Effect of Tillage Patterns and Seeding Rates on Vegetative Growth Traits of Two-row Barley (Hordeum distichum L.) at Two Locations

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Abstract

Two field experiments were conducted during the 2024–2025 winter season at Alqosh (36.84°N, 43.01°E; 583 masl) and Zakho (37.15°N, 42.69°E; 439 masl), both located in semi-arid Mediterranean climates with annual precipitation of 450–500 mm. Wheat stubble fields were used to evaluate four tillage patterns: one-pass (V1) and two-pass (V2) vertical disc plowing, and one-pass (C1) and two-pass (C2) sweep cultivation. A strip-plot design was employed, with tillage patterns as main plots and two seeding rates (140 and 180 kg ha^{-1}) as sub-plots. The results revealed that the locations significantly influenced vegetative traits such as plant height, biomass, flag leaf area, and soil moisture. Alqosh consistently outperformed Zakho, likely due to its superior soil properties (higher field capacity and organic matter), greater rainfall (276.5 mm vs. 269.1 mm), access to supplemental irrigation, and more favorable temperatures all contributing to improved vegetative growth.Tillage patterns significantly affected plant height, flag leaf area, relative water content, and soil moisture. The two-pass sweep cultivator produced the shortest plants (46.16 cm) and smallest flag leaves (2.74 cm^2), while the two-pass vertical disc plow resulted in the lowest relative water (41.08%) and soil moisture content (11.05%). Seeding rate had no significant impact on any trait, indicating no agronomic or economic benefit from higher rates. Significant interactions among location, tillage, and seeding rate highlight the complexity of their effects. Biological yield showed strong positive correlations with all traits, especially plant height (r = 0.76) and flag leaf area (r = 0.71 .(

Keywords: Barley-Vegetative - Tillage-Seeding rates

Introduction

Barley is the fourth most economically important cereal crop globally after wheat, maize, and rice [10]. In Iraq and the Kurdistan Region, it is widely cultivated for animal feed, though its yield remains low due to limited use of improved varieties and modern agronomic practices, including optimal tillage and seeding rates. As a rainfed crop, its performance is also highly dependent on annual rainfall.

Seeding rate define as the amount of seed sown per unit area is crucial for achieving optimal plant populations, which support better growth and yield. Proper rates prevent seed wastage, reduce costs, and improve crop consistency. Since cultivars differ in yield components, evaluating varieties across a range of seeding rates is necessary to determine the optimum [26]. Over-sowing beyond the optimal rate may raise costs without improving yield [22]. Several factors such as location, climate, seed size, germination rate, sowing method, row spacing, and soil fertility can significantly impact crop performance. Sowing date also influences tillering and growth, making population management essential for stable yields.

Tillage plays a key role in soil preparation and crop establishment. In the Kurdistan Region, vertical disc plows and sweep cultivators are commonly used. The vertical disc plow (one-way disc plow) combines features of disc and harrow plows, and performs well in shallow, hard, or sticky soils where moldboard plows are less effective. Its rotating concave discs reduce soil friction, improving performance in tough conditions [23]. Sweep cultivators use tines with shovels to break soil clods and control weeds by disturbing the topsoil, uprooting or burying weeds to block photosynthesis. Acting between a plow and a harrow, they selectively disrupt soil around crops, enhance aeration, conserve moisture through surface mulching, and improve rainwater infiltration [7]. Based on this, the study aimed to evaluate barley vegetative growth under different seeding rates and tillage patterns, focusing on the two most commonly used tillage equipment in rain-fed systems. Trials were conducted at two locations during the 2024–2025 winter growing season .

Materials and Methods

Two field experiments were performed during winter growing season 2024-2025, at two locations (Alqosh which located between longitudes 43.01 (°E), latituates 36.84 (°N), and elevation 583 masL, the location represents the typical semi-arid climate of Mediterranean 450-500 mm annual precipitation), the second location is Zakho which located at 42.69 (°E) longitude, 37.15 (°N) latitude and 439 masL. (https://sy.maptons.com/2968760). The climate of Zakho is warm and temperate with rainy winters usually. The average annual rainfall is approximately 799 mm. Winter barley is usually planted in early October or November and harvested in early June of the following year.

Three samples of soil at depth of 0-20cm from different sites of each field strip were taken before and after plowing, mixed thoroughly and placed in polyethylene bags, kept at the laboratory for further measurements.

The land of wheat stubble for the harvest season of June 2024 was plowed by four tillage patterns for 30m strip length, with vertical disc or sweep cultivator. The experiment was designed as a strip -plot in split block arrangements with three replications. The experiment involved the first factor representing four different tillage patterns (single pass vertical disc plow (V1), double pass vertical disc plow back and forth (V2), single pass sweep cultivator (C1) and double pass sweep cultivator back and forth (C2). These were identified as main plots, while the two seeding rates horizontal distribute randomly to the vertical strips of tillage and designated as sub-plot. A combined analysis of the two- location experimental data was conducted using SAS 2003 to evaluate the treatment effects across both locations.

The plot area of 3.6 m2 (includes 6 rows of 3 meters length and 1.2-meter width with 0.2-meter space .(

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Table (1): Metrological data for the two locations during the experimental growing seasons.

	Zakho				Alqosh
Months	R.H%	Tempt.(ºC)		Rainfall (mm)	Rainfall (mm)
		Max.	Mini.		
November 2024	56	20.1	10.1	30.9	23
December2024	56	15.9	5.4	19.8	5
January 2025	49	16.2	4.3	5.3	4
February 2025	44	12.7	2.8	52.6	47
March 2025	35	23.2	11.1	11.6	8
April 2025	44	25.6	15.00	38.4	72
May 2025	23	34.5	20.7	10.5	9.5
Total				169.1mm 50mm 50mm	8mm Sep.&Oct. 168.5 50mm 50mm
				269.1	276.5mm

Source: Alqosh Agriculture Division -Nineveh.

Meteorological data for the Alqosh location was not available, as access requires approval from the General Authority of Meteorology and Seismic Monitoring of Iraq due to security considerations.

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Table (2): Physical and chemical properties of the soil at the two locations.

Characters	Units	Locations		Characters	Units	Locations	
		Alqosh	Zakho			Alqosh	Zakho
Sand	%	8.41	18.41	$CaCO_3$	%	16.11	14.23
Silt	%	46.25	48.75	pH	----	7.65	7.87
Clay	%	45.34	32.84	E.C.e	$Ds.m^{-1}$	0.148	0.210
Texture	----	Silty clay	Silty clay loam	Available P	mg/ Kg	4.62	5.87
F.C	%	28.89	27.87	Exchangeable K	mg /Kg	16.19	17.82
MC	%	23.18	24.12	Total N	mg /Kg	78	83
CEC	emole/Kg	27.28	26.88	Total O.M	%	2.11	1.94

Source: Agricultural Testing Laboratory, Duhok

Two row barley seeds of June 2024 harvest variety Al-Noor supplied by Agricultural Research Department / Nineveh were cleaned sieved with sieves of 3.3 mm and 2.8mm apertures of to remove all chaffs, impurities and inert matters, to obtain (100 %) purity and uniform size seeds between 3.3 -2.8 mm were used for sowing, the standard germination test was performed according to International Seed Testing

Association ISTA rules (2018), as four replicates of 100 seeds each at (20 ºC) for eight days, thereafter at the end of the test normal germination percentages and thousand kernels weight (TKW), in gram were recorded .

The seeds were sown at two seeding rates 140 and 180 kg. ha-1. which were adjusted based on germination% and field establishment 80%.

.[9]recommended adjusting seeding rates by dividing the recommended seeding rate by the Pure Live Seed (PLS) percentage, which is the product of germination % by purity %. However, as seeds were typically cleaned using sieves. The adjusted seeding rates were modified based on dividing the recommended rate by the product of the germination % (Ger.%) by expected field establishment % (estab. %, 80%). [17.[

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Table (3): Seed specifications and seeding rate adjustment

Seed rate $kg.ha^{-1}$	TKW (g)	Ger.%	Estab. 80%	Adjusted seed rate $kg.\ ha^{-1}$	$g.m^2$	g. plot $3.6m^2$	(g). row
140	30	84	80	208.3	20.83	74.98	12.50
180	30	84	80	267.9	26.79	96.44	16.07

Seed weight per row (g)=seed rate (kg. ha) x row length (m) x row spacing (m) /10

[2]

Table (4): Specifications of the plows used in the experiment.

Plough type	Equipment Width, cm	Number of discs or shears	Distance between discs or shear,cm	Disc diameter, cm	Shear type
Vertical disc	300	12	25	65	
Sweep cultivator	280	11	25		Sweep Duck Foot

Since the season was dry and due to unusual delayed rainfall, the field area of 528m2 (44 x 12 m) of each location was irrigated by twin-nozzle rotating overhead sprinkler irrigation system was applied on 19-1-2025 (24 days after sowing), as the quantity of sprayed water from the twin nozzle of single head for twenty seconds was collected in plastic container, then the amount was converted to liters per hours multiply by four sprinkler nozzles and by three hour, then the total sprayed water in liters was 26400 liters converted to rainfall (mm) equivalent by applying this application. The two locations were irrigated twice, the first on 18-1-2025 and the second on 15-16-2025, with an amount equivalent to 50 mm of rain per irrigation

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Volume of rainfall –Unit's calculator, https//unitscalculator.com, amount of rain.

Unitscalculator.com. www.engineersfield.cm

Vegetative growth traits

Plant height (cm) was measured at growth stage over-ripe- grain very hard, can't be dented by thumbnail [18], BBCH-SCALE-92), ten of main tillers were randomly selected from two middle rows per plot, the height was measured from plant base at ground surface to tip of the terminal spikelet excluding awns using regular measuring tape and the mean was calculated and recorded.

Number of total tillers.m-2, was measured at growth stage over-ripe- grain very hard, can't be dented by thumbnail at the time of maturity ([18], BBCH-SCALE-92.(

Sample of 2.5 m length of two middle rows was cut on soil surface to cover an area of 1m2 (2.5 m x 2 rows x 0.2m spacing) for each plot and the number of total tillers was counted (both effective and non-effective tillers .(

Flag leaf area, cm2, was measured at growth stage when end of heading-spikes fully emerged ([18], BBCH-SCALE -59); Ten flag leaves from the main tillers of two middle rows were randomly selected and cut at the base of blade, and one side of leaf area was measured by the formula:

Flag leaf area = Length x Width x 0.75 (0.75 the equation conversion factor).[28.[

Leaf area index, was measured at growth stage when end of heading-spikes fully emerged ([18], BBCH-SCALE -59); The leaf area index represents the total sum of single-sided leaf area per unit of ground surface area [19.[

The weight of all leaves blade from the area of 400 cm2 (20 cm row length x 20cm row space) from two middle rows per plot was recorded to be used in calculation. Twenty leaves blade was randomly selected their weight together and the sum of their area was recorded, the total leaf area was measured by following equation:

Total leaf Area (LA) = X/(Y) × W

Where X represent leaf segment area (cm2(

Y represents leaf segment weight (g(

While W represents the total leaf weight (g). [13[

Total leaf Area (LA) = (sum of single sided twenty leaves area.cm2)/(weight of twenty leaves.g) × weight of leaves from 400cm2 area cut.

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Thereafter the following equation was used to calculate leaf area index.

Leaf area index = (leaf area)/(ground area) [19[

In this case = (total leaf area for 400 cm2 harvested ground area)/(400cm2 ground area(

Then the LAI equation was applied (modified as we used fresh weight, since [16] reported that the correlation between leaf area index with both fresh and dry weight was, 0.98.

Above ground biomass (Biological yield, kg.ha-1(

Sample of 1m2 (2.5 m length x 2 x 0.2m space) from two middle rows per plot was harvested at maturity and sun-dried, the total above ground surface plant biomass (straw + grain) was weighed using accuracy electronic balance of two decimal points, and then converted to kg.ha-1, by the formula below:

Biological yield (kg ha-1) = (Biological yield harvested area (kg))/(area harvested (m2)) x 10000

[25]

Above ground biological yield kg.ha-1 = (biomass wieght of 2.5 m of two middle row)/(row length (2.5m)X number of row (2)X row to row distance (0.2 m)) x 10000

[5]

Flag leaf relative water %, was measured at growth stage when end of heading-spikes fully emerged ([18], BBCH-SCALE -59 .(

Relative water content is described as the amount of water in a leaf at the time of sampling relative to the maximal water a leaf can hold. It is an important parameter in water relation studies, e.g. it allows the calculation of the osmotic potential at full turgor.

Relative water content is probably the most appropriate measure of plant water status in term of the physiological consequence of cellular water deficit. Water potential as an estimate of the energy status of plant water is useful in dealing with water transport in the soil-plat-atmosphere continuum.

Ten flag leaves of randomly selected barley plants per plot long pieces of flag leaf blade were cut using scissors to 6- to 10-cm, starting from the leaf tip [21], weighed immediately (FW). The leaves were subsequently immersed in distilled water in a vial slightly longer than the sample, for duration water overnight at 5°C, following which they blotted with tissue to remove water on leaf surface and their turgid weight (TW) was quantified. Subsequently, the leaves underwent drying in an oven set at 80 °C for 24 h to determine their dry weight (DW). The RWC was calculated as follow:

RWC (%) = [(FW−DW) / (TW−DW)] × 100.

,[6])quoted from [27.([

Soil moisture content %, the soil moisture content (S.M.C.): will be determined using the oven method by drying the soil samples at 105°C for 24 h. according to [29.[

It was measured at growth stage when end of heading-spikes fully emerged ([18], BBCH-SCALE -59 (

For moisture determination, soil samples were weighed before and after drying in oven at 105°C for 24 hours. The loss in weight was considered moisture content in soil and was calculated using the following expression [25] quoted from [14:[

Moisture content % = ([(wet soil weight)-(oven dry soil weight)] x 100)/(oven dry soil weight(

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The soil moisture content % at depth of 20cm for each plot from quadrate of 1m2 (1.25 x 0.80m) to involve four middle rows with 0.2m space in between) was determined

Results and Discussion

The results display in Table (5) demonstrated that location had a significant effect on several vegetative traits, including mean plant height, above-ground biomass, flag leaf area, and soil moisture percentage. Among the studied locations, Alqosh exhibited superior performance in these traits, which were (59.26, 6890.8, 4.04 and 14.43) for these traits respectively, compared to Zakho location (42.92, 5471.7, 3.14 and 10.49) for the same traits respectively .

In contrast, the number of total tillers, leaf area index (LAI) and the relative water content (RWC%) of the flag leaf did not show significant variation between locations.

The observed superiority of the Alqosh location can be attributed primarily to its favorable soil properties, notably its higher moisture retention capacity, as indicated by its slightly greater field capacity, 28.89% and 27.87% and organic matter for both locations (table 2). As well as the soil moisture % during this stage were 14.43% and 10.49%, for both locations respectively (Table 5.(

Additionally, Alqosh benefits from more advantageous climatic conditions, including higher rainfall 276.5 and 269.1mm for Alqosh and Zakho respectively, including supplementary irrigation water, moreover the optimal temperature ranges, which together contribute to improved vegetative growth performance compared to Zakho location.

Regarding the influence of tillage patterns, plant height, flag leaf area, flag leaf relative water content (%), and soil moisture content (%) showed significant differences. The effects were generally similar, except that two passes cultivator resulted in lower plant height (46.16) and flag leaf area (2.74), while two passes vertical disc led to lower flag leaf relative water content (41.08%) and soil moisture content (11.05%.(

Therefore, using two passes for either tillage patterns is not advisable.

Although, as a general rule of thumb, higher seeding rates influence crop growth behavior due to inter- and intra-specific competition, it is unexpected that seeding rates had no significant impact on any of the measured traits. Adverse environmental condition, including delayed rainfall and water shortage, affected field establishment, which resulted in an insignificant effect on the total number of tillers, as they remained similar across bothseeding rates.

Therefore, using excessive seeding rates provides no economic benefit and only increases crop production costs.

These findings contradict those of [11], who reported that a seeding rate of 120 kg ha^{-1} significantly enhanced flag leaf area and biological yield in barley. Moreover, a higher seeding rate of 200 kg ha^{-1} resulted in superior crop growth rate and biological yield.

Also conversed the results of [1] who studied the effect of four seeding rates [100, 130, 160, and 190 kg ha-1] on the growth and yield of four barley cultivars [IPA256, Amal, Buhooth 22, and Baraq]. They reported that the seeding rate of 100 kg ha-1 gave the highest average leaf area of 14.52 cm2.

And the seeding rate of 190 kg ha-1 outperformed the crop growth rate, biological yield.

The results presented in Table (6) elaborate on the interaction effects among the studied factors between locations and tillage patterns showed significant differences for all measured traits, with the exception of leaf area index, which was not significantly affected. The highest plant height values were observed at Alqosh for one and two passes vertical disc

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and one pass cultivator, with measurements of 59.49, 61.93, and 62.42, respectively. In contrast, the lowest values were recorded across all other interaction combinations.

The highest number of total tillers (665.83) was recorded for one pass of the vertical disc at Zakho, but the lowest was (479.67) for one pass cultivator at Alqosh. For biological biomass, the highest values were observed at Alqosh with both one and two passes vertical disc and one pass cultivator, surpassing the values at Zakho, particularly with two passes vertical disc, which yielded 4740.0.

A similar trend was observed for flag leaf area, where the highest values were recorded at Alqosh under the one-pass and two-pass vertical disc patterns and the one-pass cultivator which were (4.35, 4.75, and 4.10, respectively), while the lowest values (2.51) was observed at Zakho with two-pass cultivator.

Flag leaf relative water content% of was highest at Zakho for both one and two passes cultivator (54.72 and 57.77) respectively. Whereas the lowest values occurred at Zakho under one and two passes vertical disc (41.50, 34.71) respectively. Finally, soil moisture content% was consistently higher at Alqosh for all tillage patterns, the highest was (16,54) for two passes cultivator but the lowest at Zakho, especially under one and two passes the vertical disc (9.08 and 9.80) respectively .

Among the interactions between locations and seeding rates, significant differences were observed in plant height, biomass, flag leaf area, and soil moisture percentage. Overall, the general trend showed that Alqosh, at both seeding rates, outperformed the Zakho location at the same rates.

Regarding the interaction between tillage patterns and seeding rates, significant differences were observed in plant height, flag leaf area, and flag leaf relative water percentage. The lowest plant height (43.63) was recorded for two passes cultivator under 180 seeding rate, while the other combinations showed similar values. A similar trend was observed for flag leaf area, as the lowest value (2.47) was also occurred under the same interaction combination. However, flag leaf relative water percentage behaved differently, as the lowest values were recorded for two passes vertical disc at both seeding rates (41.79% and 40.38%) respectively.

The results of the second-order interaction between locations, tillage patterns, and seeding rates presented in Table (7), revealed to significant differences across all interactions for all measured traits with the exception of leaf area index, which was not significantly affected. Generally, Alqosh location, with all tillage patterns under both seeding rates surpassed Zakho for all interactions combinations. The highest plant height (64.70) was observed at Alqosh under the one-pass cultivator with a seeding rate of 140. In contrast, the lowest plant height (34.87) was recorded at Zakho under one-pass vertical disc with a 140 rate and the two-pass cultivator with 180 rate (36.15.(

The maximum number of total tillers (738.0) was observed with the two-pass vertical disc at a seeding rate of 140 at Alqosh, whereas the minimum (434.33) was recorded under the one-pass cultivator with 180 seeding rates, also at Alqosh.

The highest biomass values (7803 and 7143) were obtained at Alqosh under the two-pass vertical disc and the one-pass cultivator patterns respectively, both with a seeding rate 140. In contrast, the lowest biomass value (4047) was recorded at Zakho under two-pass vertical disc with the same seeding rate.

For flag leaf area, the two-pass vertical disc with 140 seeding rates at Alqosh showed the highest value (4.83), outperforming all other interaction combinations. Conversely, the lowest value (2.07) was recorded under two-pass cultivator with 180 seeding rates at Zakho .

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With respect flag leaf water percentage, the highest value (58.70%) was recorded under one-pass cultivator with 180 seeding rates, followed by two-pass cultivator with both 140 and 180 rates. In contrast, the lowest values (34.65% and 34.78%) were observed under two-pass vertical disc with 140 and 180 seeding rates at Zakho .

In terms of soil moisture content, the highest value (18.15%) was observed under two-pass cultivator with 180 seeding rates. Conversely, the lowest values (8.13% and 8.51%) were recorded under the one-pass vertical disc with 140 rate and the two-pass vertical disc with 180 rates, both at Zakho.

Table (5): Effect of tillage patterns and seeding rates on vegetative traits of two-row barley, combination of two locations.

Factors interactions		Characters						
		Plant height, cm	Number of total tillers. m^2	Above ground biological mass.kg. ha-1	Flag leaf area cm^2	Leaf area index	Flag leaf relative water % R.W.C	Soil moisture %
Locations with Tillage patterns interactions								
Alqosh	Vertical one pass	59.49ab	596.00abc	6723.3 ab	4.35a	2.72	50.53abc	14.39ab
	Vertical two passes	61.93a	630.17ab	7446.7 a	4.75a	2.73	47.46bc	12.3bc
	Cultivator one passes	62.42a	479.67c	7035.0 a	4.10ab	2.84	50.84abc	14.48ab
	Cultivator two passes	53.20bc	508.83 bc	6358.3 abc	2.97cd	2.94	53.55ab	16.54a
Zakho	Vertical one pass	41.29d	665.83a	6086.7 abc	3.39bcd	2.69	41.50cd	9.08d
	Vertical two passes	41.45d	535.33abc	4740.0 c	3.19cd	1.82	34.71d	9.80cd
	Cultivator one passes	49.82c	638.50ab	5923.3 abc	3.47bc	2.98	54.72ab	11.75c
	Cultivator two passes	39.12d	550.83abc	5136.7 bc	2.51d	2.33	57.77a	11.31cd
Location with seeding rates ($kg.ha^{-1}$) interactions								
Alqosh	140	60.56a	593.42	6935.0 a	4.22a	2.83	49.69	13.82a
	180	57.95a	513.92	6846.7 a	3.86ab	2.78	51.50	15.04a
Zakho	140	43.26b	600.33	5505.0 b	3.14b	2.53	46.67	10.64b
	180	42.57b	594.92	5438.3 b	3.14b	2.38	47.69	10.33b
Tillage patterns with seeding rates ($kg.ha^{-1}$) interactions								
Vertical one pass	140	47.66ab	643.17	6538.3	3.73a	2.32	44.86ab	10.80
	180	53.12ab	618.67	6271.7	4.01a	3.10	47.17ab	12.68

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Vertical two passes	140	52.27ab	610.83	5925.0	4.10a	2.29	41.79b	11.36
	180	51.11ab	554.67	6261.7	3.85a	2.26	40.38b	10.74
Cultivator one pass	140	59.04a	588.33	6541.7	3.89a	3.02	50.66ab	13.09
	180	53.20ab	529.83	6416.7	3.68a	2.79	54.90a	13.14
Cultivator two passes	140	48.69ab	545.17	5875.0	3.01ab	3.11	55.40a	13.67
	180	43.63b	514.50	5620.0	2.47b	2.16	55.92a	14.18

Table (6): Effect of tillage patterns and seeding rates interactions on vegetative traits of two-

Locations	Plant height, cm	Number of total tillers.m^2	Above ground biological mass.kg.ha^{-1}	Flag leaf area cm^2	Leaf area index	Flag leaf relative water % R.W.C	Soil moisture %
Alqosh	59.26a	553.67	6890.8 a	4.04a	2.81	50.59	14.43a
Zakho	42.92b	597.63	5471.7 b	3.14b	2.45	47.18	10.49b
Tillage patterns							
Vertical disc one pass	50.39bc	630.92	6405.0	3.87a	2.71	46.02bc	11.74bc
Vertical disc two passes	51.69ab	582.75	6093.3	3.97a	2.27	41.08c	11.05c
Cultivator one pass	56.12a	559.08	6479.2	3.78a	2.91	52.78ab	13.11ab
Cultivator two passes	46.16c	529.83	5747.5	2.74b	2.63	55.66a	13.93a
Seeding rates.kg.ha^{-1}							
140	51.91	596.88	6220.0	3.68	2.68	48.18	12.23
180	50.26	554.42	6142.5	3.50	2.58	49.59	12.69

According to Duncan's Multiple Range Test (1955), for each character and each experimental factor, means that share the same letter are not significantly different at the 5% level.

According to Duncan's Multiple Range Test (1955), for each character and interaction, means that s hare the same letter are not significantly different at the 5% level

Table (7): Effect of tillage patterns, seeding rates and locations interaction on vegetative traits

Alqosh	Vertical one pass	140	60.45ab	625.33abc	6883 ab.	4.59ab	2.47	46.00abc	13.46bc
		180	58.53ab	566.67abc	6563 abc	4.11abcd	2.98	55.06ab	15.33ab
	Vertical two passes	140	61.82ab	738.00a	7803 a	4.83a	2.54	48.94abc	11.64bcd
		180	63.03ab	522.33bc	7090 ab	4.67ab	2.92	45.98abc	12.98bc
	Cultivator one passes	140	64.70a	525.00bc	7143 a	4.39abc	3.03	50.58ab	15.24ab
		180	60.14ab	434.33c	6927 ab	3.80abcd	2.64	51.10ab	13.71bc
	Cultivator two passes	140	55.30bcd	485.33bc	5910 abc	3.06cde	3.30	53.25ab	14.94ab
		180	51.11cdef	532.33bc	6807 ab	2.88de	2.58	53.86ab	18.15a
Zakho	Vertical one pass	140	34.87h	661.00ab	6193 abc	2.87de	2.17	43.72abc	8.13d
		180	47.71defg	670.67ab	5980 abc	3.91abcd	3.21	39.28bc	10.03cd
	Vertical two pass	140	42.72hg	483.67bc	4047 c	3.36bcde	2.03	34.65c	11.09cd
		180	40.19hg	587.00abc	5433 abc	3.03cde	1.60	34.78c	8.51d
	Cultivator one passes	140	53.38bcde	651.67ab	5940 abc	3.39bcde	3.01	50.74ab	10.93cd
		180	46.26efg	625.22abc	5907 abc	3.55abcd	2.95	58.70a	12.58bc
	Cultivator two passes	140	42.09hg	605.00abc	5840 abc	2.95de	2.92	57.56a	12.40bc
		180	36.15h	496.67bc	4433 bc	2.07e	1.74	57.99a	10.22cd

According to Duncan's Multiple Range Test (1955), for each character and interaction, means that share the same letter are not significantly different at the 5% level.

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The impact of tillage patterns independent of locations and seeding rate as they were clearly associated with soil characteristics and meteorological conditions. The traits performance which was significantly influenced by tillage patterns are summarized in Table 8.

Table (8): Tillage patterns that significantly impact some vegetation characteristics.

Tillage patterns	Trait's response			
	Plant height cm	Flag leaf area cm^2	Flag leaf water %	Soil moisture%
Vertical one pass	Enhance	Enhance	Impair	Impair
Vertical two passes	Enhance	Enhance	Impair	Impair
Cultivator one pass	Enhance	Enhance	Enhance	Enhance
Cultivator two passes	Impair	Impair	Enhance	Enhance

As there was no previous research specifically involving the particular tillage patterns used in this study for a comparable assessment of crop responses, the findings are unique. Additionally, since the one-pass and two-pass plowing treatments were performed immediately after each other, the effects may have been less distinct. The differences in crop response might be more pronounced if the tillage passes were conducted at different times with a longer interval between them.

The results showed that the use of a cultivator led to higher soil moisture content, which in turn enhanced flag leaf water content (Table 8). However, the two-pass cultivator treatment negatively affected plant height and flag leaf area. These findings contrast with those of [4], who compared single and double passes with a tine cultivator, as well as chisel plow, moldboard plow, and disk plow treatments. Their results demonstrated that tillage practices significantly influenced soil moisture content at both 0–20 cm and 20–40 cm soil depths. The highest soil moisture content and the lowest bulk density were recorded in soils tilled with a chisel plow or moldboard plow.

However, such variation on the effects of tillage patterns was also noticed by [20] who conducted experiment at Girda Rasha, Erbil, Iraq, to evaluate the effect of different tillage systems on soil physical properties and barley growth, their results showed significant different in soil moisture content, The tillage methods also affected plant height of barley crop, and the highest plant height was recorded for rotary plow and the lowest was for no tillage .

[3]conducted experiment during the 2012-2013 growing season in a clayey soil to study the effect of using two types of plows on the growth and productivity components of wheat, two cultivars (Bigal and Sham 6) and two types of plows (moldboard plow and disc plow). Disc plow outperformed in plant height, while the interaction between Bigal cultivar and disc plow showed the best results in plant height .

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The correlations between each pair of vegetative traits, as illustrated in Table 9, revealed that biological yield was positively related to all traits, with the strongest correlations observed with plant height (r = 0.76) and flag leaf area (r = 0.71), respectively .

Table (9): Pearson Correlation coefficients between each pair of variables with corresponding p-values (n=16.(

Correlation	Biological yield, kg. ha^{-1}	Plant height (cm)	Number of total tillers.m^2	Flag leaf area, cm^2	Leaf area index	Flag leaf relative water %	Soil moisture content %
Biological yield, kg. ha^{-1}	1.00	0.76 0.0005	0.28 0.2783	0.71 0.0017	0.46 0.0689	0.20 0.4351	0.45 0.0756
Plant height (cm)		1.00	-0.08 0.7548	0.82 <.0001	0.57 0.0205	0.15 0.5647	0.62 0.0092
Number of total tillers.m^2			1.00	0.27 0.3115	0.09 0.7232	-0.11 0.6781	-0.41 0.1129
Flag leaf area, cm^2				1.00	0.42 0.1022	-0.16 0.5364	0.24 0.3555
Leaf area index					1.00	0.39 0.1324	0.50 0.0449
Flag leaf relative water %						1.00	0.50 0.0423
Soil moisture content %							1.00

Conclusion

This part of the research focused on vegetative characteristics particularly biological yield, which is considered one of the most economically important traits for animal feed and can be summarized as follows:

The Alqosh location outperformed Zakho, producing 6,890.8 kg.ha-1 and 5,471.7 kg.ha-1, respectively. This difference is likely due to more favorable soil properties and climatic conditions at Alqosh, particularly higher rainfall. In contrast, seeding rate had no significant effect on biological yield,

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indicating that higher seeding rates are unnecessary and may only increase production costs.

Regarding plowing patterns, although the differences were not statistically significant, the one-pass vertical disc and one-pass cultivator treatments produced higher biological yields than their respective two-pass counterparts. Biological yields were 6,405.0 kg. ha-1 and 6,479.2 kg. ha-1 for the one-pass vertical disc and cultivator, respectively, compared to 6,093.3 kg. ha-1 and 5,747.5 kg. ha-1 for the two-pass treatments. Thus, the one-pass tillage treatments demonstrated the best overall performance.

For the interaction between plowing patterns and seeding rates, although also statistically no significant, the combination of one-pass vertical disc with a seeding rate of 140 kg. ha-1 produced 6,538.3 kg. ha-1, closely followed by one-pass cultivator with the same seeding rate at 6,541.7 kg. ha-1. These combinations outperformed all other treatment combinations.

Based on these findings, it is recommended to implement the one-pass tillage method combined with a moderate seeding rate (140 kg. ha-1) to maximize biological yield.

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