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C-qualitative characteristics of introduced rye, barley and wheat grain crops under different seeding rates and irrigation systems in two different agro -environment sites in Nineveh - Iraq

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ABSTRACT
A field trail was conducted during the 2023–2024 season at two environmentally different locations, Telkaif 20 km north of Mosul and Jleokhan19 km southeast of Mosul, in Nineveh Governorate. The study involved three trial factors. The first factor was three cereal crops: Rye (*Secale cereale* L.), 2-row Barley (*Hordeum distichum* L.), and bread Wheat (*Triticum aestivum* L.). The second factor included three Seeding rates (200, 300, and 400 grains.m^{-2}), while the third factor was two irrigation regimes (supplementary Irrigation SI and rain fed). The trail was laid out in a randomized complete block design (RCBD) using a split-plot design. Barley was the fastest crops to mature and reach the full maturity stage (Z-94), followed by Wheat and then Rye, with a clear varying ripening time. At the Telkaif site. Barley exceled the other crops in grain yield—especially under SI with seeding rate of 400 grains.m^{-2}. Conversely. Wheat recorded the greatest test weight. Regarding quality characteristics, Barley had the highest Gluten percentage %, while Rye showed the highest Protein percentage% under rain fed conditions with low seeding density. At the Jleokhan site. Barley showed the highest Grains Yield under SI with higher seeding density. Wheat recorded the highest test weight. In terms of quality characteristics, Rye showed the highest Protein percentage % under rain fed with low seeding rate, whereas Barley showed the highest gluten percentage % regardless of irrigation regime. These results indicate the success agronomic of rye under rain fed and supplemental irrigation conditions in northern Iraq

KEY WORDS: Rye, Barley, Wheat, MRA-SI- Seeding rates.

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ج- الخصائص النوعية لمحاصيل الحبوب من الشيلم والشعير والحنطة في ظل معدلات بذار وأنظمة ري مختلفة في موقعين بيئيين مختلفين في نينوى- العراق

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الملخص
أجريت تجربة حقلية خلال الموسم الزراعي (**2023-2024**) في موقعين متباينين بيئياً هما تلكيف 20 كم شمال الموصل وجليوخان 19 كم جنوب شرق الموصل واللذان يقعان ضمن الحدود الإدارية لمحافظة نينوى. تضمنت الدراسة ثلاثة عوامل، العامل الأول هو ثلاث أنواع من المحاصيل الحبوبية والتي تتبع العائلة النجيلية وهي: الشيلم (***Secale cereale* L.**) والشعير الثنائي الصف (***Hordium distichum* L.**) وحنطة الخبز (***Triticum aestivum* L.**)، والعامل الثاني ثلاث مستويات من البذار (200 و300 و400 حبة. م$^{-2}$) والعامل الثالث نمطين للري (تكميلي وديمي)، طبقت التجربة باستخدام تصميم القطاعات العشوائية الكاملة (**RCBD**) وفق نظام الألواح المنشقة **Split plot Design**. اتضح أن الشعير كان متفوقًا في الوصول إلى مرحلة النضج الكامل (**Z-94**)، يليه الحنطة ثم الشيلم، مع وجود فرق زمني واضح بين المحاصيل الثلاثة. في موقع تلكيف أظهرت النتائج تفوق محصول الشعير على باقي المحاصيل في صفات الإنتاجية , و بالنسبة للصفات النوعية سجلت حبوب الحنطة أعلى وزن اختباري ، سجل الشعير أعلى نسبة كلوتين، فيما تفوق الشيلم في نسبة البروتين عند الري المطري ومعدل البذار المنخفض.اما في موقع جليوخان حقق الشعير أعلى وزن حاصل حبوب عند الري التكميلي ومعدل البذار المرتفع، سجل محصول الحنطة أعلى وزن اختباري للحبوب. وبالنسبة للصفات النوعية، سجل الشيلم أعلى نسبة بروتين تحت الري المطري ومعدل البذار المنخفض، بينما سجل الشعير أعلى نسبة كلوتين بغض النظر عن نظام الري، مع انخفاض نسبي عند زيادة كثافة البذار. تشير هذه النتائج في الموقعين إلى امكانية نجاح زراعة محصول الشيلم تحت ظروف كل من الري بالأمطار والري التكميلي في شمال العراق.

الكلمات المفتاحية: الشيلم، الشعير، القمح، **MRA-SI**- معدلات البذار.

INTRODUCTION

Cereals like Wheat (*Triticum aestivum* L.), Barley (*Hordeum vulgare* L.), and Rye (*Secale cereale* L.), are the most important components of world grain production for food and feed under both rain fed and supplementary irrigation. These crops play a crucial role in global food security, in arid semi-arid regions, especially in Moderate Rainfall Areas MRA and High Rainfall Areas HRA, where they are fulfilling human dietary requirements (Altai et al., 2024). In addition to their nutritional importance, the winter cereals hold high economic value due to their widespread using in food processing industries. The cereal grain quality relies on both physical and chemical characteristics such as test weight, protein %, ash %, and gluten %. These traits are used to evaluate grain milling, baking, and market acceptance (Zecevic et al., 2014). Differences in quality traits have been studied among cereal species. (Rani et al., 2021). Determination of crop growth stages is an important requirement for success field management, as it helps to accurate timing of seeding, irrigation, fertilization, and plant protection .The Zadok's growth scale is based on 10 main growth stages: 0-Germination - 1 Seedling growth 2 –Tillering – 3-Stem elongation- 4-Booting – 5-Ear emergence - 6-Flowering - 7-Milk development - 8-Dough development- 9-Ripening. Each scale consists of 2 numbers; the 1st. Number means the growth stage, and the 2nd. Number means the number of plant parts (leaves, tillers or spikes). So, this scale ranges from 00 to 99. (Anderson et al., 2000). The most important factor influencing both Grains Yield and quality in cereal production is Irrigation regime. Studies showed that full irrigation levels increased yield, whereas deficit irrigation or reliance SI or rainfall alone leads to sever yield reductions (Al-Otayk et al., 2019; Kanwal et al., 2020; Aissaoui & Fenni, 2021).In the same times full irrigation or enough SI improved grain quality, and test weight, compared with rain fed irrigation (Tari, 2016; Al-Ajrawi, 2023).Interactions between irrigation and seeding rate, may also influence grain quality traits. SI under high-density planting can reduced the negative effects of plant competition on protein and gluten percentage, but such effect are less pronounced under rain fed irrigation. (Farooq et al., 2022). Its influence extends to chemical and physical properties that determine commercial and nutritional value. Many studies have showed that SI can enhance grain protein and gluten levels by minimizing water stress during the stage of grain filling in addition to improving nitrogen uptake and protein building (Moustafa et al., 2021; Ranazai et al., 2024). Ash percentage also increased under SI conditions, due to improved translocation of nutrients to developing grains (Gebremedhin & Haile, 2023). The response of grain quality to irrigation is not always uniform. Some trails have shown that rain fed conditions may result in higher protein and gluten concentrations compared with SI, this response mostly due to protein concentration in grain under moderate water stress (Al-Ajrawi, 2023). Test weight responses to irrigation depend to genotype and environmental conditions (Abu Al-Nadr, 2019; Ereku et al., 2012). Results also showed that severe reductions in irrigation can reduce grain yield, but the protein levels remain within acceptable commercial levels (King et al., 2024). Seeding rate is another important factor affecting cereal yield and grain quality through its effect on plant density and competition . Higher seeding rates increased competition for light, water, and nutrients, this competition may lead to reductions in grain percentages of protein and gluten (Lachutta, 2024). Other studies have showed that high seeding rates can enhance test weight or protein percentage under specific environment for such cultivars (Al-Hamadani, 2020; Mahmoud et al., 2016; Al-Dulaimi et al., 2015). Other researches has indicated the effect of seeding rate on grain yield. The optimal grain productivity achieved at moderate to high planting densities, while lower densities reduced yield potential (Batool et al., 2022; Indoush et al., 2020; Preiti et al., 2021). These results have been observed in different cereal crops, with varies results depending on environment and management practices. The interaction between irrigation system and seeding rate plays a clear role in both Grains Yield and quality .Seeding rate determines the plant competition, while irrigation system response to availability of soil moisture during plant growth stages, and influencing metabolic pathways related to grain formation (Zecevic et al., 2014). High plant densities, with limited water availability often caused in reduced protein and gluten accumulation; but SI can reduced these tensions by enhancing N uptake and protein synthesis, causing good grain quality even under high plant densities (Ranazai et al., 2024). In the same time excessive irrigation may diluted the grain protein concentration when water supply is over crop requirements (Zhang et al., 2023). Good optimization of field managements is essential to achieve a sustainable balance between high productivity and suitable quality across different ecological locations. Grain quantity and quality traits in cereal crops are depend on interactions among many factors like genetic factors, irrigation system, seeding rate, and environmental conditions. Therefore, this study was designed to determine the feasibility of introducing rye cultivation in Iraq as an alternative crop in crop rotations under rain fed and supplemental irrigation conditions and at different seeding rates.

MATERIALS AND METHODS

Experimental Locations: A field experiment was conducted during the 2023–2024 seeding season in Telkaif 20 km north of Mosul and Jleokhan19 km southeast of Mosul, in Nineveh Governorate. The two locations are classified as Moderate Rainfall Area MRA.**Experimental Factors: First Factor – Crop Species:** Three cereal crops were used: **Rye (*Secale cereale* L.)** – A commercial Turkish cultivar introduced for the first time in Iraq, considered a promising variety. **Barley (*Hordeum vulgare* L.)** – The cultivar "Nora," a white, two-row Barley type. **Wheat (*Triticum aestivum* L.)** – The cultivar "Abu Ghraib," a bread Wheat variety. **Second Factor – Seeding Rates:** Three Seeding rates were applied to all three crops: 200 grains·m^{-2}, 300 grains·m^{-2}, and 400 grains·m^{-2}. **Third Factor – Irrigation Regime:** Two irrigation systems were implemented: **Rain fed**

irrigation, and **Supplemental irrigation**, with two saturated irrigations applied at critical growth stages (one during flowering and the other during grain filling) based on plant water requirements. **Experimental Design:** The experiment was arranged in a **Randomized Complete Block Design (RCBD)** using a **Split-Plot Design** with three replications. The main plots were assigned to the irrigation regimes, while the sub-plots were assigned to the Seeding rates. The experimental unit measured 2 m². A 10-meter distance was left between irrigation types to avoid cross-effects. Data were statistically analyzed using the Statistical Analysis System **(SAS 9.0)** software **(Antar and Al-Wakkaa, 2017**), and treatment means were compared using Duncan's Multiple Range Test **(Duncan, 1955). Land Preparation and Field Operations**: Prior to seeding, a saturated irrigation was applied, and the land was left for 10 days to allow weed and previous crop grains to germinate. Then before sowing cereals crops a general herbicide (glyphosate- 250 ml. per 20-liter water) at the 2-3 leaf growth stage of weeds in the field to eliminate all emerging vegetation and ensure a weed-free field. Ten days after herbicide application, a conservation agriculture planter was used to open furrows 20 cm apart. The land was then marked and divided into experimental units, each measuring 2 m², consisting of five Seeding lines. A 50 cm distance was left between plots to facilitate field operations, and a 75 cm gap was maintained between blocks. After crops sowing, in the Z-13 Zadok's growth stage between 15-20 Feb. (2,4, D – 1.5 Litter per Hectare) herbicide was sprayed to control Broad leaves weeds in crops fields. Seeding date in Tel kaif: December 3, 2023.Seeding date in Jleokhan: December 6, 2023. **Fertilizer Application:** Recommended fertilization rates were applied at both experimental sites, based on guidelines provided by the Nineveh Agriculture Directorate as follows: Urea fertilizer ($CO(NH_2)_2$, 46% N) at a rate of 80 kg·ha^{-1}, split into two equal doses: First half at seeding. Second half during the tillering stage (February 15, 2024). Di-Ammonium Phosphate (DAP) fertilizer (18% N, 46% P_2O_5, 0% K) at a rate of 80 kg·ha^{-1} applied once at seeding time. **Soil texture** at the Telkaif and Jleokhan location srespectively: (Clay) (Clay Loam). respectively: Nov.2023: (89mm) (39mm)– Dec.2023: (48mm) (51mm)-Jan.2024: **Monthly rainfall averages** (mm) at the Telkaif and Jleokhan locations (119mm) (98mm) -Feb.2024: (66mm) (197mm) March2024: (154mm) (122mm)- April2024: (24.5mm) (30mm)- May2024: (65.5mm) (47.5mm). Total: (566mm.) (584.5mm). **Source: Nineveh Agriculture Directorate / Planning Department Studied Traits:** 1-Growth stages- 2-Grains Yield (gm.m^{-2})- 3-Test Weight kg.hectoliter^{-1} - 4-Ash percentage in grains (%) - 5-Protein percentage in grains (%)- 6-Gluten percentage in grains (%).

RESULTS AND DISCUSSION

1-Effect of the study factors on Growth Stages according to the Zadok, s growth scale from (Z41 to Z94) for the three crops in the Telkaif and Jleokhan locations:

Monitoring the growth stages of the three crops at the two experimental sites using the Zadok's growth scale indicated that there were no differences in growth stages attributable to seeding rates or irrigation systems within each site. The only observed differences were among the three crops themselves with respect to their growth stages. Accordingly, observations of the growth stages of the three crops were recorded and summarized in Table (1).Table (1) shows, based on the recorded observation dates during the late growth stages, the presence of statistically significant differences in growth stages among the three crops.On 16 March 2024, Rye reached growth stage Z-41, corresponding to the beginning of the booting stage and the extension of the flag leaf. In contrast, Barley and Wheat were both at growth stage Z-49 on the same date, representing the end of the booting stage and the emergence of the awns from the base of the flag leaf. On 29 March 2024, Rye attained growth stage Z-43, indicating the Boots just visible swollen at the base of the flag leaf. At the same time, Barley reached growth stage Z-57, characterized by the emergence of three-quarters of the spike, whereas Wheat reached growth stage Z-59, corresponding to complete spike emergence. By 6 April 2024, Rye had progressed to growth stage Z-59, signifying full spike emergence. During the same period, Barley was at growth stage Z-71, marking the beginning of the milk development stage, while Wheat reached growth stage Z-69, indicating anthesis complete. On 19 April 2024, Rye reached growth stage Z-69, corresponding to the completion of anthesis. Barley, however, advanced to growth stage Z-85, representing the soft dough stage, whereas Wheat was at growth stage Z-83, indicating the early dough stage. On 26 April 2024, Rye attained growth stage Z-73, which corresponds to the beginning of the milk stage. In the same time, Barley reached full maturity and harvest at Z-94 growth stage, while Wheat was at hard dough stage Z-87 growth stage. Rye reached the late milk stage Z-77, On 9 May 2024. In the same time Wheat reached complete maturity and harvest growth stage Z-94. On 18 May 2024, Rye reached hard dough stage growth stage Z-87. And on 30 May 2024, Rye reached full maturity and harvest growth stage Z-94. These results agree with studies presented by (Anderson et al. (2000).

Table 1. Growth Stages according to the Zadok's growth scale for the three crops.

Date	**Growth stage according to the Zadok's growth scale**		
	Rye	**Barley**	**Wheat**
2024/3/16	Z-41	Z-49	Z-49
2024/3/29	Z-43	Z-57	Z-59
2024/4/6	Z-59	Z-71	Z-69
2024/4/19	Z-69	Z-85	Z-83
2024/4/26	Z-73	Z-94	Z-87
2024/5/9	Z-77	----	Z-94
2024/5/18	Z-87	----	----
2024/5/30	Z-94	----	----

2-a- Grain Yield gm.m^{-2} in Telkaif:

Table (2), indicated that the crop type significantly affected grain yield .Barley Grains Yield 411.69 gm.m^{-2} was significantly higher than Wheat and Rye, which recorded the lowest value of 124.41 gm.m^{-2}. This superiority of Barley in Grains Yield is due to its superiority in traits of yield components. In seeding rate factor, the highest Grains Yield (335.17 gm.m^{-2}) was obtained with 400 grains.m^{-2}, whereas the lowest Grains Yield (255.52 gm.m^{-2}) was recorded at 200 grains.m^{-2}.In irrigation systems factor, SI produced the highest Grains Yield (383.32 gm.m^{-2}) compared to the rain fed system (199.69 gm.m^{-2}).The triple interaction showed that Barley under supplementary irrigation and at a Seeding rate of 400 grains·m^{-2} produced the highest Grains Yield (600.40 gm.m^{-2}), which did not differ significantly from that of Wheat under the same irrigation and Seeding conditions. The lowest Grains Yield (78.19 gm.m^{-2}) was obtained from Rye grown under rain fed conditions and at 200 grains.m^{-2}, which also did not differ significantly from Rye under the same irrigation regime and Seeding rates of 300 and 400 grains.m^{-2}.These results are consistent with the findings of Dongqing et al. (2019), Hayawi and Hamad (2021), and Dong et al. (2022), who reported that using a Seeding rate of 400 grains.m^{-2} resulted in the highest significant grain yield. These results also agree with those of Mursalova et al. (2015), who found that supplemental irrigation recorded the highest significant Grains Yield compared with the rain fed system.

Table 2. Effect of the three factors and their interactions on the grain yield

Irrigation system	Crop	Seeding rate grains.m-2			Irrigation X Crop	Irrigation means	Crop mean
		200	300	400			
Rain fed	Rye	78.19 k	102.45 k	111.37 j k	97.34 f		
	Barley	267.91 e f	311.23 d e	333.96 d	304.37 c		
	Wheat	174.73 g h i	193.72 g h	223.67 f g	197.37 d		
SI	Rye	130.45 i j k	155.24 h i j	168.77 h i	151.48 e		
	Barley	463.89 b c	492.74 b	600.40 a	519.01 a		
	Wheat	417.93 c	447.61 b c	572.86 a	479.46 b		
Irrigation X Seeding rate grains.m-2	Rain fed	173.61 d	202.47 c	223.00 c		199.69 b	
	SI	337.42	365.20	447.34		383.32	

		b	b	a		a	
Crop X Seeding rate grains.m-2	**Rye**	104.32 d	128.85 d	140.07 d			124.41 c
	Barley	365.90 b	401.99 b	467.18 a			411.69 a
	Wheat	296.33 c	320.66 c	398.26 b			338.42 b
Seeding rate grains.m-2		255.52 c	283.83 b	335.17 a			

2-b-Grains Yield gm.m^{-2} - Jleokhan.

The results presented in Table (3) indicated that the crop type significantly affected grain yield .Barley Grains Yield 319.47 gm.m^{-2} was significantly higher than Rye, which recorded the lowest value of 93.55 gm.m^{-2}. The low yield of Rye in Grains Yield is due to its inferior performance in traits of yield components. In seeding rate factor, the highest Grains Yield (262.08 gm.m^{-2}) was obtained with 400 grains.m^{-2}, whereas the lowest Grains Yield (218. 61gm.m^{-2}) was recorded at 200 grains. m^{-2}.In irrigation systems factor, SI produced the highest Grains Yield (302.91 gm.m^{-2}) compared to the rain fed system (180.04 gm.m^{-2}). Higher plant density can enhance Grains Yield when adequate environmental resources are available. Finally, the triple interaction among crop type, seeding rate, and irrigation system showed that Barley grown under supplemental irrigation at 400 grains.m^{-2} produced the highest Grains Yield (440.15 gm.m^{-2}). In contrast, Rye under rain fed irrigation at 200 grains.m^{-2} recorded the lowest Grains Yield (76.06 gm.m^{-2}), which did not differ significantly from its interactions with other seeding rates (300 and 400 grains.m^{-2}) under the same irrigation system. These findings are consistent with those of Iqbal et al. (2020) and Al-Mashhad ani (2020), who reported that a seeding rate of 400 grains.m^{-2} resulted in the highest grain yield. The results also agree with Tari (2016) and Al-Otayk et al. (2019), who found that supplemental irrigation achieved higher grain yields compared with rain fed conditions. These results are in agreement with previous studies.

Table 3. Effect of the three factors and their interactions on the Grains yield (gm. m-2). Jleokhan.

Irrigation system	**Crop**	**Seeding rate grains.m-2**			**Irrigation X Crop**	**Irrigation mean**	**Crop mean**
		200	**300**	**400**			
Rain fed	**Rye**	76.06 g	80.30 g	80.30 g	78.89 f		
	Barley	202.80 e	210.32 e	238.36 d e	217.16 d		

	Wheat	229.91 d e	238.89 d e	263.39 d	244.07 c		
	Rye	95.09 f g	106.53 f g	123.01 f	108.21 e		
SI	**Barley**	401.31 b	423.90 a b	440.15 a	421.79 a		
	Wheat	306.49 c	402.42 b	427.26 a b	378.72 b		
Irrigation X Seeding rate grains.m-2	**Rain fed**	169.59 d	176.50 c d	194.02 c		180.04 b	
	SI	267.63 b	310.95 a	330.14 a		302.91 a	
Crop X Seeding rate grains.m-2	**Rye**	85.57 e	93.42 e	101.66 e			93.55 b
	Barley	302.06 c	317.11 b c	339.25 a b			319.47 a
	Wheat	268.20 d	320.65 a b	345.33 a			311.39 a
Seeding rate grains.m-2		218.61 c	243.73 b	262.08 a			

3-a - Test Weight (kg. hL^{-1}) – Telkaif.

Table (4) shows that in the crop type factor; there was a significant difference in the test weight between the studied crops. The Wheat crop achieved the highest significant value for test weight, which was (80.38 kg.hL^{-1}), while the Barley crop recorded the lowest significant value for this trait, which was (65.05 kg.hL^{-1}).Seeding rate factor show a significant superiority for the (200 grains.m^{-2}) in test weight over the other seeding rates, with a value of (75.39 kg.hL^{-1}), while the lowest significant test weight (72.02 kg.hL^{-1}) was with the seeding rate of (400 grains.m^{-2}). No significant differences were observed between the SI system and the rain-fed irrigation system. Results indicated significant differences in the interaction between seeding rate and irrigation system .Interaction between SI and (200 grains.m^{-2}) seeding rate, recorded the highest significant value for test weight, which was (74.90 kg.hL^{-1}).This interaction was not differ from the rain-fed irrigation system with the seeding rate of (200 grains.m^{-2}).The lowest significant value for test weight (71.65 kg.hL^{-1}) and (72.39 kg.hL^{-1}) respectively was recorded when using both the rain-fed and SI systems with a seeding rate of (400 grains.m^{-2}).The interaction between crop type and irrigation system showed significant differences in test weight. The Wheat crop gave the highest test weight under the rain-fed irrigation system, with a value of (80.54 kg. hL^{-1}), and was not significantly different from the Wheat grown under the supplementary irrigation system, which had a value of (80.23 kg. hL^{-1}). Meanwhile, the Barley crop grown under the supplementary irrigation system recorded the lowest significant value for the studied trait, which was (64.02 kg. hL^{-1}), and it was not significantly different from the Barley crop grown under the rain-fed irrigation system, which had a value of (66.08 kg. hL^{-1}).

Table 4. Effect of the three factors and their interactions on the Test weight kg. hctoliter-1 – Telkaif

Irrigation system	**Crop**	**Seeding rate grains.m-2**			**Irrigation X Crop**	**Irrigation means**	**Crop mean**
		200	**300**	**400**			
Rain fed	**Rye**	76.13 b c	75.53 b c	74.59 c	75.42 b		
	Barley	69.53 d	65.00 e f	63.70 e f	66.08 c		
	Wheat	81.93 a	80.81 a	78.87 a b	80.54 a		
SI	**Rye**	76.71 b c	76.60 b c	74.65 c	75.99 b		
	Barley	66.24 d e	64.01 e f	61.80 f	64.02 d		
	Wheat	81.77 a	80.42 a	78.50 a b	80.23 a		
Irrigation X Seeding rate grains.m-2	**Rain fed**	75.87 a	73.78 b c	72.39 c d		74.01 a	
	SI	74.90 a b	73.68 b c	71.65 d		73.41 a	
Crop X Seeding rate grains.m-2	**Rye**	76.42 c d	76.07 d	74.62 d			75.70 b
	Barley	67.89 e	64.50 f	62.75 f			65.05 c
	Wheat	81.85 a	80.61 a b	78.69 b c			80.38 a
Seeding rate grains.m-2		75.39 a	73.73 b	72.02 c			

3-b - Test Weight (kg. hL^{-1}) – Jleokhan.

Data presented in Table (5) demonstrate that crop type had a significant effect on test weight .Wheat recorded the highest significant test weight, reaching (78.29 kg.hL^{-1}), whereas Barley showed the lowest significant value, amounting to (58.07 kg.hL^{-1}).With respect to seeding rate, the results revealed a clear and significant superiority of the seeding rate of 200 grains.m^{-2}, which produced the highest test weight (70.55 kg.hL^{-1}). In contrast, the seeding rate of 400 grains.m^{-2} resulted in the lowest significant value for this trait, reaching (67.37 kg. hL^{-1}). Regarding irrigation systems, no significant differences were detected between supplemental irrigation and rain fed conditions. Statistical analysis indicated significant differences in the interaction between seeding rate and irrigation system. The combination of supplemental irrigation with a seeding rate of 200 grains.m^{-2} achieved the highest significant test weight (70.87 kg. hL^{-1}) and did not differ significantly from rain fed irrigation combined with the same seeding rate. Results indicated significant differences in the interaction between seeding rate and irrigation system .Interaction between Rain fed and (400 grains.m^{-2}) seeding rate, recorded the lowest significant value for test weight, which was (67.02 kg.hL^{-1}).This interaction was not differ from the SI system with the same seeding rate of (400 grains.m^{-2}).Interaction between Wheat and SI produced the highest test weight (78.50 kg.hL^{-1}), without significant difference with Wheat and Rain fed conditions. The lowest significant value (57.67 kg. hL^{-1}), was recorded in the interaction between Barley with Rain fed irrigation, which did not differ significantly from interaction of Barley and SI (58.47 kg. hL^{-1}). Interaction between crop type and seeding rate showed that Wheat combined with 200 grains.m^{-2} achieved the highest test weight (79.88 kg. hL^{-1}). While, Barley interaction with seeding rates of 300 and 400 grains.m^{-2} recorded the lowest test weight values, reaching (56.40 and 56.63 kg. hL^{-1}) respectively. Regarding the triple interaction among crop type, irrigation system, and seeding rate, the results indicated that Wheat grown under both supplemental and rain fed irrigation systems at a seeding rate of 200 grains.m^{-2} achieved the highest significant test weight, with mean values of (79.86 and 79.90 kg. hL^{-1}), respectively. On the other hand, Barley cultivated under rain fed irrigation at a seeding rate of 300 grains.m^{-2} recorded the lowest significant value (55.70 kg. hL^{-1}). This value did not differ significantly from Barley grown under supplemental irrigation at the same seeding rate, nor from Barley cultivated under either irrigation system at a seeding rate of 400 grains.m^{-2}.These findings are consistent with those reported by Harmeet Singh and Rashpal (2022), as well as Preiti et al. (2021), who observed a clear and significant advantage of the seeding rate of 200 grains.m^{-2} over other seeding rates in terms of test weight.

Table 5. Effect of the three factors and their interactions on the test weight kg. hctoliter-1 - Jleokhan

Irrigation system	Crop	Seeding rate grains.m-2			Irrigation X Crop	Irrigation means	Crop means
		200	300	400			
Rain fed	Rye	69.95 de f	68.86 e f	68.19 f	69.00 c		
	Barley	60.83 g	55.70 h	56.47 h	57.67 d		
	Wheat	79.90 a	77.90 be	76.42 c	78.07 a		
SI	Rye	71.23 d	70.59 d e	69.28 e f	70.37 b		
	Barley	61.51 g	57.10 h	56.80 h	58.47 d		
	Wheat	79.86 a	78.57 a b	77.07 b c	78.50 a		
Irrigation X Seeding rate grains.m-2	Rain fed	70.23 a	67.49 c	67.02 c		68.25 a	
	SI	70.87 a	68.75 b	67.72 c		69.11 a	
Crop X Seeding rate grains.m-2	Rye	70.59 d	69.72 de	68.73 e			69.68 b
	Barley	61.17 f	56.40 g	56.63 g			58.07 c
	Wheat	79.88 a	78.24 b	76.74 c			78.29 a
Seeding rate grains.m-2		70.55 a	68.12 b	67.37 c			

.4-a -Ash Percentage (%) – Telkaif.

Table (6) indicates significant differences in ash percentage among the crop types. Barley recorded the highest value at (2.07%), while Rye showed the lowest (1.85%), though this was not significantly different from Wheat. Regarding Seeding rates, no significant differences were observed among the three rates. Similarly, no significant differences were found between the two irrigation systems in terms of ash percentage. In the triple interaction, the highest ash percentage was recorded in Barley under rain fed irrigation and a Seeding rate of 400 grains.m^{-2} (2.14%), which was not significantly different from the same treatment under supplementary irrigation (2.10%). The lowest ash percentage was recorded in Rye grown at 300 grains.m^{-2} under both irrigation systems, at (1.80% and 1.81%), respectively.

Table 6. Effect of the three factors and their interactions on the Ash percentage (%).Telkaif.

Irrigation system	Crop	Seeding rate grains.m-2			Irrigation X Crop	Irrigation means	Crop means
		200	300	400			
Rain fed	Rye	2.00 a - f	1.80 f	1.83 d e f	1.88 b		
	Barley	2.02 a -e	2.03 a - d	2.14 a	2.07 a		
	Wheat	1.83 e f	1.83 d e f	1.89 b - f	1.85 b		
SI	Rye	1.80 f	1.81 f	1.87 c - f	1.82 b		
	Barley	2.07 a b	2.07 a b c	2.10 a	2.08 a		
	Wheat	1.98 a -f	1.97 a - f	1.99 a - f	1.98 a		
Irrigation X Seeding rate grains.m-2	Rain fed	1.95 a	1.89 a	1.95 a		1.93 a	
	SI	1.95 a	1.95 a	1.99 a		1.96 a	
Crop X Seeding rate grains.m-2	Rye	1.90 c d	1.80 d	1.85 c d			1.85 b
	Barley	2.05 a b	2.05 a b	2.12 a			2.07 a
	Wheat	1.91 c d	1.90 c d	1.94 b c			1.92 b
Seeding rate grains.m-2		1.95 a	1.92 a	1.97 a			

4-b-Ash percentage (%)-Jleokhan.

The data presented in Table (7) indicate that crop type did not significantly affect ash percentage (%), as no statistical differences were observed among the three crops. Similarly, the seeding rates used in the study showed no significant effect on ash percentage, with no statistically meaningful differences among treatments. The irrigation system factor also did not result in significant differences between supplemental and rain fed irrigation. Finally, the triple interaction among crop type, seeding rate, and irrigation system showed that the highest ash percentage (2.19%) was obtained for Wheat grown under rain fed irrigation at a seeding rate of 200 grains. m^{-2}.These results indicate that ash percentage is relatively stable across crop types, seeding rates, and irrigation systems, with only minor numerical variations observed under specific interactions.

Table 7. Effect of the three factors and their interactions on the Ash percentage (%).

Irrigation system	**Crop**	**Seeding rate grains.m-2**			**Irrigation X Crop**	**Irrigation means**	**Crop means**
		200	**300**	**400**			
Rain fed	**Rye**	2.03 a b c	2.00 a b c	2.00 a b c	2.01 a		
	Barley	1.93 c	2.09 a b c	2.15 a b	2.06 a		
	Wheat	1.99 a b c	2.01 a b c	1.98 b c	1.99 a		
SI	**Rye**	2.10 a b c	1.97 b c	1.99 a b c	2.02 a		
	Barley	2.03 a b c	2.07 a b c	2.10 a b c	2.07 a		
	Wheat	2.19 a	1.93 c	2.11 a b c	2.08 a		
Irrigation X Seeding rate grains.m-2	**Rain fed**	1.99 b	2.03 a b	2.04 a b		2.02 a	
	SI	2.11 a	1.99 b	2.07 a b		2.05 a	
Crop X Seeding rate grains.m-2	**Rye**	2.07 a b	1.98 b	2.00 a b			2.02 a
	Barley	1.98 b	2.08 a b	2.13 a			2.06 a
	Wheat	2.09 a b	1.97 b	2.04 a b			2.04 a
Seeding rate grains.m-2		2.05 a	2.01 a	2.06 a			

5-a -Protein Percentage (%)-Telkaif.

Table (8): indicated that the crop type factor had a significant effect on grain protein content. Barley recorded the highest protein percentage at (11.68%), whereas Wheat showed the lowest significant value of (11.09%), which did not differ significantly from Rye. In Seeding rate factor, the results indicated that there were no significant differences between the three seeding rates. In irrigation system factor, rain fed results showed a significant superiority in protein percentage which recorded a (11.92%), compared to (10.86%) under the SI system. A reduction in rainfall during the grain filling stage could cause a limited carbohydrate accumulation in the grains in favor of higher protein content. In the triple interaction the results showed that Barley grown under rain fed irrigation at seeding rates of 200 and 400 grains.m^{-2}, recording values of (12.73% and 12.67%), respectively. Wheat recorded the lowest protein content, reaching (9.97%) when it's grown under SI at a seeding rate of 400 grains.m^{-2}

Table 8. Effect of the three factors, and their interactions on Protein percentage (%)- Telkaif.

Irrigation system	Crop	Seeding rate grains.m-2			Irrigation X Crop	Irrigation means	Crop means
		200	300	400			
Rain fed	Rye	11.80 a - d	11.10 c - f	11.20 b - f	11.37 b c		
	Barley	12.67 a	12.47 a b	12.73 a	12.62 a		
	Wheat	11.90 a - d	11.30 b - e	12.13 a b c	11.78 b		
SI	Rye	11.90 a-d	11.20 b - f	11.17 b - f	11.42 b c		
	Barley	10.70 d e f	10.67 d e f	10.87 c - f	10.74 c d		
	Wheat	10.40 e f	10.87 c - f	9.97 f	10.41 d		
Irrigation X Seeding rate grains.m-2	Rain fed	12.12 a	11.62 a b	12.02 a		11.92 a	
	SI	11.00 b c	10.91 c	10.67 c		10.86 b	
Crop X Seeding rate grains.m-2	Rye	11.85 a	11.15 a	11.18 a			11.39 a b
	Barley	11.68 a	11.57 a	11.80 a			11.68 a

	Wheat	11.15 a	11.08 a	11.05 a			11.09 b
Seeding rate grains.m-2		11.56 a	11.27 a	11.34 a			

5-b- Protein Percentage (%)- Jleokhan.

Table (9): indicated that the crop type factor had a significant effect on grain protein content. Rye recorded the highest protein percentage at (11.29%), whereas Wheat showed the lowest significant value of (10.19%). This variation maybe due to genetic and metabolic differences between the crops. The results of seeding rate factor indicates that, seeding rates of 200 and 300 grains.m^{-2} produced the highest protein Percentages, (10.75% and 10.68%), respectively, while the highest seeding rate (400 grains.m^{-2}) resulted in the lowest protein Percentage (10.44%). This protein percentage reduction at higher densities may be due to competition. In irrigation system factor, rain fed results showed a significant superiority in protein percentage which recorded a (10.85%), compared to (10.39%) under the SI system. A reduction in rainfall during the grain filling stage could cause a limited carbohydrate accumulation in the grains in favor of higher protein content. Finally, the triple interaction between factors showed a clear superiority for Rye sown at 200 grains.m^{-2} under rain fed conditions, recording the highest protein percentage of 11.90%. Wheat under SI at 400 grains.m^{-2} recorded the lowest protein percentage value (9.50%). These results are agree with Saudi et al. (2016) results, who indicated that lower to moderate seeding rates (200–300 grains.m^{-2}) produced higher protein content compared to higher rates (400 grains.m^{-2}). They also agree with Ahmed (2020), who reported a significant advantage of rain fed over SI in protein accumulation.

Table 9. Effect of the three factors, and their interactions on Protein percentage (%).

Irrigation system	Crop	Seeding rate grains.m-2			Irrigation X Crop	Irrigation means	Crop means
		200	300	400			
Rain fed	**Rye**	11.90 a	11.20 b	11.23 b	11.44 a		
	Barley	10.70 c d e	10.60 d e f	10.84 b - e	10.71 c		
	Wheat	10.40 e f g	10.86 b - e	9.96 g h	10.41 d		
SI	**Rye**	11.30 b	11.10 b c	11.00 b c d	11.13 b		
	Barley	10.20 f g	9.93 g h	10.10 g	10.08 e		

	Wheat	10.00 g	10.40 e f g	9.50 h	9.97 e		
Irrigation X Seeding rate grains.m-2	**Rain fed**	11.00 a	10.89 a b	10.68 b c		10.85 a	
	SI	10.50 c	10.48 c	10.20 d		10.39 b	
Crop X Seeding rate grains.m-2	**Rye**	11.60 a	11.15 b	11.12 b			11.29 a
	Barley	10.45 c d	10.27 d	10.47 c d			10.40 b
	Wheat	10.20 d	10.63 c	9.73 e			10.19 c
Seeding rate grains.m-2		10.75 a	10.68 a	10.44 b			

6-a- Gluten percentage (%) – Telkaif.

Table (10) indicated that Barley was significantly superior in gluten percentage with an average value of (28.4%) comparing with the other studied crops. While Wheat was the lower crop in gluten percentage (25.0%). In the results of irrigation system factor, no significant differences were observed between rain fed and SI. Rain fed irrigation produced a slightly higher numerical value than SI.The results of seeding rate factor showed that 200 grains.m^{-2} resulted the highest gluten percentage (27.4%), while the seeding rates of 300 and 400 grains.m^{-2} recorded lower significant values of (26.0% and 26.9%), respectively.Concerning the interaction between crop type and irrigation system, Barley grown under rain fed conditions achieved a significantly higher gluten percentage (29.3%), with no significant difference compared to Barley cultivated under supplemental irrigation. In contrast, Wheat grown under both rain fed and supplemental irrigation systems recorded the lowest significant mean gluten percentages, reaching (25.1% and 24.8%), respectively.The results of interaction between irrigation system and seeding rate indicated that the rain fed system combined with a seeding rate of 200 grains.m^{-2} produced the highest gluten percentage (27.8%) without significant differences with seeding rates of 300 and 400 grains.m^{-2} under the same irrigation system .This result caused by the effects between water stresses combined with plant density. In the interaction between irrigation and seeding rate, the highest gluten percentage was observed at the seeding rate of 200 grains.m^{-2} (26.9%) with SI, although it was lower under rain fed conditions. The lowest significant value (26.0%) was recorded under SI combined with a seeding rate of 300 grains.m^{-2}. In the interaction between crop type and seeding rate, Barley showed significant superiority across all seeding rates, especially at 400 grains.m^{-2}, where gluten percentage reached (28.9%). Wheat at a seeding rate of 300 grains.m^{-2}, recorded the lowest significant values (23.7%). This suggests that Wheat appears to be negatively affected by increased density. In the triple interaction, the results showed that Barley grown under rain fed conditions with a seeding rate of 400 grains.m^{-2} achieved the highest gluten percentage (30.4%). Wheat recorded the lowest significant gluten percentage (23.3%), under SI combined with 300 grains.m^{-2} which the minimum value was observed without any significant difference from Wheat grown at the same seeding rate under rain fed irrigation

Table 10. Effect of the three factors and their interactions on the Gluten % - Telkaif

Irrigation system	Crop	Seeding rate grains.m-2			Irrigation X Crop	Irrigation means	Crop means
		200	300	400			
Rain fed	Rye	29.6 a b	27.4 a -f	26.0 c - g	27.7 a b		
	Barley	28.1 a-e	29.3 a b c	30.4 a	29.3 a		
	Wheat	25.6 d - g	24.1 f g	25.7 d - g	25.1 c		
SI	Rye	26.3 b - g	24.8 e f g	27.1 a - f	26.1 b c		
	Barley	28.4 a - d	27.1 a – f	27.3 a - f	27.6 a b		
	Wheat	26.1 c - g	23.3 g	24.9 e f g	24.8 c		
Irrigation X Seeding rate grains.m-2	Rain fed	27.8 a	26.9 a	27.4 a		27.4 a	
	SI	26.9 a	25.1 b	26.4 a b		26.1 a	
Crop X Seeding rate grains.m-2	Rye	28.0 a b c	26.1 b c d	26.6 b c d			26.9 b
	Barley	28.3 a b	28.2 a b	28.9 a			28.4 a
	Wheat	25.9 c d e	23.7 e	25.3 d e			25.0 c
Seeding rate grains.m-2		27.4 a	26.0 b	26.9 a b			

6-b- Gluten percentages (%) – Jleokhan.

The results presented in Table (11) indicate that Barley significantly outperformed the other crops in terms of gluten percentage, reaching (42.3%), followed by Rye at (33.2%), while Wheat recorded the lowest value at (29.5%). This difference can be attributed to the genetic nature of the crops, as Barley varieties have a distinct protein composition that may result in higher gluten concentrations under specific water or nutrient conditions. Several studies have highlighted that the genetic makeup of a crop is the primary determinant of gluten percentage (Wolde et al., 2019), with Barley often surpassing Wheat in protein percentage under most environmental conditions. No significant differences were observed between rain fed and supplemental irrigation for gluten percentage, likely due to sufficient rainfall during the growing season. Similarly, seeding rate did not significantly affect gluten percentage, although a slight decline was noted with increasing plant density, likely due to competition for nutrients. Gluten percentage is known to be influenced by plant density, with higher densities potentially reducing gluten concentration and certain grain quality traits (Habib et al., 2019). The bilateral interaction between crop type and seeding rate showed that Barley consistently recorded the highest significant gluten percentages across the three seeding rates (43.1%, 42.7%, and 41.1%), while Wheat recorded the lowest values. A slight decrease in gluten percentage was observed for all crops with increasing seeding rate, indicating that crop type has a stronger influence than seeding rate, as the relative ranking of the three crops remained unchanged. Analysis of the interaction between crop type and irrigation system revealed significant differences. Barley under both rain fed and supplemental irrigation achieved the highest gluten percentages (43.1% and 41.4%, respectively). Although the difference between irrigation systems was not significant, rain fed irrigation numerically produced higher gluten values. Wheat under both rain fed and supplemental irrigation recorded the lowest values (29% and 30%, respectively). The interaction between irrigation system and seeding rate showed that rain fed irrigation combined with seeding rates of 200 and 300 grains.m^{-2} produced the highest average gluten percentages (36% and 36.1%), whereas supplemental irrigation combined with seeding rates of 300 and 400 grains.m^{-2} recorded the lowest values (34.1% and 34%, respectively). This reduction may be attributed to higher plant density under water stress, which can reduce gluten percentage. For the triple interaction among crop type, irrigation system, and seeding rate, Barley grown under rain fed conditions with seeding rates of 200 and 300 grains.m^{-2} achieved the highest significant gluten percentages (44.2% for both). In contrast, Wheat under rain fed irrigation with a seeding rate of 300 grains.m^{-2} recorded the lowest value (28.4%), which did not differ significantly from Wheat under the same irrigation system with seeding rates of 200 and 400 grains.m^{-2}.

Table 11. Effect of the three factors and their interactions on the Gluten % Jleokhan

Irrigation system	Crop	Seeding rate grains.m^{-2} 200	300	400	Irrigation X Crop	Irrigation means	Crop means
Rain fed	Rye	34.3 c d	35.7 c	34.4 c d	34.8 b		
	Barley	44.2 a	44.2 a	40.9 b	43.1 a		
	Wheat	29.5 e f	28.4 f	29.0 e f	29.0 d		
SI	Rye	31.7 d e f	32.1 d e	31.0 d e	31.6 c		
	Barley	41.9 a b	41.2 a b	41.2 a b	41.4 a		
	Wheat	31.2 d e f	29.1 d e	29.7 d e	30.0 c d		
Irrigation X Seeding rate grains.m-2	Rain fed	36.0 a	36.1 a	34.8 a b		35.6 a	
	SI	34.9 a b	34.1 b	34.0 b		34.3 a	
Crop X Seeding rate grains.m-2	Rye	33.0 b	33.9 b	32.7 b			33.2 b
	Barley	43.1 a	42.7 a	41.1 a			42.3 a
	Wheat	30.4 c	28.8 c	29.4 c			29.5 c
Seeding rate grains.m-2		35.5 a	35.1 a	34.4 a			

CONCLUSIONS

1-Due to the successful introduction and cultivation of Rye (*Secale cereale*) in Iraq—this crop represents a new genetic asset for Iraqi agriculture. It has been incorporated into a promising breeding program, aiming to produce triticale for the first time in Iraq through hybridization with late-maturing Wheat cultivars. The objective is to develop high-yielding triticale varieties with strong adaptability to rainfed conditions and water stress in Nineveh Governorate and across Iraq.

2-Important recommendation for cultivation of Rye in low-rainfall regions, as a promising crop alternative to Barley and due to its highly drought tolerance and ability to survive under water-stress conditions.

3-Advise to planning further studies across diverse and wide agro-ecological zones to assess Rye responses to different seeding dates, irrigation regimes, and fertilization levels. This will help in developing optimal management practices for semi-arid regions in northern Iraq, in addition to studies under supplementary irrigation conditions.

4-Continued research on developing new Rye varieties through selection is recommended.

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