RESEARCH ARTICLE Indian Journal of Agricultural Research, Volume 60 Issue 2: 221-228 (February 2026)

Effect of Nano Phosphorus Fertilizer Levels and Seed Rates on Barley Growth under Different Tillage Equipment

Ali Hussein Awad[1], Marwan Noori Ramadhan[1], Qusay Sameer Sabah[1], Aqeel Johni Nassir[1] 10.18805/IJARe.AF-989

ABSTRACT

Background: The major benefits of using tillage technology to agriculture are mainly in soil management and fertilizer application. These can help attack major problems such as soil degradation and increase agricultural productivity. The effect both of nutrients and of the quantity of seed have a major effect on the barley growth and the yield. Nanofertilizers can improve the uptake of nutrients and crop performance.

Methods: A field experiment was conducted in Al-Qurna District aimed at determining the growth characteristics and yield of barley. Two different tillage systems (Chisel and Moldboard plow) and quantities of seed (40, 60 and 80 Kg/ha) (Sr1, Sr2 and Sr3) were compared under the influence of three levels of the nano-phosphorus fertilizer (0, 1.25 and 2.5 ml/litter) (Nf1, Nf2 and Nf3).

Result: The chisel plow outperformed the moldboard plow in terms of flag leaf area, number of spikes per square meter and grain yield. The moldboard plow outperformed in terms of plant height and biological yield. SR2 achieved the highest average number of spikes per square meter, grain yield and biological yield. As for nano-phosphorus fertilizer levels, the Nf3 outperformed in terms of plant height, flag leaf area, number of spikes per square meter, grain yield and biological yield.

Key words: Chisel plow, Flag leaf area, Grain yield, Moldboard plow, Soil penetration resistance.

INTRODUCTION

Various tillage techniques, such as chiseling and moldboard plowing, greatly influence the growth and production of barley. Chisel plowing lessens the soil bulk density, resulting in improved aeration and rooting of the crops while it retains moisture which is of utmost importance in the production of barley. Turning the soil with the moldboard plow also helps control weeds and bury remaining crops. In deeper layers, though, it can occasionally result in soil compaction, which can negatively affect root development. Even though the moldboard plow can improve early soil conditions, the chisel plow might have a bigger long-term effect on barley yields (Wasaya *et al*., 2019). The choice between a moldboard plow and a chisel plow depends on specific crop requirements and soil conditions.

Since cereal grains are a staple food for people and a source of energy since their high carbohydrate content provides the body with the calories it needs, they are extremely significant (Lazim and Ramadhan, 2020). Knowing the amount of seed is essential for estimating crop performance in terms of resilience to various environmental conditions and agricultural pests, as well as its nutritional content and yield.

The application of nanotechnology in agriculture has grown in recent years and it is a helpful instrument for reaching the objective of sustainable food production. By supplying nutrients more effectively, these fertilizers seek to solve the problems with conventional fertilizers. This technique is a successful sustainability approach because it can boost production and nutritional value while lowering environmental impacts (Samreen and Rasool, 2025).

[1]Department of Agricultural Machines and Equipment, College of Agriculture, University of Basrah, Iraq.

Corresponding Author: Marwan Noori Ramadhan, Department of Agricultural Machines and Equipment, College of Agriculture, University of Basrah, Iraq. Email: marwan.ramadhan@uobasrah.edu.iq

How to cite this article: Awad, A.H., Ramadhan, M.N., Sabah, Q.S. and Nassir, A.J. (2026). Effect of Nano Phosphorus Fertilizer Levels and Seed Rates on Barley Growth under Different Tillage Equipment. *Indian Journal of Agricultural Research.* **60(2):** 221-228. doi: 10.18805/IJARe.AF-989.

Submitted: 10-10-2025 **Accepted:** 20-11-2025 **Online:** 27-11-2025

Since phosphorus is a structural element of plant nucleic acids in addition to biofilms and is necessary for plant development, it plays a significant role in tissue and cell division (Navea *et al*., 2024). Because leaves absorb nutrients far more quickly than roots do, foliar sprays are now a quick and efficient way to correct nutritional issues. Quick nutrient absorption through the leaves is necessary for quick deficit correction since it gives the plant the nutrients it lacks and fortifies it. Although conventional tillage systems and common fertilization practices have been studied in cereal crops, there is a lack of studies examining the interactive effect of tillage system type (chisel versus moldboard plow), seed application quantities and nano-phosphorus fertilizer levels on barley growth and yield. The effectiveness of nano-fertilizer applications and their response to different soil preparation methods also remain insufficiently explored in barley cropping systems. A large proportion of the agricultural land in the study area suffers from soil salinity and fertility deterioration due to repetitive

agricultural practices and scarce water resources. The experiment aims to evaluate the efficiency of different tillage systems and the response of barley plants to seed and nano-phosphorus fertilizer under realistic conditions. The selection of these factors is also of practical importance, as the results obtained can be used to improve soil and crop management in salt-affected environments.

MATERIALS AND METHODS

During the 2022-2023 wintertime agricultural season, an experiment was conducted in the Al-Qurna District, north of Basrah Governorate. The site is characterized by long, hot, arid summers and cool, dry winters' climate, with an average temperature of 17.8°C during the experiment period and total rainfall during the growing season of approximately 58.7 mm (local meteorological station). The aim was to study the effects of tillage systems, barley seed quantities and nano-phosphorus fertilizer application levels on barley growth and yield (Table 1). Before plow work, a samples of soil was gathered out of the field down to a deepness of 30 cm and several samples were mixed to produce a composite sample that accurately represents the field (Muhsin *et al*., 2021). Table 2 displays the findings of a soil analysis.

The nano-phosphorus fertilizer was a liquid fertilizer (Shock brand), 80% phosphorus. It was dissolved in water according to the concentration of each treatment (0, 1.25 and 2.5 ml/litter of water). Spraying was done at the tillering stage and the stem elongation stage. The nano-phosphorus fertilizer was sprayed early in the morning at a rate of 1 liter per experimental unit. A 20-liter sprayer was used for the spraying process and a spreader was added to the spray solution to increase the contact surface between the leaf surface and the solution.

The experiment was conducted in a split-split-plot arrangement using a randomized complete block design (RCBD) with three replicates. Tillage systems occupied the main plots, seed quantities occupied the subplots and nano-fertilizer application levels were distributed to the sub-sub-plots. Treatments were randomly distributed within each block, resulting in a total of $2 \times 3 \times 3 \times 3$ experimental units (54 experimental units). The Linear model was:

$$Y_{ijkl} = \mu + \rho_i + T_i + \varepsilon_{il} + S_j + (TS)_{ij} + \varepsilon_{ijl} + F_k + (TF)_{ik} + (SF)_{jk} + (TSF)_{ijk} + \varepsilon_{ijkl}$$

Where,

Y_{ijkl}: Observation value.

μ: Overall mean.

ρ_i: Block effect.

T_i: Effect of tillage systems.

ε_{il}: Random error for main plots.

S_j: Effect of seed quantities.

$(TS)_{ij}$: Effect of interaction between tillage systems and seed quantities.

ε_{ijl}: Random error for split plots.

F_k: Effect of fertilizer.

$(TF)_{ik}$: Effect of interaction between tillage systems and fertilizer.

$(SF)_{jk}$: Effect of interaction between seed quantities and fertilizer.

$(TSF)_{ijk}$: Effect of interaction between tillage systems, seed quantities and fertilizer.

ε_{ijkl}: Random error for split-split plots.

The field was prepared for the experiment after tilling the soil according to each tillage treatment. Tillage was carried out using a three-bottom moldboard plow and a chisel plow. The field was leveled and allocated to 54 test plots. Each of the test plots had an area of twelve square meters. A 1 meter gap was left between test plots to guarantee that nearby test plots were not impacted. Additionally, a one-meter gap was maintained between replications. The experimental unit contained 15 lines, each 4 m long and 20 cm apart. Barley seeds were planted on November 12/2022. The field was also fertilized with 120 kg N/ha in the form of urea (46% nitrogen) in two batches, the first during the emergence stage and the second during the tillering stage. Before planting, potassium fertilizer was administered in one batch at 80 kg K/ha in the form of potassium sulfate (42% potassium). Traditional surface irrigation was used during the experiment, with two to three irrigations per month depending on plant needs and

Table 1: Treatments codes.

Tillage systems	Chisel plow moldboard plow	Code
Seed quantities	40 kg/ha	Sr1
	60 kg/ha	Sr2
	80 kg/ha	Sr3
Nano-phosphorus fertilizer	0 ml/litter	Nf1
	1.25 ml/litter	Nf2
	2.5 ml/litter	Nf3

Table 2: Initial soil properties at the beginning of the experiment.

Soil properties	Unit	Value
Organic matter	g/kg	2.1
Available N	mg/kg	15.2
Available P	mg/kg	6.9
Available K	mg/kg	112.3
EC	dS/m	9.2
pH		7.3
Sand	%	9.7
Silt	%	41.1
Clay	%	49.2
Texture		Silty clay
$CaCO_3$	g/kg	237.14
K^+	mmol/L	0.61
Na^{2+}	mmol/L	11.46
Ca^{2+}	mmol/L	12.75
Mg^{2+}	mmol/L	9.22
SO_4^{2-}	mmol/L	14.27
HCO_3^-	mmol/L	4.82
Cl^-	mmol/L	10.51

climatic conditions. Pulling weeds was completed as needed. Harvesting took place on April 12, 2023. The analyses were conducted in the laboratories of the College of Agriculture.

Statistical analysis

To confirm that the assumptions for the statistical analysis were met. Data normality was tested prior to performing the statistical analysis. Data were analyzed statistically using the GenStat 12th Edition statistical software using analysis of variance and presented as x±standard error. The mean value were subjected to comparison via the least significant difference (LSD) at the probability threshold of 0.05.

RESULTS AND DISCUSSION

Plant height

The results indicated differences in the tillage systems' impact on plant height, with the moldboard plow registering the maximum value of 73.85 cm, while the chisel plow registered a low value of 67.26 cm (Table 3). The reason for the variation in plant height between tillage systems may be attributed to the fact that the moldboard plow turns the soil and buries crop residues below the surface, creating a cleaner bed for the seeds, especially in the early stages of growth. Ramadhan, (2024) also indicated an increase in oat plant height by 9.823 and 6.838% under moldboard plow in clay and silty clay soils compared to plowing with a tiller.

Additionally, SR3 had the highest average plant height of 73.22 cm, with no significant difference from SR2. Meanwhile, SR1 had the lowest average plant height of 66.11 cm (Table 3). This can be explained by the fact that high seeding rates cause plants to compete for resources. These results corroborate the study by Singh and Sarlach (2022).

Table 3 showed a significant superiority of the Nf3 fertilizer level, with the peak a height of 73.22 cm, whereas the Nf1 level had low value of 66.11 cm. During crucial growth stages, a steady supply of nutrients is provided by applying nano-phosphorus fertilizer in two dosages. Phosphorus's role in encouraging root development and boosting the absorption of more nitrogen (Boukhalfa-Deraoui *et al*., 2020; Jamir *et al*., 2025), which aids in cell elongation and division, may be the cause of the taller stems under Nf3 level.

Flag leaf area

Table 4's findings demonstrated that the type of tillage used had a noteworthy impact on the average size of the flag leaf area. The chisel plow stood out with an average of 11.62 cm^2, than the moldboard plow, which averaged 6.28 cm^2.

The highest average for flag leaf area being the Nf3 level (10.48 cm^2), the difference being not significant from the Nf2 level. The lowest average given by the Nf1 level was 7.58 cm^2 and was not significant from the Nf2 level. Increasing the supply of phosphorus by means of nano-phosphorus fertilizer, could increase the chlorophyll formation, the increased capability for photosynthesis, would add to increased leaf growth. The results are in agreement with those of Xaza'al and Raheem (2024).

The treatment Chisel: SR2 produced the largest flag leaf area 13.13 cm^2, while Moldboard: SR3 produced the smallest value for this character 5.31 cm^2 but was not significantly different from the value for Moldboard: SR2 or Moldboard: SR1.

Number of spikes per square meter

The results in Table 5 indicated an important advantage for the tillage method of using a chisel plow; a remarkable number of spikes was produced, yielding a maximum of

Table 3: Effect of tillage systems, seeding rate and fertilization on plant height (cm).

		Fertilization				
Tillage	Seed rate	Nf1	Nf2	Nf3	Tillage.Seed rate	Tillage
Chisel	SR1	57.33±2.72	60.00±1.15	63.66±2.33	60.33±1.424	67.25±1.473
	SR2	65.00±3.21	69.33±5.66	73.66±0.33	69.33±2.260	
	SR3	67.00±4.16	71.66±2.33	77.66±1.76	72.11±2.130	
Moldboard	SR1	68.33±2.90	72.66±3.48	74.66±1.66	71.88±1.678	73.85±0.914
	SR2	72.33±1.45	75.33±2.18	78.33±3.28	75.33±1.490	
	SR3	71.33±3.84	74.33±1.45	77.33±1.45	74.33±1.527	
Chisel		63.11±2.25	67.00±2.53	71.66±2.24		
Moldboard		70.66±1.57	74.11±1.31	76.77±1.26		
	Seed rate				**Seed rate**	
	SR1	62.83±3.03	66.33±3.27	69.16±2.77	66.11±1.76	
	SR2	68.66±2.27	72.33±3.02	76.00±1.80	72.33±1.50	
	SR3	69.16±2.71	73.00±1.36	77.50±1.02	73.22±1.29	
	Fertilization	66.88±1.61	70.55±1.63	74.22±1.39		
	Tillage	**Seed rate**	**Tillage.Seed rate**	**Fertiliser**	**Tillage.Fertiliser**	**Seed rate. Fertiliser**	**Tillage.Seed rate.Fertiliser**
LSD	5.999*	4.773*	6.181ns	3.122**	ns	ns	ns

*Significant at the 0.05 probability level; **Significant at P<0.01 probability level; ns: Not significant.

175.22 spikes/m^2. In contrast, the moldboard plow gave a small value, only managed a 148.22 spikes/m^2. Chisel plows are designed with a view to producing a minimum disturbance of the soil at the same time effectively loosening compact layers. This gives a better soil structure in the regions where feeding roots are located, which are so important for root development and for the taking up of nutrition elements and water. Plants grown under such conditions are much more apt to produce good wheat spikes.

The SR2 seeding rate produced the highest average number of spikes, hitting 208.72 spikes/m^2, but it did not differ significantly from the rate SR3. On the other hand, the SR1 seeding rate had the lowest average, coming in at 92.83 spikes/m^2. The variation in spike numbers between the different seeding rates likely stems from variations in plant density. When plant density increases, the number of plants per unit area goes up, which results in more spikes count. These findings align with the conclusions drawn by Seadh *et al*. (2022).

The Nf3 fertilizer level stood out, achieving the top average of 210.94 spikes/m^2 and it didn't show a significant difference compared to the Nf2 level. Meanwhile, the Nf1

Table 4: Effect of tillage systems, seeding rate and fertilization on flag leaf area (cm^2).

		Fertilization					
Tillage	Seed rate	Nf1	Nf2	Nf3	Tillage.Seed rate	Tillage	
Chisel	SR1	8.86±2.01	9.62±2.79	12.80±0.96	10.40±1.20	11.62±0.786	
	SR2	11.20±2.84	13.50±4.30	14.50±1.97	13.10±1.66		
	SR3	9.25±2.43	11.6±0.57	12.9±2.47	11.20±1.15		
Moldboard	SR1	7.15±1.38	7.22±2.59	7.89±2.19	7.42±1.06	6.28±0.536	
	SR2	5.07±1.27	5.24±1.77	8.02±2.07	6.11±0.99		
	SR3	3.84±0.60	5.50±1.02	6.56±1.22	5.30±0.63		
Chisel		9.79±1.28	11.60±1.59	13.40±0.99			
Moldboard		5.36±0.74	5.99±1.00	7.49±0.96			
	Seed rate				**Seed rate**		
	SR1	8.00±1.15	8.42±1.78	10.38±1.54	8.93±0.86		
	SR2	8.16±1.96	9.41±2.79	11.29±1.94	9.62±1.26		
	SR3	6.55±1.64	8.58±1.47	9.75±1.88	8.29±0.96		
	Fertilization	7.57±0.89	8.80±1.14	10.47±0.98			
	Tillage	**Seed rate**	**Tillage.Seed rate**	**Fertiliser**	**Tillage.Fertiliser**	**Seed rate. Fertiliser**	**Tillage.Seed rate.Fertiliser**
LSD	5.188*	1.588ns	4.038*	1.787**	ns	ns	ns

*Significant at the 0.05 probability level; **Significant at P<0.01 probability level; ns: Not significant.

Table 5: Effect of tillage systems, seeding rate and fertilization on the number of spikes per square meter.

		Fertilization					
Tillage	Seed rate	Nf1	Nf2	Nf3	Tillage.Seed rate	Tillage	
Chisel	SR1	67.66±4.97	107.60±35.9	134.30±62.0	103.20±22.89	175.22±16.69	
	SR2	213.30±25.4	227.00±34.8	239.30±43.7	226.50±18.12		
	SR3	157.30±67.1	164.30±24.1	266.00±34.8	195.80±28.87		
Moldboard	SR1	32.66±9.82	91.33±22.7	123.30±62.0	82.44±23.41	148.22±20.71	
	SR2	152.60±58.2	158.00±69.8	262.00±88.1	190.80±40.66		
	SR3	94.00±36.0	179.30±35.8	240.60±75.9	171.30±33.88		
Chisel		146.1±29.6	166.3±23.5	213.20±31.3			
Moldboard		93.11±26.4	142.8±27.0	208.60±43.7			
	Seed rate				**Seed rate**		
	SR1	50.16±9.24	99.50±19.3	128.83±39.3	92.83±16.0		
	SR2	183.00±31.5	192.50±38.1	250.66±44.2	208.72±22.0		
	SR3	125.60±36.9	171.83±19.6	253.33±37.7	183.61±21.8		
	Fertilization	119.61±20.3	154.61±17.6	210.94±26.1			
	Tillage	**Seed rate**	**Tillage.Seed rate**	**Fertiliser**	**Tillage.Fertiliser**	**Seed rate. Fertiliser**	**Tillage.Seed rate.Fertiliser**
LSD	17.3*	68*	ns	60.9*	ns	ns	ns

*Significant at the 0.05 probability level; **Significant at P<0.01 probability level; ns: Not significant.

level yielded the lowest average, reaching 119.61 spikes/m², without significantly differing from the Nf2 level. The use of nano-phosphorus fertilizers may promote better root growth, which improves nutrient and water absorption. Further more, increased uptake of nitrogen, which play a role in increasing plant vegetative growth, including the number of tillers, as well as reducing tiller mortality. These findings align with the work of Poudel *et al*. (2023).

Grain yield

Table 6 indicated that the grain yield produced by the chisel plow system was significantly superior, recording a maximum of 2395.83 kg/ha, compared to the grain yield produced by the moldboard plow system, which recorded the lowest average of 2115.73 kg/ha. Improving soil structure with chisel plows allows for better root penetration and development. Stronger root systems improve the aptitude of plants for absorbing nutrients and water, resulting in healthier and more productive plants. Ebrahimian *et al*. (2022) found an increase in wheat yield under a chisel plow system compared to a moldboard plow system in silty-loam soil.

The SR2 recorded the highest grain yield, reaching 2,720.94 kg/ha, compared to the other rates, without a significant difference from the SR3 seeding rate. Meanwhile, the SR1 recorded the lowest grain yield, reaching 1,827.87 kg/ha, without a significant difference from the SR3 seeding rate. As the number of seeds planted increases to the optimum amount, plants count increases and there is often a rise in spike count. Therefore, grain yield increases under high plant density compared to lower and higher amounts. The results are in agreement with Islamzade *et al*. (2024).

Table 6 indicated that the grain yield produced by the Nf3 fertilizer level was significantly superior, recording a maximum of 3149.61 kg/ha, in comparison to Nf1 fertilizer level, which had the lowest average of 1542.97 kg/ha, without significantly differing from the Nf2 level. Phosphorus is essential for photosynthesis and energy transfer in plants and promotes better root growth (Kantwa *et al*., 2025). By providing sufficient phosphorus during critical growth stages, nanofertilizers enhance the efficiency of plant photosynthesis and energy storage, improve nutrient and water uptake, leading to better grain growth and increased grain yield. These findings are consistent with those reported by Taskin and Guneset (2023).

Biological yield

Table 7 demonstrated that the biological output produced by the moldboard plow system was much superior, recording greatest biological production of 9467.30 kg/ha, compared to chisel plow system, which recorded the lowest average of 8291.86 kg/ha. Even though the chisel plow's advantages in fostering root growth and minimizing soil disturbance resulted in higher seed productivity, the moldboard plow's capacity to produce a clean seedbed, redistribute nutrients and enhance moisture availability can all lead to higher biological yields.

Table 6: Effect of tillage systems, seeding rate and fertilization on grain yield (kg/ha).

		Fertilization				
	Seed rate	Nf1	Nf2	Nf3	Tillage.Seed rate	Tillage
Chisel	SR1	1203.50±323.94	1735.60±373.80	2823.56±241.45	1920.88±286.48	2395.83±223.17
	SR2	2423.03±948.06	2668.20±339.93	3630.80±1169.2	2907.34±482.10	
	SR3	1676.90±446.54	1853.00±69.913	3547.90±221.45	2359.26±331.75	
moldboard	SR1	935.90±136.13	1891.53±602.34	2377.10±893.57	1734.84±378.32	2115.72±221.19
	SR2	1886.96±485.78	2242.23±730.50	3474.40±535.18	2534.53±381.89	
	SR3	1131.53±207.92	2058.00±350.29	3043.90±832.74	2077.81±384.48	
Chisel		1767.81±362.99	2085.60±207.80	3334.08±373.24		
moldboard		1318.13±214.08	2063.92±295.79	2965.13±416.73		
	Seed rate				Seed rate	
	SR1	1069.70±168.15	1813.56±318.94	2600.33±425.81	1827.86±231.29	
	SR2	2155.00±491.25	2455.21±372.70	3552.60±576.14	2720.93±301.74	
	SR3	1404.21±251.78	1955.50±166.19	3295.90±401.50	2218.53±248.68	
	Fertilization	1542.97±211.56	2074.76±175.36	3149.61±275.03		
	Tillage	**Seed rate**	**Tillage.Seed rate**	**Fertiliser**	**Tillage.Fertiliser**	**Seed rate. Fertiliser**	**Tillage.Seed rate.Fertiliser**
LSD	246*	624.6*	ns	722.5**	ns	ns	ns

*Significant at the 0.05 probability level; **Significant at P<0.01 probability level; ns: Not significant.

The SR2 seeding rate gave the highest average biological output of 9,858.91 kg/ha, which was quite similar to the SR3 seeding rate, as Table 7 demonstrates. The SR1 seeding rate, on the other hand, had the lowest average of 8,083.60 kg/ha and was also didn't show a significant difference from the SR3 rate. The total biomass rises as the number of plants increases in a given area in proportion to the number of seeds planted per unit area. Having more plants up to an optimal level also improves photosynthesis since higher overall canopy coverage results in higher photosynthetic efficiency. The results are consistent with those of Singh and Sarlach (2022).

The Nf3 level significantly outperformed all fertilization levels, yielding the highest average of 11,557.48 kg/ha, while the Nf1 yielded the lowest average of 6,696.11 kg/ha, without significantly differing from the Nf2 level (Table 7). Reducing nutrient loss due to leaching or surface runoff by adding nano-phosphorus fertilizers ensures more phosphorus is available to the plant over time, leading to better growth and increased biological yield. These results correspond to the conclusions of Poudel *et al*.(2023).

Table 7: Effect of tillage systems, seeding rate and fertilization on the biological yield (kg/ha).

		Fertilization				
Tillage	Seed rate	Nf1	Nf2	Nf3	Tillage.Seed rate	Tillage
Chisel	SR1	5459.58±1424.8	6620.24±669.72	9773.70±969.82	7284.51±836.81	8291.85±616.26
	SR2	8270.03±1933.2	8699.61±1452.0	11133.80±3613.2	9367.84±1331.8	
	SR3	6754.14±741.09	6629.38±1640.3	11286.10±1095.0	8223.21±978.04	
Moldboard	SR1	5553.81±712.02	9774.71±3007.7	11319.50±4149.2	8882.67±1724.2	9467.30±832.99
	SR2	8509.53±354.46	9332.74±2889.9	13207.60±2064.3	10349.90±1259.4	
	SR3	5629.53±220.65	9254.19±1027.7	12624.00±3364.2	9169.24±1433.4	
Chisel		6827.92±831.45	7316.41±746.24	10731.23±1150.6		
Moldboard		6564.29±541.65	9453.88±1242.7	12383.73±1676.5		
	Seed rate				**Seed rate**	
	SR1	5506.69±712.66	8197.48±1548.0	10546.60±1936.7	8083.59±949.67	
	SR2	8389.78±880.62	9016.18±1453.2	12170.70±1917.9	9858.91±897.08	
	SR3	6191.84±427.57	7941.78±1045.8	11955.00±1610.2	8696.23±849.55	
	Fertilization	6696.10±482.40	8385.15±749.40	11557.48±1006.51		
	Tillage	**Seed rate**	**Tillage.Seed rate**	**Fertiliser**	**Tillage.Fertiliser**	**Seed rate. Fertiliser**
LSD	1054.3*	1386.2*	ns	2789.2**	ns	ns

Tillage.Seed rate.Fertiliser: ns

*Significant at the 0.05 probability level; **Significant at P<0.01 probability level; ns: Not significant.

Correlation analysis

The results showed that there are divergent relationships between the studied traits (Table 8). For example, a statistically significant and positive correlation is observed between grain yield and each of plant height, flag leaf area and number of spikes per square meter (0.420**, 0.295*, 0.817**, respectively). A statistically significant and positive correlation is also observed between biological yield and each of plant height, number of spikes per square meter and grain yield (0.446**, 0.717**, 0.884**, respectively). While some cases have been observed where strong or statistically significant relationships do not appear between some traits, this may be because some plant characteristics may have evolved independently of each other, resulting in a weak or insignificant correlation.

Soil penetration resistance

Table 9's findings show that soil penetration resistance has significantly increased in the moldboard plow treatment, reaching 1563 MPa, while the chisel plow treatment yielded the lowest average, at 1426 MPa. This may be attributed to the role of the moldboard plow in cutting, turning and breaking up the soil layer, thus increasing its density and penetration resistance compared to the chisel plow, which loosens the soil with a lower degree of fragmentation of soil clumps.

The results in Table 9 indicate a significant increase in soil penetration resistance at harvest, reaching 1577 MPa, compared to the post-tillage penetration resistance value, which was 1411 MPa. Water from irrigation shuffles soil particles which might be causing them to gather in the pores, packing the soil, so, the soil gets denser.

Table 8: Correlation analysis.

	Plant height	Flag leaf area	Number of spikes per square meter	Grain yield
Flag leaf area	-0.081			
Number of spikes per square meter	0.483**	0.198		
Grain yield	0.420**	0.295*	0.817**	
Biological yield	0.446**	0.100	0.717**	0.884**

*,**Significant at the 0.05 and 0.01 levels respectively.

Table 9: Effect of plow type and measurement time on soil penetration resistance (MPa).

	Chisel	Moldboard	Mean
After tillage	1358.3±73.5	1464.3±31.8	1411.3±42.9
Before harvest	1493.0±16.4	1661.3±10.9	1577.1±38.6
Mean	1425.6±45.2	1562.8±46.5	
	Time	**plow type**	**Time.Plow type**
LSD	85.6**	85.6**	ns

*Significant at the 0.05 probability level; **Significant at P<0.01 probability level; ns: Not significant.

CONCLUSION

The chisel plough was superior in relation to flag leaf area, number of spikes and grain yield due to the less resistance to soil penetration under the chisel plough compared to the moldboard plow. Seeding quantity SR3 was superior with regard to number of spikes, number of grains in spike, grain and biological yield. The Nf3 fertilizer level obtaining the greatest average across all examined indices. The highest means for flag leaf area derived from the Chisel: SR2 treatment. According to this study, combining chisel plowing with a seeding rate of 60 kg /ha and a concentration of nano phosphorus, 2.5 ml/liter, has resulted in promising crop yields in Silty Clay conditions in the Al-Qurna region. The results indicate that refining tillage methods, seeding rates and fertilizer applications could enhance barley production. Multi-season verification experiments would be a way to assess the long term effects of the application. Further more, examining the mobility of nano-phosphorus in the soil could shed light on how plants take it up.

ACKNOWLEDGEMENT

Authors wish to convey their sincere appreciation to the College of Agriculture for the support they have provided.

Conflict of interest

The authors declare no conflicts of interest regarding this manuscript.

REFERENCES

Boukhalfa-Deraoui, N., Hanifi-Mekliche, L., Mekliche, A., Cheloufi, H. and Babahani, S. (2020). Influence of phosphorus fertilizers application on phosphorus use efficiency and grain protein of winter wheat in alkaline-calcareous soil, Southern Algeria. *Indian Journal of Agricultural Research*. **54(1):** 51-57. doi: 10.18805/IJARe.A-435.

Ebrahimian, E., Koocheki, A., Nasiri Mahallati, M., Khorramdel, S. and Beheshti, A. (2022). Study on tillage systems and residue management application on yield and yield components of wheat (*Triticum aestivum* L.) in mashhad condition. *Journal of Agroecology*. **14(3):** 415-427. doi: 10.22067/JAG.V1I1.41560.

Islamzade, R., Islamzade, T., Hasanova, G., Huseynova, S. and Babayeva, T. (2024). Effect of NPK fertilization and seed rate on barley (*Hordeum vulgare*) yield, yield component and nitrogen dynamics in semi-arid conditions. *Journal of Agriculture Faculty of Ege University*. **61(3):** 307-319. doi: 10.20289/zfdergi.1437062.

Jamir, T.I., Sharma, Y.K. and Uchoi, A. (2025). Nutrient composition, uptake, yield and phosphorus use efficiency of black gram as influenced by soil amendments and phosphorus in acidic soil of Nagaland. *Agricultural Science Digest*. **45(4):** 606-612. doi: 10.18805/ag.D-6214.

Kantwa, C.R., Saras, P.K., Vyas, K.G., Chaudhari, H.L., Choudhary, R.R., Patel, S.A., Singh, S.R.K. and Patel, B.J. (2025). Effect of wheat varieties and integrated nutrient management practices on nutrient content, uptake and soil nutrient status. *Indian Journal of Agricultural Research*. **59(2):** 239-243. doi: 10.18805/IJARe.A-6050.

Lazim, S.K. and Ramadhan, M. (2020). Study effect of a static magnetic field and microwave irradiation on wheat seed germination using different curves fitting model. *Journal of Green Engineering*. **10(1):** 3188-3205.

Muhsin, S.J., Ramadhan, M.N. and Nassir, A.J. (2021). Effect of organic manure and tillage depths on sunflower (*Helianthus annuus* L.) production. *IOP Conference Series: Earth and Environmental Science*. **735(1):** 12070. doi: 10.1088/1755-1315/735/1/012070.

Navea, I.P., Yang, S., Tolangi, P., Sumabat, R.M., Zhang, W. and Chin, J.H. (2024). Enhancement of rice traits for the maintenance of the phosphorus balance between rice plants and the soil. *Current Plant Biology*. 100332. doi: 10.1016/j.cpb.2024.100332.

Poudel, A., Singh, S.K., Jiménez-Ballesta, R., Jatav, S.S., Patra, A. and Pandey, A. (2023). Effect of nano-phosphorus formulation on growth, yield and nutritional quality of wheat under semi-arid climate. *Agronomy*. **13(3):** 768. doi: 10.3390/agronomy13030768.

Ramadhan, M.N. (2024). Assessment of the yield and yield attributing characters of oat (*Avena sativa* L.) grown under different tillage methods and NPK fertilizer rates in semi-arid conditions. *All Life*. **17(1):** 2304338. doi: 10.1080/26895293.2024.2304338.

Samreen, T. and Rasool, S. (2025). Nutrient management through nano-biofertilizers for smart agriculture. *Nanoscience and Soil-Water Interaction in Agroecosystem*. (pp. 228-243). doi: 10.1201/9781003429289-11.

Seadh, S.E., El-Kassaby, A.T., Mansour, M. and El-Waseef, M.M.M. (2022). Response of some barley cultivars to different sowing dates, N-fertilizer and seeding rates. *Journal of Plant Production*. **13(1):** 9-15. doi: 10.21608/jpp.2022.117187.1084.

Singh, H. and Sarlach, R.S. (2022). Effect of seeding rate on growth and yield of barley (*Hordeum vulgare* L.). *Pharma Innovation Journal*. **11(9):** 1848-1852.

Taskin, H. and Gunes, A. (2023). Synthetic nano-hydroxyapatite as an alternative phosphorus source for wheat grown under field conditions. *Journal of Plant Nutrition*. **46(15):** 3653-3666. doi: 10.1080/01904167.2023.2210157.

Xaza'al, M.N.S. and Raheem, A.H. (2024). The effect of phosphorus fertilizer types and varieties on growth and yield of Sorghum [*Sorghum bicolor* (L.) Moench]. *Kirkuk University Journal for Agricultural Sciences*. **15(4):** 237-250. doi: 10.58928/ku24.15420.

Wasaya, A., Yasir, T.A., Ijaz, M. and Ahmad, S. (2019). Tillage effects on agronomic crop production. *Agronomic Crops: Management Practices*. **2:** 73-99. doi: 10.1007/978-981-32-9783-8_5.