Evaluation of two promising rainfed wheat cultivars affected by seeding rates in conventional and conservation tillage systems

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Abstract: This experiment was conducted to evaluate two promising rainfed wheat cultivars affected by different seeding rates in conventional and conservation tillage systems in the research field of the Dryland Agriculture Research Institute (DARI), Sararood branch, Kermanshah, Iran. The experiment layout was designed as strip-split plot in a randomized complete block design with three replications during two consecutive growing seasons of 2017-2018 and 2018-2019. The tillage systems were placed next to each other as a separate site at two levels: conventional tillage and conservation tillage (no tillage). Wheat cultivars were set horizontally at two levels (Baran and Rijaw) and the seeding rate was set vertically with eight levels (75, 100, 125, 150, 175, 200, 225, 250 kg ha^{-1}). The combined results indicated that no-tillage increased soil organic carbon by 0.18%, but decreased grain yield non-significantly at 5% level by 18.2% via reducing yield components. In this experiment, a significant difference was observed between cultivars in terms of yield components, but the grain yield was not significantly different. The comparison of different seeding rates also showed a significant difference between all studied traits except the number of seeds per spike and grain yield. In addition, the maximum protein content was achieved in conventional tillage, Baran cultivar, and seeding rate of 75 kg ha^{-1}. Finally, based on the results of interactions, the maximum grain yield (2293.7 kg ha^{-1}) was obtained by conventional tillage, Rijaw cultivar, and seeding rate of 175 kg ha^{-1}k, while the lowest yield (1323.02 kg ha^{-1}) was achieved in the no tillage, Baran cultivar, and the seed rate of 75 kg ha^{-1}.

Keywords: wheat, Cultivars, density, protein, soil organic carbon, tillage

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1 Introduction

Rainfed wheat (*Triticum aestivum* L.), the most important crop in the world (Twizerimana et al, 2020; Anwar et al, 2015), has the highest level of cultivation and production among crops. However, its average yield (1432 kg ha^{-1}) is low in Iran (Ahmadi et al, 2019). Since about 47% of arable lands in Iran is rainfed, and the average rainfall is low, and conversely the evaporation rate is very high, any activity intended to increase rainfall retention in the soil can increase crop production (Ahmadi et al, 2019). To facilitate the seedbed preparation, the rainfed farms in Iran, burn or graze the crop residues; after crop harvesting; and in both cases, a lack of soil organic matter, reduced soil water retention and ultimately reduced drylands yield are expected (Barut and Celik, 2017). In addition, conventional tillage

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operations applied to the seedbed preparation cause destructive effects on soil quality by reducing soil organic matter (Haddaway et al., 2017).

Therefore, in the last few decades, minimum tillage and no tillage systems have been introduced as a suitable alternative to conventional tillage system (Grigoras et al., 2013; Lu et al., 2018; Khursheed et al., 2019; Rusu, 2014). No-tillage as one of the conservation tillage systems, increases soil moisture retention due to plant residues and it is considered as a compatible method in rainfed areas to increase crop yield (Alamooti and Hedayatipoor, 2019; Fuhrer and Chervet, 2015; Hedayatipoor and Alamooti, 2020; Khursheed et al., 2019). The no-till system appears to increase water retention in the soil by reducing moisture evaporation, increasing permeability and protecting the soil from heavy rainfall (Sarauskis et al., 2009). It also improves the agricultural products and enhances food security in the world by increasing the preservation of crop residues in the soil, while reducing greenhouse gas emissions and thus decreasing climate change effect (Ghimire et al., 2017; Mangalassery et al., 2014). Rusu (2014) pointed out that no-tillage decreased energy consumption, therefore it increases energy efficiency, soil organic matter content, and water availability and reduces runoff, and also the erosion potential.

Yang and Cheng (2016) declared that the application of no-till system with returning plant residues to the soil, improved soil phosphatase activity, phosphodiesterase activity, alkaline phosphomonoesterase and acid phosphomonoesterase; Therefore increasing the amount of phosphorus in the soil and also reduces the need to apply this fertilizer. They also found that increasing soil moisture and organic matter could enhance the soil nutrients available, including K, Mg, Fe, Mn, Zn and B. In addition, Grigoras et al. (2013) have described the increasing fertilizers use efficiency by no-tillage system.

Effective performance of no-tillage or zero tillage has been mentioned in numerous literatures, including decreased runoff and soil loss, increased yield (Ghosh et al., 2015), decreased leaching of nutrients, especially nitrates (Khan et al., 2017), enhanced soil aggregate stability, reduced soil erosion, better soil fertility, nutrient cycling and earthworm activity (Khursheed et al., 2019). It also mitigates crop production costs by reducing the use of fuel, labor, and tillage machinery (Roger et al., 2018). No-tillage enhances soil aggregates, better soil organic carbon content and soil arbuscular mycorrhizal fungal community (Lu et al., 2018). Furthermore improved bulk density, better soil moisture content and soil porosity, soil organic matter, improved microbial biomass carbon (Mangalassery et al, 2014) and intensification of organic matter and aggregate stability of soil have been reported (Barut and Celik, 2017).

Increasing the seed consumption during planting is essential to ensure sufficient crop density to take advantage of increased water and available nutrients due to enhanced soil organic matter in no-tillage systems. An appropriate seeding rate can increase water use efficiency, wheat grain yield and benefit to cost ratio (Chauhdary et al., 2016). On the other hand, determining the optimal crop density for wheat in no-tillage conditions is very important due to different environmental conditions such as soil quality, amount of water available and seedling survival in winter cold (Zecevic et al., 2014). In addition, the consumption of different amounts of seeds for planting is one of the most important management factors affecting wheat yield due to providing suitable conditions for the plant to use water sources, nutrients and sunlight. However, various wheat cultivars have different reactions to seed rate due to their different tillering ability (Lollato et al., 2017; Zecevic et al., 2014).

Therefore, since the no-tillage system will probably increase the crop yield via improving the soil quality characteristics, especially moisture and soil organic matter content, this experiment was designed using different seeding rates to use water resources stored in the soil on two new dryland wheat cultivars. Thus, the main objective of this study was to investigate soil organic carbon, yield components, grain yield as well as grain protein percentage under the influence of different tillage systems, sowing rates and wheat cultivars.

2 Materials and methods

This study was conducted in the research field of the

Dryland Agriculture Research Institute (DARI), Sararood branch, Kermanshah, located in the northwest of Iran (34° 20′ N and 47° 20′ E and 1351.6 m above sea level), during two consecutive growing seasons of 2017-2018 and 2018-2019. Some of the meteorological parameters of the experimental field during the two years are shown in Table1.

Table 1 Meteorological statistics of Sararood Dryland Agricultural Research Station during the two consecutive years (2017-2019)

Months	Year	Min temperature (℃)	Max temperature (℃)	Ave temperature (℃)	Number of frost days 0 (℃)	Rainfall (mm)	Sunshine duration (h)	Evaporation (mm)
Oct	2017	0	33	17.1	2	0	279.9	200.8
	2018	7.8	33.2	19.8	0	25.6	207.3	216.5
Nov	2017	-1.6	29.4	14.75	3	40	173.1	199.9
	2018	0.6	24.4	12.4	0	140	148.4	75.4
Dec	2017	-5.6	16.8	6.2	19	17.4	177.8	0
	2018	-3.2	16.2	7.2	8	152.1	98.8	12.8
Jan	2018	-6	19.4	7.15	15	53.5	153.5	0
	2019	-12	15.2	2.7	22	56.4	144.3	0
Feb	2018	-8.4	17.8	4.65	15	127.6	141.5	0
	2019	-6.2	15.8	4.2	23	117.1	147	0
Mar	2018	-2.6	22	9.7	4	42	168.4	0
	2019	-5.2	18.8	5.1	23	63.8	197.6	0
Apr	2018	-0.2	28.2	13.65	1	74.4	206.7	82.6
	2019	-2.3	23.3	9.6	4	208.5	160.4	0
May	2018	2.4	28.2	14.4	0	159.8	193.8	120.6
	2019	-0.9	31.6	15.5	1	18.6	280.2	196.2
June	2018	9.4	34.2	21.65	0	6.5	317.3	238.1
	2019	7.7	37.9	23.5	0	0.4	338.6	306.8
July	2018	11	41	28	0	0	362.4	449.1
	2019	11.5	43	26.9	0	0	367.3	418.9

Table 2 Physical and chemical characteristics of experimental soil field

Years	Clay (%)	Silt (%)	Sand (%)	K (mg kg^{-1})	P (mg kg^{-1})	N (%)	OC (%)	pH	EC (ds m^{-1})	Fertilizer recommendations (kg ha^{-1})
2017 2018	52	26	22	300	10	0.11	1.1	7.57	1.9	Urea 70 Superphosphate Triple 50
2018 2019	53	27	20	301	12	0.12	0.99	7.5	2	Urea 70 Superphosphate Triple 50

To analyze the physical and chemical properties of the soil, 10 soil samples (Five samples from 0-15 cm depth and five samples from 15-30 cm depth) were taken randomly from different zones of the field in the form of W letter shape and at the end a composite soil sample was prepared and sent to the laboratory. Fertilization was carried out according to the results of soil analysis (Table 2).

The experiment layout was strip-split plot in a randomized complete block design with three replications. The tillage systems including conventional and conservation tillage (no tillage) were placed next to each other as a separate site at two levels. Wheat cultivars were located horizontally at two levels (Baran and Rijaw) and the seeding rate was considered vertically with eight levels (75, 100, 125, 150, 175, 200, 225, and 250 kg ha^{-1}). The seeding rates used were exactly based on the seed consumption of farmers in the region. Because the number of seed consumed varies in the range of 75 to 250 kg ha^{-1} depending on the amount of rainfall and stressful environmental conditions in the region.

To set up the experiment, in the conventional tillage system, preparation of seedbed was done using a traditional desi plow or moldboard plow. In conservation system or no-tillage, there was no soil interference or disturbance and sowing was done directly on the previous year's crop residues (rainfed wheat). Due to the value of wheat straw in the region, by adjusting the blade of the combine, most of the residues were removed from the field and only the standing mass remained in the field. In both systems, the seeds and recommended fertilizers drilled into soil directly by Sazeh kesht Aske 2200 ^{TM} grain drill with 13 furrow rows. Sowing depth was 5 cm and fertilizer was placed 4 cm below the seed position.

Wheat seeds (Baran and Rijaw cultivars as the top newly released rainfed cultivars in the region) were planted on November 1, 2017. In the second year, unfortunately, the study site was changed due to severe damages of wheat brown beetle larva (*Anisoplia austriaca* Hrbst), therefore seeds were sown in December 5, 2018. In this study, the plots were designed with 20 m long planting lines (13 planting lines) and 17.5 cm space between planting lines.

Weed control was performed by herbicides: Tribenuron methyl DF 75% (Granstar ^{R}) 80 g ha^{-1} and Clodinafop propargyl EC 8% (Topik ^{R}) 0.8 l ha^{-1}, in tillering stage.

At the ripening stage, 5 plants were randomly selected from each experimental plot and plant height and yield components (number of spikes per square meter, number of seeds per spike, 1000-grain weight) were measured. To measure grain yield, after removing the marginal effects, 34.65 m^2 were harvested per plot. Random grain samples harvested in each plot were used to determine grain protein by Kjeldahl (1883) method.

In addition, after harvesting and removing the plant debris from each experimental plot, soil sample was taken from the depth of 0-30 cm and the percentage of soil organic carbon was determined by Walkley and Black (1934) method.

Statistical data analysis was performed using IRRISTAT statistical software and the means comparison by the least significant difference (LSD) method at 5% and 1% probability levels.

3 Results and discussion

3.1 Soil organic carbon content

The results of variance analysis showed that the effects of the year and cultivar × seeding rate at 1% level and the effects of tillage, seeding rate and interaction of tillage × seeding rate were significant at the 5% level on soil organic carbon content (Table 3).

According to the means comparison results in Table 4, soil organic carbon in the second year of the study was less than the first year, which was probably due to the difference in the climatic conditions of the study area in the second year compared to the first year. As Table 1 shows, the amount of rainfall and the average temperature were higher in the second year and this probably increased the activity of bacteria breaking down organic matter in the soil and thus reducing its amount. Reduction of soil organic matter in rice growing areas has already been proven due to increased mineralization and oxidation of soil organic matter under increasing ambient temperature condition (Ghimire et al., 2017). As far as the authors know, there is not any study on soil organic carbon in wheat with no-till systems under different climatic conditions.

Table 3 Combined variance analyses (Anova) of soil organic carbon, rainfed wheat yield, and yield components as affected by different wheat cultivars and seeding rates in conventional and no-tillage systems

Source of Variance	df	Soil organic carbon	Plant height	Number of spikes per square meter	Number of seeds per spike	1000 grain weight	Grain yield	Seed protein
Year	1	0.26**	15236.80**	115788**	135**	63.48**	9996630**	1.67**
Tillage	1	1.63*	5804.33^{ns}	17461.3**	1195.01**	25.52**	6362410^{ns}	4.02^{ns}
Year × Tillage	1	0.0015^{ns}	326.39**	0.88025^{ns}	190**	1.33^{ns}	3467180*	1.39*
Ea	8	0.01	1.34^{ns}	691.31	10.54	1.88	364444	0.14
Cultivar	1	0.06^{ns}	12714.00^{ns}	3631.38*	328.13**	147.7**	965796^{ns}	5.96^{ns}
Year × Cultivar	1	0.01^{ns}	5048.47**	0.63022^{ns}	8.75^{ns}	2.61^{ns}	7709.3^{ns}	0.70*
Tillage × Cultivar	1	0.01^{ns}	409.70^{ns}	202.13^{ns}	9.63^{ns}	0.80^{ns}	455115^{ns}	0.06**
Year × Tillage × Cultivar	1	0.0019^{ns}	606.10**	12.5052^{ns}	10.54^{ns}	2.34^{ns}	13169.9^{ns}	0.000002^{ns}
Eb	8	0.08	6.45	552.72	24.52	1.31	145146	0.11
Seeding rate	7	0.14*	323.25**	76363**	51.98^{ns}	3.02**	191810^{ns}	17.69**
Year × Seeding rate	7	0.02^{ns}	37.56**	263.02^{ns}	17.48^{ns}	0.09^{ns}	142719^{ns}	0.24*
Tillage × Seeding rate	7	0.04*	12.78^{ns}	258.38^{ns}	34.07*	0.02^{ns}	36037.2^{ns}	0.05^{ns}
Year × Tillage × Seeding rate	7	0.01^{ns}	8.69**	96.22^{ns}	8.67^{ns}	0.03^{ns}	65838.1^{ns}	0.03^{ns}
Ec	56	0.01	2.47	733.63	9.88	0.95	67986	0.09
Cultivar × Seeding rate	7	0.03**	12.46^{ns}	1707.99**	32.2^{ns}	0.15^{ns}	102682^{ns}	0.31*
Year × Cultivar × Seeding rate	7	0.003^{ns}	18.69**	167.30^{ns}	15.42^{ns}	0.11^{ns}	117543^{ns}	0.08^{ns}
Tillage × Cultivar × Seeding rate	7	0.01^{ns}	9.41^{ns}	442.26*	16.46^{ns}	0.20^{ns}	52399.2^{ns}	0.06^{ns}
Year × Tillage × Cultivar × Seeding rate	7	0.02^{ns}	14.55**	78.99^{ns}	29.59*	0.072^{ns}	58545.4^{ns}	0.10^{ns}
Ed	56	0.01	2.63	726.14	9.97	1.17	93816.1	0.11
CV%		11.1	1.7	9.9	15.2	3.1	16.8	3.4

Note: Data presented are Mean of Square, df: degrees of freedom.

CV: Coefficient of Variation, ** Significant at $p < 0.01$, *Significant at $p < 0.05$, ns: Non- significant.

In this experiment, the percentage of soil organic carbon in the no-tillage was higher than in conventional tillage systems (Table 4). Conventional tillage reduced soil organic carbon by 0.18%. Since conventional tillage increases the infiltration of the required water and the oxygen by the bacteria breaking down the organic matter, such a trend seems reasonable. According to Lal et al. (2007), conventional tillage has caused a loss of 75% of organic matter in the soil.

The increase of soil organic matter in no-till system compared to the conventional tillage has also been proven by West and Post (2002).

Rusu (2014) reported that organic matter content could be enhanced by 2%-7.6% at the minimum and no-tillage systems compared with the conventional tillage. Enhanced soil carbon contents were reported in long-term no-tillage treatment (Mathew et al., 2012). In addition, the increase of soil organic matter in no-till system has been attributed to the improvement of soil aggregation and conservation in micro and macro aggregates (Bhattacharyya et al., 2012). It is likely that the increase in soil organic matter in no-till system is due to a reduction in its loss due to wind and water erosion (Baker et al., 2007). Increasing soil organic matter due to no-till and retaining crop residues on the soil surface leads to increased soil microbial activity, increased water and nutrient availability, soil aggregation, and regulation of soil temperature and acidity (Lal et al., 2007).

The different seeding rates showed that with increasing from 75 to 150 kg ha^{-1}, the soil organic carbon increased and then up to 200 kg ha^{-1}sowing rate had a constant trend.

Table 4 Simple mean comparison of soil organic carbon, rainfed wheat yield, and yield components as affected by different wheat cultivars and seeding rates in conventional and no-tillage systems

Treatments	Soil Organic carbon %	Plant height (cm)	Number of spikes per square meter	Number of seeds per spike	1000 Grain weight (gr)	Grain yield (kg ha^{-1})	Seed protein %
Year							
2017-2018	1.05	104.69	296.2	19.8	35.8	2046.1	10.02
2018-2019	0.97	86.87	247.1	21.5	34.7	1589.7	9.84
LSD 5%	0.03	0.39	8.7	1.08	0.4	200.917	0.13
Tillage system							
Conventional tillage	0.92	101.28	281.2	23.2	35.6	2000	10.07
No-tillage	1.1	90.28	262.1	18.2	34.9	1635.9	9.78
LSD 5%	0.07	30.62	8.7	1.08	0.4	3155.6	2
Cultivar							
Baran	1.03	103.92	276.07	19.42	36.1	1747.04	10.1
Rijaw	0.99	87.64	267.38	22.03	34.4	1888.88	9.75
LSD 5%	0.17	120.42	7.82	1.65	0.38	148.88	1.42
Seeding rate (kg ha^{-1})							
75	0.9	101.37	185.7	21.46	35.6	1662.7	11.27
100	0.91	99.75	202	20.96	35.6	1767.6	10.73
125	0.97	97.42	238.08	21.75	35.4	1889.7	10.34
150	1.08	96.51	281.9	22.29	35.4	1919.2	10.07
175	1.08	94.51	303.1	21.71	35.3	1911.4	9.79
200	1.08	93.8	311.4	20	35.2	1829.5	9.45
225	1.05	92.12	311.7	19.88	34.8	1816.1	9.10
250	1.03	90.76	339.6	17.75	34.6	1747.02	8.67
LSD 5%	0.1	4.18	11.06	2.8	0.2	257.8	0.33

Zahed et al. (2011) reported that with increasing wheat plant density from 150-375 plants m^{-2}, leaf area index increased significantly, which is due to the faster development of plant canopy in higher densities. Therefore, the amount of radiation received, is improved by the plant canopy. Then, the improved rate of photosynthesis resulted in more dry matter production (organic matter), which ultimately enhanced the soil organic matter. Increased canopy cover and consequently enhanced light absorption in wheat cultivars with increasing density has been proven by Bastos et al. (2020).

Results of tillage system × seeding rate interactions showed that the maximum soil organic carbon was 1.23% in the no-till and seed rate of 150 kg (data not shown). In addition, based on the results of the interaction of cultivar × seeding rate, the maximum organic carbon was 1.13% in the Baran cultivar and 175 kg seed rate. The response of the Rijaw cultivar to the seeding rate was slightly different and therefore the maximum organic carbon (1.09%) was achieved at the 150 kg ha^{-1} (data not shown).

3.2 Plant height

Plant height was affected significantly by year, seeding rate and interactions of year × tillage, year × cultivar, year × tillage × cultivar, year × seeding rate, year × tillage × seeding rate, year × cultivar × seeding rate (Table 3). As shown in Table 4 the plant height was higher in the first year of research than the second year, which was due to the delay in the emergence and reduced access to seasonal rainfall and ultimately decreased growth in the second year.

Although plant height increased slightly under conventional till, it was not significant. However, the interaction effect of year × till was significant and the maximum amount was obtained in the first year and the conventional tillage system at 108.88 cm (data not shown).

In addition, based on the interactions of year × cultivar, the maximum plant height was obtained in the first year and Baran cultivar as 100.7 cm. In this experiment, different amounts of seeding significantly affected the plant height and the maximum value was obtained at 75 kg ha^{-1} and plant height decreased with increasing seed rate from 75 to 250 kg ha^{-1} (Table 4). It is possible that the increase in seeding rate enhanced the competition between plants for water and nutrient uptake in rainfed conditions and due to insufficiency inputs, plant growth and height reduced in high crop densities.

In contrast, Twizerimana et al. (2020) examined different seeding rates from 112.5 to 225 kg ha^{-1} and reported a maximum plant height and leaf area at seeding rate of 225 kg ha^{-1}. Similarly, Chauhdary et al. (2016) observed an increase in plant height with an increased sowing rate from 100 to 160 kg ha^{-1}. However, this increase was not significant. In another study, the maximum plant height was obtained under the influence of 150 kg ha^{-1} (Anwar et al., 2015).

Plant height was affected by many interactions. As shown in Figure 1, plant height in Baran cultivar was higher than Rijaw cultivar during different tillage systems, seeding rate and in different experimental years. Plant height was reduced by implementing no-till system. In addition, in all cases, the maximum plant height was obtained from 75 kg ha^{-1} of seed rates and the application of more seeds reduced the height.

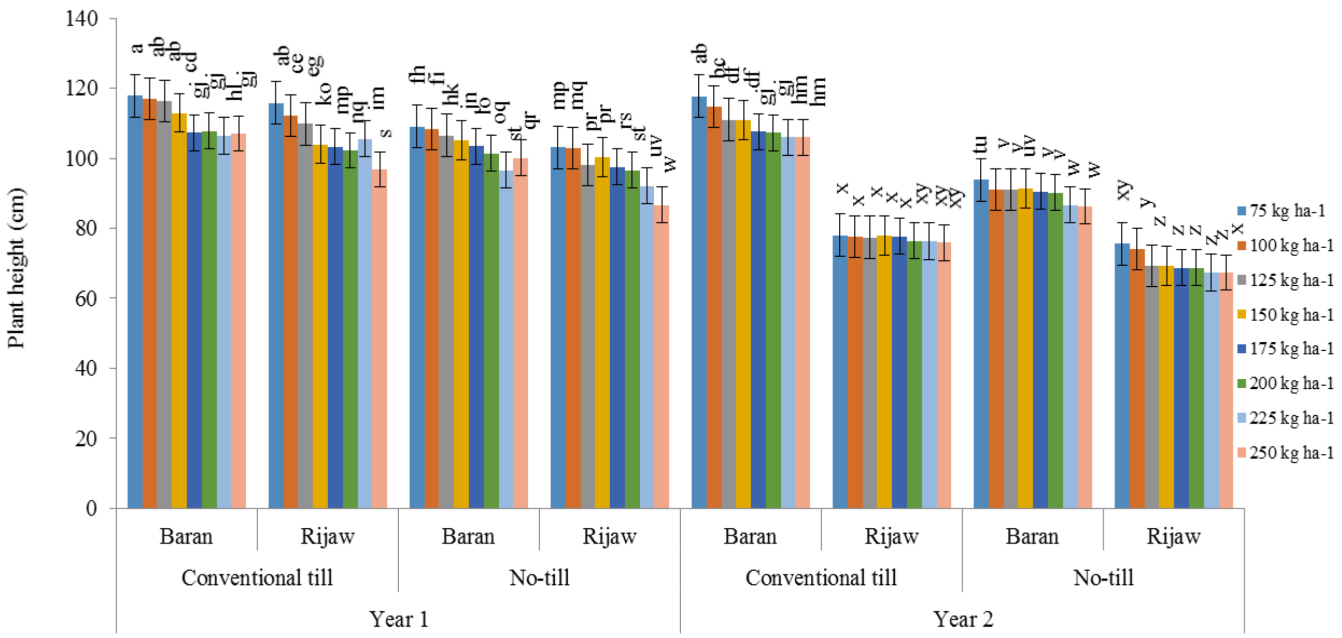

Figure1 Plant height of rainfed wheat cultivars as affected by different seeding rate and tillage systems over two growing seasons (The bars represent the standard error)

Note: Different letters mean significant differences (*p<0.05*) between averages

3.3 Yield components

Yield components including, the number of spikes, numbers of seeds per spike and 1000-grain weight were affected by more experimental treatments (Table 3). According to the means comparison, the number of spikes and 1000-grain weight increased in the first year and in the second year, the number of seeds enhanced. Despite the higher rainfall in the second year, delay in planting probably postponed the emergence and the start of tillering, and ultimately reducing the number of fertile tillers that play an important role in wheat grain yield.

Comparison of different tillage systems also showed the superiority of the conventional system compared to the no-till system on yield components. It seems that improving the soil physical condition has accelerated the emergence, improved nutrient uptake and thus increased plant growth and yield. It is also possible that the conventional tillage increases the absorption of sunlight and accelerates soil warming, and therefore improves the emergence and establishment of the plant (Roger et al., 2018). A similar study showed that penetration resistance and bulk density, which are criteria for soil compaction, were lower in the conventional tillage system than in the no-till system. This increases root elongation and improves root penetration into the depths of the soil (Barut and Celik, 2017).

Khan et al. (2017) compared different tillage systems and found the maximum yield in conventional and deep tillage. These researchers showed that soil permeability, soil porosity and saturated hydraulic conductivity decreased in no-till system, but conventional tillage increased root permeability into the soil, facilitated water and nutrient uptake, and increased plant establishment and leaf area index improving the grain yield and biomass. Conventional tillage reduces soil penetration resistance and loosens the deeper soil layer, thus enhancing the uptake of mobile nutrients from deep soil areas (Jabro et al., 2010).

Similarly, an increase in the number of spikes and the number of seeds per spike in wheat, barley and oat was observed in the conventional system (Schillinger, 2005).

In this experiment, different genetic characteristics between the two wheat cultivars caused significant differences between them in terms of yield components, so that the number of spikes and 1000-grain weight in Baran cultivar and the number of seeds per spike in Rijaw cultivar were higher. Differences in tiller number among new wheat cultivars have been reported by Lollato et al. (2017).

Bastos et al. (2020) reported the very different tillering potential of wheat cultivars, which leads to differences in the number of spikes per unit area. They considered the number of spikes and the number of seeds per spike as the most important factors for determining yield and recommended applying higher density or utilizing cultivars with high tillering potential under stress conditions.

Seed sowing ratios also created a significant difference on the number of spikes and 1000-grain weight, so that with increasing seed consumption from 75 to 250 kg ha^{-1}, the number of spikes m^{-2} increased, but the 1000 grain weight decreased (Table 4).

Chauhdary et al. (2016), studied different wheat seeding rates from 100 to 160 kg $ha^{-1}$and reported the maximum tiller numbers at 160 kg ha^{-1}, but at this density, the lowest number of seeds per spike and 1000-seed weight was obtained. In a similar study, the maximum number of spikes per $m-^{2}$, number of seeds per spike and 1000 seed weight were achieved at 150 kg ha^{-1} (Anwar et al., 2015).

Based on the results of interactions, as shown in Figure 2, the maximum number of spikes was obtained in Rijaw cultivar, conventional tillage system, and 250 kg ha^{-1} seeding rate.

Previously, based on the results of simple effects, the maximum number of spikes was obtained in Baran cultivar, and thus, based on the results of interactions, Rijaw cultivar is superior. According to the Figure 2, Baran cultivar in no-till conditions has a greater decrease in the number of spikes, while in Rijaw cultivar this difference is less.

The number of spikes is an important and effective component in wheat grain yield. Reducing the number of spikes in no tillage conditions probably reduces the growth and development of the root system and the absorption of water and nutrients, especially from the lower soil layers due to soil compaction. Besides, it may be more sensitive to Baran cultivar, thus, the amount of tillering and the number of spikes was also decreased. In addition, based on the results of interactions, the maximum number of seeds per spike was obtained in the first year of the experiment, in the conventional tillage system, Rijaw cultivar and the seeding rate of 125 kg (Figure 3). The superiority of Rijaw cultivar continued in both conditions of no-till and conventional tillage during the second year. Here, too, the trend of reducing the number of seeds per spike in no-till conditions in Baran cultivar is more significant than Rijaw showing that this cultivar is more sensitive to soil compaction, probably. The difference in wheat cultivars in terms of yield in response to different tillage systems has been proven during a three-year experiment (Woźniak, 2013).

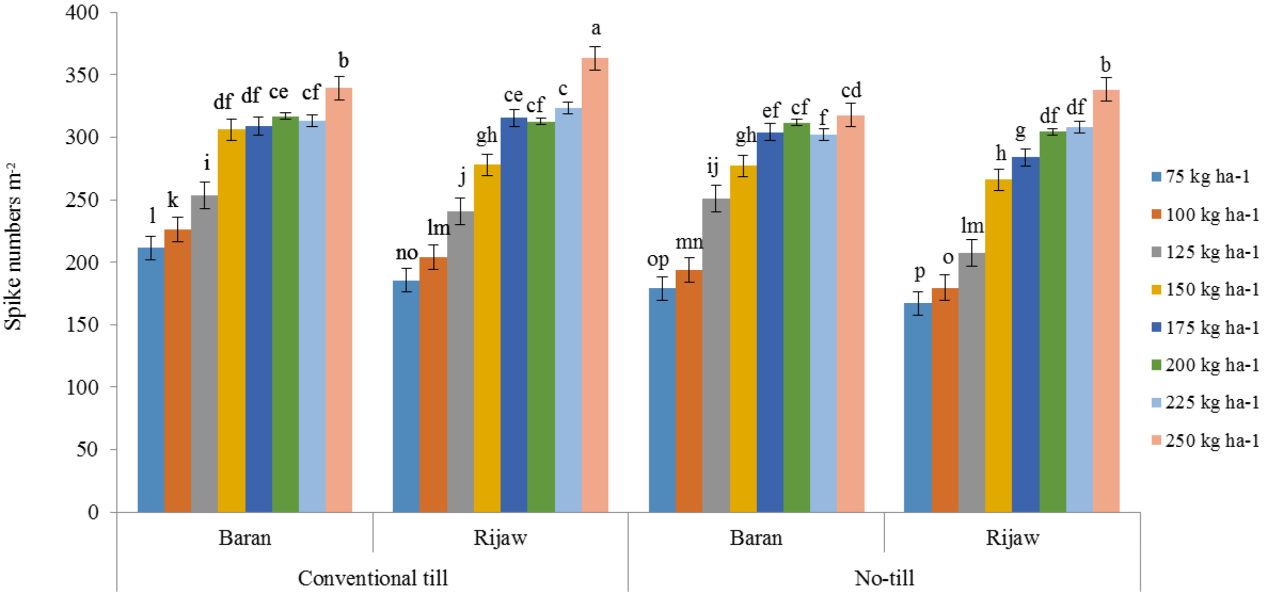

Figure 2 Spike numbers of rainfed wheat cultivars as affected by different seeding rate and tillage systems (The bars represent the standard error)

Note: Different letters mean significant differences (*p<0.05*) between averages

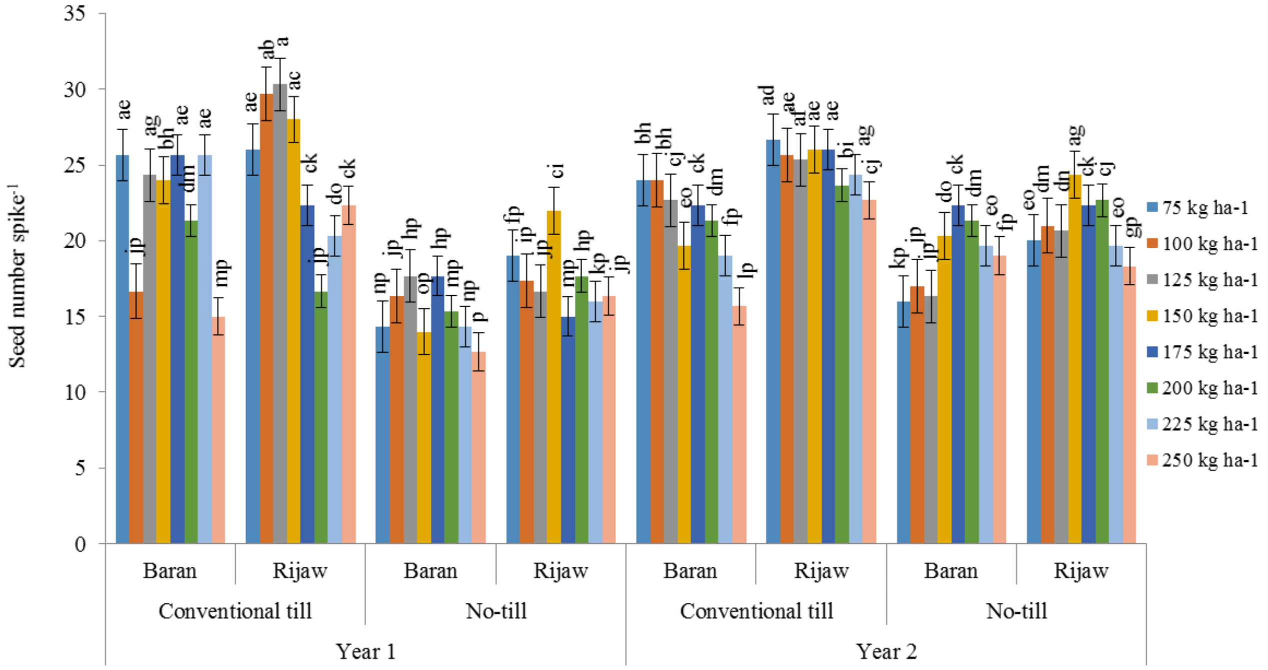

Figure 3 Seed number per spike of rainfed wheat cultivars as affected by different seeding rate and tillage systems over two growing seasons (The bars represent the standard error)

Note: Different letters mean significant differences (*p<0.05*) between averages

3.4 Grain yield

Grain yield under the influence of year and interaction of year × tillage showed significant differences. Based on the obtained data, grain yield increased by 28.7% in the first year compared to the second year. Since in the first year of the experiment, soil organic carbon, plant height and yield components, which are effective traits in grain yield, were higher, such a result seems reasonable.

Examination of different tillage treatments also showed that the implementation of no-till system, reduced grain yield by 364 kg ha^{-1} (18.2%), however, this difference was not significant (Table 4). In the same study, decreased wheat and maize yield was attributed to enhanced soil penetration resistance and soil bulk density in minimum and no-tillage systems (Rusu et al., 2011).

Grigoras et al. (2013) also attributed the 353 kg ha^{-1} reduction in wheat yield in the no-till system to increased soil compaction, reduced soil porosity, and increased weed competition. However, these researchers recommended the no-till system due to the increased efficiency of fertilizer application in wheat production.

Based on the results of interactions, the maximum grain yield was achieved in the conventional tillage system in the first year. In the second year, the difference between the two systems was greater, so that, this difference was 95.3 and 632.8 kg ha^{-1} in the first and second year of the experiment, respectively. It is possible that delaying planting in second year caused increased soil compaction during the early autumn rains and the lack of airflow in no-till reduced the temperature in the surface soil layer and the seedling experienced a further yield reduction through delayed emergence and the start of tillering.

The decrease in soil temperature in the no-till system has strongly affected the growth of wheat and corn in the early stages of growth. Enhancing the bulk density and penetration resistance during different soil depths in no-till system, which has finally reduced the maize yield, has been demonstrated by Fabrizzi et al. (2005).

During a four-year study, Schillinger (2005) reported a 5% reduction in yield of wheat, barley and oat in a no-till system. The reason for this yield decrease was reduction in the available water content in the root zone and as a result, the number of spikes and the number of seeds per spike decreased. This researcher argued that in a conventional system, the movement of water to the upper layers is stopped by disconnecting the soil capillary property and the water remains available to the roots.

Woźniak (2013) in a 3-year study reported that the grain yield of durum wheat improved by conventional tillage comparing with reduced tillage and herbicide tillage, and recommended the minimum tillage only in years with rainfall less than 300 mm.

In this experiment, grain yield in Rijaw cultivar was 142 kg ha^{-1} higher than Baran cultivar, however, the difference was not significant. Comparison of different seeding rates also showed that with increasing seed consumption from 75 to 150 kg ha^{-1}, the grain yield increased by 104.9 to 256.5 kg ha^{-1}, however, this difference was not significant.

During a two-year study in semi-arid regions of Pakistan, Chauhdary et al. (2016) using different seeding rates from 100 to 160 kg ha^{-1}, obtained the maximum number of tillers per plant, grain yield and benefit cost ratio at 160 kg ha^{-1} treatment. Therefore, grain yield increased by 9.49% and 22.52%, at this density compared to 130 and 100 kg ha^{-1}, respectively.

Sun et al. (2013) found that grain yield was the maximum when seed rate of 270 kg ha^{-1} was used, however, it was not significantly different from using 225 kg ha^{-1}. They also reported an increase in radiation efficiency of winter wheat under this condition. In addition, Twizerimana et al. (2020) by examining different seeding rates from 112.5 to 225 kg ha^{-1}, reported the maximum grain yield at 225 kg ha^{-1}. They stated that improvement in plant height, leaf area, the number of spikes, and the number of seeds were the reason for increased seed yield. In the same study, using seed rate range of 125-175 kg ha^{-1}, the maximum wheat yield was obtained at 125 kg ha^{-1} (Malik et al., 2009). In another study, Iqbal et al. (2010), by comparing different seed quantities from 125 to 200 kg ha^{-1}, reported the maximum grain yield under seed rate of 150 kg ha^{-1}. Lollato et al. (2017) studied different sowing rates (0.6, 0.95, 1.3, 1.65, and 2 million seeds per acre) in new wheat cultivars and reported that the maximum grain yield was achieved at a density of 950,000 plants and higher seed consumption did not increase grain yield. Furthermore, Bavec et al., (2007) compared different sowing rates of wheat cultivars (350-800 seeds m^{-2}) and observed that with increasing seed consumption, leaf area index increased. Thus, the maximum amount was obtained at 800 seeds m^{-2}. In similar studies, the maximum plant height, number of seeds per spike, number of spikes per square meter, 1000 seed weight and grain yield were achieved at 150 kg ha^{-1} (Anwar et al., 2015).

During a four-year study, Schillinger (2005) studied different sowing rates (120-280 seeds m^{-2}) and concluded that the yield was not significantly different in all treatments because at lower sowing rates, increasing tiller number per plant and increasing number of seeds per spike, compensated for the reduction in the seeding rate. Therefore, by applying accurate seeding rate, the number of seeds can be reduced to 50% of the recommended amount.

Laghari et al. (2011) studied the different seed quantities as 125-200 kg among different cultivars, and concluded that the improvement of nutrients uptake (nitrogen, phosphorus, potassium), enhanced vegetative characteristics, crop growth rate, plant height, number of tillers, spike length, 1000-seed weight, spike weight and finally promoted grain yield at 125 kg ha^{-1}. They warned that the higher seeding rate as 200 kg causes greater internode length, more lodging, lower 1000-grain weight and delayed maturity.

Furthermore, Hu et al. (2018) examined the conventional till and straw mulching with minimum till using different seed rates from 225-480 seeds m^{-2}, and found that during 4 growing seasons, the number of spikes, number of seeds and grain yield were higher in the conventional till system. They concluded that in the no-till system, the minimum soil temperature is lower in the growth stages, especially at tillering stage, and in this system, pest damage also increased. Finally, the use of straw mulching with minimum till was recommended only in very dry seasons. Moreover, various seeding rates in conventional till and no-till systems did not differ significantly, at least in terms of grain yield.

3.5 Grain protein content

The grain protein showed a significant difference under the influence of the year and in the second year, the protein content was 0.18% less. The protein content in wheat grain increases in dryland and under water restriction conditions. Since, according to Table 1, the amount of rainfall in the first year (521.2 mm) was less than in the second year (782.5 mm), such a result seems logical.

In a three-year study, the maximum protein content and wet gluten in wheat cultivars were achieved in years with lower rainfall (Woźniak, 2013). In addition, in this experiment, the interaction effects of year × tillage were significant. The protein content increased in the conventional tillage system during both years, resulting in a greater difference in the wheat protein in the conventional tillage compared with no-till in the second year (data not shown).

During a six-year experiment on clay and silt loam soils, it was found that grain yield and wheat protein percentage decreased in the no-till system (McConkey et al., 2002). Enhanced grain protein and wet gluten content by conventional tillage was reported by Woźniak (2013). The interaction of year × cultivar and tillage × cultivar was also significant in this trait. Thus, the protein content was higher in Baran cultivar than Rijaw during the two years. Meanwhile, the protein percentage of both cultivars decreased slightly in the second year. The increase in protein content in Baran cultivar under the influence of conventional and non-till system was more than in Rijaw cultivar. However, the no-till system reduced the protein content of both cultivars (data not shown).

In this experiment, different seeding rates showed a significant effect on protein content.

Based on the results of the average comparisons in Table 4, the maximum protein content was obtained at 75 kg and with increasing the seed rate from 75 to 250 kg ha^{-1}, the protein content decreased by 0.56% to 2.6%. It seems that increasing the number of plants per unit area has reduced the number of nutrients absorbed by each plant due to competition between them and therefore, the protein content has been decreased.

During a three-year study, Zecevic et al. (2014) reported various responses of cultivars to different sowing rates in terms of yield and yield components and grain gluten percentage, and the maximum number of tillers m^{-2}, 1000-seed weight and protein percentage among all cultivars observed in 650 germinated seeds/m^2. Likewise, the maximum protein and starch content were reported in seed rate of 112.5 and 150 kg, respectively (Twizerimana et al., 2020). Bastos et al. (2020) argued that with increasing plant density from 100 to 500 plants m^{-2}, the protein content in wheat cultivars decreased.

4 Conclusion

According to the two-year findings of this experiment, given the increase in rainfall in the second year, and the delays in sowing date, yield and effective traits in yield decreased. The conventional tillage system reduced soil organic matter by 0.18%, increased grain yield by 364 kg ha^{-1} (18.2%) by increasing yield components. In this experiment, a significant difference was observed between cultivars in terms of number of spikes at 5% and number of seeds per spike and 1000-grain weight at 1% level, but the difference between cultivars was not significant in terms of grain yield, despite the increase of 141.84 kg ha^{-1} in Rijaw cultivar. On the other hand, the protein content in Baran cultivar was 0.36% higher than Rijaw.

Comparison of different seeding rates also showed a significant difference between all studied traits except the number of seeds per spike and grain yield. Similarly, the highest protein content was obtained at the seed rate of 75 kg ha^{-1} and the protein content decreased with increasing the seeding rate. Finally, based on the results of interactions, the maximum grain yield was obtained by conventional tillage system, Rijaw cultivar with seeding rate of 175 kg ha^{-1} as 2293.7 kg ha^{-1}, while the lowest value of this trait was achieved in the no tillage system, Baran cultivar and the seed rate of 75 kg ha^{-1} as 1323.02 kg ha^{-1}. Therefore, application of conventional tillage system, Rijaw cultivar with seeding rate of 175 kg ha^{-1} recommended in the region.

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