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Research article

WEED GROWTH DYNAMICS ASSOCIATED WITH RAINFED WHEAT (*TRITICUM AESTIVUM* L.) ESTABLISHMENT UNDER DIFFERENT TILLAGE SYSTEMS IN POTHWAR

Safdar Ali[1*],Muhammad Azim Malik[1], Muhammad Ansar[1], and Rahmatullah Qureshi[2]

[1]Department of Agronomy, PirMehr Ali Shah, Arid Agriculture University, Rawalpindi, Pakistan.
[2]Department of Botany, PirMehr Ali Shah, Arid Agriculture University, Rawalpindi, Pakistan.
[*]Corresponding author E-mail: safdaraliarid@yahoo.com
Mobile No: +92-308-5261880

ABSTRACT: Initially Germination and finally crop establishment are the major problems of rainfed wheat in drought condition, if the crop has been germinated well then the winter rains are sufficient to establish the wheat in rainfed areas of Pakistan. Field experiment was conducted at University Research Farm of PirMehr Ali Shah, Arid Agriculture University Rawalpindi, Pakistan to research out the wheat crop establishment and weed population dynamics under different tillage systems integrated with glyphosate herbicide under wheat-fallow rotation through randomized complete block design during summer and winter seasons of 2012-13. The experiment comprised of seven tillage treatments viz. T_1 = 1 MB Plowing + 8 Cultivations, T_2 = 1 MB Plowing + 4 Cultivations, T_3 = 1 Disc Harrowing + 4 Cultivations, T_4 = 1 Chiseling + *Glyphosate herbicide, T_5 = 1 MB Plowing + *Glyphosate herbicide, T_6 = 1 Disc Harrowing + *Glyphosate herbicide and T_7 = No-Till + *Glyphosate herbicide. The tillage treatments in combination with glyphosate herbicide were applied during fallow period of summer season 2012 and sowing of wheat cv. Chakwal-50 was done in winter season 2012-13. Wheat establishment and weed growth dynamics were determined through different scientific variables viz. number of tillers m^{-2}, shoot length $plant^{-1}$, root length $plant^{-1}$ anddry biomass m^{-2} at 45 DAS of wheat and weed density m^{-2}, weed species diversity and weeds dry biomass m^{-2} at two stages i.e. 60 DAS and 150 DAS of wheat, respectively. Results showed significant effect of treatments on number of tillers m^{-2} and dry biomass m^{-2} of wheat, while, non-significant on shoot length and root length of wheat; whereas, weeds density m^{-2}, weeds species diversity and weeds dry biomass m^{-2} were significantly affected by different tillage systems at both 60 DAS and 150 DAS stages of wheat. There were significant dynamics in diversity, density and dry biomass of weeds between both stages. Based on these results and cluster analysis of wheat establishment and weeds growth data, it is concluded that wheat crop was well established under T_1, T_2, T_5 and $T_6$and the weed growth was minimum under T_1 and T_7; therefore $T_1$is recommended to the farmers of Pothwar region of Pakistan; whereas, further investigations are required to conclude the adaptation of reduced or no-till system in semi-arid zones of Pakistan.

Key words: Weeds growth; Wheat establishment; Deep tillage; No-tillage; Herbicide

INTRODUCTION

Rainfed agriculture has an important contribution in the economy of Pakistan. In rainfed areas, the production of crops is mainly dependent on rainfall [36] and these areas comprise the 17% of the total crop growing area of country [2]. Wheat (*Triticumaestivum* L.), being staple food of Pakistan, is a major winter crop of rainfed areas [19]. The wheat contributes 2.7% to GDP and 13.1% to value addition in agriculture of Pakistan (GOP, 2011). In irrigated areas of Punjab, it was grown on an area of 6691 thousand hectares along with 19041 thousand tons of production with an average yield of 2737 kg ha^{-1} whereas, wheat crop in barani tract, covered an area of 549 thousand hectares with 431 thousand tons of production having 1005 kg ha^{-1} average yield in the Province (GOP, 2011). According to a report wheat can yield more than 2965 kg ha^{-1} in rainfed areas, which shows its high potential [8] but, in these areas, average per acre yield remains extremely low due to scarce soil moisture, low soil fertility and dense weed infestation [37]; [34] and [4]. Among the different yield limiting factors of wheat crop, weed infestation is the most prevailent in reducing wheat yield [18]; [45] and [27] According to an estimate, weeds may reduce yields ranging from 20 to 40% [3]. Weeds are considered as, unwanted plants that germinate in the agricultural lands and interfere with the growth of desirable plants [40] and [17].

Weeds compete with main crop plants for macro and micro-nutrients, soil moisture, space and solar radiation [24]. They act as alternate host for several insect-pests and diseases and weaken the crop plant. They considerably deteriorate both the quality and quantity of the produce [38]; [18] and [31]. They also impede cultural operations and hinder harvesting of crops [21]. Some weeds also release toxic chemicals (Allelo-chemicals) which hamper growth and development of crop plants [11] and [22]. In a scientific survey about wheat problems, 28.8 % respondents ranked the weeds as a 1st major constraint of wheat crop [25]. Therefore, farming community is giving more attention and spending more money comparatively on weed control than other crop inputs to improve their crop productivity. Weed abundance, distribution and composition in a cropped field vary with nature of crop, moisture availability, location, cropping systems and cultural practices. Tillage is often used as a weed control system but with the development and widespread adoption of minimum and zero-tillage systems the effects of tillage on weed dynamics are becoming more important especially in case of conservation tillage as weed management problems is more expected in zero-till systems and reduced tillage/ conservation tillage. This study was carried out with the objective to assess the effect of different tillage systems integrated with glyphosate herbicide on wheat crop establishment and weed population dynamics.

MATERIALS AND METHODS

The experiment was conducted on loamy soil of Kahuta soil series belonging to the great group (UdicHaplustalfs) having E. C. 0.92 $dscm^{-1}$, pH 7.20, organic matter 0.63%, saturation percentage 36%, available phosphorus 5.32 mg kg^{-1} and available potassium 100 mg kg^{-1} during summer and winter seasons of 2012-13 at University Research Farm of PirMehr Ali Shah, Arid Agriculture University Rawalpindi (latitude 33°36'0"N, longitude 73°02'0"E, and altitude 500 masl), Pakistan, to evaluate the growth and establishment of wheat and weed flora under different tillage systems in rainfed conditions. The rainfall at the experimental site during year 2012, kharif-2012, winter-2012-13 and study period (both seasons) was 431.31, 281.55, 332.91, and 614.46 mm, respectively (Table 1). Field was surveyed and selected one year before for the proper selection of a weed infested field. Seven tillage systems viz. T_1 = 1 MB Plowing + 8 Cultivations, T_2 = 1 MB Plowing + 4 Cultivations, T_3 = 1 Disc Harrowing + 4 Cultivations, T_4 = 1 Chiseling + *Glyphosate herbicide, T_5 = 1 MB Plowing + *Glyphosate herbicide, T_6 = 1 Disc Harrowing + *Glyphosate herbicide and T_7 = No-Till + *Glyphosate herbicide were applied in the fallow period of summer season (2012); whereas, the winter wheat cv. Chakwal-50 (a high yielding, drought tolerant and disease resistant cultivar for rainfed areas of Punjab Pakistan) was sown on October 23rd, 2012 in 22.5 cm apart rows.

In T_1, deep tillage with moldboard plough at the onset of moon soon was done followed by 8 shallow cultivations with cultivator applied after each rainfall including seedbed preparation. Sowing was done with conventional seed-cum-fertilizer drill. In T_2, one moldboard plowing was done at the onset of monsoon and then 4 cultivations were done including preparatory tillage. Sowing was done with conventional seed-cum-fertilizer drill. In T_3, one disc-harrowing was applied after the 1st flush of weeds followed by 4 cultivations including preparatory tillage and sowing was done with conventional seed-cum fertilizer drill. In T_4, one chisel plowing was done before the onset of monsoon and then fallow period weeds was controlled with glyphosate when needed and wheat was sown by direct drilling with no-till drill. In T_5, one moldboard plowing was done at monsoon initiation and then onward, the weeds were controlled by spraying glyphosate when needed and then direct seeding was done with no-till drill. In T_6, one disc-harrowing was done at the 1st flush of weeds after monsoon rains and the fallow period weeds were controlled by using glyphosate as per requirement and the winter wheat was directly seeded with no-till drill. In T_7, No-tillage practice was done before seeding of crop, but the weeds during fallow period were controlled with a non-selective herbicide (glyphosate). The glyphosate (Round up) was applied at the rate of 2.5 liters per hectare when needed (twice) during the experimental duration. Then direct seeding of wheat was done with no-till drill.The experiment was laid out in Randomized Complete Block Design having four replications. Wheat seed was obtained from Barani Agricultural Research Institute, (BARI) Chakwal. Experiment was fertilized with NPK at the rate of 90:60:60 Kg ha^{-1}, respectively. The fertilizers were applied in the form of Urea (46% N), diammonium phosphate (DAP) (18%N, 46% P2O5) and sulfate of potash (SOP) (50% K2O) as sources of N-P-K, respectively. Whole Phosphorus and Potash were applied at the time of seed bed preparation but nitrogen was applied in two splits, first at sowing time and second at tillering stage. The net plot size was 13.5 m x 13.5 m for each treatment. Establishment of wheat was evaluated by recording the no. of tillers m^{-2}, shoot length $plant^{-1}$, root length $plant^{-1}$ and dry biomass m^{-2} of wheat at 45 DAS. Similarly the growth of weeds was determined through different scientific variables like, weed population density m^{-2}, weed species diversity and weed dry biomass m^{-2} at 60 days after sowing of wheat (DAS) and at 150 DAS of wheat by the integrated use of different techniques given by [17]Qureshi and R. A. Memon, 2008;[41].

A one m^2 measuring quadrate was used to record the data about different variables of wheat and weeds. To record the number of tillers m^{-2} of wheat the total number of tillers of wheat in all quadrates were divided to the total number of quadrats studied. Shoot length $plant^{-1}$ of wheat was recorded by recording the mean value of the length of shoots of ten randomly selected plants of wheat in an experimental unit. Root length $plant^{-1}$of wheat was recorded by recording the mean value of the length of roots of ten randomly selected plants of wheat in an experimental unit. Dry biomass m^{-2} of wheat was determined by dividing dry weight of all plants of wheat in all quadrats to the total number of quadrats studied.

Population density m^{-2} of weeds was recorded by dividing total number of plants in all quadrats to the total number of quadrats studied. The weeds species diversity was recorded by using Shannon index viz.

$$H' = -\sum_{i-1}^{R} p_i \ln p_i$$

Where, p_i is the proportion of characters belonging to the i^{th} type of letter in the string of interest.Weeds dry biomass m^{-2} was recorded by dividing dry weight of all plants of weeds in all quadrats to the total number of quadrats studied.

To analyze the data of weeds 1 was added to the values for taking their natural log to squeeze the data before statistical analysis. The Data were analyzed by using computer software (statistic 8.1) and treatment means were compared with least significance difference test (LSD) at 5% level of significance.

* = Twice application, MB = Moldboard plowing, DAS = Days after sowing,

Table 1: Meteorological data of the experimental site during study period

Month	Total Rainfall (mm / month)	Mean Min. Temp. (C°)	Mean Max. Temp. (C°)	Mean Humidity (%)	Mean Sunshine (Hours / day)
May-2012	3.25	18.91	35.96	35.06	10.83
Jun-2012	14.30	23.06	39.87	29.97	9.10
Jul-2012	61.41	25.50	36.83	55.41	9.32
Aug-2012	153.35	24.06	32.53	72.96	6.87
Sep-2012	84.30	20.63	30.53	74.19	7.50
Oct-2012	16.30	13.31	27.69	60.99	9.09
Nov-2012	1.00	6.38	23.65	58.85	0.00
Dec-2012	28.30	3.25	18.58	55.39	5.96
Jan-2013	0.00	1.50	15.86	62.05	6.52
Feb-2013	213.40	7.61	16.82	79.71	4.55
Mar-2013	17.90	10.76	23.99	65.30	7.86
Apr-2013	20.95	14.99	28.83	53.46	9.13

Source: Meteorological Observatory, Soil and Water Conservation Research Institute,(SAWCRI) Chakwal

RESULTS

Results showed that the number of tillers per unit area of wheat was significantly affected by different tillage systems (Table 2). Maximum number of tillers per unit area of wheat were recorded in T_7 (No-Till + Glyphosate) while it was minimum in T_4 (1 Chiseling + *Glyphosate herbicide). The data showed that the root length and shoot length of wheat was statistically non-significant (Table 2), however, the root length was recorded maximum in T_1 (1 MB Plowing + 8 Cultivations) followed by T_7 (No-Till + *Glyphosate herbicide) and T_2 (1 MB Plowing + 4 Cultivations) but was minimum in T_3 (1 Disc Harrowing + 4 Cultivations). Similarly the maximum shoot length was recorded in T_5 (1 MB Plowing + *Glyphosate herbicide) which was followed by T_1 (1 MB Plowing + 8 Cultivations). The lowest shoot length was obtained in T_7 (No-Till + *Glyphosate herbicide) as compared to other tillage systems (Table 2). Likewise the maximum dry biomass of wheat was produced under T_5 (1 MB Plowing + *Glyphosate herbicide) followed by T_6 (1 Disc Harrowing + *Glyphosate herbicide) which was statistically at par with each other (Table 2). The dry matter accumulation at tillering was the lowest in case of T_7 (No-Till + *Glyphosate herbicide) which significantly differed from all other tillage systems. The cluster analysis of establishment data of wheat at 45 DAS grouped T1, T2, T5 and T6 under same group (Fig 2).

Table 2: Wheat establishment parameters as affected by different tillage systems

Treatment	Tillers (m^{-2})	Shoot Length (cm)	Root Length (cm)	Dry biomass (gm^{-2})
T1	507.50 ab*	66.80 NS	14.74 NS	706.50 ab*
T2	543.50 ab	62.56	13.98	785.30 ab
T3	445.00 ab	64.91	13.28	572.80 bc
T4	425.50 b	63.35	13.51	658.50 abc
T5	541.00 ab	67.22	13.96	849.15 a
T6	438.50 ab	64.41	13.32	805.00 a
T7	558.50 a	61.97	14.31	457.25 c

NS = Non- significant, *=Any two means in a column not sharing a common letter differ significantly at 5% level of probability

Data regarding density of weeds showed that **w**eed density m^{-2} differed significantly while comparing both stages (Table 3). At 60 DAS of wheat, the maximum weed density was recorded in T_5 (1 MB Plowing + *Glyphosate herbicide), followed by T_3 (1 Disc Harrowing + 4 Cultivations) and T_2 (1 MB Plowing + 4 Cultivations) whereas, the lowest weed density was recorded in T_7 (No-Till + *Glyphosate herbicide). At 150 DAS stage of wheat maximum number of weeds plants were found in T_6 (1 Disc Harrowing + *Glyphosate herbicide) that did not differ from all other treatments except T_1 (1 MB Plowing + 8 Cultivations) which had minimum number of weeds at maturity. T_1 (1 MB Plowing + 8 Cultivations) was also statistically at par with T_7 (No-Till + *Glyphosate herbicide), T_5 (1 MB Plowing + *Glyphosate herbicide), and T_2 (1 MB Plowing + 4 Cultivations). The density data of weeds at both stages reflect that all tillage systems resulted in decrease in weeds density m^{-2} at 150 DAS of wheat as compared to 60 DAS of wheat except T_7 (No-Till + *Glyphosate herbicide)and T_6 (1 Disc Harrowing + *Glyphosate herbicide) showing increase in weed density m^{-2}.

Table 3: Weed growth parameters as affected by different tillage systems at two stages

Treatment	At 60 DAS			At 150 DAS		
	Weed Density (m^{-2})	Diversity of weeds	W. Dry Biomass (m^{-2})	Weed Density (m^{-2})	Diversity of weeds	W. Dry Biomass (m^{-2})
T_1	50.00 ab*	1.38	15.625 b*	22.25 b*	1.9	60.74 c*
T_2	66.38 ab	1.12	20.65 b	48.67 ab	1.83	99.27abc
T_3	72.00 ab	1.2	19.803 b	59.59 a	1.73	79.85bc
T_4	62.00 ab	1.28	18.263 b	58.50 a	1.62	155.74a
T_5	99.50 a	1.2	21.913 ab	47.50 ab	1.68	115.07abc
T_6	54.75 ab	1.51	29.588 a	69.17 a	1.7	146.45 ab
T_7	26.88 b	1.37	14.275 b	41.95 ab	1.93	72.16 c

***=** Any two means in a column not sharing a common letter differ significantly at 5% level of probability

The cluster tree of tillage systems drawn upon the growth data of weeds at both stages showed that T_1 and T_7 were similar (Fig. 1). A total of 9 weed species including broad-leaved, grasses and perennials were found at 60 DAS of wheat, whereas 13 weed species were observed at 150 DAS,. At both stages, *Convolvulus arvensis, Asphodelustenuifolius, Fumariaindica, Chenopodium album* and *Euphorbia helioscopia* were the most abundant species.Similarly, data regardingShannon's index ofweed diversity presented in Table 3 showed that the value of Shannon's index at 60 DAS ranged from 1.12 in T_2 (1 MB Plowing + 4 Cultivations) to 1.36 in T_1 (1 MB Plowing + 8 Cultivations), whereas at 150 DAS, this range increased from 1.62 in T_4 (1 Chiseling + *Glyphosate herbicide) to 1.94 in T_7 (No-Till + *Glyphosate herbicide) indicating more diversity at 150 DAS as compared to 60 DAS of wheat stage. At 60 DAS, the highest weed species were found in T_2 (1 MB Plowing + 4 Cultivations) (9 Species) and the lowest in T_1 (1 MB Plowing + 8 Cultivations)(6 weed species) while at 150 DAS 14 species were found in T_4 (1 Chiseling + *Glyphosate herbicide) and the lowest in T_7 (No-Till + *Glyphosate herbicide) with only 9 weed species (Table 4).

Table 4: Weed species found in the experimental plot during two growth stages of wheat

Weed species found at 60 DAS of wheat	Weed species found at 150 DAS of wheat
Convolvulus arvensis	*Convolvulus arvensis*
Asphodelustenuifolius	*Asphodelustenuifolius*
Fumariaindica	*Fumariaindica*
Chenopodium album	*Chenopodium album*
Euphorbia helioscopia	*Euphorbia helioscopia*
Euphorbia druncoculoide	*Euphorbia druncoculoide*
Lathyrusaphaca	*Lathyrusaphaca*
Vicia sativa	*Vicia sativa*
Viciacracca	*Viciacracca*
	Sonchusarvensis
	Melilotusindica
	AvenaFatua
	Hordeumvulgare
	Cirsiumarvense
	Anagellisarvensis
	Carthamusoxyacantha

Likewise mean weeds dry biomass m^{-2} was also significantly affected by tillage systems (Table 3). The highest dry biomass of weeds was recorded in T_6 (1 Disc Harrowing + *Glyphosate herbicide) which was statistically at par with T_5 (1 MB Plowing + *Glyphosate herbicide), and significantly differed from all other tillage treatments. The dry biomass was the lowest at 60 DAS of wheat in T_7 (No-Till + *Glyphosate herbicide) as compared to other treatments, but it was significantly low in T_1 (1 MB Plowing + 8 Cultivations) at 150 DAS stage that was statistically at par with T_7 (No-Till + *Glyphosate herbicide).

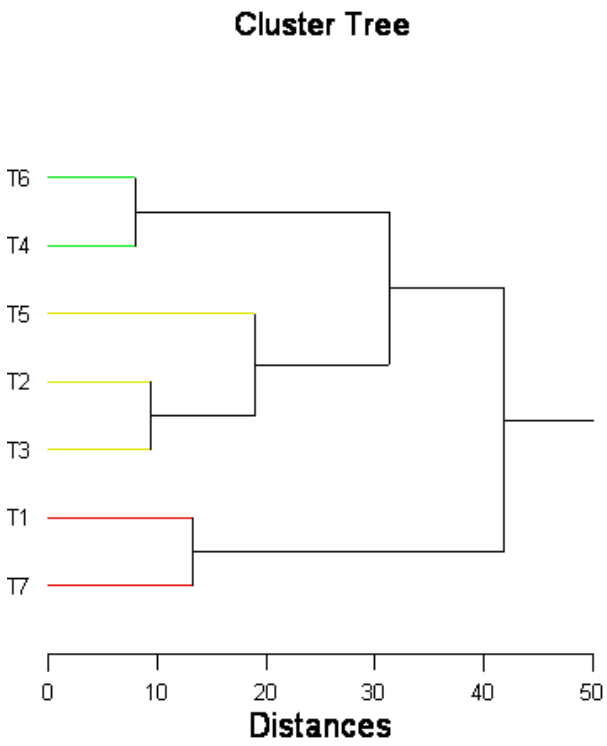

Fig. 1: Clustering of Tillage Systems on the base of weeds growth at 60 DAS and 150 DAS of wheat.

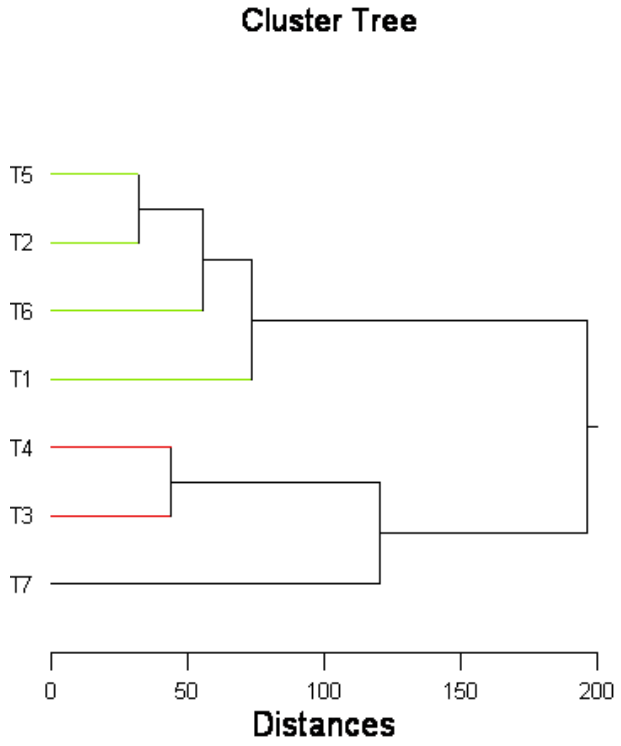

Fig.2 Clustering of Tillage Systems on the base of wheat establishment at 45 DAS

DISCUSSIONS

Number of tillers per unit area is an important yield component of wheat. Higher yields are often associated with the higher number of fertile tillers per unit area. The number of tillers per unit area of wheat was significantly differed under different tillage systems (Table. 2). Maximum number of tillers per unit area were recorded in T_7 (No-Till + *Glyphosate herbicide) and minimum from T_4 (1 Chiseling + *Glyphosate herbicide). The higher number of tillers per m^{-2} in T_7 (No-Till + *Glyphosate herbicide) may be attributed due to soil moisture and temperature variation/stress. These results are in line with the findings of [42] and [33], who reported a significant difference in number of tillers due to tillage systems and found the highest tillers in no-till system and are contrary to the findings of [14] who reported no significant effect of tillage on number of tillers per unit area. [26] Also found maximum number of tillers per unit area of wheat under maximum tillage intensity. Similarly, root elongation and distribution reflect crop's potential to take up the nutrients and water from the soil profile. Data about root length of wheat at 45 DAS given in table 2 showed that there were no significant differences in root length under different tillage systems. However, the maximum root length was observed in T_1 (1 MB Plowing + 8 Cultivations) followed by T_7 (No-Till + *Glyphosate herbicide) and T_2 (1 MB Plowing + 4 Cultivations). The minimum root length was observed in case of T_3 (1 Disc Harrowing + 4 Cultivations). The longer root length in T_1 (1 MB Plowing + 8 Cultivations) may be due to the reason that the roots may more penetrate in the soil with more tillage practices as in case of conventional tillage. These results do not agree with the findings of [35] who reported significant effect of tillage on root length. In another investigation, the root length of soybean crop was recorded longer under no-tillage than under conventional tillage [39] Likewise, the data regarding shoot length indicated that the effects of tillage systems on wheat shoot length were found statistically non-significant (Table 2); however, the maximum shoot length was recorded in T_5 (1 MB Plowing + *Glyphosate herbicide) which was followed by T_1 (1 MB Plowing + 8 Cultivations). The shortest shoot length was obtained in T_7 (No-Till + *Glyphosate herbicide) as compared to other tillage systems. The increased shoot length in these systems may be attributed due to shoot growth enhancement effects of deep tillage system. These results are in accordance with the findings of [12] who also found no significant difference of tillage systems on height of plants. The data about the dry biomass of wheat accumulated at 45 DAS stage under different tillage systems showed that tillage systems significantly affected the dry biomass of wheat (Table 2). The maximum dry biomass was produced under T_5 (1 MB Plowing + *Glyphosate herbicide) followed by T_6 (1 Disc Harrowing + *Glyphosate herbicide) and both were statistically at par with each other. The minimum dry matter was accumulated in case of T_7 (No-Till + *Glyphosate herbicide).

The maximum dry matter accumulation at tillering stage in T_5 (1 MB Plowing + *Glyphosate herbicide) might be attributed due to more availability of moisture, temperature and aeration. In another investigation Hobb'*set al*. (1998) reported maximum dry biomass in zero-tillage system. According to the cluster analysis the crop was well established under T1, T2, T5 and T6 (Fig 2). The data recorded on weed density at both stages showed the variable density under different tillage systems (Table 3). Statistically, tillage systems proved significant differences on weed density m^{-2}. At 60 DAS of wheat, the maximum weed density was recorded in T_5 (1 MB Plowing + *Glyphosate herbicide), followed by T_3 (1 Disc Harrowing + 4 Cultivations) and T_2 (1 MB Plowing + 4 Cultivations); whereas, the minimum weed density was recorded in T_7 (No-Till + *Glyphosate herbicide). In the same way at 150 DAS stage of wheat maximum number of weeds plants were found in T_6 (1 Disc Harrowing + *Glyphosate herbicide) and minimum in T_1 (1 MB Plowing + 8 Cultivations) at maturity (Table 3). The density data of weeds at both stages reflect that all tillage systems resulted in decrease in weeds density m^{-2} at 150 DAS of wheat stage as compared to 60 DAS of wheat except T_7 (No-Till + *Glyphosate herbicide) and T_6 (1 Disc Harrowing + *Glyphosate herbicide) who showed increase in weed density m^{-2} at 150 DAS of wheat. According to the cluster analysis of tillage systems drawn upon the growth data of weeds at both stages, there was minimum growth of weeds under T_1 and T_7 (Fig. 1). [9] also reported significant effects of tillage on weeds composition. These results are also in line with the findings of [28] and [13] who reported increased density in reduced tillage systems while are in contrast to the results obtained by [43] who reported more weed density m^{-2} in conventional tillage as compared to other tillage systems. These results are also supported by the findings of [23] who investigated that, in wheat crop, intensity of grasses, sedges and other minor weeds was enhanced at maturity over their intensity at 30 DAS under conventionally sown wheat, while intensity of broad-leaved weeds (BLWs) declined at maturity over their intensity at 30 DAS. Likewise, the data presented in Table 4 showed that at 60 DAS of wheat, the weed species present in experimental area were *Convolvulus arvensis*, *Asphodelustenuifolius*, *Melilotusindica*, *Chenopodium album*, *Fumariaindica, Euphorbia helioscopia, Euphorbia druncoculoide, Lathyrusaphaca, Vicia sativa* and *Viciacracca;* while at 150 DAS of wheat, other than these weed species like *Melilotusindica*, *Sonchusarvensis*, *Avenafatua*, *Hordeumvulgare*, *Cirsiumarvens*e, *Anagellisarvensis* and *Carthamusoxyacantha* were also observed. A total of 9 weed species including broad-leaved, grasses and perennials were found at 60 DAS of wheat, whereas 13 weed species were observed at 150 DAS. At both stages, *Convolvulus arvensis, Asphodelustenuifolius, Fumariaindica, Chenopodium album* and *Euphorbia helioscopia* were the most abundant species. Data regardingShannon's index ofweed diversity presented in Table 3 showed that the value of Shannon's index at 60 DAS ranged from 1.12 in T_2 (1 MB Plowing + 4 Cultivations) to 1.36 in T_1 (1 MB Plowing + 8 Cultivations), whereas at 150 DAS, this range increased from 1.62 in T_4 (1 Chiseling + *Glyphosate herbicide) to 1.94 in T_7 (No-Till + *Glyphosate herbicide) indicating more diversity at 150 DAS as compared to 60 DAS of wheat stage. At 60 DAS, the maximum number of weed species (9 Species) was found in T_2 (1 MB Plowing + 4 Cultivations), while minimum (6 weed species) in T_1 (1 MB Plowing + 8 Cultivations); whereas, at 150 DAS, maximum number of weed species (14 species) were found in T_4 (1 Chiseling + *Glyphosate herbicide) and the minimum (9 weed species) in T_7 (No-Till + *Glyphosate herbicide) (Table 3). Similarly, weeds dry biomass per unit area was also significantly affected by tillage systems (Table 3). The highest dry biomass of weeds was recorded in T_6 (1 Disc Harrowing + *Glyphosate herbicide) which was statistically at par with T_5 (1 MB Plowing + *Glyphosate herbicide). The minimum dry biomass of weeds was in T_7 (No-Till + *Glyphosate herbicide) at 60 DAS of wheat; whereas minimum in T_1 (1 MB Plowing + 8 Cultivations) at 150 DAS stage that was statistically at par with T_7 (No-Till + *Glyphosate herbicide). [48] also found significant difference among tillage systems in weed biomass m^{-2}. These results are not in agreement with [8] who found a higher weed mass in NT than in CT.

CONCLUSION

Based on these results it is concluded that wheat crop was well established under T_1, T_2, T_5 and $T_6$and the weed growth was minimum under T_1 and T_7; therefore $T_1$is recommended to the farmers of Pothwar region of Pakistan; whereas, further investigations are required to conclude the adaptation of reduced or no-till system in semi-arid zones of Pakistan.

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