an additional technique alongside with other non-chemical techniques. Which clearly indicates IWM could not be achieved without adapting non-chemical weed control methods (Harker & O'Donovan, 2013; Bajwa et al., 2015). Prior to sowing, stale seedbed technology formation controlled narrow and broadleaved weeds density at early crop period (Sindhu et al., 2010). While perennials weed efficiently, control by pre-sown tillage operations is the most efficient strategy (Brandsaeter et al., 2017).

As weeds are the major contributor in reduction of wheat productivity and also deterioration of its quality. Being a staple food of many countries it is essential to enhance the productivity of wheat to ensure food security. This could be achieved by removal of weed seed banks through stale seedbed technology. No such studies have been undertaken in the past in the agro ecological system of wheat-cotton cropping system of south Punjab Pakistan. Hence, present work has been undertaken to investigate the influence of stale seedbed technique on the weeds dynamics and yield performance of wheat. The generated information will help in developing efficient weed control strategies that will help in the reduction of weed seed banks. The aim of this study was to evaluate weed dynamics under stale seedbed technology and to observe its effects on wheat productivity.

Materials and Methods

The research experiment was conducted at the farm area of MNS-University of Agriculture, Multan, Pakistan. The research area is located at 30˚ N latitude and 71˚ E longitude at an altitude of 122 m above the mean sea level in the arid tract of southern Punjab. Multan has an arid climate with cold days in winter and hot during summer. In summer, the temperature goes maximum 49 ºC, while in winter, it showed minimum 1 ºC (Majid et al., 2020). Stale seedbed was prepared on a field on which soybean crop was grown in the previous season. The experiment had eight treatments (Table 1).

Prior to sowing an additional tillage, paraquat and glyphosate were applied as pre-planting. Moreover, at 35 DAS Atlantis was applied as post-emergence treatments were applied according to plan. While making combinations of herbicides to be applied, respective doses of herbicides were reduced per unit area into two or three halves depending on the type of combination that is a mixture of two or three herbicides, respectively. Required amounts of water and herbicide were determined on the basis of gross plot area. Weedy plots remained infested with native weed population throughout the cropping season. All treatments were laid out RCBD with three replications. Wheat crop took 4 times irrigation during the whole growing season excluding rain outbreaks. Crop was sown during the first week of December, 2018. To provide the optimum nutrition for growth and developmental DAP for phosphorus (P), SOP for potassium (K) and urea for nitrogen (N) was used at 120: 80: 60 kg ha^{-1}, respectively. Weeds density and dry weight data were recorded at 30, 45, 60, 75, 90 days and at harvest stage of crop from each experimental unit. While, yield attributes were determined at the harvest stage of the crop. Observations on various yield attributes like productive tillers m^{-2}, spike length (cm), grains spike^{-1}, thousand grain weight were recorded at maturity. All agronomic parameters were recorded by using the randomly quadrate three times in each plot and then averaged. Grain and straw yield was recorded at harvest and biological yield was determined.

Table 1 List of different treatments used in this study

S. No.	Treatments	Herbicide dose (a.i.)
1	One till + no herbicide	-
2	One till + glyphosate 48% SL at	711 mL/ha
3	One till + paraquat 20% SL	494 mL/ha
4	One till + atlantis 6% WG	15 g/ha
5	One till + glyphosate at 48% SL mL/ha + paraquat 20% SL	356 mL/ha + 237 mL/ha
6	One till + glyphosate 48% SL followed by atlantis 6% WG	356 mL/ha + 7.5 g/ha
7	One till + paraquat 20% SL followed by atlantis 6% WG	247 mL/ha + 7.5 g/ha
8	One till + glyphosate 48% SL at + paraquat 20% SL followed by atlantis 6% WG	237 mL/ha + 165 mL/ha + 5 g/ha

Results

Cronopus didymus density (m^{-2})

Density of *Cronopus didymus* (Lesser swinecress) was recorded at different intervals during the whole season and data related to density of *C. didymus* are shown in Table 2. First data was recorded after 30 days of sowing. At 30 DAS, maximum *C. didymus* density (55.33 m^{-2}) was recorded in treatment where one till + no herbicide was employed. While minimum, in plots tilled once and applied paraquat to soil and the plots with one till + glyphosate soil applied, *C. didymus* density was 20 and 23.66 m^{-2}, respectively. *C. didymus* density of 40.00 m^{-2} was reported in treatment where one till + atlantis application was carried out, and in treatment having received one till + paraquat followed by atlantis, *C. didymus* population was 29.00 m^{-2}. Density of *C. didymus* was 26.66 m^{-2} in treatment one till + glyphosate + paraquat and treatment one till + glyphosate followed by atlantis. While in plots treated with one till + glyphosate + paraquat followed by Atlantis *C. didymus* density was 30.00 m^{-2}.

At 45 DAS, maximum density of *C. didymus* was 81.33 m^{-2} in plots receiving one till + no herbicide and it was followed by density of 65.33 m^{-2} in treatment one till + paraquat. *C. didymus* growth and development was maximum at that point of time and ground was covered by *C. didymus*. Whereas, minimum 13.33 m^{-2} was observed in treatment one till + paraquat followed by atlantis and it was followed by one till + atlantis and one till + glyphosate + paraquat followed by atlantis, *C. didymus* population of 14.66 and 16.33 m^{-2}, respectively. At 60 DAS, maximum *C. didymus* density was 43.66 m^{-2} in plots with one till + no herbicide and it was followed by density of 35.66 m^{-2} in one till + paraquat. *C. didymus* density was 33, 20.66 and 25.66 m^{-2} in plots receiving one till + glyphosate, one till + glyphosate + Paraquat and one till + glyphosate followed by atlantis, respectively. Plots treated with one till + atlantis showed minimum density 12 m^{-2} which was followed by the plots with one till + paraquat followed by atlantis and one till + glyphosate + paraquat followed by atlantis (13 and 14.33 m^{-2}), respectively.

Data collected after 75 DAS showed that *C. didymus* has completed its flowering and seed setting and density was also reduced. Minimum *C. didymus* density was 2.66 m^{-2} in the plots receiving one till + paraquat followed by atlantis and one till + glyphosate + paraquat followed by atlantis. Whereas, one till + no herbicide showed maximum *C. didymus* density of 40.66 m^{-2}. At harvest, minimum was observed in 1.66 m^{-2} in the plots applied with paraquat followed by atlantis and one till + glyphosate + paraquat followed by atlantis. While no herbicide treated plot showed maximum *C. didymus* density 22.33 m^{-2} at harvest. Significant reduction in *C. didymus* indicates its life cycle was almost completed in these days.

Table 2 *Cronopus didymus* density as affected by stale seedbed and weed control treatments at 30, 45, 60 and 75 DAS and at harvest in the wheat field

Treatments	30 DAS	45 DAS	60 DAS	75 DAS	At harvest
T_1	55.33^{a}	81.33^{a}	39.33^{a}	40.66^{a}	22.33^{a}
T_2	23.66^{de}	37.86^{c}	32.00^{ab}	21.66^{b}	20.66^{ab}
T_3	20.66^{e}	65.33^{b}	34.66^{ab}	17.66^{c}	14.33^{bc}
T_4	40.00^{b}	14.66^{d}	12.00^{c}	8.33^{d}	5.33^{d}
T_5	26.66^{cd}	32.66^{c}	28.00^{b}	5.33^{e}	2.66^{d}
T_6	26.66^{cd}	29.66^{c}	29.66^{ab}	15.00^{c}	7.66^{cd}
T_7	29.00^{c}	13.33^{d}	13.00^{c}	2.66^{e}	1.66^{d}
T_8	30.66^{c}	16.33^{d}	14.33^{c}	2.66^{e}	1.66^{d}
HSD-Tukey's value	4.72	12.50	11.15	2.84	6.74

T_1: one till + no herbicide, T_2: one till + glyphosate 48% SL at 711 mL a.i /ha, T_3: one till + paraquat 20% SL at 494 mL a.i /ha, T_4: one till + atlantis 6% WG at 15 g a.i /ha, T_5: one till + glyphosate at 48% SL 356 mL a.i /ha + paraquat 20% SL at 247 mL a.i /ha, T_6: one till + glyphosate 48% SL at 356 mL a.i /ha followed by atlantis 6% WG at 7.5 g a.i /ha, T_7: one till + paraquat 20% SL at 247 mL a.i /ha followed by atlantis 6% WG at 7.5 g a.i /ha, T_8: one till + glyphosate 48% SL at 237 mL a.i /ha + paraquat 20% SL at 165 mL a.i /ha Followed by atlantis 6% WG at 5 g a.i /ha. Means sharing same alphabets do not differ significantly by using the HSD test at alpha 0.05.

Cronopus didymus **dry weight (g m^{-2})**

C. didymus (Lesser swinecress) dry weight was determined on an interval basis and has been presented in Table 3. Data recorded at 30 DAS, dry weight of *C. didymus* in treatment one till + no herbicide was (6.33 g/m^2) while in treatment one till + glyphosate + paraquat recorded minimum (1.86 g/m^2) *C. didymus* dry weight. At 45 DAS, *C. didymus* dry weight was high as its growth and development was significantly increased during this period which resulted in increase in nutrient and other resources uptake by lesser swine cress. During this period, dry weight of *C. didymus* in treatment one till + no herbicide was (17.72 g/m^2) whereas, in treatment one till + glyphosate followed by atlantis showed minimum (4.29 g/m^2) dry weight of *C. didymus.* After 60 DAS of crop, *C. didymus* dry biomass was (18.33 g m^{-2}) in treatment one till + no herbicide while, the minimum (4.38 g/m^2) was in one till + glyphosate + paraquat followed by atlantis which was followed by one till + glyphosate followed by atlantis and one till + paraquat followed by atlantis (5.78 g/m^2) and (5 g/m^2), respectively. Similarly, maximum (20.21 g/m^2) dry weight 75 DAS in one till + no herbicide while minimum (5.37 g/m^2) observed in one till + glyphosate + paraquat followed by atlantis.

Data recorded at harvest of crop showed maximum dry weight of *C. didymus.* The growth and development of *C. didymus* was completed at this period as a result maximum biomass was produced. Maximum (40.21 g/m^2) was in one till + no herbicide while minimum (7.06 g/m^2) observed in one till + glyphosate + paraquat followed by atlantis which was followed by one till + paraquat followed by atlantis which produced (7.56 g/m^2) dry weight. Other treatments which included one till + glyphosate and one till+ paraquat produced (24.68 g/m^2) and (17.66 g/m^2) which is followed by one till + atlantis that contain 16.26 g/m^2 whereas, one till + glyphosate + paraquat and one till + glyphosate followed by atlantis produced (9.63 g/m^2) and (12.68 g/m^2), respectively.

Table 3 *Cronopus didymus* dry weight as affected by stale seedbed and weed control treatments at 30, 45, 60, 75 DAS and at harvest in the wheat field

Treatment	30 DAS	45 DAS	60 DAS	75 DAS	At Harvest
T_1	6.33^{a}	17.72^{a}	18.43^{a}	20.21^{a}	44.21^{a}
T_2	3.16^{bc}	14.40^{b}	13.61^{b}	16.99^{b}	24.68^{b}
T_3	2.92^{bc}	13.91^{b}	14.13^{b}	15.54^{b}	17.66^{c}
T_4	3.81^{b}	5.29^{c}	5.96^{c}	14.9^{b}	16.26^{c}
T_5	1.86^{d}	4.86^{c}	6.58^{c}	7.16^{c}	12.68^{d}
T_6	2.24^{cd}	4.29^{c}	5.78^{c}	6.85^{c}	9.63^{e}
T_7	2.08^{cd}	3.38^{c}	5.27^{c}	6.26^{c}	7.56^{ef}
T_8	2.07^{d}	2.59^{c}	4.78^{c}	5.37^{c}	7.06^{f}
HSD- Tukey's value	1.08	2.74	2.65	3.04	2.12

T_1: one till + no herbicide, T_2: one till + glyphosate 48% SL at 711 mL a.i /ha, T_3: one till + paraquat 20% SL at 494 mL a.i /ha, T_4: one till + atlantis 6% WG at 15 g a.i /ha, T_5: one till + glyphosate at 48% SL 356 mL a.i /ha + paraquat 20% SL at 247 mL a.i /ha' T_6: one till + glyphosate 48% SL at 356 mL a.i /ha followed by atlantis 6% WG at 7.5 g a.i /ha, T_7: one till + paraquat 20% SL at 247 mL a.i /ha followed by atlantis 6% WG at 7.5 g a.i /ha, T_8: one till + glyphosate 48% SL at 237 mL a.i /ha + paraquat 20% SL at 165 mL a.i /ha Followed by atlantis 6% WG at 5 g a.i /ha. Means sharing same alphabets do not differ significantly by using the HSD test at alpha 0.05.

Chenopodium album density (m^{-2})

Chenopodium album (lamb's quarters) density was recorded at various intervals during the whole season and data regarding the density of *C. album* can be seen in Table 4. First data was recorded after 30 DAS at this point maximum (6.33 m^{-2}) *C. album* density was recorded in treatment one till + no herbicide which was followed by one till + atlantis which produced (5.66 m^{-2}). As *C. album* was at an early stage of its growth and development. While, minimum density was in treatments one till + glyphosate, one till + paraquat and one till + glyphosate followed by Atlantis density was (0.66 m^{-2}). *C. album* density of (1), (1.33) and (1.66) meter^{-2} was reported in treatment one till + glyphosate + paraquat and treatment one till + paraquat followed by atlantis and one till + glyphosate + paraquat followed by atlantis, respectively. Data 45 DAS showed an increase in its density. Density of *C. album* was maximum (7.33 m^{-2}) in one till + no herbicide whereas, minimum (0.33 m^{-2}) was observed in treatment one till + glyphosate + paraquat followed by atlantis and it was followed by one till + paraquat followed by atlantis which showed (0.66 m^{-2}) *C. album* density. Data recorded at 60 DAS showed the highest density of *C. album*. As *C. album* found favorable conditions for growth and development its density maximized at this period of time. At that period maximum *C. album* density was (8.33 m^{-2}) in one till + no herbicide whereas, minimum in one till + paraquat followed by atlantis whereas not a single plant was observed which was followed by one till + glyphosate + paraquat followed by atlantis where (0.33 m^{-2}) *C. album* was present. *C. album* density of (2.33), (2.0) and (2.33) m^{-2} was recorded in one till + glyphosate, one till + paraquat and one till + atlantis, respectively. Treatment one till + glyphosate + paraquat and one till + glyphosate followed by Atlantis showed (3 m^{-2}) plants of *C. album*. Data collected after 75 DAS showed decrease in *C. album* density. As *C. album* initiating is flowering and seed setting. Minimum *C. album* density was in the one till + paraquat followed by atlantis and one till + glyphosate + paraquat followed by atlantis where, not a single plant of *C. album* was observed. Whereas, one till + no herbicide showed maximum *C. album* density of (4.66 m^{-2}). At harvest *C. album* almost negligible density was observed in treated plots, minimum was observed one till + paraquat followed by atlantis and one till + glyphosate + paraquat followed by atlantis. While in untreated one till + no herbicide plot showed maximum *C. album* density (3.66 m^{-2}) at harvest.

Table 4 *Chenopodium album* density as affected by stale seedbed and weed control treatments at 30, 45, 60, 75 DAS and at harvest in the wheat field

Treatments	30 DAS	45 DAS	60 DAS	75 DAS	At Harvest
T_1	6.3^{a}	7.33^{a}	8.33^{a}	4.66^{a}	3.66^{a}
T_2	1.00^{b}	3.00^{b}	2.33^{bc}	2.00^{b}	1.33^{b}
T_3	1.00^{b}	2.33^{bc}	2.66^{bc}	4.00^{a}	1.00^{b}
T_4	5.66^{a}	1.66^{bcd}	1.33^{cd}	1.00^{c}	1.00^{b}
T_5	1.00^{b}	2.66^{b}	3.00^{b}	0.66^{c}	1.66^{b}
T_6	1.00^{b}	3.00^{b}	3.00^{b}	1.00^{c}	1.00^{b}
T_7	1.33^{b}	0.66^{cd}	0.00^{d}	0.00^{d}	0.00^{c}
T_8	1.66^{b}	0.33^{d}	0.33^{d}	0.00^{d}	0.00^{c}
HSD- Tukey's value	1.96	1.92	1.45	0.86	0.91

T_1: one till + no herbicide, T_2: one till + glyphosate 48% SL at 711 mL a.i /ha, T_3: one till + paraquat 20% SL at 494 mL a.i /ha, T_4: one till + atlantis 6% WG at 15 g a.i /ha, T_5: one till + glyphosate at 48% SL 356 mL a.i /ha + paraquat 20% SL at 247 mL a.i /ha' T_6: one till + glyphosate 48% SL at 356 mL a.i /ha followed by atlantis 6% WG at 7.5 g a.i /ha, T_7: one till + paraquat 20% SL at 247 mL a.i /ha followed by atlantis 6% WG at 7.5 g a.i /ha, T_8: one till + glyphosate 48% SL at 237 mL a.i /ha + paraquat 20% SL at 165 mL a.i /ha Followed by atlantis 6% WG at 5 g a.i /ha. Means sharing same alphabets do not differ significantly by using the HSD test at alpha 0.05.

Chenopodium album dry weight (g/m^2)

Dry weight of *C. album* was recorded at predetermined intervals as presented in the Table 5. At 30 DAS, *C. album* as well as crop was on initial growth stages. Herbicide residues could have hindered the growth process of weeds at this crop stage. Data recorded at 30 DAS revealed maximum dry weight (2.20 g/m^2) of *C. album* in treatment one till + atlantis where, pre-planting herbicide application was not done which is followed by one till + no herbicide which produced (1.33 g/m^2). In treatment one till + glyphosate + paraquat *C. album* dry weight was (0.43 g/m^2) was minimum which was statistically at par with one till + glyphosate, one till + paraquat and one till + glyphosate followed by atlantis. Rest of pre-plant herbicide treated plots also showed low dry weight of *C. album*. After 45 DAS, *C. album* dry weight was increased as its growth and development was also increased. During this period, dry weight of *C. album* in treatment one till + no herbicide was (3.23 g/m^2) whereas in treatment one till + glyphosate + paraquat followed by atlantis showed minimum (0.16 g/m^2) which is followed by one till + paraquat followed by atlantis producing 0.39 g/m^2 dry weight of *C. album*. After 60 DAS of crop, *C. album* dry biomass was showed an increasing trend in treatment one till + no herbicide showed maximum dry matter (5.23 g/m^2) while the minimum was zero in one till + paraquat followed by atlantis where not a single *C. album* plant observed which was followed by one till + glyphosate + paraquat followed by atlantis which produced (0.16 g/m^2) dry biomass. Similarly, little increase in *C. album* dry weight was recorded after 75 DAS, maximum dry weight (5.84 g/m^2) was recorded in one till + no herbicide, while minimum was zero in one till + paraquat followed by atlantis and one till + glyphosate + paraquat followed by atlantis where no *C. album* density was observed. Obtained data at harvest of crop showed that *C. album* maximum dry weight. Growth and development of *C. album* was completed at this period as a result of this maximum biomass was produced. Maximum (6.53 g/m^2) was in one till + no herbicide while minimum zero observed in one till + paraquat followed by atlantis and one till + glyphosate + paraquat followed by atlantis. Other treatments which included one till + glyphosate and one till + paraquat) produced (4.51) and (3.20) g/m^2 which is followed by one till + atlantis that contain (2.81 g/m^2) whereas, one till + glyphosate + paraquat and one till + glyphosate followed by atlantis produced (2.90) and (3.22) g/m^2, respectively.

Table 5 *Chenopodium album* dry weight as affected by stale seedbed and weed control treatments at 30, 45, 60, 75 DAS and at harvest in the wheat field

Treatments	30 DAS	45 DAS	60 DAS	75 DAS	At Harvest
T_1	1.3^{ab}	3.23^{a}	5.23^{a}	5.84^{a}	6.53^{a}
T_2	0.65^{b}	1.78^{b}	1.60^{b}	4.5^{ab}	4.21^{b}
T_3	0.65^{b}	1.24^{b}	1.77^{b}	3.85^{b}	3.20^{c}
T_4	2.20^{a}	0.98^{b}	1.00^{bc}	2.13^{c}	2.81^{c}
T_5	0.43^{b}	1.54^{b}	1.74^{b}	1.16^{cd}	2.90^{c}
T_6	0.65^{b}	1.16^{b}	1.40^{b}	1.62^{c}	3.22^{c}
T_7	1.10^{ab}	0.39^{b}	0.00^{c}	0.00^{d}	0.00^{d}
T_8	0.81^{ab}	0.16^{b}	0.16^{c}	0.00^{d}	0.00^{d}
HSD- Tukey's value	1.53	1.67	1.23	1.44	0.88

T_1: one till + no herbicide, T_2: one till + glyphosate 48% SL at 711 mL a.i /ha, T_3: one till + paraquat 20% SL at 494 mL a.i /ha, T_4: one till + atlantis 6% WG at 15 g a.i /ha, T_5: one till + glyphosate at 48% SL 356 mL a.i /ha + paraquat 20% SL at 247 mL a.i /ha, T_6: one till + glyphosate 48% SL at 356 mL a.i /ha followed by atlantis 6% WG at 7.5 g a.i /ha, T_7: one till + paraquat 20% SL at 247 mL a.i /ha followed by atlantis 6% WG at 7.5 g a.i /ha, T_8: one till + glyphosate 48% SL at 237 mL a.i /ha + paraquat 20% SL at 165 mL a.i /ha Followed by atlantis 6% WG at 5 g a.i /ha. Means sharing same alphabets do not differ significantly by using the HSD test at alpha 0.05.

Yield parameters

Results related to tiller height showed that herbicide treated plots were statistically different from the one till + no herbicide treatment (Fig. 1). Statistically significant maximum tiller height was (99.20 cm) noticed in one till + glyphosate + paraquat followed by atlantis treatment. While one till + no herbicide showed minimum tiller height (86.46 cm). Tiller height (96.13 cm) was observed in treatment one till + atlantis. Treatment one till + paraquat showed tiller height (93.20 cm). While in plot, having one till + paraquat followed by atlantis resulted tiller height (92.33 cm) which was at par with treatment one till + glyphosate + paraquat that showed (92.26 cm). In treatment one till + glyphosate, tiller height (91.53 cm) was observed which was statistically similar with the tiller height (90.53 cm) in treatment one till + glyphosate followed by atlantis.

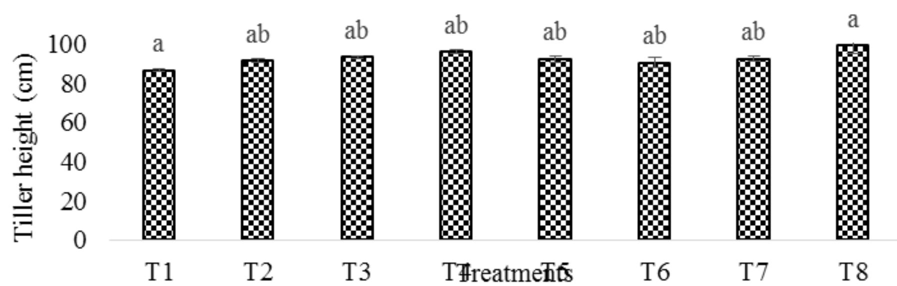

Fig. 1 Wheat tiller height (cm) as affected by stale seedbed and chemical weed control treaments. T_1: one till + no herbicide, T_2: one till + glyphosate 48% SL at 711 mL a.i./ha, T_3: one till + paraquat 20% SL at 494 mL a.i./ha, T_4: one till + atlantis 6% WG at 15 g a.i./ha, T_5: one till + glyphosate at 48% SL 356 mL a.i./ha + paraquat 20% SL at 247 mL a.i./ha, T_6: one till + glyphosate 48% SL at 356 mL a.i./ha followed by atlantis 6% WG at 7.5 g a.i./ha, T_7: one till + paraquat 20% SL at 247 mL a.i./ha followed by atlantis 6% WG at 7.5 g a.i./ha, T_8: one till + glyphosate 48% SL at 237 mL a.i./ha + paraquat 20% SL at 165 mL a.i./ha followed by atlantis 6% WG at 5 g a.i./ha. Means sharing same alphabets do not differ significantly by using the HSD test at alpha 0.05. HSD-Tukey's $_{0.05}$ = 12.91.

Statistically significant differences among untreated and treated herbicide treatment for productive tillers were shown in Fig. 2. Maximum (247) fertile tillers m^{-2} were observed in one till + glyphosate + paraquat followed by atlantis. Whereas, minimum (156.67) fertile tillers m^{-2} were observed in plot one till + no herbicide. Next maximum was observed in one till + paraquat followed atlantis and one till + glyphosate followed atlantis. In herbicide treated plot one till + atlantis, low tillers m^{-2} was recorded.

Statistically non-significant effect of stale seedbed formation and herbicide use on spike length was shown in Fig. 3. Maximum (17.30 cm) spike length was recorded in one till + glyphosate + paraquat followed by atlantis treatment where combined pre-planting and post-emergence herbicides was applied. Whereas, minimum (15.46 cm) spike length was observed in one till + no herbicide where not a single herbicide was applied.

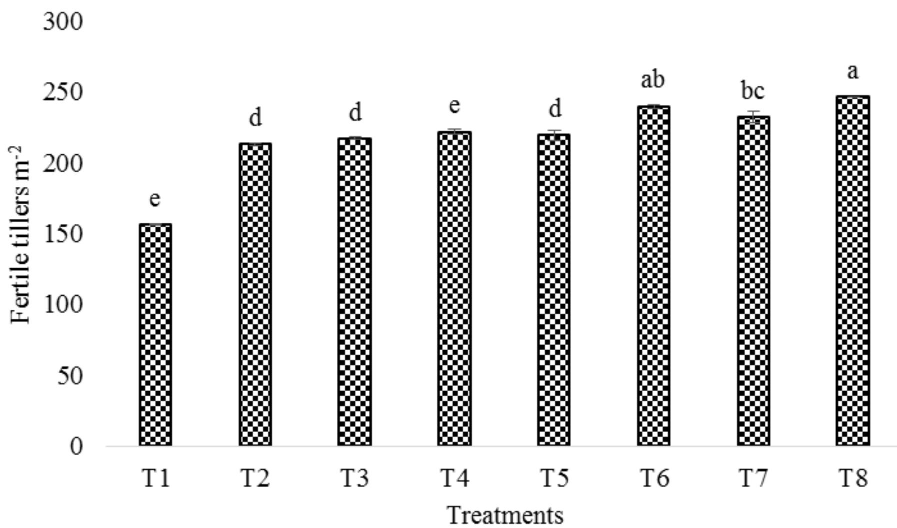

Fig. 2 Number of fertile tillers m^{-2} of wheat as affected by stale seedbed and chemical weed control treatments. T_1: one till + no herbicide, T_2: one till + glyphosate 48% SL at 711 mL a.i./ha, T_3: one till + paraquat 20% SL at 494 mL a.i./ha, T_4: one till + atlantis 6% WG at 15 g a.i./ha, T_5: one till + glyphosate at 48% SL 356 mL a.i./ha + paraquat 20% SL at 247 mL a.i./ha, T_6: one till + glyphosate 48% SL at 356 mL a.i./ha followed by atlantis 6% WG at 7.5 g a.i./ha, T_7: one till + paraquat 20% SL at 247 mL a.i./ha followed by atlantis 6% WG at 7.5 g a.i./ha, T_8: one till + glyphosate 48% SL at 237 mL a.i./ha + paraquat 20% SL at 165 mL a.i./ha followed by atlantis 6% WG at 5 g a.i./ha. Means sharing same alphabets do not differ significantly by using the HSD test at alpha 0.05. HSD-Tukey's $_{0.05}$ = 12.97.

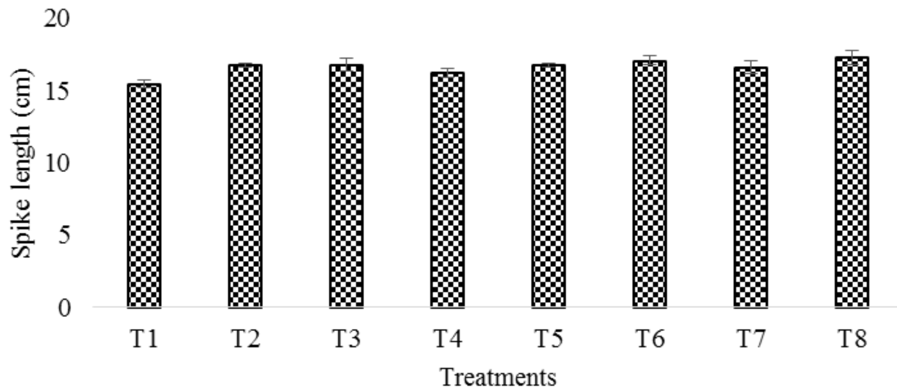

Fig. 3 Spike length (cm) of wheat as affected by stale seedbed and chemical weed control treatments. T_1: one till + no herbicide, T_2: one till + glyphosate 48% SL at 711 mL a.i./ha, T_3: one till + paraquat 20% SL at 494 mL a.i./ha, T_4: one till + atlantis 6% WG at 15 g a.i./ha, T_5: one till + glyphosate at 48% SL 356 mL a.i./ha + paraquat 20% SL at 247 mL a.i./ha, T_6: one till + glyphosate 48% SL at 356 mL a.i./ha followed by atlantis 6% WG at 7.5 g a.i./ha, T_7: one till + paraquat 20% SL at 247 mL a.i./ha followed by atlantis 6% WG at 7.5 g a.i./ha, T_8: one till + glyphosate 48% SL at 237 mL a.i./ha + paraquat 20% SL at 165 mL a.i./ha followed by atlantis 6% WG at 5 g a.i./ha. Means sharing same alphabets do not differ significantly by using the HSD test at alpha 0.05. HSD-Tukey's $_{0.05}$ = 2.12.

Data related to spikelet spike^{-1} was showed a non-significant difference among treated and untreated plots shown in Fig. 4. Maximum spikelet spike^{-1} (18) was observed in one till + glyphosate which is statistically similar with the treatment one till + paraquat, one till + atlantis and one till + glyphosate + paraquat followed by atlantis. Whereas, minimum (17) spikelet spike^{-1} was observed in one till + no herbicide. Treatment one till + glyphosate followed by atlantis showed (17.67) spikelet spike^{-1} which was at par with one till + paraquat followed by atlantis. Statistically non-significant difference observed for grains spike^{-1} shown in Fig. 5. Maximum grains spike^{-1} (53.67) were recorded in one till + glyphosate + paraquat followed by atlantis. Contrarily plot having one till + no herbicide showed minimum (50) grains spike^{-1}.

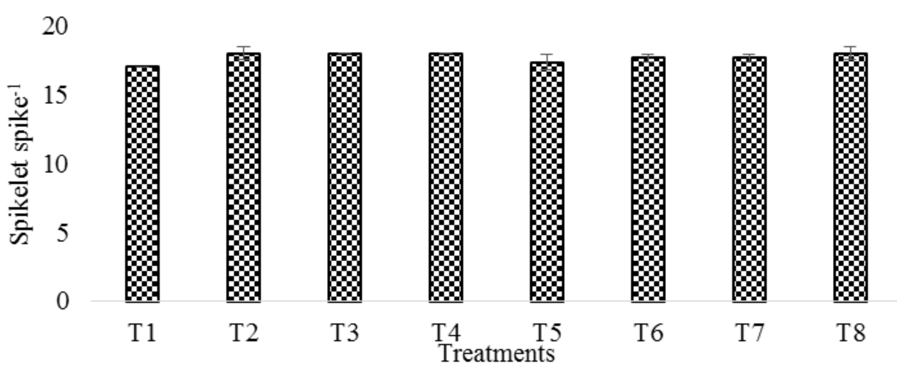

Fig. 4 Number of spikelet spike^{-1} of wheat as affected by adoption of stale seedbed and chemical weed control treatments. T_1: one till + no herbicide, T_2: one till + glyphosate 48% SL at 711 mL a.i./ha, T_3: one till + paraquat 20% SL at 494 mL a.i./ha, T_4: one till + atlantis 6% WG at 15 g a.i./ha, T_5: one till + glyphosate at 48% SL 356 mL a.i./ha + paraquat 20% SL at 247 mL a.i./ha, T_6: one till + glyphosate 48% SL at 356 mL a.i./ha followed by atlantis 6% WG at 7.5 g a.i./ha, T_7: one till + paraquat 20% SL at 247 mL a.i./ha followed by atlantis 6% WG at 7.5 g a.i./ha, T_8: one till + glyphosate 48% SL at 237 mL a.i./ha + paraquat 20% SL at 165 mL a.i./ha followed by atlantis 6% WG at 5 g a.i./ha. Means sharing same alphabets do not differ significantly by using the HSD test at alpha 0.05. HSD-Tukey's $_{0.05}$ = 2.02.

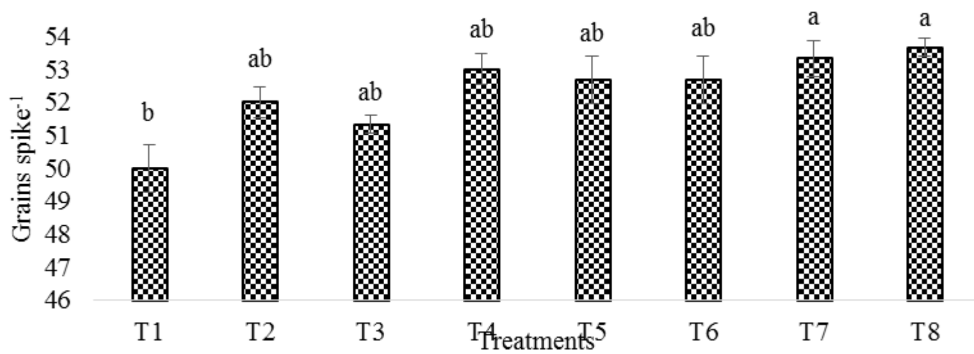

Fig. 5 Number of grains spike^{-1} of wheat as affected by adoption of stale seedbed and chemical weed control treatments. T_1: one till + no herbicide, T_2: one till + glyphosate 48% SL at 711 mL a.i./ha, T_3: one till + paraquat 20% SL at 494 mL a.i./ha, T_4: one till + atlantis 6% WG at 15 g a.i./ha, T_5: one till + glyphosate at 48% SL 356 mL a.i./ha + paraquat 20% SL at 247 mL a.i./ha, T_6: one till + glyphosate 48% SL at 356 mL a.i./ha followed by atlantis 6% WG at 7.5 g a.i./ha, T_7: one till + paraquat 20% SL at 247 mL a.i./ha followed by atlantis 6% WG at 7.5 g a.i./ha, T_8: one till + glyphosate 48% SL at 237 mL a.i./ha + paraquat 20% SL at 165 mL a.i./ha followed by atlantis 6% WG at 5 g a.i./ha. Means sharing same alphabets do not differ significantly by using the HSD test at alpha 0.05. HSD-Tukey's $_{0.05}$ = 3.24.

Data related to 1000- grains weight (g) showed statistically significant difference among treatments shown in Fig. 6. Statistically maximum 1000- grains weight (31.88 g) was observed in one till + glyphosate + paraquat followed by atlantis. Whereas, statistically minimum (21.33 g) 1000-grains weight was noticed in one till + no herbicide. Remaining all treatments exhibited statistically similar results. In which one till + glyphosate followed by atlantis showed next highest (28.33 g) 1000- grains weight that is statistically at par with one till + paraquat followed by atlantis, one till + paraquat, one till + glyphosate, one till + atlantis and one till + glyphosate + paraquat, respectively. Collected data related wheat biological yield showed statistically significant results (Fig. 7). Maximum biological yield (9.27 tons/ha) was obtained in one till + glyphosate + paraquat followed by atlantis and significantly lowest (6.23 tons/ha) was recorded in one till + no herbicide treatment. Next maximum biological yield of (8.74 tons/ha) in treatment one till + paraquat followed by atlantis. While, treatment one till + paraquat that produced (8.39 tons ha^{-1}). Which is followed by the treatment one till + glyphosate + paraquat that produced (7.78 tons/ha). In treatment one till + atlantis wheat biological yield was (7.55 tons/ha) whereas, in treatment one till + glyphosate resulted in wheat crop biological yield of (7.41 tons/ha) which was followed by one till + glyphosate followed by atlantis biological yield of wheat was (7.28 tons/ha).

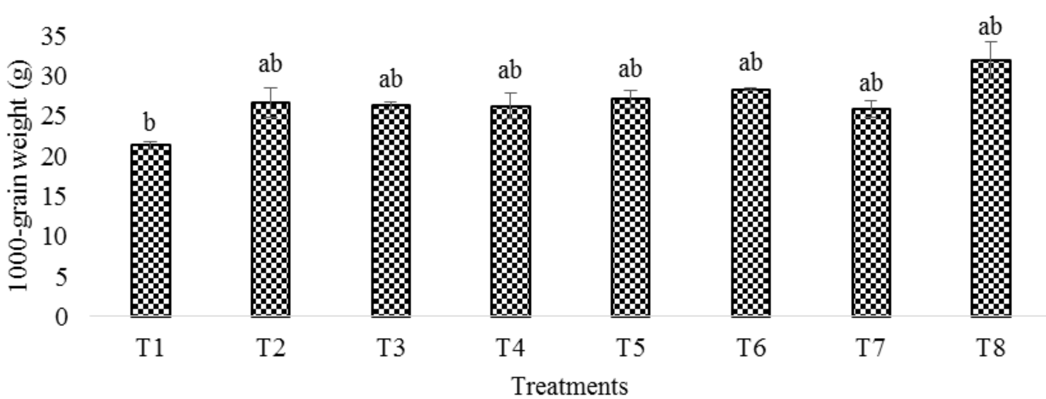

Fig. 6 1000-grain weight of wheat as affected by adoption of stale seedbed and chemical weed control treatments. T_1: one till + no herbicide, T_2: one till + glyphosate 48% SL at 711 mL a.i./ha, T_3: one till + paraquat 20% SL at 494 mL a.i./ha, T_4: one till + atlantis 6% WG at 15 g a.i./ha, T_5: one till + glyphosate at 48% SL 356 mL a.i./ha + paraquat 20% SL at 247 mL a.i./ha, T_6: one till + glyphosate 48% SL at 356 mL a.i./ha followed by atlantis 6% WG at 7.5 g a.i./ha, T_7: one till + paraquat 20% SL at 247 mL a.i./ha followed by atlantis 6% WG at 7.5 g a.i./ha, T_8: one till + glyphosate 48% SL at 237 mL a.i./ha + paraquat 20% SL at 165 mL a.i./ha followed by atlantis 6% WG at 5 g a.i./ha. Means sharing same alphabets do not differ significantly by using the HSD test at alpha 0.05. HSD-Tukey's value $_{0.05}$ = 8.502.

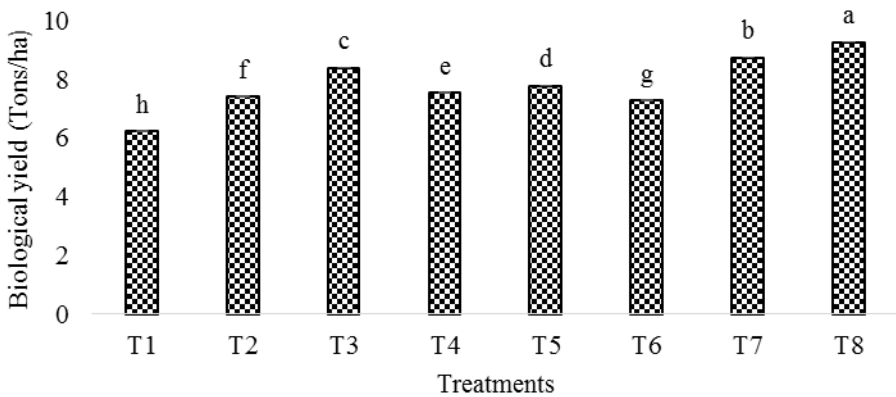

Fig. 7 Biological yield (Tons/ha) as affected by adoption of stale seedbed and chemical weed control treatments. T_1: one till + no herbicide, T_2: one till + glyphosate 48% SL at 711 mL a.i./ha, T_3: one till + paraquat 20% SL at 494 mL a.i./ha, T_4: one till + atlantis 6% WG at 15 g a.i./ha, T_5: one till + glyphosate at 48% SL 356 mL a.i./ha + paraquat 20% SL at 247 mL a.i./ha, T_6: one till + glyphosate 48% SL at 356 mL a.i./ha followed by atlantis 6% WG at 7.5 g a.i./ha, T_7: one till + paraquat 20% SL at 247 mL a.i./ha followed by atlantis 6% WG at 7.5 g a.i./ha, T_8: one till + glyphosate 48% SL at 237 mL a.i./ha + paraquat 20% SL at 165 mL a.i./ha followed by atlantis 6% WG at 5 g a.i./ha. Means sharing same alphabets do not differ significantly by using the HSD test at alpha 0.05. HSD-Tukey's $_{0.05}$ = 0.062.

Data related to grain yield showed statistical differences among all treatments (Fig. 8). Statistically maximum 4.65 tons/ha of grain yield was observed in the treatment one till + glyphosate + paraquat followed by atlantis and statistically lowest 1.84 tons/ha of grain yield was recorded in treatment one till + no herbicide. Next best treatment was one till + glyphosate followed by atlantis that showed grain yield of (3.94 tons/ha) and it was statistically similar with the treatment one till + paraquat followed by atlantis in which yield of grain was (3.54 tons/ha). In treatment one till + glyphosate + paraquat showed grain yield of (3.44 tons/ha) which was similar as one till + one till + atlantis plot which showed (3.41 tons/ha). Treatments one till + glyphosate and one till + paraquat produced grain yield of 3.27 and 3.23 tons/ha, respectively.

All experimental treatments showed significant influence on the harvest index of wheat (Fig. 9). Statistically maximum harvest index was (33.73%) achieved in one till + glyphosate followed by one till + atlantis plot that is statistically at par with one till + glyphosate + paraquat followed by one till + atlantis plot which showed HI 33.49%. Statistically the minimum harvest index was (22.18%) recorded in one till + no herbicide. In treatment one till + glyphosate HI of (30.40%) was observed and in treatment one till + one till + atlantis plot HI was (29.57%). Harvest index of (28.61%) was reported in treatment one till + paraquat. Whereas, in treatment one till + paraquat followed by one till + atlantis plot harvest index was (27.57%) observed. In treatment one till + glyphosate + paraquat HI of (25.75%) was recorded.

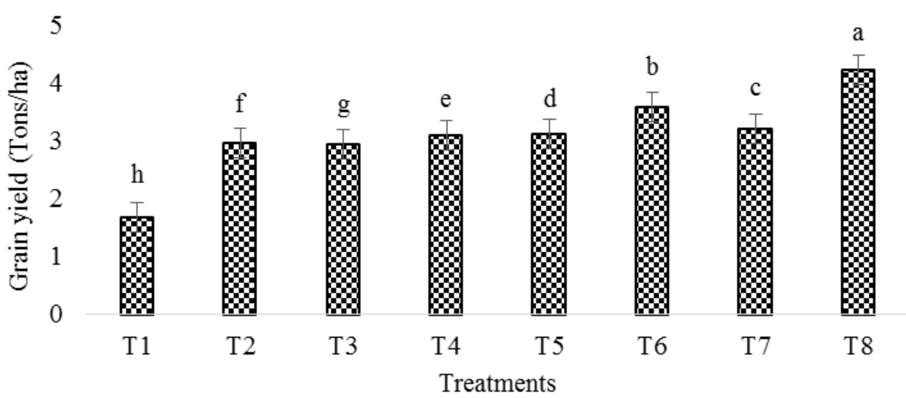

Fig. 8 Grain yield (Tons/ha) of wheat as affected by adoption of stale seedbed and chemical weed control treatments. T_1: one till + no herbicide, T_2: one till + glyphosate 48% SL at 711 mL a.i./ha, T_3: one till + paraquat 20% SL at 494 mL a.i./ha, T_4: one till + atlantis 6% WG at 15 g a.i./ha, T_5: one till + glyphosate at 48% SL 356 mL a.i./ha + paraquat 20% SL at 247 mL a.i./ha, T_6: one till + glyphosate 48% SL at 356 mL a.i./ha followed by atlantis 6% WG at 7.5 g a.i./ha, T_7: one till + paraquat 20% SL at 247 mL a.i./ha followed by atlantis 6% WG at 7.5 g a.i./ha, T_8: one till + glyphosate 48% SL at 237 mL a.i./ha + paraquat 20% SL at 165 mL a.i./ha followed by atlantis 6% WG at 5 g a.i./ha. Means sharing same alphabets do not differ significantly by using the HSD test at alpha 0.05. HSD-Tukey's $_{0.05}$ = 1.41.

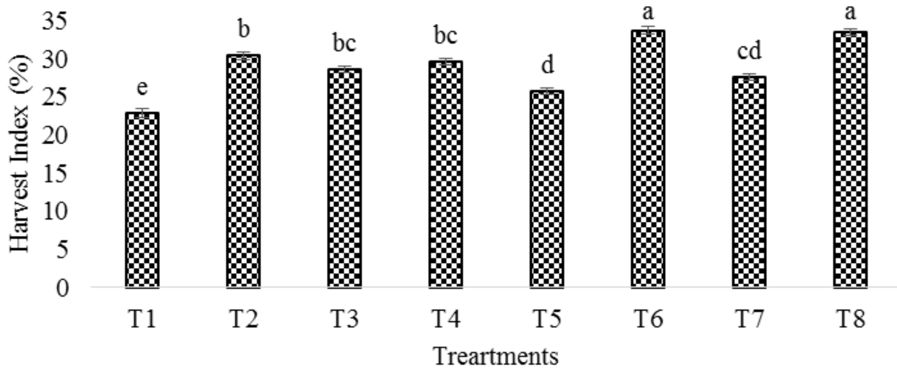

Fig. 9 Harvest Index (%) of wheat as affected by adoption of stale seedbed and chemical weed control treatments. T_1: one till + no herbicide, T_2: one till + glyphosate 48% SL at 711 mL a.i./ha, T_3: one till + paraquat 20% SL at 494 mL a.i./ha, T_4: one till + atlantis 6% WG at 15 g a.i./ha, T_5: one till + glyphosate at 48% SL 356 mL a.i./ha + paraquat 20% SL at 247 mL a.i./ha, T_6: one till + glyphosate 48% SL at 356 mL a.i./ha followed by atlantis 6% WG at 7.5 g a.i./ha, T_7: one till + paraquat 20% SL at 247 mL a.i./ha followed by atlantis 6% WG at 7.5 g a.i./ha, T_8: one till + glyphosate 48% SL at 237 mL a.i./ha + paraquat 20% SL at 165 mL a.i./ha followed by atlantis 6% WG at 5 g a.i./ha. Means sharing same alphabets do not differ significantly by using the HSD test at alpha 0.05. HSD-Tukey's $_{\mathbf{0.05}}$ = 2.51.

Discussion

During the study, it was interesting to note that by adoption of stale seed bed technology with an additional tillage controlled grassy weeds present in the wheat field. Hence the grassy weeds were absent. However, the broad leaf (BL) weeds especially Lesser Swine cress and lamb's quarters were the weeds dominating in the wheat field. Post emergence application of atlantis reduced both of the BL weeds to a varying degree based on varying post emergence treatments. Stale seedbed could be the reason of low density of *C. didymus* during 30 DAS, because during sowing time germinated weeds were removed by pre-emergence herbicide and at 30 DAS left over seed were germinated which was in its initial growth stages. Moreover, low weed population in herbicide treated plots can be attributed to the residual effect of herbicides and formation of stale seedbed technology. It is supported by findings of the Government of Western Australia (2020), who revealed that pre-emergence herbicide application restricts the radical growth of weeds and minimizes crop weeds competition at early crop growth stages. So at the initial stage in all herbicide treated plots significant lower *C. didymus* density was recorded. After 30 days of sowing at about the start of January 2019, *C. didymus* density was high. *C. didymus* started developing flowers and the whole study area was covered by *C. didymus*. As *C. didymus* found favorable conditions for growth and development its density maximized at this period of time. This was mainly due to its growth pattern and presence of favorable climatic condition and abundant supply of nutrients. At this stage *C. didymus* was initiated flowering and significant reduction in density of *C. didymus* in herbicide treated plots can be due to the use of post emergence herbicide (atlantis). Data recorded at 60 DAS shows decrease in *C. didymus* density as it was about to complete its life cycle. While during 75 DAS, *C. didymus* almost negligible density was observed in treated plots.

Overall, *C. didymus* density showed an increasing trend up to 45 DAS, which means that field provided optimum environment which helped in growth and development. Because, till 45 DAS *C. didymus* density was at the highest level, so wheat crop faced maximum competition till 45 DAS. Hence, there is a necessity to manage *C. didymus* within 45 DAS. *C. didymus* management within this highest competition period is more suitable as it grows more aggressively in this period and utilizes the available resources more effectively as compared to wheat crop plant. During the whole season *C. didymus* density was efficiently controlled in those treatments where stale seedbed followed by post emergence herbicide application. This study is similar to the outcomes of Khaliq et al. (2014); Hussain et al. (2015); Brunori and Puricelli (2020) who reported that weeds density significantly controlled by pre plant herbicide which was followed by post-emergence within the period of 2 to 4 weeks after sowing when weeds growth and development was maximum. Post-emergence weeds density could be significantly reduced by the herbicide application. Data related to dry weight of *C. didymus* showed a significant difference of total dry matter accumulation among one till + no herbicide and one till + herbicide treated plot. This substantial gap clears the importance of pre plant and post plant herbicide use which control the weeds at early crop growth stages and restrict growth of weeds by helping the wheat crop dominating the weed crop competition. These outcomes find similarity with results of Mahmood et al. (2013); Sanbagavalli et al. (2016) who reported that stale seedbed technology and use of herbicides significantly reduce the weeds dry weight in wheat crop. The

At 30, 45 DAS density was not as high as *C. album* was at emergence stage and germination was not completed. *C. album* density was not maximum, at the early growth crop stages of crop. Low weeds density in treated plots can be attributed to the residual effect of herbicides and stale seedbed technology. While in an untreated plot low level of *C. album* density was attributed to stale seedbed technology. *C. album* density was observed maximum at the period of up to 60 DAS in treatment where no herbicide was applied while the herbicide treated plots recorded significant lower weeds density upon growing season. In no herbicide treated plot provides optimum environmental conditions which help *C. album* in growth and development. Because, till 60 DAS *C. album* density was at highest level, so wheat crop also faced maximum competition by *C. album* till 60 DAS. So there is a necessity to manage *C. album* within 60 DAS. *C. album* management within this highest competition period are more suitable as it grows more aggressively in this period and utilizes the abundantly available resources more effectively as compared to wheat crop plant. While in dry matter accumulation one till + no herbicide treatment, *C. album* found favorable conditions it develop vigorously and accumulate more biomass while, significantly lower dry weight in plots one till + paraquat followed by atlantis and one till + glyphosate + paraquat followed by atlantis could be attributed to effectiveness of combined application which increase the efficiency of herbicides. The outcomes of this study are similar to the results of Riemens et al. (2007); Mahmood et al. (2013); Meena et al. (2017); Beam et al. (2019) who reported that stale seedbed technology and use of pre and post-emergence herbicides significantly reduce the weeds count m^{-2} and dry weight (g/m^2) of weeds in wheat crop.

Presented data showed that stale seedbed formation and herbicides application provide an opportunity to wheat crop plants to suppress weeds and improve crop growth rate by utilization of plant resources efficiently. Significant lower tiller height in no herbicide treated plot can be attributed to higher weeds interference as compared to herbicide treated plots. Whereas, in one till + glyphosate + paraquat followed by atlantis pre-planting glyphosate + paraquat and post-emergence atlantis herbicides were applied as a result of that there was low competition for available resources and nutrients was observed. All available resources were efficiently utilized by wheat plants that resulted in improved height of tiller. The findings of present study show similar results as Hameed et al. (2019); Misbahullah et al. (2019) who revealed that tiller height significantly influenced by weeds density it could be improved by use of pre plant as well as post plant herbicides.

Statistically maximum fertile tillers m^{-2} was recorded in one till + glyphosate + paraquat followed by atlantis where combined pre-planting one till + glyphosate + paraquat and after that post-emergence atlantis herbicide was also applied. Overall, during the whole growing season in this treatment crop has favorable conditions for growth and development due to minimum weeds density and crop weed competition. In these treatments pre-planting herbicide was applied for the formation of a stale seedbed that controls earlier weeds flush that was followed by atlantis application. In results this favorable condition helps in producing more fertile tillers $m^{-2.}$ Whereas, in treatment one till + no herbicide no application of herbicide was undertaken due to this reason crop was faced high weed completion due to high infestation with various weeds during whole growing duration. While one till + atlantis showed a significant low level of productive tiller which could be attributed to higher weed interference at early crop growth stages. This revealed the importance of pre plant herbicides to suppress weeds at earlier stages. Outcomes of this study are similar to the results of Nanher and Raghuvir (2015); Asad et al. (2017); Misbahullah et al. (2019) who reported that herbicidal control of weeds significantly increases the number of productive tillers m^{-2}.

Non-significant difference observed among yield attributes due to genetic characteristics of this cultivar which was not significantly influenced by environmental stresses or weeds competition. Maximum spike length was observed where, combined pre-planting (glyphosate and paraquat) and post-emergence (atlantis) herbicide was applied. This could be attributed to lower weed density and weed interference for a longer period by formation of stale seedbed and post-emergence herbicide application that helps the crop plant to maximize crop growth and achieve their genetic potential, due to this crop showing higher length of spike. This study result is comparable with the result of Naseer ud Din et al. (2011) who stated an increase in the spike length was observed in herbicides treated plots in comparison with weedy check plots.

Yield parameters (spikelet spike^{-1}, grains spike^{-1}) showed non-significant difference was observed. Maximum (spikelet spike^{-1}, grains spike^{-1}) was recorded where pre-planting (glyphosate and paraquat) and post-emergence (atlantis) herbicides was applied as sole and as well as in reduced form. That helps the wheat crop attain a luxuriant environment during critical growth stages throughout the growing season of crop. This can be the reason for the crop to show a higher number of spikelet spike^{-1} in treated plots. The outcomes of this study are supported by findings of Shehzad et al. (2012); Mahmood et al. (2013); Asad et al. (2017), Hameed et al. (2019); Misbahullah et al. (2019) who reported an increase in the number of spikelet spike^{-1} and grains spike^{-1} by application of herbicides to control weeds in wheat crop.

Maximum 1000-grains weight was achieved in treatment one till + glyphosate + paraquat followed by atlantis. This could be attributed to the better weed control during growing season by formulation of stale seedbed and application of pre-planting herbicides (glyphosate, paraquat) that provide low weed interference at earlier crop stages and after 30 days of sowing application of post-emergence herbicide (atlantis) that restrict the weeds growth reduce in results competition period was also reduce as compared to no herbicide treated plot for wheat crop. This helped the wheat plants in growth and development by making more nutrients and other plant resources available throughout the crop season that put a significant effect on growth and development. Statistically lowest 1000- grains weight was observed in one till + no herbicide. This is accredited to the competition among weeds and wheat plants. So, available resources of plants are exposed to weeds. Major portion was used by those unwanted plants. This resulted in the decrease in wheat growth owing to the less availability of plant resources. Crop plants are unable to produce assimilates efficiently under this competitive environment. The findings of this study are comparable with the results of Ali et al. (2016) who stated that use of herbicides before and after the sowing control the weeds efficiently and in response crop plants increases 1000-grains weight ultimately wheat crop productivity also improves.

Biological yield was maximum in treatment one till + glyphosate + paraquat followed by atlantis as weeds were efficiently controlled by the combined application of herbicides with stale seedbed technology. So, wheat plants growth and development was maximum in this treatment. Contrarily, in treatment one till + no herbicide weeds were present for the whole crop growing season that help weeds to interfere with crop plant in resource utilization ultimately restrict the growth and development. Significantly, next maximum biological yield was recorded in one till + paraquat followed by atlantis as a result of presence of favorable environment for crop growth and development. In one till + glyphosate followed by atlantis, limitation in the availability of nutrients and other resources resulted in slight decrease in biological yield that attributed to low residual effect of glyphosate due to reduce dose application which deteriorate quickly and ultimately wheat crop were exposed to weeds competition or longer period of time. This study showed similar results as Matloob et al. (2015) who stated that the weed competition period significantly influenced growth and development of crops. Maximum crop growth development and synthates accumulation were recorded where, minimum competition was recorded.

Higher grain yield was observed in plot one till + glyphosate + paraquat followed by atlantis this could be ascribed to better weed control during the growing season. Wheat crop growth and development improved and crop plants utilized available nutrients and other plant resources efficiently that put a positive effect on growth processes of wheat plants. While the minimum grain yield could be dedicated to the interspecific competition among weeds and wheat plants which resulted in lower grain yield (Melander & McCollough, 2020). Weeds are the efficient resource utilizer as compared to crop plants because most of weeds are C_4 plants but wheat crop is a C_3 plant. So, weed plants utilizes the major proportion of available resources of plants that resulted in the serious reduction in wheat crop growth and development (Schluter & Weber, 2020; Nathalie et al., 2020). Plots where sole or combined pre plant and post emergence herbicide were applied. Here a bit more weeds interference period was observed in these treatments i.e. one till + atlantis plot were exposed to higher weed interference period till first irrigation resulted decrease in grain yield (Korres et al., 2020). Whereas, in treatment one till + glyphosate + paraquat, one till + glyphosate and one till + paraquat only pre plant herbicides in sole and combined form were applied and after their residual effect deterioration crop plants were exposed to weeds interference till harvest. These outcomes are supported by the results of Naseer ud Din et al. (2011); Shehzad et al. (2012); Nanher and Raghuvir (2015); Farooq et al. (2018); Hameed et al. (2019) who unfolded that an increase in grain yield through controlling weeds by use of herbicides prior and after the sowing of wheat crop. All herbicide treated plots showed significant higher harvest index percentage than no herbicide treatment. So it’s clear that a better weed control strategy provides a favorable environment for crop growth processes and improves the harvest index. This study is in line with Tollenaar et al. (1994); Pageau and Trembla (1996); Hameed et al. (2019) who stated that weed competition reduced harvest index and maximum decline in harvest index was due to weed interference. Use of herbicide to control of weeds significantly increases the harvest index.

Conclusion

Controlling weeds by using stale seedbed in wheat crop could increase wheat yield by 60 %. During 60 DAS, weeds growth and development was found to be most aggressive. According to the study results, it can be concluded that in field conditions weeds were efficiently controlled particularly grassy weeds at early crop growth stages of wheat by stale seedbed formation + pre-planting herbicides with an additional tillage. Later on post-emergence herbicide also significantly reduces the weeds density and provide a low interspecific competition period during whole growing season of crop that help to produce an economical wheat grain yield. Farmers having heavy infestation of grassy weeds in wheat fields can get economical wheat productivity by adopting stale seed bed technology to control grassy weeds. Furthermore, the use of post emergence herbicide like atlantis can keep a check on weeds during first 60 DAS. However, the stale seedbed technology also needs to be tested under varying cropping systems for adaptability under the backdrop of changing climate.

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