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TILLAGE SYSTEMS AND SEEDING RATES EFFECT ON YIELD COMPONENTS, SEED YIELD AND BIOLOGICAL YIELD OF BARLEY CULTIVARS

Marwan N. Ramadhan

Machines and agricultural machineries dept., Agric. College, Basrah University, Basrah, Iraq.

malali841@gmail.com

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Abstract

A field experiment was conducted to evaluate the effect of conventional tillage (CT), Reduced tillage (RT) and No-Tillage (NT) systems using three seeding rates (100, 120, and 140 kg ha^{-1}) of two barley species *Hordeum vulgare* L. cultivars namely Arivat and IPA-99. The aim of the experiment was to develop management strategy for selecting tillage system, seeding rate, and cultivar to increase yield of barley under semi-arid conditions. The experiment was laid out in randomized complete block design with split-split plots arrangement having tillage systems as main plot, cultivars as sub plot and seed rates as sub-sub plot. CT and RT was more effective in enhancing tiller number, plant height, spike number, seed yield and biological yield as compared with NT. Tiller number, plant height, spike number, seed yield and biological yield for the highest seeding rate was 24.253, 5.285, 44.142, 31.108, and 9.128% respectively greater than for the lowest. IPA-99 cultivar had more tillers per unit area, spike number, seed yield, biological yield, harvest index and higher plants than Arivat cultivar. However, Arivat cultivar had higher kernel per spike and thousand kernel weight. Negative correlation coefficients were found between spikes number and kernels per spike of -0.691 and spikes number and kernels weight of -0.943. Applying seed rate of 140 kg ha^{-1} with IPA-99 cultivar under CT seems to the promising combination for semiarid barley.

Key words: Chisel plow. Moldboard plow. Conservation tillage. Seed yield. Biological yield. TKW: thousand kernel weight.

1.Introduction

Tillage affects the development of roots function as it plays a somewhat more important role in the development of crops [1]. Root system works as a bridge between the impact of agricultural operations on the soil and changes in the shoot and yield [2]. The tillage system increases the availability of water for the crop by facilitating the growth of roots in the regions at the soil section, which loses water by evaporation (surface layers) or remain until physiological maturity of the crop (deep layers) [3]. Advantageous and disadvantageous attributes of each tillage system can vary with soil and climate differences. Tillage process accelerates losing the organic matter from the soil by increasing the process of vital oxidation and increasing soil erosion [4]. NT farming has been adopted by many farmers to reduce costs, external energy inputs, increase profits, maintain the soil water and increase soil organic matter [5]. [6] mentioned the benefits of using NT as it allows early farming through the elimination of delay caused by the tillage process. Some of the drawbacks of NT system could be emergence delayed, low plant density [7], and increase the weed infestation and insect pests [8], which can be overcome by using various tillage systems. To obtain good seeds production tillage process must be suitable for the type of crop and soil.

The study of [9] revealed that deep-tillage with moldboard plow gave the highest number of tiller per plant superior to the disc plow and harrows for shallow tillage depths. [13] Found that plant height was significantly higher for disc plow, followed by chisel plow, compared with NT. The date of [14] showed that CT (moldboard plow) gave the highest spike m^{-2} followed by RT (shallow straw cultivator) followed by NT. With respect to kernels per spike, [15] found no significant differences for CT (autumnal plowing + spring disking) and RT (autumnal chisel plow + spring disking) and NT as it was 17.4, 17.6, 19.7 kernels $spike^{-1}$ respectively. The effects of tillage system on TKW were also reported by [14], TKW was 44.3, 46.4, 46.7 g for CT (moldboard plow), RT (shallow straw cultivator), NT respectively. Data from a previous study conducted by [16] indicate that barley yield was 2122.5, 1766.5, and 1159.5 ton ha^{1} for CT (moldboard 30-40 cm) and RT (chisel 25-30 cm) and NT respectively. It has been also reported that RT (chisel plow) and CT (disk plow) gave the highest seed yield without significant difference between them 151 and 134 g m^{-2} respectively, while it was 70 g m^{-2} for NT [13]. [14] reported significant effect of tillage systems on biological yield, the highest yield produced by CT followed by RT followed by NT.

Selecting suitable seeding rate is important factor to increase seed yield. [16] found significant effect of seeding rates on tiller number as it was 69.8, 78.9, 88.1, and 102.3 tiller per meter length for seeding rates 67, 135, 202, and 270 kg ha^{-1} averaged for three cultivars. Yield component characters are responsible for the increasing in the final yield. [16] reported significant effects when using seeding rates of 50, 140, 230, and 320 kg ha^{-1} on yield component as it increased the number of spikes by 144, 255, 300, and 344 spike m^{-2} and decreased kernels number by 55, 46, 41, and 37 and decreased TKW by 46.43, 43.86, 43.00, and 42.14 g respectively in Alaska. The effect of seeding rate on seed yield reported by [16], seed yield increased when seeding rate increased. [11] found that seed yield of Arivate cultivar increased from 2476.74 to 3334.64 kg ha^{-1} as seeding rate increased from 100 to 140 kg ha^{-1} in a silty clay loam soil. [22] found that increasing seeding rate from 100 to 130 kg ha^{-1} increased biological yield significantly from 7966 to 10796 kg ha^{-1}. Seeding rates have also significant effect on harvest index. The study of [22] revealed that harvest index increased significantly from 38.1 to 38.8 % when increasing seeding rate from 100 to 130 kg ha^{-1}. Cultivars respond differently to various soil conditions and climate, so when selecting cultivars correctly it is possible to obtain high production of crops. The present study was conducted to find the best tillage system, seeding rate, and barley cultivar to improve barley production under semiarid condition.

2.Materials and methods

A field study was conducted during the growing season of 2011-2012 in Shat Al-Arab shier, Basrah province, Iraq. The soil is silty clay loam. Three tillage treatments were applied (conventional tillage, reduced tillage, and no-tillage).

Conventional Tillage (CT) consisted of one pass with 3 unit moldboard plow (Mb) at 30 cm depth. Reduced Tillage (RT) consisted of one pass with super-heavy duty chisel plow (Ch) with 45 cm long tines worked the soil to a depth of 15 cm. No-Tillage (NT) consisted of direct sowing. Two cereal cultivars sown in the autumn October 21 at three sowing rates into three tillage systems. Cereal cultivars were Arivat (local cultivar) and IPA-99 6-row barley, sown at 100, 120, and 140 kg ha^{-1}. Tests conducted in petri dishes before sowing showed that all seed had 97% germination. Nitrogen fertilizer was applied (in the form of urea 46% N) at a rate of 120 kg ha^{-1}, in three equal doses at sowing, during tillering, and at anthesis.

Phosphorus fertilizer (46% P_2O_5) was added by 80 kg ha^{-1} before planting [23]. Individual plots were 4.5 m^2

Plant height in centimeters was measured for 20 plants randomly selected from each sub-sub plot. Three row segments with 1 m length were harvested in a sickle within each sub-sub plot on April 17 to measure the number of tiller and yield components of barley. Spikes number were measured. Kernels per spike was calculated as average based on 50 spikes, and thousand kernel weight was calculated from harvested area yield by weighing 1000 kernel by electronic scale (± 0.01 g) after passing spikes through a hand-fed thresher. Seed and biological yield (13% moisture content) was calculated by harvesting the entire plot area and then making a unit area conversion. Harvest index was calculated by divided seed yield/biological yield [24].

Soil bulk density (ρb) was measured using samples obtained by cores method [25]. Soil porosity (E) was calculated according to Vomocil method reported by [26]. A penetrometer was used, based on [27], to calculate soil penetration resistance for the uncultivated and cultivated soil. Cone index (C.I.) was then calculated [28]. Cohesion (C) was measured using the [29] method. Irrigation water has EC of 4.47 dS m^{-1} and pH of 7.3. E.C. was measured by conductivity meter CC-501 and pH was measured by pH-meter WTW pH 315i. The data presented in Table (1). Air temperature and precipitation were retrieved from general authority for meteorological (Fig. 1).

The experimental design was a randomized complete block design in a split-split plot arrangement with three replications. Main plots were tillage systems, subplots were barley cultivars, and sub-sub plots were sowing rates. There were 18 plots (i.e. 6 subplots in each whole plot).

An analysis of variance for all data was conducted using IBM SPSS Statistics 19. Treatments were considered significantly different if the P value was < 0.05. Treatment means were separated using Fisher's protected least significant difference at 0.05 probability level. Correlation coefficients were calculated between studied traits (Tab.2).

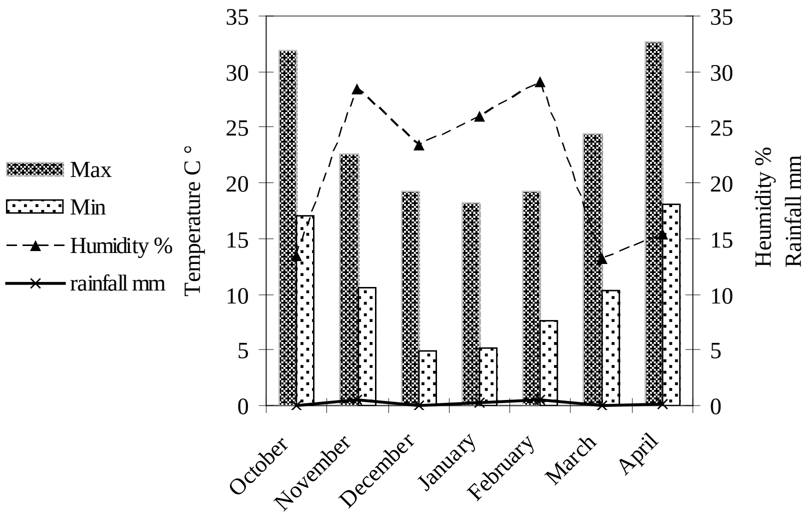

Figure 1 Monthly temperature, relative humidity, and total amount of rainfall in the period from October to April during 2011/2012 season.

Table 1 Physical, chemical and mechanical properties of the experimental field soil.

Depth cm	*ρb* Mg m^{-3}	*C.I.* kN m^{-2} Un cultivated	Cultivated Mb†	Cultivated Ch‡	*E* %	*C* kN m^{-2}	Sand (g kg^{-1})	Silt (g kg^{-1})	Clay (g kg^{-1})	Texture	PH	E.C. dS m^{-1}
0 -10	1.40	3948.38	102.10	106.81	43.94	7.24	112.56	540.68	346.76	SCL	7.41	6.28
10-20	1.43	4127.85	116.23	119.38	43.53	8.24	112.35	511.45	376.2	SCL		
20-30	1.45	4486.80	120.95	127.23	43.12	9.93	124.19	502.18	373.63	SCL		
30-40	1.44	4307.32	111.52	114.66	43.26	8.96	123.6	508.13	368.27	SCL		

†MB: Moldboard; ‡Ch: Chisel.; SCL: Silty clay loam

Table 2 Correlation coefficients.

	Tillers m^{-2}	Spikes m^{-2}	Plant height
Spikes m^{-2}	0.838**		
Plant height	0.663**		
Kernels $spike^{-1}$		-0.691**	
Seed yield		0.962**	
TKW		-0.943**	
Biological yield	0.844**	0.913**	0.791**

**. Correlation is significant at the 0.01 level (2-tailed).

3.Results and discussions

3.1.Number of tiller

The effect of tillage systems on tillers m^{-2} shown in Table (3). CT resulted in significant ($p<0.01$) higher number of tillers m^{-2} than RT and NT 20.674 and 50.632 % respectively. This could be due to the lower penetration resistance (Table 1) in root zone and facilitating root growth and proliferation, which enhance nutrients absorption and supply adequate water requirements. This is turning favorably for increased tillers production. Similar finding was observed by [9], [10], and [11].

The increased tiller number for CT compared to RT is probably resulted from tillage depth differences between CT (30 cm) and RT (15 cm) treatments, in addition increased soil pulverization produced by moldboard plow compared with chisel plow which decreased soil penetration (Table 1) and increased porosity and contacts between soil particles and seeds [10].

It can be inferred from the data presented in Table (3) that tillers m^{-2} increased significantly ($p<0.01$) from 339.989 to 422.448 tiller m^{-2} as seeding rate increased from 100 to 140 kg ha^{-1}. This might be due to the fact that more plants emerged as the seeding rate was increased which is reflected on the total number of tillers per unit area. These results are agreed with the findings of [30] and [11], who reported that tillers m^{-2} increased with increasing seeding rate.

The effect of barley cultivars is shown in Table (3). The IPA-99 cultivar had significant ($p<0.01$) higher number of tillers than Arivat cultivar it was 399.662 and 373.178 tillers m^{-2} respectively. This result could be attributed to the variation of genetic ability of cultivars.

A tillage cultivar interaction was not observed for number of tillers. The original data points, however, revealed that the following interaction gave the highest number of tillers per m^2 CT×140 ($p<0.01$) 486.807 tillers m^{-2}, IPA-99×140 ($p<0.05$) 431.425 tillers m^{-2}, CT×IPA-99×140 and CT×IPA-99×120 ($p<0.05$) 492.622 and 487.233 tillers m^{-2} respectively without differences between them.

Table 3 The effect of tillage systems, seeding rates and barley cultivars on tillers m^{-2}.

Cultivar	Seeding Rate kg ha^{-1}	Tillage type NT	RT	CT	Cultivar×Rate mean	Cultivar mean
Arivat	100	220.709g	312.086f	425.226c	319.340E	
	120	313.108f	375.135d	471.931a	386.724C	373.178B
	140	332.513ef	426.908c	480.992a	413.471B	
Tillage×Cultivar mean		288.777	371.376	459.383		
IPA-99	100	296.329f	353.046e	432.541bc	360.638D	
	120	339.079e	394.453cd	487.233a	406.922B	399.662A
	140	350.811e	450.841b	492.622a	431.425A	
Tillage×Cultivar mean		328.740	399.446	470.798		
Seeding Rate kg ha^{-1}					Seeding Rate mean	
	100	258.519f	332.566de	428.883b	339.989C	
	120	326.093e	384.794c	479.582a	396.823B	N/A
	140	341.662d	438.874b	486.807a	422.448A	
Tillage mean		308.758C	385.411B	465.091A		

Data followed by the same letter (capital letters for the main effects, Tillage×Cultivar, and Cultivar×Rate) and (small letters for the interaction effects) are not significantly different using LSD at P<0.05.

. Each sub-sub plots contains 9 rows with 3 m long and 15 cm row spacing. The seeds were scattered in each row. Neither grass or broadleaf weeds were a problem in this experiment. The weeds were removed by hands extraction.

3.2.Plant height

Table (4) showed the significant ($p<0.01$) effect of tillage systems on plant height. Plant height increased for CT and RT by 4.727 and 2.780 % respectively without differences between them compared with NT. These results could be due to CT and RT systems encouraged the emergence and early growth of plants. This is in accordance with the results that reported by [12], [13], and [11].

The results also showed a significant ($p<0.01$) increase in plant height with an increase in seeding rate (Table 4). Increasing seeding rate from 40 to 120 kg ha^{-1} increased plant height from 89.048 to 93.755 cm (5.285 %). Similar finding was observed by [19], [31], and [11]. Increasing the seeding rate increased the number of plants per unit area resulting in increased competition for light due to increased plant density, resulting increased shading between plants, which leads to a reduction in the proportion of red light to far red light which are responsible for increasing the length of the plant by encouraging the production of Gibberellins which stimulates stem elongation by stimulating cell division and elongation to get enough light [32]. This is confirmed by the significant ($p<0.01$) positive correlation coefficient between plant height and number of tiller m^{-2} reaching 0.663.

The results revealed that barley cultivars had a significant (p<0.01) effect on the plant height. IPA-99 cultivar showed higher plants when compared with Arivat cultivar (Table 4). This may be attributed to the differences between cultivars ability and increased tillering for IPA-99 compared with Arivat (7.096 %) which results in more competition for light.

The results also showed that there was significant effect in terms of the Tillage×Cultivar (p<0.05). No interaction existed for Tillage×Rate, Rate×Cultivar and Tillage×Cultivar×Rate (Table 4).

Table 4 The effect of tillage systems, seeding rates and barley cultivars on plant height (cm).

Cultivar	Seeding Rate kg ha^{-1}	Tillage type NT	RT	CT	Cultivar×Rate mean	Cultivar mean
	100	84.625	88.258	89.123	87.336	
Arivat	120	87.000	89.991	91.166	89.386	89.348B
	140	88.385	91.373	94.212	91.324	
Tillage×Cultivar mean		86.670D	89.874C	91.500C		
	100	87.943	90.906	93.434	90.761	
IPA-99	120	92.307	93.961	94.804	93.690	93.546A
	140	95.023	95.682	97.852	96.186	
Tillage×Cultivar mean		91.758BC	93.516B	95.363A		
Seeding Rate kg ha^{-1}					Seeding Rate mean	
	100	86.284	89.582	91.279	89.048C	
	120	89.653	91.976	92.985	91.538B	N/A
	140	91.704	93.528	96.032	93.755A	
Tillage mean		89.214B	91.695A	93.432A		

Data followed by the same letter (capital letters for the main effects, Tillage×Cultivar, and Cultivar×Rate) and (small letters for the interaction effects) are not significantly different using LSD at P<0.05.

3.3.Number of spike m^{-2}

Spike number was significantly (p<0.01) affected by tillage systems. Data in Table 5, indicated that CT registered the highest values of 287.193 spike m^{-2} compared with RT and NT which was 262.650 and 212.686 spike m^{-2} respectively. These findings could be attributed to increased number of tiller by 20.674 and 50.632 % compared with RT and NT respectively. Similar results were also reported by [14] and [11].

The influence of seeding rates on spike number is shown in Table 5, which clarified that highest seeding rate of 140 kg ha^{-1} caused significant (p<0.01) increase in number of spikes m^{-2} 296.124 compared to the lowest seeding rate of 100 kg ha^{-1} which recorded the lowest number of spikes m^{-2} 205.439. This could be assigned to positive influences of seeding rates in increasing tiller number by 24.253 % as it increased from 100 to 140 kg ha^{-1}. The increasing response of spike number observed with increasing seeding rate is in agreement with [30] and [11]. This confirms by the significant (p<0.01) positive correlation coefficient between number of spike m^{-2} and number of tiller m^{-2} which was 0.838.

The data obtained clearly showed that significant (p<0.01) effect of barley cultivars on spike number (Table 5). The highest value was 281.882 spikes m^{-2} for IPA-99, while it was 226.471 spikes m^{-2} for Arivat. The increased number of tiller per unit area for IPA-99 reflects on increased number of spike, as it was 7.096 % more than Arivat.

In the respect of the interaction effect, data obtained revealed a significant effect of the Tillage×Rate (p<0.01) and Tillage×Cultivar×Rate (p<0.01) interaction (Table 5). Using CT×140 kg ha^{-1} and CT×IPA-99×140 kg ha^{-1} gave the highest number of spike 339.514 and 372.952 spikes m^{-2} respectively. However, there were no significant Tillage×Cultivar and Rate×Cultivar interactions.

Table 5 The effect of tillage systems, seeding rates and barley cultivars on number of spike m^{-2}.

Cultivar	Seeding Rate kg ha^{-1}	Tillage type NT	RT	CT	Cultivar×Rate mean	Cultivar mean
	100	141.357i	193.260h	209.615gh	181.411	
Arivat	120	197.493h	243.062ef	256.341e	232.298	226.471B
	140	218.075g	272.956d	306.077c	265.703	
Tillage×Cultivar mean		185.642	236.426	257.344		
	100	209.300gh	230.306fg	248.797ef	229.468	
IPA-99	120	240.989f	298.535c	329.380b	289.635	281.882A
	140	268.903de	337.779b	372.952a	326.545	
Tillage×Cultivar mean		239.731	288.873	317.043		
Seeding Rate kg ha^{-1}					Seeding Rate mean	
	100	175.328h	211.783g	229.206f	205.439C	
	120	219.241fg	270.798d	292.860c	260.967B	N/A
	140	243.489e	305.368b	339.514a	296.124A	
Tillage mean		212.686C	262.650B	287.193A		

Data followed by the same letter (capital letters for the main effects, Tillage×Cultivar, and Cultivar×Rate) and (small letters for the interaction effects) are not significantly different using LSD at P<0.05.

3.4.Number of kernel per spike

Kernels per spike of barley as affected by experiment parameters are shown in Table 6. Significant (p<0.01) differences were found in the effect of tillage systems on kernels spike^{-1}. NT had higher number of kernel per spike than RT and CT, it was 1.539 and 2.952 % respectively. [15] found non-significant increase in the kernels per spike associated with NT, whereas [11] found similar findings. The cause of the low number of kernels per spike for CT and RT systems may be due to a significant increase in the number of spikes m^{-2} for the CT and RT, due to the inverse relationship between the number of spikes and the number of kernels per spike. This confirms the significant (p<0.01) negative value of the correlation coefficient between the number of kernels spike^{-1} and the number of spikes reaching -0.691.

Similarly, seeding rate had the same effect on kernels per spike (Table 6). It decreased significantly (p<0.01) from 32.610 to 32.269 (1.056%) as seeding rate increased from 100 to 140 kg ha^{-1}. This trend accords with the [19] and [11] who examined that the highest number of kernels spike^{-1} was produced at the lowest seeding rates, but at the highest seeding rate, kernels number decreased significantly. Increasing seeding rate led to a decline in the number of kernels spike^{-1} as a result of mutual compensation between yield components as the seeding rate 140 kg ha^{-1} gave the highest average of number of spikes 296.124 spike m^{-2} compared with the seeding rate 100 kg ha^{-1} which gave 205.439 spike m^{-2}. The reason for the decrease could be attributed to the competition between plants when increasing seeding rate, which starts at the emergence of kernel sites, since the number of kernels establishments reduced of all plant, and is determined by plant ability to compete with other plants [33]. This may be also due to other reasons related to plant development, when increasing the seeding rate increases the intensity of competition for nutrients among yield components, it is known that there are a number of effective tiller originates first, allowing the exploitation of most of the nutrients available during the period of formation, followed by kernel filling stage and this number is controlled by what is available of the ready-made nutrients [34].

The analysis of variance showed significant (p<0.01) cultivars effect on kernels spike^{-1} (Table 6). It was 33.577 and 31.293 kernel spike^{-1} for Arivat and IPA-99 cultivar respectively. The higher kernels spike^{-1} for Arivat cultivar could be attributed to lower spike per m^2, which was decreased by 19.657 % compared with IPA-99 cultivar.

The results also showed that there was significant effect in terms of the Tillage×Rate interaction ($p<0.01$), Significant effects were observed either for Tillage×Cultivar ($p<0.01$), Cultivar×Rate ($p<0.01$) and Tillage×Cultivar×Rate ($p<0.01$) interactions (Table 6).

Table 6 The effect of tillage systems, seeding rates and barley cultivars on No. kernels spike^{-1}.

Cultivar	Seeding Rate kg ha^{-1}	Tillage type NT	RT	CT	Cultivar×Rate mean	Cultivar mean
	100	34.386a	33.829d	33.202g	33.805A	
Arivat	120	34.149b	33.527e	33.016h	33.564B	33.577A
	140	33.949c	33.385f	32.758i	33.364C	
Tillage×Cultivar mean		34.161A	33.580B	32.992C		
	100	31.835j	31.353m	31.058p	31.415D	
IPA-99	120	31.673k	31.244n	30.959q	31.292E	31.293B
	140	31.512l	31.168o	30.843r	31.175F	
Tillage×Cultivar mean		31.674D	31.255E	30.953F		
Seeding Rate kg ha^{-1}					Seeding Rate mean	
	100	33.111a	32.591d	32.130g	32.610A	
	120	32.911b	32.386e	31.987h	32.428B	N/A
	140	32.731c	32.277f	31.801i	32.269C	
Tillage mean		32.917A	32.418B	31.973C		

Data followed by the same letter (capital letters for the main effects, Tillage×Cultivar, and Cultivar×Rate) and (small letters for the interaction effects) are not significantly different using LSD at $P<0.05$.

3.5.Thousand kernel weight g

Tillage systems effect on TKW are presented in Table 7. The results showed that the tillage systems have significant ($p<0.01$) effects on TKW. NT treatment gave highest value of 28.991 g while CT gave value of 26.146 g. This is in agreement with [12] and [11] non-significantly. The low TKW for CT and RT systems may be due to the increase in the number of spikes per m^{-2} for the CT and RT systems compared with NT (Table 5). This confirms the significant ($p<0.01$) negative value of correlation coefficient between TKW and the number of spikes reaching -0.943.

The results showed a significant ($p<0.01$) decrease in TKW with an increase in the seeding rate (Table 7). Increasing seeding rate from 40 to 120 kg ha^{-1} decreased the TKW from 28.908 to 26.638 g. TKW largely affected by high plant densities, led to a case of competition between plants, resulting in reduced dry matter manufactured processed in the source which transferred to the sinks, as the manufactured materials are distributed to a large number of spikes and thus less weight of kernels. This is in accordance with [30], [19], and [11] non-significantly.

The effect of barley cultivars had significant ($p<0.01$) effect on TKW (Table 7). The highest value was 28.250 g for Arivat cultivar while it was 26.797 g for IPA-99 cultivar. This may be partially explained by higher spikes for IPA-99 than Arivat cultivar which was 281.882 and 226.471 spike m^{-2} respectively.

The interactions between Tillage×Cultivar and Tillage×Cultivar×Rate were not statistically significant (Table 7). However, there were significant interactions for Tillage×Rate ($p<0.01$) and Rate×Cultivar ($p<0.01$).

Table 7 The effect of tillage systems, seeding rates and barley cultivars on TKW g.

Cultivar	Seeding Rate kg ha^{-1}	Tillage type NT	RT	CT	Cultivar×Rate mean	Cultivar mean
	100	30.686	29.201	27.967	29.285A	
Arivat	120	29.443	27.875	26.482	27.933C	28.250A
	140	29.053	27.423	26.125	27.534D	
Tillage×Cultivar mean		29.728	28.167	26.858		
	100	29.959	28.415	27.222	28.532B	
IPA-99	120	27.563	26.076	24.717	26.119E	26.797B
	140	27.242	25.620	24.364	25.742F	
Tillage×Cultivar mean		28.255	26.703	25.435		
Seeding Rate kg ha^{-1}					Seeding Rate mean	
	100	30.323a	28.808b	27.595e	28.908A	
	120	28.503c	26.976f	25.600h	27.026B	N/A
	140	28.148d	26.522g	25.245i	26.638C	
Tillage mean		28.991A	27.435B	26.146C		

Data followed by the same letter (capital letters for the main effects, Tillage×Cultivar, and Cultivar×Rate) and (small letters for the interaction effects) are not significantly different using LSD at P<0.05.

3.6.Seed yield kg ha^{-1}

It was found from ANOVA that seed yield was significantly (p<0.01) affected by tillage systems. It can be seen from Table 8 that CT and RT experienced higher seed yield compared to NT (18.335 and 15.167 % respectively). This is in accordance with the results reported by [16], [13], [14], and [11]. This was because of increased soil disruption, low bulk density and increased porosity which facilitate the movement of the roots and increase its ramifications to reach greater depths subsequently increases the absorption of water, especially in drought periods, and nutrients from soil profile and thus increased dry matter production, which part of it goes into kernel. In addition to lower values of penetration resistance of CT and RT compared with NT (Table 1). Which increased the movement of water downward, speed up tapping the excess water, prevent soil waterlogging, and increase the ventilation. Which are reflected accordingly to increase seed yield. On coarse, silty clay loamy soils with well-developed tillage pans, such as those exist in the experiment soil, depth of tillage can have a large influence on plant growth and yields. The tillage pan depth on the experiment soil was 20-23 cm (Table 1). The moldboard plow (30 cm depth) penetrated the tillage pan on soil, but the chisel plow did not penetrate the deep pan in the soil. Failure to penetrate the tillage pan in the soil may be the reason chisel plowing resulted in lower yields than the moldboard plow. This response indicates that the disruption of tillage pans is also important for barley production.

The results revealed the significant (p<0.01) effect of seeding rates on seed yield (Table 8). Seed yield increased by 31.196 % when seeding rate increased from 100 to 140 kg ha^{-1}. The effects of seeding rate on the seed yield are similar to the results obtained by [20], [19], [21], and [11]. Increasing the seeding rate led to increase the number of plants per unit area, consequently increasing the number of tiller and this in turn caused an increase in the number of spikes, the results indicated that increasing seeding rate from 100 to 140 kg ha^{-1} increased the number of spike by 44.142 % which caused an increase in the number of kernels m^{-2}, which in turn compensate the decline in the number of kernels per spike and TKW. Seed yield is very dependent on the number of kernels produced per m^{-2} [35]. This result is supported by the significant (p<0.01) positive correlation coefficient between the seed yield and number of spikes per unit area which amounted to 0.962.

It was found from ANOVA that the effect of cultivars on seed yield was significant ($p<0.01$) (Table 8). Using IPA-99 cultivar increased the seed yield by 9.929 % compared with Arivat cultivar. These results could be attributed to higher number of spike m^{-2} which was increased by 24.467 % for IPA-99 compared with Arivat. This difference may also be due to the variation of genetic ability of cultivars.

There were no significant effects for Tillage×Rate, Tillage×Cultivar and Cultivar×Rate interactions, however, a significant ($p<0.05$) Tillage×Cultivar×Rate interaction was found for seed yield (Table 8). Using CT×IPA-99×140 kg ha^{-1} or RT×IPA-99×140 kg ha^{-1} gave the highest seed yield without differences between them.

Table 8 The effect of tillage systems, seeding rates and barley cultivars on seed yield kg ha^{-1}.

Cultivar	Seeding Rate kg ha^{-1}	Tillage type			Cultivar×Rate	Cultivar
		NT	RT	CT	mean	mean
	100	1492.073g	1909.468f	1946.623f	1782.721	
Arivat	120	1985.691ef	2271.905d	2241.056de	2166.217	2124.012B
	140	2151.117de	2498.858bc	2619.314b	2423.096	
Tillage×Cultivar mean		1876.293	2226.744	2268.998		
	100	1996.224ef	2052.171ef	2103.574e	2050.657	
IPA-99	120	2103.802e	2432.193c	2520.638bc	2352.211	2335.224A
	140	2308.425cd	2697.332ab	2802.660a	2602.806	
Tillage×Cultivar mean		2136.150	2393.899	2475.624		
Seeding Rate kg ha^{-1}					Seeding Rate mean	
	100	1744.148	1980.820	2025.099	1916.689C	
	120	2044.746	2352.049	2380.847	2259.214B	N/A
	140	2229.771	2598.095	2710.987	2512.951A	
Tillage mean		2006.222B	2310.321A	2372.311A		

Data followed by the same letter (capital letters for the main effects, Tillage×Cultivar, and Cultivar×Rate) and (small letters for the interaction effects) are not significantly different using LSD at $P<0.05$.

3.7.Biological yield kg ha^{-1}

The effect of tillage systems on biological yield is given in Table 9. Tillage systems had significant ($p<0.01$) effect on biological yield. The higher value was 8259.432 kg ha^{-1} for CT, while it was 7224.813 kg ha^{-1} for NT. [13], [14], and [11] reported an increases in biological yield with CT compared with NT. The highest biological yield for CT could be attributed to an increasing number of tiller by 50.632 %, number of spike by 35.031 %, and plant height by 4.727 % respectively compared with NT.

The seeding rates had significant ($p<0.01$) effect on biological yield (Table 9). The biological yield increased from 7565.593 to 8256.219 kg ha^{-1} (9.128 %) when increasing the seeding rate from 100 to 140 kg ha^{-1}. The increasing response of biological yield observed with seeding rates is in agreement with [22] and [11]. Increasing the seeding rate led to an increasing number of tiller m^{-2}, plant height and number of spikes m^{-2} (Table 3, 4, and 5) and this leads to an increase in light interception and thereby increase the efficiency of photosynthesis which increases the dry matter yield. This trend supports by significant ($p<0.01$) positive correlation coefficients between biological yield and plant height, tillers m^{-2}, and spikes m^{-2} which was 0.791, 0.844, and 0.913 respectively.

The effect of barley cultivars has also significant ($p<0.01$) on biological yield (Table 9). The higher biological yield was 8171.092 kg ha^{-1} for IPA-99 cultivar, while it was 7564.121 kg ha^{-1} for Arivat cultivar.

The higher number of tiller m^{-2}, spike m^{-2}, and plant height for IPA-99 cultivar contributed to the higher biological yield. It may also be attributed to the genetic susceptibility of cultivars.

The results also indicated that there were significant effect for Tillag×Rate (p<0.01), Tillag×Cultivar (p<0.01), and Rate×Cultivar (p<0.01) interactions. There was no significant effect for Tillag×Cultivar×Rate interaction (Table 9).

Table 9 The effect of tillage systems, seeding rates and barley cultivars on biological yield kg ha^{-1}.

Cultivar	Seeding Rate kg ha^{-1}	Tillage type NT	RT	CT	Cultivar×Rate mean	Cultivar mean
	100	6583.756	7555.895	7632.479	7257.377F	
Arivat	120	6793.556	7814.396	7794.012	7467.321E	7564.121B
	140	7301.632	8265.333	8336.034	7967.667C	
Tillage×Cultivar mean		6892.981F	7878.541D	7920.842C		
	100	7253.462	8053.306	8314.658	7873.809D	
IPA-99	120	7479.391	8309.768	8494.926	8094.695B	8171.092A
	140	7937.086	8712.742	8984.487	8544.772A	
Tillage×Cultivar mean		7556.646E	8358.605B	8598.024A		
Seeding Rate kg ha^{-1}					Seeding Rate mean	
	100	6918.609i	7804.601f	7973.568e	7565.593C	
	120	7136.473h	8062.082d	8144.469c	7781.008B	N/A
	140	7619.359g	8489.037b	8660.260a	8256.219A	
Tillage mean		7224.814C	8118.573B	8259.433A		

Data followed by the same letter (capital letters for the main effects, Tillage×Cultivar, and Cultivar×Rate) and (small letters for the interaction effects) are not significantly different using LSD at P<0.05.

3.8.Harvest index %

The effect of tillage systems on harvest index is shown in Table 10. Harvest index was not affected by tillage systems. It was 28.641, 28.380, and 27.679 % for CT, RT, and NT respectively. These data are in agreement with those reported by [14].

The seeding rates had significant (p<0.01) effect on harvest index (Table 10). It increased with increasing seeding rate as it was 25.287, 29.021, and 30.392 % for seeding rates of 100, 120, and 140 kg ha^{-1} respectively. The increasing number of spike with increasing seeding rate led to increase the number of kernel m^{-2}, subsequently increased seed yield by 31.108 % while the biological yield increased by 9.128% as the seeding rate increased from 100 to 140 kg ha^{-1}. [22] and [18], also reported of higher harvest index achieved with higher seeding rate.

Statistical analysis also showed that there were no significant differences among barley cultivars on harvest index (Table 10). It was 27.955 and 28.512 % for Arivat and IPA-99 cultivars respectively.

According to ANOVA and data presented in Table 10 it is evident that no significant interactions existing between Tillage×Rate, Tillage×Cultivar, and Rate×Cultivar. However, Tillage×Cultivar×Rate interaction was significant (p<0.01).

Table 10 The effect of tillage systems, seeding rates and barley cultivars on harvest index %.

Cultivar	Seeding Rate kg ha^{-1}	Tillage type NT	RT	CT	Cultivar×Rate mean	Cultivar mean
	100	22.541e	25.297d	25.638cd	24.492	
Arivat	120	29.156bc	29.14bc	28.746bc	29.014	27.965
	140	29.498b	30.227ab	31.441a	30.389	
Tillage×Cultivar mean		27.065	28.221	28.608		
	100	27.549c	25.476d	25.238d	26.088	
IPA-99	120	28.189bc	29.312bc	29.595ab	29.032	28.521
	140	29.132bc	30.869ab	31.333ab	30.445	
Tillage×Cultivar mean		28.29	28.553	28.722		
Seeding Rate kg ha^{-1}					Seeding Rate mean	
	100	25.045	25.387	25.438	25.29C	
	120	28.673	29.226	29.17	29.023B	N/A
	140	29.315	30.548	31.387	30.417A	
Tillage mean		27.678	28.387	28.665		

Data followed by the same letter (capital letters for the main effects, Tillage×Cultivar, and Cultivar×Rate) and (small letters for the interaction effects) are not significantly different using LSD at P<0.05.

4.Conclusions

The results of this study showed that barley seed yield generally enhanced using CT and RT systems compared with NT for two barley cultivars. Responses to seeding rates were significant, which resulted in increased seed and biological yield. Seed yields tended to be greatest with highest seeding rates compared with lowest seeding rates. IPA-99 seed yield was greater than those of Arivat. The results indicate that farmers in the southern plains can successfully produce barley under CT and seeding rate of 140 kg ha^{-1} for Iba99 cultivar. NT should be considered as the last alternative because of a low productivity potential.

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تأثير انظمة الحراثة واصناف الشعير وكميات البذار في مكونات الحاصل وحاصل الحبوب والحاصل الحيوي

مروان نوري رمضان

قسم المكائن والآلات الزراعية، كلية الزراعة، جامعة البصرة، البصرة، العراق.

malali841@gmail.com

الخلاصة

نفذت تجربة حقلية لمعرفة تأثير انظمة الحراثة التقليدية (CT)، الحراثة المختصرة (RT)، ونظام الزراعة بدون حراثة (NT) باستخدام ثلاث كميات بذار هي 100 و 120 و 140 كغم هكتار$^{-1}$ وصنفين من الشعير *Hordeum vulgare* L. هما Arivat و IPA-99. كان الهدف من هذه التجربة تطوير استراتيجية إدارية لاختيار نظام الحراثة وكمية البذار والصنف لزيادة غلة الشعير تحت الظروف شبه الجافة. حللت البيانات إحصائياً تبعاً لطريقة تحليل التباين للقطاعات المنشقة-المنشقة على وفق تصميم القطاعات العشوائية الكاملة، احتلت انظمة الحراثة القطع الرئيسية والاصناف القطع الثانوية ومعدلات البذار القطع تحت الثانوية. كانت الحراثة التقليدية (CT) واقل حراثة (RT) اكثر تأثيرا في تحسين عدد الاشطاء وارتفاع النبات وعدد السنابل وحاصل الحبوب والحاصل الحيوي مقارنة بالزراعة بدون حراثة. كان عدد الاشطاء وارتفاع النبات وعدد السنابل وحاصل الحبوب والحاصل الحيوي لكمية البذار الاكبر 24.253، 5.285، 44.142، 31.108 و 9.128% اكبر من كمية البذار الاقل. تفوق الصنف IPA-99 في عدد الاشطاء في وحدة المساحة وعدد السنابل وحاصل الحبوب والحاصل الحيوي ودليل الحصاد وارتفاع النبات مقارنة بالصنف Arivat. بينما تفوق الصنف Arivat في عدد الحبوب في السنبلة ووزن الالف حبة. وجد معامل ارتباط سالب بين عدد السنابل وعدد الحبوب بالسنبلة 0.691- ووزن الحبة 0.943-. بينت النتائج ان معدل البذار 140 كغم هكتار$^{-1}$ والصنف IPA-99 تحت نظام الحراثة التقليدية التركيبة الواعدة لإنتاج الشعير تحت الظروف شبه الجافة.

كلمات مفتاحية: المحراث الحفار. المحراث المطرحي. الحراثة الحافظة. حاصل الحبوب. الحاصل الحيوي.

TKW: وزن الالف حبة.