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Seeding rate and nitrogen fertilizer level for black barley under rain-fed conditions

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ABSTRACT: Increasing grain production yield is crucial to achieving profitable production systems. The optimal seeding rate and nitrogen fertilization at the right dose are substantial production factors for a higher barley crop yield, especially in rainfed conditions. The experiment aimed to determine the optimal black barley seeding and nitrogen fertilizer rate under rainfed conditions in Kirkuk district, northern Iraq. The agronomic characteristics of black barley were evaluated at seeding rates (200, 300 and 400 seeds m^{-2}) and different rates of nitrogen applications (0, 40 and 80 kg N ha^{-1}). These seeding rates at 300 and 400 seeds m^{-2} significantly affect Spikes m^{-2}, straw yield and biological yield compared to 200 seeds m^{-2}. Most studied traits were affected significantly by nitrogen fertilizer, where 80 kg N ha^{-1} recorded the highest value in spike length, m^{-2}, grains $spike^{-1}$, grain yield, biological yield and harvest index compared to 40 kg N ha^{-1}. Moreover, seeding rate x N fertilization had a significant influence on most of the studied traits, where 300 seeds m^{-2} × 80 kg N ha^{-1} significantly affected spike length, spikes m^{-2}, grains $spike^{-1}$, grain yield and harvest index, while straw yield and biological yield responded significantly to 400 seeds m^{-2} × 40 kg N ha^{-1}. The most measured traits, especially grain yield, were impacted by nitrogen application rather than seeding rates. In this region, black barley should be sown with 300 seeds m^{-2} with an application of 80 kg N ha^{-1} to obtain better grain yields under rainfed conditions.

Keywords: *Hordeum distichum* L.; plant density; urea fertilization; rain-fed agriculture.

Taxa de semeadura e nível de fertilizante nitrogenado para cevada preta (*Hordeum distichum* L.) sob condições de sequeiro

RESUMO: O aumento do rendimento da produção de grãos é crucial para a obtenção de sistemas de produção rentáveis. A taxa ótima de semeadura e a fertilização com nitrogênio na dose certa são fatores de produção substanciais para um maior rendimento da cultura da cevada, especialmente em condições de sequeiro. O experimento teve como objetivo determinar a taxa ideal de semeadura e de fertilizante de nitrogênio para cevada preta, sob condições de sequeiro no distrito de Kirkuk, norte do Iraque. Avaliou-se as características agronômicas da cevada preta em taxas de semeadura (200, 300 e 400 sementes m^{-2}) e diferentes doses de aplicação de nitrogênio (0, 40 e 80 kg N ha^{-1}). As taxas de semeadura de 300 e 400 sementes m^{-2} afetam significativamente o número de espigas m^{-2}, a produtividade de palha e a produtividade biológica em comparação com 200 sementes m^{-2}. A maioria das características agronômicas estudadas foram significativamente afetadas pela adubação nitrogenada, sendo que 80 kg N ha^{-1} gerou os maiores valores em comprimento de espiga m^{-2}, grãos $espiga^{-1}$, produtividade de grãos, rendimento biológico e índice de colheita, quando comparado com 40 kg N ha^{-1}. Além disso, a interação taxa de semeadura x adubação com N, influencia significativamente na maioria das características agronômicas, visto que 300 sementes m^{-2} × 80 kg N ha^{-1} possibilitaram melhores respostas quanto ao comprimento de espigas, espigas m^{-2}, grãos $espiga^{-1}$, produtividade de grãos e colheita índice; todavia, a produtividade de palha e a produtividade biológica foram melhores na interação de 400 sementes m^{-2} × 40 kg N ha^{-1}. A maioria das características medidas, especialmente o rendimento de grãos, foram impactadas pela aplicação de nitrogênio e não pelas taxas de semeadura. Nessa região, a semeadura de cevada preta deve ser com 300 sementes m^{-2} com aplicação de 80 kg N ha^{-1} para obter melhores rendimentos de grãos sob condições de sequeiro.

Palavras-chave: *Hordeum distichum* L.; densidade de plantas; fertilização com uréia; agricultura dependente da chuva.

1. INTRODUCTION

Barley (*Hordeum distichum* L.) is listed as a second crop after wheat in Iraq (ALRIJABO; ALAMIN, 2019). It belongs to the two-rowed barley group and is commonly cultivated in the northern regions of Iraq under rain-fed conditions. Barley has high efficiency in moisture absorption under limited rain-fed conditions, which helps to resist water stress and drought. Barley has a low water requirement and can be cultivated where irrigation water is unavailable (SINGH et al., 2020).

In Kirkuk governorate, barley could be produced under rain-fed conditions, and irrigation systems for grains and green and dry animal feed could be supplemented. During

2020, barley total grain yield production in rain-fed areas in Iraq was estimated at 77.6% with an average of 1502 kg ha^{-1}, while it reached 1817 kg ha^{-1} in irrigated areas with an average of 22.4%. The total cultivated area with barley in Kirkuk governorate reached 1559 ha in 2020, with an average of 1989 kg ha^{-1} (CSO, 2020; STATISTICAL REPORT No. 61, 2021).

Recent data in Iraq shows a major reduction in barley grain yield compared to global yield, which reached 3140 kg ha^{-1}(FAOSTAT, 2020). This reduction is mainly caused by precipitation, where most of the barley grain production in Iraq is produced under rain-fed conditions (CSO, 2020). Also, an unbalanced distribution of precipitation during crop growth stages will cause a yield reduction.

Moreover, soil degradation and inappropriate barley management practices like crop seeding rate and nitrogen fertilization are major problems under rain-fed conditions. Most farmers in the region do not use nitrogen fertilization at recommended levels. Also, one of the reasons for the low productivity per unit area is the weed diffusion in this area, which drains soil moisture and is one of the main problems that causes a yield reduction by 30-50% (Hayawi, 2022); all these factors caused barley grain yield reduction.

The seeding rate is an important factor affecting barley grain yield by determining plant population, which influences tillering, spike density, yield and yield components. Increasing the seeding rate above the recommended rate may decrease grain yield due to the increased water requirements, which are very limited in semi-arid areas. Meanwhile, seeding rates below the recommended rate also decrease grain yield due to low population per unit area. Therefore, optimized seeding rate selection is crucial to obtain an optimal grain yield under dry climate conditions.

In a study on seeding rate effects (100, 120, 140 and 160 kg ha^{-1}) on some barley traits under irrigation conditions, AL-Dulaimy et al. (2015) found that increasing seeding rate gradually had a significant influence on plant height, spikes m^{-2} and barley grain yield. In contrast, the augmented seeding rates did not affect grain $spike^{-1}$. In another study established by Al-Freeh et al. (2015) on barely (100, 120, 140 and 160 kg ha^{-1}) under irrigation conditions, the outcomes illustrate that most studied traits responded significantly to seeding rates except 1000-grain weight. In the same context, the authors present that seeding amount at 160 kg ha^{-1} gives significant plant height means, but 120 kg ha^{-1} gives the highest mean in spikes m^{-2} and barely grain yield, while the highest grains spike $^{-1}$ had achieved under 100 kg ha^{-1}. Hecht et al. (2016) obtained 7.5 t. ha^{-1} of the barley grain yield at 230 seeds m^{-2} compared to 340 seeds m^{-2}. Kadhim (2020) found that plant height, spikes m^{-2}, 1000 grain weight and barley grain yield significantly increased with increasing seeding rates from 100-150 and to 200 kg ha^{-1} under irrigation conditions, while in contrast, grains $spike^{-1}$ decreased significantly by increasing seeding rate.

Soil fertility, especially nitrogen nutrients, must be considered to determine the best seeding rate due to its importance in crop growth stages, especially at the tillering stage (KOHISTANI; CHOUDHARY, 2019). Generally, plants need more nitrogen than other mineral elements, and nitrogen plays a big role in producing high yields. Nitrogen has a vital role in increasing crop yield, and applying a proper amount is a key factor for obtaining a suitable yield of barley; also, yield components and grain quality depend on the appropriate application of nitrogen fertilizer. Therefore, nitrogen is the main nutrient for achieving high barley yield (TEHULIE; ESKEZIA, 2021). Gadri et al. (2020) concluded that barley requirements differ from nitrogen fertilizers according to the availability of water resources. The barley's nutritional needs are less under water deficit conditions than in irrigation conditions. Mansoor; Jeber (2020) examined the influence of (0, 50, 100, 150, 200 and 250 kg N ha^{-1}) on barley agronomic traits under irrigation conditions; they found that spike m^{-2}, grain $spike^{-1}$ and grain yield increased significantly and linearly as a result of rising nitrogen fertilizer doses starting 0 - 250 kg N ha^{-1}, while 1000-grain weight increased significantly through apply 200 kg N ha^{-1}. Also, they conclude that high nitrogen fertilization doses produce a positive augment in barley grain yield. In addition, Talib et al. (2021) obtained similar results, where a significant value for biological yield was obtained under 250 kg N ha^{-1}, while the uppermost harvest index was achieved by 150 kg N ha^{-1}.

Regarding seeding rate and nitrogen fertilizer interaction, Khumalo (2019) recommended that 160 - 180 seeds m-2 with 80 kg N ha^{-1} be used for sowing barley beneath parched land conditions within Western Cape, South Africa, to obtain optimum grain yield. Also, Habiaremye et al. (2021) recommend farmers in the Palouse region, Pacific Northwest, United States sow barley at 375 seeds m^{-2}, with 95 kg N $ha^{-1,}$ to optimize grain yield intended for human consumption.

In general, seeding rate and nitrogen fertilization are essential for barley production in Kirkuk governorate due to the lack of previous studies focusing on seeding rate and nitrogen fertilizer under rain-fed agricultural systems. Therefore, this experiment was designed to determine the best seeding rate and nitrogen fertilization level for local black barley that grew under rain-fed conditions in Kirkuk district, Iraq, to obtain the best grain yield.

2. MATERIALS AND METHODS

A study was carried out to determine the best seed rate and nitrogen amount used for black barley (Hordeum distichum L.), a local variety under rain-fed conditions in the region, from 2021 to 2022, in an experiment established at a local farmer field in Kirkuk district in the north of Iraq (35° 28' N – 44° 19' E) and 331 m above sea level. The annual rainfall amount in the region is about 300 mm, with 91% of rains from early November until late April. Therefore, the area is considered within the semi-rainfall regions in Iraq.

The factorial trial has three replicates, established in RCB Design; the first factor included seeding rates (200, 300 and 400 seed m^{-2}), while the second factor was nitrogen doses (0, 40 and 80 kg N ha^{-1}). The soil was plowed twice with a moldboard plow, followed by a harrow plowing; the experimental unit area was (2.0 m × 5.0 m), including ten rows with 5.0 m length and 0.2 m distance between the rows.

The experimental units were bordered by 2 m from each other to prevent nitrogen fertilizer from leaking. Soil samples were collected before sowing at a depth of 0.3 m for physical and chemical properties analysis, as shown in Table 1.

Table 1. Physical and chemical properties of the soil at the study site.
Tabela 1. Propriedades físicas e químicas do solo no local de estudo.

Properties	Property value	Measuring unit
Soil reaction (pH)	7.2	—
Electrical conductivity	1.7	ds m^{-1}
Soil texture	silty loam	—
available nitrogen	13.28	mg g^{-1}
available phosphorus	10.9	mg g^{-1}
available potassium	150	mg g^{-1}
organic matter	5.3	g kg^{-1}

Black barley seeds were sown in late November; urea fertilizer (46 % N) was used as a nitrogen source where the dose was applied in two stages, first at the sowing stage and the second at the heading stage on the Zadoks growth scale (ZADOKS et al., 1974). Also, triple super phosphate fertilizer (46 % P_2O_5) was applied with an amount of 120 kg ha^{-1} during soil preparation for sowing. Recommended agronomic practices for barley crops were applied in the growing season. Randomly, ten plants were selected in the central harvestable row in each experimental unit for assessments and Data collection for studied traits: Plant height (cm) was measured starting from the soil surface to spike top without awns, Spike length (cm) was measured starting from the spike base to the top without awns, Spikes m^{-2} have been counted for $1m^2$ for each experimental unit, grains per spike: ten spikes been selected randomly from each experimental unit for average counting, 1000-grain weight (g): were weighed for each experimental unit, grain yield (kg ha^{-1}) estimated through harvesting $1m^2$ for each experimental unit, then converted into kg ha^{-1}, straw yield (kg ha^{-1}) estimated through equation (biological yield - grain yield), biological yield (kg ha^{-1}): estimated through weighing harvested plants of $1m^2$ above ground surface for each experimental unit then converted into kg ha^{-1}; harvest index (%): estimated as a percentage for grain yield to biological yield.

Statistical analysis for studied traits was carried out according to the analysis of variance according to randomized complete block design standard procedure for factorial experiments using statistical analysis software version 9.0 (SAS-V9, 2002). The treatments' means were compared using the least significant differences test on a significant level of 0.05. The Person correlation coefficient analysis was conducted to determine the relation among studied traits as an impact by studied factors.

3. RESULTS

3.1. Plant height

Seeding rate, nitrogen doses and their interaction did not significantly affect barley plant height (Table 2).

Table 2. Barley plant height (cm) at the different seeding rate, nitrogen level and their interaction.
Tabela 2. Altura das plantas de cevada (cm) em função da taxa de semeadura, nível de nitrogênio e sua interação.

Seeding rates (Seed m^{-2})	Nitrogen fertilizer levels (Kg ha^{-1})			Average
	0	40	80	
200	47.67	50.40	52.33	50.13
300	50.97	49.40	50.43	50.27
400	48.20	49.90	52.77	50.29
Average	48.95	49.90	51.84	
LSD (P= 0.05)	Seeding rates n.s	Nitrogen levels n.s		Interaction n.s
CV %	7.58			

3.2. Spike length

The spike length increased significantly with nitrogen fertilizer application compared to the control treatment Table 3, where 80 kg N ha^{-1} recorded a maximum average spike length of 5.38 cm and 5.28 cm for 40 kg N ha^{-1}. In contrast, the control treatment recorded a minimum average spike length of 4.77 cm. This occurred due to the role of nitrogen in increasing plant effectiveness, especially plant cell divisions and elongation, which led to an increase in spike length. Similar results were reported by Dubey et al. (2018 b) and Guddisa et al. (2020). The highest spike length of barley was recorded at the highest level of nitrogen fertilizer treatment. Significant seeding rate × nitrogen fertilizer interaction was observed on spike length, where it recorded 6 cm by the interaction between 300 seeds m^{-2} × 80 kg N ha^{-1} while the lowest was for 200 seeds m^{-2} × 0 N ha^{-1} 4.67 cm; this happened due to effect of highest level of nitrogen fertilizer with numerous of appropriate plants for every unit area (plant population).

Table 3. Barley spike length (cm) at the different seeding rate, nitrogen level and their interaction.
Tabela 3. Comprimento da espiga da cevada (cm) em função da taxa de semeadura, nível de nitrogênio e sua interação.

Seeding rates (Seed m^{-2})	Nitrogen fertilizer levels (Kg ha^{-1})			Average
	0	40	80	
200	4.67	5.60	4.77	5.01
300	4.83	5.13	6.00	5.32
400	4.80	5.10	5.37	5.09
Average	4.77	5.28	5.38	
LSD (P= 0.05)	Seeding rates n.s	Nitrogen levels 0.48		Interaction 0.83
CV %	9.38			

3.3. Spikes m^{-2}

Table 4 presents the seeding rate and nitrogen fertilizer effect on spikes m^{-2}. 300 seeds m^{-2} significantly increased the spikes number, which was 460.3 spikes m^{-2}, which did not differ significantly from 400 seeds m^{-2}, but it differed significantly with 200 seeds m^{-2}, which were 346 spikes m^{-2}. The reason behind the increasing spikes in m^{-2} is that the mounting seeding rate leads to an increase in plants for each unit area (plant population); previous results agreed with Al-Dulaimy et al. (2015) and Kadhim (2020). Where they report that increasing seeding rates cause increasing in spikes m^{-2} also, the reason for spikes m^{-2} reduction at a high seeding rate of 400 seeds m^{-2} compared to 300 seeds m^{-2} is due to the extreme intra-plant competition on growth requirements, especially water and soil nutrients which are negatively reflected on several fertile tillers and this led to a low number of spikes per plant. The same results are found by Al-Freeh et al. (2015). A seeding rate above 120 kg ha^{-1} caused a reduction in spikes m^{-2}. Also, the author found that spikes m^{-2} for 120 kg ha^{-1} increased significantly compared to 100, 140 and 160 kg seed ha^{-1}.

Spikes m^{-2} increased significantly and linearly with increasing nitrogen fertilizer levels, where the highest average of spikes m^{-2} 460.4 was recorded under 80 kg N ha^{-1}, compared to the control treatment of 362.8 spike m^{-2}. This happened due to nitrogen availability during plants' early growth stages, which increased the number of productive tillers and extended the period of spike formation. Mansoor; Jeber (2020) found a significant increase in spikes m^{-2} by increasing nitrogen fertilizer levels.

Interaction between 300 seeds m^{-2} × 80 kg N ha^{-1} recorded the utmost value of spikes m^{-2} (530.7), compared to 200 seeds m^{-2} × 0 kg N ha^{-1} by 320 spike m^{-2}.

Table 4. Barley spikes m^{-2} at different seeding rate, nitrogen level and their interaction.
Tabela 4. Espigas por m² de cevada em função da taxa de semeadura, nível de nitrogênio e sua interação.

Seeding rates (Seed m^{-2})	Nitrogen fertilizer levels (Kg ha^{-1})			Average
	0	40	80	
200	320.0	338.0	380.0	346.0
300	406.7	443.7	530.7	460.3
400	361.7	473.7	470.7	435.3
Average	362.8	418.4	460.4	
LSD (P= 0.05)	Seeding rates 25.22	Nitrogen levels 25.22		Interaction 43.68
CV %	6.1			

3.4. Grains spike $^{-1}$

As shown in Table 5, no significant difference was observed in grains spike $^{-1}$ between seeding rate levels, while significant influences were found between nitrogen fertilizer levels and interactions. 40 and 80 kg N ha^{-1} record the same significance level in grains spike $^{-1}$, 25.60 and 23.27 compared to 0 kg N ha^{-1} (20.14). This is linked to increasing the plant's ability to uptake nitrogen during the application and use in spikelet development during the flowering stage.

Moreover, nitrogen increases the number of fertile florets in the spike, leading to more grains. In addition, nitrogen extends the period of grain formation in spikes, then increases grain number per spike. These findings agree with Awulachew (2019) and Terefe et al. (2018), who found an increase in grain spike^{-1} by increasing nitrogen fertilizer levels.

Interaction of 300 seeds m^{-2} × 80 kg N ha^{-1} was higher significant in grains spike^{-1} (26.40), compared to 400 seeds m^{-2} × 0 kg N ha^{-1} (18.94). This happened due to the appropriate seeding rate per unit area and nitrogen fertilizer dose, which provide the nutrients for higher spiked florets, increasing the number of fertile grains. Spike $^{-1}$. Grains spike^{-1} trait was in significant and positive correlation (p = 0.01) with spikes m^{-2} (r = 0.721) (Table 5).

Table 5. Barley grains spike^{-1} at different seeding rates, nitrogen levels, and interactions.
Tabela 5. Espigas por m² de cevada em função da taxa de semeadura, nível de nitrogênio e sua interação.

Seeding rates (Seed m^{-2})	Nitrogen fertilizer levels (Kg ha^{-1})			Average
	0	40	80	
200	21.10	20.33	24.80	22.08
300	20.39	23.57	26.40	23.45
400	18.94	25.90	25.60	23.48
Average	20.14	23.27	25.60	
LSD (P= 0.05)	Seeding rates n.s	Nitrogen levels 3.02		Interaction 5.23
CV %	13.14			

3.5. 1000-grain weight

Results of seeding rate, nitrogen fertilizer level and their interaction on barley 1000-grain weight are shown in Table 6, where no significant effects were observed between seeding rates and nitrogen fertilizer levels. However, the interaction between (200 seeds m^{-2} × 0 kg N ha^{-1}) and (300 seed m^{-2} × 0 kg N ha^{-1}) also 300 seed m^{-2} × 40 kg N ha^{-1} significantly influenced 1000-grain weight with 37 g, while 300 seeds m^{-2} × 40 kg N ha^{-1} had the lowest value with 33.33 g. These results are similar to Al-Freeh et al. (2015), and Amarjeet et al. (2020), which report that 1000-grain weight did not affect barley seeding rates; also, the results of the present experiment are in accord with Dubey et al. (2018 b), Terefe et al. (2018) and Guddisa et al. (2020) results, which found no significant influence of nitrogen fertilizer on barley 1000 grain weight.

One thousand grain weight had a significant and positive (p=0.05) correlation (r=0.429) with plant height (Table 11), and this supports the possibility of the negative influence of seeding rate and nitrogen fertilizer level on 1000 grain weight and plant height (Table 2) of barley. The same outcomes are found by Awulachew (2019) and Legasie (2019).

Table 6. Barley 1000 grain weight (g) at the different seeding rate, nitrogen level and their interaction.
Tabela 6. Peso de 1000 grãos de cevada (g) em função da taxa de semeadura, nível de nitrogênio e sua interação.

Seeding rates (Seed m^{-2})	Nitrogen fertilizer levels (Kg ha^{-1})			Average
	0	40	80	
200	37.00	37.00	36.33	36.78
300	37.00	33.33	35.67	35.33
400	36.33	35.67	35.00	35.67
Average	37.00	37.00	36.33	36.78
LSD (P= 0.05)	Seeding rates n.s	Nitrogen levels n.s		Interaction 3.59
CV %	5.77			

3.6. Grain yield

Seeding rates did not have significance on barley grain yield, while nitrogen fertilizer levels significantly affect grain yield (Table 7). Grain yield had significant values under 40 and 80 kg N ha^{-1}, recording 2407.8 and 2275.0 kg ha^{-1}, respectively, whereas grain yield for nill N ha^{-1} was 1865.6 kg ha^{-1}. This happened because of the nitrogen role, which increased yield components, for instance, spikes m^{-2} and grains spike^{-1} (Tables 4 and 5), which reflect positively on grain yield. Results are similar to those of Kohistani; Choudhary (2019), Parashar et al. (2020 a), Gadri et al. (2020) and Habiyaremye et al. (2021) findings, nitrogen fertilizer application gave significant grain yield in barley compared to non-application.

Table 7. Barley grain yield (kg ha^{-1}) at the different seeding rate, nitrogen level and their interaction.
Tabela 7. Produção de grãos de cevada (kg ha^{-1}) em função da taxa de semeadura, nível de nitrogênio e sua interação.

Seeding rates (Seed m^{-2})	Nitrogen fertilizer levels (Kg ha^{-1})			Average
	0	40	80	
200	1941.7	2090.0	2065.0	2032.2
300	1920.0	2110.0	2750.0	2260.0
400	1735.0	2625.0	2408.3	2256.1
Average	1865.6	2275.0	2407.8	
LSD (P= 0.05)	Seeding rates n.s	Nitrogen levels 231.98		Interaction 401.8
CV %	10.64			

3.7. Straw yield

The straw yield was influenced significantly by seeding rates, where straw yield was significantly higher for 300 and 400 seeds m^{-2} (5275.6 kg ha^{-1}) and (5148.3 kg ha^{-1})

sequentially compared with 200 seeds m $^{-2}$ (4755.6 kg ha $^{-1}$) as noted in table 8. Increasing straw yield happened due to increased plant population, which depended on high seeding rates for 300 and 400 seeds m $^{-2}$ compared to 200 seeds m $^{-2}$. TOLESA et al. (2019) stated that increasing seeding rate caused a significant increase in plant population and straw yield. No significant differences were observed between nitrogen fertilizer levels.

Interaction between 400 seeds m $^{-2}$ × 40 kg N ha $^{-1}$ significantly influenced straw yield (5655 kg ha $^{-1}$), while the least was for 400 seeds m $^{-2}$ × 0kg N ha $^{-1}$ recorded 4370 kg ha $^{-1}$. These consequences clearly show that nitrogen fertilizer had an essential role in the seeding rate in increasing straw yield. Table 11 shows that straw yield had a significant positive correlation (p=0.01) with spikes m $^{-2}$ (r=0.660), grains spike $^{-1}$ (r=0.552) and grain yield (r = 797); this could be the reason behind the increasing straw yield.

3.8. Biological yield

Table 9 shows the influence of seed rate, nitrogen level and their interaction on biological yield, where 300 seeds m $^{-2}$ record significant influence on biological yield (7535.6 kg ha $^{-1}$), contrary to 200 seeds m $^{-2}$ (6791.1 kg ha $^{-1}$). This is due to a significant plant population increase in spikes m $^{-2}$ and straw yield (Tables 4 and 8) for seeding rates 300 and 400 seeds m $^{-2}$ compared to 200 seeds m $^{-2}$. These outcomes are the findings of Tolesa et al. (2019) and Bekele et al. (2020), who report that increasing the seeding rate increased biological yield.

3.9. Harvest index

The Harvest index did not significantly affect seeding rates, but nitrogen fertilizer levels and their interaction with seeding rates significantly affected the harvest index Table 10. The harvest index was influenced significantly by applying 40 and 80 kg N ha $^{-1}$, which records 29.91% and 31.34%, respectively, while 0 kg N ha $^{-1}$ records 28.08 % only. This happened due to the positive impact of nitrogen fertilization use on increasing grain yield with biological yield (Tables 7 and 9), which increased the harvest index. It also explains the ratio between the biological yield and barley grain yield. These outcomes are harmonious with Talib et al. (2021), who found that nitrogen fertilizer application caused a significant increase in the harvest index for barley compared to non-nitrogen fertilizer application. Interaction between 300 seeds m $^{-2}$ × 80 kg N ha $^{-1}$ significantly influenced the harvest index by 33.34 %, while 300 seed m $^{-2}$ × 0 N kg N ha $^{-1}$ had 26.62 % only.

Table 8. Barley straw yield (kg ha $^{-1}$) at the different seeding rate, nitrogen level and their interaction.
Tabela 8. Produção de grãos de cevada (kg ha $^{-1}$) em função da taxa de semeadura, nível de nitrogênio e sua interação.

Seeding rates (Seed m $^{-2}$)	Nitrogen fertilizer levels (Kg ha $^{-1}$)			Average
	0	40	80	
200	4671.7	4730.0	4865.0	4755.6
300	5306.7	5015.0	5505.0	5275.6
400	4370.0	5655.0	5420.0	5148.3
Average	4782.8	5133.3	5263.3	
LSD (P= 0.05)	Seeding rates 485.55	Nitrogen levels n.s		Interaction 840.8
CV %	9.60			

Table 9. Barley biological yield (kg ha $^{-1}$) at the different seeding rate, nitrogen level and their interaction.
Tabela 9. Produtividade biológica de cevada (kg ha $^{-1}$) em função da taxa de semeadura, nível de nitrogênio e sua interação.

Seeding rates (Seed m $^{-2}$)	Nitrogen fertilizer levels (Kg ha $^{-1}$)			Average
	0	40	80	
200	6613.3	6830.0	6930.0	6791.1
300	7226.7	7125.0	8255.0	7535.6
400	6105.0	8280.0	7828.3	7404.4
Average	6648.3	7411.7	7671.1	
LSD (P= 0.05)	Seeding rates 686.13	Nitrogen levels 683.13		Interaction 1188.4
CV %	9.48			

Table 10. Barley harvest index (%) at the different seeding rate, nitrogen level and their interaction.
Tabela 10. Índice de colheita de cevada (%) em função da taxa de semeadura, nível de nitrogênio e sua interação.

Seeding rates (Seed m $^{-2}$)	Nitrogen fertilizer levels (Kg ha $^{-1}$)			Average
	0	40	80	
200	29.18	30.59	29.88	29.89
300	26.62	27.48	33.34	29.15
400	28.44	31.66	30.78	30.29
Average	28.08	29.91	31.34	
LSD (P= 0.05)	Seeding rates n.s	Nitrogen levels 1.9		Interaction 3.3
CV %	6.4			

Table 11. Pearson Correlation Coefficients among studied traits of barley.
Tabela 11. Coeficientes de Correlação de Pearson entre características estudadas da cevada.

	Spike length	Spikes m $^{-2}$	1000 grains weight	Grain yield	Straw yield	Biological yield	Harvest index
Plant height	0.203	0.135	0.280	0.429*	0.076	0.152	-0,057
Spike length		0.432*	0.240	-0,133	0.536**	0.402*	0.548**
Spikes m $^{-2}$			0.721**	-0,308	0.7436**	0.726**	0.323
1000 grains weight				-0,134	0.609**	0.604**	0.263
Grain yield					-0,169	0.552**	0.099
Straw yield						-0,0502	0.671**
Biological yield						0.797**	0.191
Harvest index							0.402*

where: n.s: no significant; * significant on prob. 0.05; ** significant on prob. 0.01.

4. DISCUSSION

Significantly higher grain yield was observed in the interaction between 300 seeds m^{-2} × 80 kg N ha^{-1} (2750 kg ha^{-1}), while 300 seed m^{-2} × 0 kg N ha^{-1}, only had 1735 kg ha^{-1}. Generally, the studied seeding rates gave low grain yields with non-nitrogen fertilizer applications. Still, when the seeding rates were associated with nitrogen fertilizer applications, the grain yield increased significantly. This could be related to nitrogen application, which improved plant growth and positively reflected on grain yield.

There was a significant positive correlation between grain yield (p = 0.01) with spike length (r = 536), spikes m^{-2} (r = 0.736) and grains spike $^{-1}$ (r = 0.609) (Table 11). Therefore, spikes m^{-2} and grains spike^{-1}, had a clear impact on increasing grain yield under the studied factors. In line with the present findings, Awulachew (2019) and Amarjeet et al. (2020) also reported that grain yield linked with grains spike $^{-1}$ in a positive and significant correlation relationship. Also, Legasie (2019) and Parashar et al. (2020 b) found a significant positive correlation between grain yield with spike length and grains spike^{-1}.

The biological yield had the same significance level under 40 and 80 kg N ha^{-1} (7411.7 and 7671.1 kg ha^{-1}), respectively, while 0 kg N ha^{-1} had the lowest average in biological yield, 6648.3 kg ha^{-1}. This happened due to an augment in nitrogen level, which led to an augment in barley spike length, spikes m^{-2}, grains spike^{-1}, grain yield (Table 2, 4, 5 and 7) and biological yield. Similar findings were reported by Dubey et al. (2018a), Kohistani; Chondhary (2019), Guddisa et al. (2020) and Parashar et al. (2020b).

Interaction between 400 seed m^{-2} x 40 kg N ha^{-1} and 300 seed m^{-2} × 80 kg N ha^{-1} had a significant influence on barley biological yield (8280 and 8255 kg ha^{-1}, respectively), while 400 seeds m^{-2} × 0 kg N ha^{-1} only recorded 6105 kg ha^{-1} biological yield. This could be due to increasing grain yield and straw yield for 400 seed m^{-2} x 40 kg N ha^{-1} and 300 seed m^{-2} × 80 kg N ha^{-1} (Tables 7 and 8). Biological yield correlated positively and significantly (p = 0.05) with spike length (r = 0.402), spikes m^{-2} (p = 0.01) (r = 726), and grains spike^{-1} (r = 604), grain yield (r = 924) also straw yield (r = 767) (Table 11). These results agreed with Legasie (2019), who found a highly significant positive correlation between biological yield and straw yield. Tolesa et al. (2019) noticed a highly significant positive correlation between biological yield with spikes m^{-2} and grain yield with straw yield in barley. Also, Parashar et al. (2020 b) obtained a highly significant positive correlation between biological yield and grain yield.

The Harvest index had a significant (p=0.01) positive correlation with spike length (r=548) and grain yield (r = 671), which also correlated positively and significantly (p = 0.05) with biological yield (r = 402) (Table 11). The present findings agree with those of Tolesa et al. (2019), who found a significant positive correlation between harvest index with spike length and grain yield. Also, Legasie (2019) noticed a significant positive correlation between harvest index and barley grain yield.

5. CONCLUSIONS

The experiment results indicate that the seeding rate did not significantly impact most studied traits, particularly grain yield and yield components like grain spike^{-1} and 1000 grain weight. Contrary to the previous results, nitrogen fertilizer significantly influenced barley grain yield and its components, especially spikes m^{-2} and grains spike^{-1}. These results conclude that nitrogen fertilizer application was more effective than the seeding rate, at least in the study area (rain-fed conditions) for black barley. This occurred due to soil nitrogen deficiency (Table 1), so the crop responded highly to nitrogen application. The study demonstrated the use of 300 seeds m^{-2} with 80 kg N ha^{-1} to achieve the maximum grain yield of black barley under rain-fed conditions in Kirkuk district, Iraq.

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