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EFFECT OF ZERO-TILLAGE AND HYBRID FARMING SYSTEMS ON WHEAT GROWTH, YIELD, AND SOIL PROPERTIES UNDER DIFFERENT IRRIGATION SYSTEMS IN AL-ANBAR, IRAQ

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Abstract:
Rapid population growth in arid and semi-arid regions, combined with limited water resources, has intensified the demand for efficient and sustainable wheat production. A field experiment was conducted during the 2023–2024 growing season in a farmer's field in Al-Anbar Governorate, Iraq (33°20′ N, 43°40′ E, 50 m a.s.l.) to evaluate the effects of three irrigation systems (sprinkler, drip, and surface), three tillage methods (disc, chisel, and broadcaster), and three seed rates (30, 40, 50 kg/ha) on wheat (Triticum aestivum L.) growth, yield, soil physical properties, and irrigation efficiency. Results indicated that plant height responded significantly to irrigation and tillage, with the sprinkler–chisel combination producing the tallest plants. Grain yield, biological yield, and harvest index remained stable across treatments, suggesting management flexibility. Soil porosity improved under sprinkler irrigation and chisel tillage, while penetration resistance was not significantly affected. Sprinkler efficiency increased with operating pressure, whereas drip irrigation achieved optimal efficiency at ~100

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kPa. Vegetative growth was more sensitive to management practices than yield components. Chisel tillage enhanced soil porosity without increasing compaction, and efficient irrigation management improved water use efficiency. These findings support the adoption of sprinkler irrigation with chisel tillage in semi-arid regions to improve plant growth and soil structure, while managing drip irrigation at moderate pressure (~100 kPa) to optimize water conservation.

Keywords: Wheat, Zero-Tillage, Irrigation Systems, Soil Properties, Al-Anbar

1-Introduction

Wheat (Triticum aestivum L.) is one of the most important cereal crops worldwide and plays a vital role in global and national food security, particularly in arid and semi-arid regions where agricultural production is constrained by limited water resources (FAO, 2003; FAOSTAT, 2013). Approximately 15% of the world's population, equivalent to about 841 million people, resides in arid and semi-arid regions, including nearly 524 million in semi-arid areas, where food production faces increasing pressure. Rapid population growth and rising living standards have further intensified food demand, posing serious challenges to food security under conditions of water scarcity and land degradation (Millennium Ecosystem Assessment, 2005).

In Iraq, wheat is a strategic crop that underpins food security, supports rural livelihoods, and reduces reliance on imports. Large areas of agricultural land are devoted to wheat cultivation, particularly in semi-arid regions such as Al-Anbar Governorate. However, wheat production in these regions is increasingly threatened by water scarcity, high temperatures, soil degradation, and the widespread use of conventional tillage practices that negatively affect soil structure, increase erosion and compaction, and reduce water use efficiency (FAO, IFAD, WFP, 2015).

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Conservation agriculture practices, particularly zero-tillage systems, have been promoted as effective strategies to address these challenges. Zero-tillage minimizes soil disturbance, improves soil physical properties, enhances soil moisture retention, and can contribute to more sustainable crop production when combined with efficient irrigation management (Hobbs *et al.,* 2008). Despite these potential benefits, the combined effects of irrigation systems, no-tillage planting methods, and seed rates on wheat growth, yield, soil physical properties, and irrigation efficiency under the semi-arid conditions of Iraq remain insufficiently investigated.

2. Materials and Methods

2.1 Site description:

The experiment was conducted during the 2023–2024 wheat growing season in a farmer's field located in Al-Anbar Governorate, western Iraq (33°20′ N, 43°40′ E; 50 m above sea level). The soil of the experimental site is classified as loamy-sandy with moderate fertility, a common soil type in semi-arid regions of Iraq (FAO, 2006). The study area is characterized by a semi-arid climate, with low annual rainfall averaging approximately 150 mm and high temperature variability, ranging from about 10°C during the winter season to nearly 45°C in summer (FAO, IFAD, WFP, 2015). Such climatic conditions impose significant constraints on wheat production and highlight the importance of efficient water and soil management practices

2.2 Experimental design:

A factorial experiment in a randomized complete block design (RCBD) with three replications was used:

- **Irrigation systems:** Sprinkler, drip, surface.
- **Tillage methods:** Disc, chisel, broadcaster.
- **Seed rates:** 30, 40, 50 kg/ha.

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2.3 Agronomic practices:

Seeds were sown according to assigned seed rates and tillage treatments. Fertilizers and pest management were applied uniformly across all plots. Irrigation was scheduled based on crop growth stage and soil moisture monitoring.

2.4 Data collection:

- **Growth parameters:** Plant height, number of tillers per plant.
- **Yield components:** Grain yield, biological yield, harvest index.
- **Soil physical properties:** Bulk density, penetration resistance, porosity.
- **Irrigation efficiency:** Water use efficiency calculated based on applied water vs. crop yield.

2.5 Statistical analysis:

Data were subjected to analysis of variance (ANOVA) to evaluate the effects of the studied factors and their interactions, and treatment means were compared using the least significant difference (LSD) test at a probability level of $p \leq 0.05$, following standard statistical procedures (Gomez and Gomez, 1984; Steel *et al.*, 1997)

Results and Discussion

Table 1 shows the effects of irrigation systems (IS), seed rates (SR), and no-tillage planting methods (M) on wheat plant height in the Anbar region. Plant height varied between 73 and 92 cm, reflecting significant differences among treatments. Sprinkler irrigation produced the tallest plants (86.9 cm), followed by drip (81.8 cm) and surface irrigation (76.4 cm), which is consistent with previous findings that uniform water distribution improves vegetative growth.

Among planting methods, disc planting (M1) resulted in the highest height (82.5 cm), followed by chisel (M2, 81.8 cm) and seed scattering (M3, 78.9 cm),

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supporting reports that precise seed placement enhances crop establishment and plant development (Lal, 2015). Regarding seed rates, 40 kg/dunam produced the tallest plants (83.6 cm), while 30 and 50 kg/dunam resulted in slightly shorter plants (80.8–80.9 cm), indicating that moderate seeding optimizes light interception and nutrient competition, in agreement with findings by (Lal, 2015). Two-way interactions showed that sprinkler irrigation combined with disc planting and 40 kg/dunam achieved maximum plant height, whereas the three-way interaction (IS × SR × M) was not significant, suggesting that each factor primarily influenced plant height independently, similar to patterns observed in semi-arid wheat studies.

Table 1. Effects of different combinations of Irrigation systems (IS), Seed rate (SR), and no-tillage planting systems (M) on Plant Height(cm) (H.P). Anbar Region

Irrigation systems(IS)	Seed rate(SR) kg/dunam	no-tillage planting systems (M)			IS* SR	
		Disc vacuoles (M1)	Chisel vacuoles (M2)	scattering wheat seeds (M3)		
Sprinkler	30	88	86	82.5	85.5	
	40	92	90	86	89.3	
	50	87.5	86	84	85.8	
Drip	30	82	81	79.5	80.8	
	40	85	84	81	83.3	
	50	83	81.5	80	81.5	
Surface	30	76	77.5	74	75.8	
	40	76.5	80	76	78.2	
	50	77	75.5	73	75.2	
LSD I*SR*M		6.14			LSD I*SR	3.03
SE ±		2.04				
CV %		4%				
IS*M						

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Irrigation system	Disc vacuoles (M1)	Chisel vacuoles (M2)	scattering wheat seeds (M3)	Average irrigation systems	
Sprinkler	89.2	87.3	84.2	86.9	
Drip	83	82.2	80.2	81.8	
Surface	77.2	77.7	74.3	76.4	
LSD IS*M		6.14		LSD IS	6.14

SR*M					
Seed rate(SR)	Disc vacuoles (M1)	Chisel vacuoles (M2)	scattering wheat seeds (M3)	Average irrigation systems	
30	82.7	81.5	78.7	80.9	
40	85.2	84.7	81	83.6	
50	82.5	81	79	80.8	
LSD SR	6.14	6.14		LSD SR*M	

M			
No-till farming systems	Disc vacuoles (M1)	Chisel vacuoles (M2)	scattering wheat seeds (M3)
Average farming systems	82.5	81.8	78.9
LSD M	6.14		

Table 2 presents the effects of irrigation systems (IS), seed rates (SR), and no-tillage planting methods (M) on the number of tillers per wheat plant in the Anbar region. Tillering varied from 9.2 to 13.6, indicating considerable variation in vegetative growth across treatments.

Among the irrigation systems, drip irrigation produced the highest average number of tillers (12.8), followed by surface irrigation (12.3) and sprinkler irrigation (10.3). These results suggest that efficient and uniform water delivery promotes tiller formation and overall vegetative development, in agreement with previous studies reporting improved shoot production under drip and efficient irrigation systems in semi-arid wheat cultivation.

Regarding planting methods, chisel planting (M2) slightly outperformed disc planting (M1) and seed scattering (M3), averaging 11.9 tillers per plant. This indicates that appropriate seed placement enhances shoot formation and canopy

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development, supporting findings by Hobbs *et al*. (2008) and Lal (2015) on the benefits of conservation tillage practices.

Seed rates also influenced tillering: the highest seeding rate (50 kg/dunam) produced the most tillers (12.4), whereas the lowest rate (30 kg/dunam) resulted in fewer tillers (11.2). This likely reflects the effect of plant density, where higher seeding rates stimulate vegetative branching and increase the number of tillers, consistent with reports by Lal (2015.

Two-way and three-way interactions (IS × SR × M) were not statistically significant, suggesting that the factors influenced tiller number mostly independently, a pattern similar to other studies under semi-arid, no-tillage conditions (Khalid *et al.,* 2018).

Table 2. Effects of different combinations of Irrigation systems (IS), Seed rate (SR), and no-tillage planting systems (M) on Number of Tiller (NO.T) . Anbar Region.

Irrigation systems(IS)	Seed rate (SR) kg/dunam	no-tillage planting systems (M)			IS* SR	
		Disc vacuoles (M1)	Chisel vacuoles (M2)	scattering wheat seeds (M3)		
Sprinkler	30	9.2	9.8	9.4	9.5	
	40	10.3	9.5	10	9.9	
	50	11.1	12	11.2	11.4	
Drip	30	12.8	12	11.6	12.1	
	40	12.7	13.1	13	13	
	50	13	13.6	13	13.2	
Surface	30	11.3	12	12.8	12	
	40	12.6	12.3	12.5	12.5	
	50	12.4	13.2	12.5	12.5	
LSD I*SR*M		N.S			LSD I*SR	0.072
SE ±		0.34				

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CV %		4.8 %			
IS*M					
Irrigation system		Disc vacuoles (M1)	Chisel vacuoles (M2)	scattering wheat seeds (M3)	Average irrigation systems
Sprinkler		10.2	10.4	10.2	10.3
Drip		12.8	12.9	12.6	12.8
Surface		12.1	12.5	12.4	12.3
LSD IS*M		N.S		LSD IS	0.72
SR*M					
Seed rate(SR)		Disc vacuoles (M1)	Chisel vacuoles (M2)	scattering wheat seeds (M3)	Average irrigation systems
30		11.1	11.3	11.2	11.2
40		11.9	11.6	11.9	11.8
50		12.2	12.9	12.1	12.4
LSD SR	0.615	N.S			LSD SR*M
M					
No-till farming systems		Disc vacuoles (M1)	Chisel vacuoles (M2)	scattering wheat seeds (M3)	
Average farming systems		11.7	11.9	11.8	
LSD M		N.S			

Table 3 presents the effects of irrigation systems (IS), seed rates (SR), and no-tillage planting methods (M) on wheat grain yield in the Anbar region. Sprinkler irrigation consistently produced the highest grain yield (6.903–7.231 kg), followed by drip irrigation (6.639 kg) and surface irrigation (6.289 kg). This indicates that uniform water distribution positively influences grain formation, which is consistent with previous studies reporting enhanced yield under

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sprinkler and drip systems compared to surface irrigation in semi-arid wheat cultivation.

Regarding planting methods, disc planting (M1) achieved the highest grain yield (6.807 kg), reflecting improved seed-soil contact and crop establishment, whereas chisel planting (M2) and seed scattering (M3) resulted in slightly lower yields. These findings agree with reports that precise seed placement enhances establishment, tillering, and ultimately grain yield under conservation tillage systems (Hobbs *et a*l., 2008; Lal, 2015).

Seed rate also influenced yield: 40 kg/dunam produced the highest grain harvest (6.716 kg), while the highest seeding rate (50 kg/dunam) led to a slightly reduced yield (6.438 kg), likely due to increased inter-plant competition and reduced resource availability per plant, in line with observations by Hobbs *et a*l., 2008; Lal, (2015).

Two-way interactions highlighted that the combination of sprinkler irrigation with disc planting maximized grain yield, and the interaction between seed rate and planting method emphasized the advantage of moderate seeding density with optimized planting systems. The three-way interaction (IS × SR × M) was not significant, suggesting that each factor primarily influenced grain yield independently.

Table 3. Effects of different combinations of Irrigation systems (IS), Seed rate (SR), and no-tillage planting systems (M) on Grain Harvest (Kg) (G.H .Anbar Region.

Irrigation systems(IS)	Seed rate(SR) kg/dunam	no-tillage planting systems (M)			IS* SR
		Disc vacuoles (M1)	Chisel vacuoles (M2)	scattering wheat seeds (M3)	
Sprinkler	30	7.431	6.814	6.619	6.955
	40	7.570	7.140	6.730	6.147
	50	6.693	6.631	6.498	6.607
Drip	30	6.835	6.715	6.578	6.709
	40	6.766	6.703	6.503	6.667

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	50	6.662	6.501	6.454	6.539
Surface	30	6.503	6.476	6.117	6.365
	40	6.470	6.507	6.026	6.334
	50	6.259	6.259	5.945	6.168
LSD I*SR*M		N.S		LSD I*SR	0.137
SE ±		0.075			
CV %		3%			

IS*M

Irrigation system	Disc vacuoles (M1)	Chisel vacuoles (M2)	scattering wheat seeds (M3)	Average irrigation systems
Sprinkler	7.231	6.862	6.616	6.903
Drip	6.764	6.640	6.512	6.639
Surface	6.424	6.414	6.029	6.289
LSD IS*M		0.137		LSD IS 0.08

SR*M

Seed rate(SR)	Disc vacuoles (M1)	Chisel vacuoles (M2)	scattering wheat seeds (M3)	Average irrigation systems
30	6.923	6.668	6.438	6.676
40	6.945	6.783	6.420	6.716
50	6.551	6.464	6.299	6.438
LSD SR 0.226	N.S			LSD SR*M

M

No-till farming systems	Disc vacuoles (M1)	Chisel vacuoles (M2)	scattering wheat seeds (M3)
Average farming systems	6.807	6.638	6.631
LSD M	0.226		

Table 4 presents the effects of irrigation systems (IS), seed rates (SR), and no-tillage planting methods (M) on wheat biological yield in the Anbar region. Sprinkler irrigation produced the highest biomass (17.24 kg), followed by drip and surface irrigation, highlighting the benefit of uniform water distribution on overall plant growth. These results align with previous findings that efficient

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water management enhances vegetative growth and total biomass accumulation in semi-arid wheat systems.

Among planting methods, disc planting (M1) achieved the highest biological yield, reflecting improved seed-soil contact and seedling establishment, which has been reported to enhance crop vigor and above-ground biomass under conservation tillage (Hobbs *et al*., 2008; Lal, 2015). Seed rate also influenced biomass: 40 kg/dunam outperformed 30 and 50 kg/dunam, suggesting that moderate seeding density optimizes plant population while minimizing inter-plant competition.

Two-way interactions revealed that the combination of sprinkler irrigation, disc planting, and 40 kg/dunam produced the highest biological yield. The three-way interaction (IS × SR × M) was not significant, indicating that each factor influenced biomass largely independently, consistent with other studies under semi-arid, no-tillage conditions.

Table 4. Effects of different combinations of Irrigation systems (IS), Seed rate (SR), and no-tillage planting systems (M) on Biological harvest (Kg) (B.H). Anbar Region.

Irrigation systems(IS)	Seed rate(SR) kg/dunam	no-tillage planting systems (M)			IS* SR
		Disc vacuoles (M1)	Chisel vacuoles (M2)	scattering wheat seeds (M3)	
Sprinkler	30	17.45	17.1	16.75	17.10
	40	18.10	18.22	17.05	17.79
	50	17.02	16.90	16.60	16.84
Drip	30	16.30	16.10	15.95	16.12
	40	16.85	16.52	16.00	16.46
	50	16.12	15.95	15.6	15.89
Surface	30	15.10	15.05	14.80	14.98
	40	15.45	15.20	14.60	15.08

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	50	15.00	14.90	14.65	14.85	
LSD I*SR*M		N.S			LSD I*SR	0.22
SE ±			0.070			
CV %			0.47%			
IS*M						
Irrigation system		Disc vacuoles (M1)	Chisel vacuoles (M2)	scattering wheat seeds (M3)	Average irrigation systems	
Sprinkler		17.52	17.41	16.80	17.24	
Drip		16.42	16.19	15.85	16.15	
Surface		15.18	15.05	14.68	14.97	
LSD IS*M			0.14		LSD IS	0.085
SR*M						
Seed rate(SR)		Disc vacuoles (M1)	Chisel vacuoles (M2)	scattering wheat seeds (M3)	Average irrigation systems	
30		16.95	16.65	16.50	16.70	
40		17.47	17.30	16.57	17.11	
50		16.38	16.25	15.95	16.9	
LSD SR	0.085	0.14			LSD SR*M	
M						
No-till farming systems		Disc vacuoles (M1)	Chisel vacuoles (M2)	scattering wheat seeds (M3)		
Average farming systems		16.93	16.34	16.66		
LSD M		0.085				

Table 5 presents the effects of irrigation systems (IS), seed rates (SR), and no-tillage planting methods (M) on wheat harvest index (H.I %) in the Anbar region. Overall, the harvest index ranged from 39.1% to 43.1%, indicating moderate efficiency in allocating biomass to grain.

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Among irrigation systems, surface irrigation achieved the highest average H.I (42.0%), followed by drip (41.1%) and sprinkler (40.0%), suggesting that surface irrigation slightly favors partitioning of biomass to grain compared to vegetative tissues. This finding aligns with previous studies reporting that irrigation method can influence biomass allocation, with surface irrigation often enhancing grain fraction in cereal crops.

Regarding planting methods, disc planting (M1) recorded slightly higher H.I (41.0%) than chisel planting (M2, 40.5%) and seed scattering (M3, 41.0%), indicating that appropriate seed placement may improve biomass partitioning efficiency, as also reported by Hobbs *et al.* (2008) and Lal (2015).

For seed rates, 30 kg/dunam produced the highest H.I (41.6%), while 50 kg/dunam slightly reduced it (40.7%), likely due to increased vegetative competition reducing grain allocation, consistent with observations by Royo *et al.* (2000) and Singh *et al*. (2012). Two-way interactions revealed that drip and surface irrigation combined with disc or chisel planting maintained higher H.I values, whereas the three-way interaction (IS × SR × M) was not significant, indicating that each factor primarily influenced harvest index independently.

Table 5. Effects of different combinations of Irrigation systems (IS), Seed rate (SR), and no-tillage planting systems (M) on Harvest Index (%) (H.I) . Anbar Region.

Irrigation systems(IS)	Seed rate(SR) kg/dunam	no-tillage planting systems (M)			IS* SR
		Disc vacuoles (M1)	Chisel vacuoles (M2)	scattering wheat seeds (M3)	
Sprinkler	30	42.6	39.8	39.5	41.6
	40	41.8	39.2	39.5	40.2
	50	39.3	39.1	39.1	39.2
	30	41.9	41.7	41.2	41.6

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Drip	40	40.3	40.6	40.6	40.5
	50	41.3	40.8	41.4	41.2
Surface	30	43.1	43.0	41.3	42.5
	40	41.9	42.8	41.3	42.0
	50	42.0	42.0	40.6	41.5
LSD I*SR*M		N.S		LSD I*SR	0.0080
SE ±			0.0048		
CV %			3%		

IS*M

Irrigation system	Disc vacuoles (M1)	Chisel vacuoles (M2)	scattering wheat seeds (M3)	Average irrigation systems	
Sprinkler	41.2	39.4	39.4	40.0	
Drip	41.2	41.0	41.1	41.1	
Surface	42.3	42.6	41.1	42.0	
LSD IS*M		0.0080		LSD IS	0.0145

SR*M

Seed rate(SR)		Disc vacuoles (M1)	Chisel vacuoles (M2)	scattering wheat seeds (M3)	Average irrigation systems
30		42.5	41.5	40.7	41.6
40		41.3	40.9	40.5	40.9
50		40.9	40.7	40.5	40.7
LSD SR	0.0145	0.0080			LSD SR*M

M

No-till farming systems	Disc vacuoles (M1)	Chisel vacuoles (M2)	scattering wheat seeds (M3)
Average farming systems	41.0	40.5	41
LSD M	0.0046		

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Table 6 presents the effects of irrigation systems (IS), seed rates (SR), and no-tillage planting methods (M) on soil penetration resistance in the Anbar region. Soil resistance varied from 73.04 to 121.91 kPa, reflecting differences in soil compaction among treatments. Sprinkler irrigation produced the highest resistance (105.24 kPa), followed by drip (94.10 kPa) and surface irrigation (79.42 kPa). This suggests that the impact of water droplets from sprinklers may slightly increase soil compaction compared to surface irrigation, consistent with previous findings in semi-arid wheat fields.

Among planting methods, disc planting (M1) recorded the highest resistance (97.05 kPa), whereas seed scattering (M3) had the lowest (88.38 kPa), indicating that intensive seed placement can increase soil density, in agreement with Hamza and Anderson (2005). Regarding seed rates, 40 kg/dunam led to the highest penetration resistance (96.09 kPa), while 50 kg/dunam resulted in the lowest (89.99 kPa), likely due to more uniform root development and soil coverage at intermediate seeding rates, as reported by Bronick and Lal (2005).

Two-way interactions showed that sprinkler irrigation combined with disc planting maximized soil resistance, whereas surface irrigation with seed scattering minimized compaction. The three-way interaction (IS × SR × M) was not significant, indicating that each factor primarily influenced penetration resistance independently.

Table 6. Effects of different combinations of Irrigation systems (IS), Seed rate (SR), and no-tillage planting systems (M) on soil penetration resistance (kPa). Anbar Region.

Irrigation systems(IS)	Seed rate(SR) kg/dunam	no-tillage planting systems (M)			IS* SR
		Disc vacuoles (M1)	Chisel vacuoles (M2)	scattering wheat seeds (M3)	
Sprinkler	30	109.16	103.27	94.84	102.42
	40	121.91	113.05	103.68	112.88

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	50	102.76	102.36	96.15	100.42	
Drip	30	100.31	90.91	90.14	93.79	
	40	92.05	97.81	90.28	93.38	
	50	99.68	92.79	92.90	95.12	
Surface	30	83.76	82.75	79.00	81.84	
	40	89.74	80.97	75.34	82.02	
	50	74.04	76.16	73.04	74.41	
LSD I*SR*M					LSD I*SR	4.726
SE ±	1.34					
CV %	2.5%					

IS*M

Irrigation system	Disc vacuoles (M1)	Chisel vacuoles (M2)	scattering wheat seeds (M3)	Average irrigation systems	
Sprinkler	111.27	106.22	98.22	105.24	
Drip	97.35	93.84	91.11	94.10	
Surface	82.51	79.96	75.79	79.42	
LSD IS*M		4.03		LSD IS	4.03

SR*M

Seed rate(SR)	Disc vacuoles (M1)	Chisel vacuoles (M2)	scattering wheat seeds (M3)	Average irrigation systems
30	97.74	92.31	87.99	92.68
40	101.23	97.27	89.77	96.09
50	92.16	90.43	87.37	89.99
LSD SR 4.03	4.03			LSD SR*M

M

No-till farming systems	Disc vacuoles (M1)	Chisel vacuoles (M2)	scattering wheat seeds (M3)
Average farming systems	97.05	93.34	88.38
LSD M	4.03		

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Table 7 presents the effects of different operating pressures on the uniformity coefficient (CU), application efficiency (AE), and overall efficiency (OE) of the sprinkler irrigation system in the Anbar region. Increasing the operating pressure from 200 kPa to 400 kPa significantly improved all efficiency parameters. The uniformity coefficient (CU) increased from 42% to 78%, indicating more even water distribution at higher pressures. Similarly, application efficiency (AE) improved from 32% to 76%, reflecting reduced water losses during irrigation. Consequently, overall efficiency (OE) increased substantially from 13.5% to 62%, demonstrating that higher operating pressures optimize the performance of sprinkler irrigation systems.

These findings are consistent with previous studies showing that sufficient operating pressure is critical to enhance water distribution uniformity and irrigation efficiency in wheat and other cereal crops (Allen *et al.,* 1998; Pereira *et al*., 2002). Maintaining adequate pressure ensures that water reaches all parts of the field uniformly, reduces runoff and deep percolation losses, and improves crop water use efficiency under semi-arid conditions.

Table.7 Effect of Different Operating Pressures on Uniformity Coefficient (CU), Application Efficiency (AE), and Overall Efficiency (OE) in Sprinkler Irrigation System. Anbar Region.

Efficiency (%)	Operating Pressure (kPa)		
	200	300	400
Uniformity (CU)	42.00	50.00	78.00
Addition Efficiency (AE)	32.00	65.00	76.00
Overall Efficiency (OE)	13.50	33.00	62.00

Table 8 presents the effects of different operating pressures on the performance of the drip irrigation system in the Anbar region, evaluated using the uniformity coefficient (CU), low-quarter distribution uniformity (DU), and coefficient of variation (CV). Increasing the operating pressure from 50 kPa to 150 kPa

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improved system performance. The uniformity coefficient (CU) increased from 88% to 95.5%, while the low-quarter distribution uniformity (DU) improved from 84% to 92%, indicating more consistent water delivery across the field. Simultaneously, the coefficient of variation (CV) decreased from 28% to 15%, reflecting reduced variability in emitter output and better irrigation uniformity.

These results align with previous studies reporting that adequate operating pressure is essential for high water distribution uniformity and minimal water losses in drip systems (Fereres and Soriano, 2007; Pereira *et al.,* 2002). Maintaining optimal pressure ensures uniform emitter output, reduces water stress on crops, and enhances water use efficiency under semi-arid conditions.

Table 8. Effect of Different Operating Pressures on Uniformity Coefficient (CU), Low-Quarter Distribution Uniformity (DU), and Coefficient of Variation (CV, qm) in Drip Irrigation System. Anbar Region.

Operating Pressure (kPa)	CU (%)	DU (%)	CV (%)
50	88.00	84.00	28
100	95.00	92.00	18
150	95.50	90.50	15

Conclusion and Recommendations

Conclusion

The results of this study demonstrated that irrigation systems, seed rates, and no-tillage planting systems significantly influenced wheat growth, yield, soil properties, and irrigation efficiency in the Anbar region. Sprinkler irrigation produced the highest plant height, biological yield, and grain yield compared with drip and surface irrigation systems. A moderate seed rate of 40 kg/dunam achieved the best balance between plant population and competition, resulting in improved crop performance. Among the planting systems, disc vacuoles (M1) provided better seed placement and crop establishment, leading to higher

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productivity. In contrast, drip irrigation improved soil porosity and reduced soil penetration resistance, indicating better soil physical conditions. Irrigation system performance also improved with higher operating pressure, where 400 kPa for sprinkler irrigation and 100–150 kPa for drip irrigation achieved the highest irrigation efficiency and uniformity. Overall, the combination of appropriate irrigation management, optimal seed rate, and suitable no-tillage planting systems can enhance wheat productivity under the environmental conditions of the Anbar region.

Recommendations

1. Adoption of sprinkler irrigation for wheat cultivation due to its superior performance in plant growth and grain yield.
2. Use of a seed rate of 40 kg/dunam as it provided the best balance between plant density and productivity.
3. Application of the disc vacuoles planting system (M1) under no-tillage conditions to improve seed placement and crop establishment.
4. The combination of sprinkler irrigation + disc planting (M1) + 40 kg/dunam seed rate is recommended for maximizing wheat yield in the Anbar region.
5. Operate sprinkler systems at about 400 kPa and drip systems at 100–150 kPa to achieve higher irrigation efficiency and uniform water distribution.
6. Drip irrigation may be considered when improving soil physical properties such as soil porosity is a priority.

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الملخص

أدى النمو السكاني السريع في المناطق القاحلة وشبه القاحلة، إلى جانب محدودية موارد المياه، إلى زيادة الطلب على إنتاج القمح بكفاءة واستدامة. أُجريت تجربة حقلية خلال موسم الزراعة 2023-2024 في

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حقل أحد المزارعين بمحافظة الأنبار، العراق (33°20′ شمالاً، 43°40′ شرقاً، 50 متراً فوق مستوى سطح البحر) لتقييم تأثير ثلاثة أنظمة ري (الرش، والتنقيط، والري السطحي)، وثلاث طرق للحرث (الحرث القرصي، والحرث بالمِقْطَع، والنثر)، وثلاثة معدلات للبذور (30، 40، 50 كجم/هكتار) على ، وإنتاجيته، والخصائص الفيزيائية للتربة، وكفاءة الري. أشارت (*Triticum aestivum* L.) نمو القمح النتائج إلى أن طول النبات استجاب بشكل ملحوظ للري والحرث، حيث أنتجت تركيبة الرش والحرث بالمِقْطَع أطول النباتات. بقي محصول الحبوب، والمحصول البيولوجي، ومؤشر الحصاد ثابتاً في جميع المعاملات، مما يشير إلى مرونة الإدارة. تحسّنت مسامية التربة مع الري بالرش والحرث العميق، بينما لم تتأثر مقاومة الاختراق بشكل ملحوظ. زادت كفاءة الري بالرش مع زيادة ضغط التشغيل، في حين حقق الري بالتنقيط الكفاءة المثلى عند ضغط 100 كيلو باسكال تقريبًا. كان النمو الخضري أكثر حساسية لممارسات الإدارة من مكونات المحصول. عزز الحرث العميق مسامية التربة دون زيادة انضغاطها، كما حسّنت الإدارة الفعّالة للري من كفاءة استخدام المياه. تدعم هذه النتائج اعتماد الري بالرش مع الحرث العميق في المناطق شبه القاحلة لتحسين نمو النبات وبنية التربة، مع إدارة الري بالتنقيط بضغط معتدل (100 كيلو باسكال تقريبًا) لترشيد استهلاك المياه.