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ORIGINAL ARTICLE

THE EFFECT OF TILLAGE DEPTH, BIO AND MINERAL NITROGEN FERTILIZER ON WHEAT PRODUCTION AND SOME SOIL PHYSICAL PROPERTIES

Marwan Noori Ramadhan

Department of Agric. Machines and Equipment, College of Agriculture, University of Basrah, Iraq.
E-mail: ramadhanalali0@gmail.com

Abstract: The appropriate management of the field through the selection of the appropriate tillage method, the right variety and the availability of nutrients suitable for growth are essential factors for the success of wheat cultivation in irrigated areas. The objective of study was to evaluate effect of three tillage depths (12, 24 and 36 cm), bio-fertilizer on two levels (not inoculation and *Azotobacter* inoculation) and four mineral nitrogen (N) fertilizer (0, 50, 100 and 150 kg N ha^{-1}) on yield component and yield of wheat (*Triticum aestivum* L., Bancal) and some soil physical properties. The experiment was laid in randomized complete block design with split-split plot arrangement, where tillage depths in main plots, bio-fertilizer in subplots and nitrogen levels in sub-sub plots have three replications. The results showed that increasing tillage depth resulted in a lower bulk density and higher porosity, available water content and root mass density. In addition, increasing tillage depth significantly increased plant height, yield components, biological and grain yield, and harvest index as well as root mass density. The results also showed that application of bio-fertilizer increased plant height, yield components, biological and grain yield, harvest index as well as root mass density. Considering N rate, there were significant effects on plant height, grain and biological yield, harvest index, root mass density and other yield components. In general, with increasing N fertilizer rates, all of these traits increased. Stepwise regression analysis emphasized the importance of grain weight as an important grain yield component.

***Key words*:** Available water content, *Azotobacter*, Bio-fertilizer, Bulk density, Root mass density, Stepwise regression.

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1. Introduction

Wheat is an important plant used as a carbohydrate source, providing the necessary feed for livestock and industry. It is also various countries 'primary food source, with the most significant area being cultivated. Wheat accounts for about 29-30 per cent of world grain production and is the most important plant for human protein sources. Soil tillage, as a necessary practice in crop production, can affect the soil physical properties that are important for plant growth. Improvements in root penetration, water infiltration and preservation of soil moisture, weed control and nutrient supply from rapid decomposition of organic matter are considered to be the main beneficial contributions of tillage to crop production. Improper tillage practices and application of nitrogen fertilizer in crop production systems may cause a range of undesirable processes such as destruction of soil structure, accelerated erosion, depletion of organic matter and fertility and disruption in cycles of water, organic carbon and plant nutrients, degradation in soil health as well as a decline in crop productivity [Ramos *et al*. (2011)]. Tillage depth as one of the processes could be used to crack subterranean layers that restrict infiltration and water drainage, as well as to improve crop rooting due to increased water availability. Modification of the profile of the soil by tillage treatment successfully disrupted the compacted subsoil layers, thereby increasing infiltration and the

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depth that crops could take up soil water. One of the critical factors in increasing crop yield is maintaining soil fertility and the use of plant nutrients in sufficient and balanced amounts. Nitrogen is required for enzyme, chlorophyll, and protein, DNA and RNA cell synthesis and is therefore essential for the plant [Saeed *et al.* (2015)]. Insufficient supply of available nitrogen results in plants with slow growth, depressed protein levels, poor low quality yield and inefficient use of water. Nitrogen fertilizers improve the grains yield and quality. If plants are supplied with nitrogen, vegetative growth will increase [Zaremanesh *et al.* (2017)]. The extensive use of chemical fertilizers has caused environmental problems during and after their application. Due to the use of fossil fuel intensives in their production, in addition to the high mineral fertilizers costs. Excessive nitrogen is lost in ionic or gaseous form through leaching, volatilization, and denitrification. If plant roots do not absorb nitrate, it is carried away by runoff or leaches into the soil along with water. Consuming contaminated crops or groundwater with a high nitrate concentration has unfavorable effects on human health. Biofertilizers are thus recommended under these conditions, and bacteria promoting growth have been used as associates or substitutes of chemical fertilizers. Atmospheric nitrogen can be fixed in the accessible structure for plants by biofertilizers [Chen (2006)], which have benefits for plant growth by production of antibiotic. Azotobacter is utilized as a biofertilizer in the cultivation of most crops. It can be grown successfully in the rhizospheric zone of different crops, for instance, wheat, corn and rice. Taking this into account, the objective of this study was to investigate the effect of tillage depths, different chemical nitrogen levels and bio-nitrogen fertilizers as *Azotobacter* on yield and yield components of wheat plants and some soil physical properties.

2. Materials and Methods

A field experiment in a split-split - plot scheme based on a completely randomized block design in three replications was conducted at Tannumah (TL), which is located in 15 km east Basra province, and Al Qurna (QL), 74 km located northwest of Basra province, Iraq, during 2019-2020 growing season. The experimental factors were: (i) three tillage depths (12, 24 and 36 cm) as main plots, (ii) two levels for Azotobacter bio-nitrogen fertilizers (with and without Inoculation) as subplots and (iii) four levels of chemical nitrogen fertilizer (0, 50, 100 and 150 kg N ha^{-1}) as sub-subplots.

Tillage depths were conducted by using three-bottom moldboard plough (1.1 m wide) as per tillage depth treatments. Until sowing, the field was prepared by ploughing using a tractor, and planking to make a fine seedbed. Azoto BARVAR-1 was used as a bio-fertilizer contains *Azotobacter vinelandii* strain 04 bacteria at 10^7 CFU per ml that fixes air nitrogen to plant absorbable forms. A stock solution was made by adding the content of an AzotoBARVAR-1 package to 5 liters of water. After filtering the solution, the prepared solution added into a sprayer to spray the seeds required for the experiment and mix thoroughly. Chemical nitrogen fertilizer used 46 per cent N in the form of urea. It was broken down into two equal parts. The first dimension of the N was applied by hand and immediately incorporated during planting time. During the stem Elongation stage, the second part was added. The area of each sub-sub plots was 4x3 m. There was a 4 m distance between two adjacent sub-sub plots for nitrogen fertilizer treatments to prevent nitrogen movement to the next plot.

Seeds of wheat (Bancal cv.) was sown at a spacing of 15 cm from row to row with 120 kg ha^{-1}. Upon planting the field was irrigated to ensure uniform germination. All other agronomic activities were kept uniform for all therapies except those under review. At maturity, the plants were harvested and traits such as plant height, number of grains per spike, and weight of 1000 grains were reported in each plot on 20 randomly selected plants. Several spikes per area unit, grain yield and biological yield were obtained from the middle of each plot by harvesting an area of 3 m^2 to avoid marginal effects. Roots were sampled at flowering stage, by taking a block of soil surrounding the plants' row (soil units size 40 cm long × 10 cm width × 30 cm depth) at each treatment. Plastic containers were used to soak soil blocks in and then poured into the sieve of 0.25 mm^2 size opening. The sieve was suspended in a large water bath and shook until the soil separated from the roots. Later, they removed the live roots on the sieve from the other organic debris. Root dry weight was determined 48 h after the roots were dried in an oven at 65°C. Calculated root mass density (mg root cm^{-3} soil). Three soil samples were taken in three soil layers (0-12, 12-24 and 24- 36 cm) to determine the soil texture and other physical and chemical properties. The results are shown in Table 1. Soil bulk density was measured for the depth ranges of (0-12, 12-24 and 24-36 cm) using core samples. Each plot was sampled three times. The same cores collected for bulk density were also used to determine the soil moisture content by the oven drying method. The soil cores were weighed, dried at 105°C for 24 h and weighed again to determine gravimetric water content.

Soil bulk density was calculated by the following equation

$$\rho b = \frac{ms}{vs}$$

Where, ρb is the soil bulk density (Mg m^{-3}), *ms* is the dry soil mass (Mg) and *vs* dry soil volume (the volume soil core) (m^3)

Soil moisture content was calculated using the following equation

$$M_c = \frac{M_w - M_d}{M_d} \times 100$$

Where, M_c Soil moisture content (%), M_w wet weight of the soil (g) and M_d dry weight of the soil (g).

Total soil porosity was calculated with the following equation [Solgi *et al.* (2018)]

$$AP = \left(1 - \frac{\rho b}{2.65}\right) \times 100$$

Where, *AP* total porosity (%), ρb dry bulk density (g cm^{-3}) and 2.65 (g cm^{-3}) is the assumed particle density.

The potential of the soil field and the permanent wilting point were determined using pressure plate equipment and the water content available was calculated using the following equation:

$$d = \frac{FC - PWP}{100} \times \rho b \times Soil\ depth$$

Where, d is available water content (cm) at a certain depth, FC is field capacity (%) and PWP is permanent wilting point (%). Meteorological data during the agricultural season were shown in Table 2.

Variance analysis (ANOVA) has been used with statistical software from GenStat 12th Edition. Mean separation was achieved using L.S.D. with a likelihood level of 0.05, where the ANOVA F-values were important. For the effects significant, the analysis of stepwise regression, at 0.05 level of probability, was performed. Data of bulk density and porosity before and after tillage were analysed statistically using paired sample t-test. While, available water content after tillage were analyzed through analysis of variance technique.

3. Results and Discussion

3.1 Bulk density, Porosity and Available water content

The numerous tillage depth practices had a significant influence on the bulk density, porosity and soil water content available. The density of soil bulks varied considerably between depths of the tillage. The bulk density reduced due to the depths of the tillage. The highest reduction in bulk density at TL site (8.04 percent) was found at tillage depth of 24 cm followed

Table 1: Soil physical and chemical properties.

Properties	Sample value	
	TL	QL
Soil texture	Silty clay	Silty Clay
Sand (%)	5.19	8.4
Silt (%)	40.7	49.89
Clay (%)	54.11	41.7
Ec_e (dS m^{-1})	9.87	7.64
pH	7.63	7.43
Available N (ppm)	52	49
Available P (ppm)	9.83	8.54
Available K (ppm)	120.3	124.4
Soluble K^+ (mEq L^{-1})	1.67	1.69
Soluble Na^+ (mEq L^{-1})	34.86	31.54
Soluble Ca_2^+ (mEq L^{-1})	24	27
Soluble Mg_2^+ (mEq L^{-1})	23	21
Cl^- (mEq L^{-1})	62	57
$CaCO_3^-$ (%)	24.8	21.75
HCO_3^- (Meq L^{-1})	2.1	1.8
O.M. (%)	0.91	1.34

Table 2: Meteorological data in the period from October to May during 2019-2020.

	Temperature °C		Humidity %	Rainfall mm
	Max	Min		
October	31.86	17.01	13.43	0
November	25.76	12.38	25.34	36.2
December	19.37	9.94	47.34	65.7
January	18.48	7.83	35.97	7.1
February	20.37	9.63	28.53	13.7
March	30.38	13.44	10.35	2.5
April	33.63	18.54	15.4	0.1

by tillage depth of 12 cm (7.43 percent). Compared with the original values before tillage, the depth of 36 cm (6.12 per cent) showed a reduction. At the QL location, the highest reduction (10.13 percent) was found at 12 cm tillage depth followed by 24 cm tillage depth (9.91 percent), while the 36 cm tillage depth decreased by 7.60 percent compared with the original pre-tillage values (Table 3).

Porosity was increased from the initial value (4.89, 4.57 and 3.74% increase in 24, 12 and 36 cm respectively) at the TL location and (6.21, 6.12 and 4.62% increase in 12, 24 and 36 cm respectively) at the QL location, at close values of original soil moisture (Table 3).

The soil available water content due to different depths of tillage, too was increased. The highest available water content was found in 36 cm tillage depth (20.06, 23.64 cm) followed by 24 cm tillage depth (13.85, 15.24 cm). Tillage depth of 12 cm showed the lowest available water content value (6.91, 7.32 cm) at the TL and QL location, respectively (Table 3).

3.2 Plant height

The plant height was significantly affected by tillage depth, biofertilizer inoculation and nitrogen application. Tillage depth significantly increased (13.652 and 12.013% as tillage depth increased from 12 to 36 cm at the TL and QL location, respectively) plant height (Table 4). This agreed with Yildirim *et al* (2018), who found that conventional tillage (25-30 cm) gives a higher mean of plant height compared to reduced tillage (10-15 cm) as it was 94.9 and 79.7 cm, respectively. Taller plants in the more in-depth tillage treatment, probably related to increasing the volume of soil explored by crop roots and, consequently, increase the available soil water and nutrient absorbed by roots for better plant growth.

Plants inoculated were also taller than non - inoculated plants (Table 4). Biofertilizer inoculation raised plant height by about 5,904 and 6,417 per cent respectively at the position of TL and QL relative to non-inoculated plants. Bacterial inoculation related to bacterial growth has been said to encourage the plant's nitrogen content and vegetative production, and this increases plant height.

The highest plant height at the TL location was observed in the maximum rate of nitrogen application (150 kg N ha^{-1}), whereas in the control treatment the minimum plant height was recorded. At the QL location,

Table 3: Bulk density, porosity, soil moisture content and available water content before and after experimental field planting at the TL and QL location.

Depth cm	Before						After							
	Bulk density kg/m^3		Porosity %		Moisture content %		Bulk density kg/m^3		Porosity %		Moisture content %		Available water content (cm)	
	TL	QL	TL	QL	TL	QL	TL	QL	TL	QL	TL	QL	TL	QL
12	1473.3	1475.97	42.86	42.82	10.88	12.72	1363.87	1326.51	44.82	45.48	10.05	13.52	6.91	7.32
24	1494.66	1508.00	42.51	42.29	11.71	13.38	1374.55	1358.54	44.59	44.88	11.09	12.02	13.85	15.24
36	1526.69	1510.67	41.99	42.25	13.49	15.30	1433.27	1395.90	43.56	44.20	14.54	16.98	20.06	23.64
							t=13.88**	t=11.923**	t=12.14**	t=10.608**			l.s.d.= 0.4557**	l.s.d.= 1.257**

the highest plant height was observed at 150 and 100 kg N ha^{-1} that didn't differ significantly from each other. At the same time, the lowest plant height was recorded in the control treatment. Application of 150 kg N ha^{-1} increased plant height by 11.699 and 8.858% at the TL and QL location, respectively, compared to control (Table 4).

3.3 Number of Spike per area unit

In the deeper tillage depth the maximum values of the spike number were reported. The 36 cm tillage depth increased the number of spike m^{-2} about 11.968 and 11.569% at the TL and QL location, respectively compared to the 12 cm tillage depth (Table 4). Yildirim *et al*. (2018) reported that tillage depth affects several spikes significantly, as it was 658 and 588 spike m^{-2} for conventional tillage (25-30 cm) and reduced tillage (10-15 cm), respectively. Increasing tillage depth efficaciously broke up soil compaction in the deeper soil layers, led to bulk density decrease (Table 3), which facilitate crop root development. The scattered root system distribution would increase the area of the root system capable of absorbing soil moisture and nutrients, resulting in more fertile tillers as compared to lower tillage depth treatment.

In addition, biofertilizer inoculation had significant effects on the amount of spikes per unit of area, since the plants treated with biofertilizer produced more spikes per unit of area than non - inoculated plants (increased by 8.998 and 8.969% at the TL and QL location, respectively) (Table 4).

It formed the data presented in Table 4 the significant effect of N fertilizer application. The nitrogen level of 100 kg N ha^{-1} recorded the highest spike number of 315.722 and 320.67 spikes m^{-2} at the TL and QL location respectively, which was statistically at par with 150 kg N ha^{-1} (311.833 and

Table 4: Main effects of tillage depth, biofertilizer and N fertilizer levels on studied traits.

Treatments	Plant height		Spikes m^{-2}		Kernels spike^{-1}		1000-grains weight		Grain yield		Biological yield		Harvest index		Root mass density	
	TL	QL	TL	QL	TL	QL	TL	QL	TL	QL	TL	QL	TL	QL	TL	QL
Tillage depth (cm)	cm	cm	No.	No.	No.	No.	g	g	kg ha^{-1}	kg ha^{-1}	kg ha^{-1}	kg ha^{-1}	%	%	mg cm^{-3}	mg cm^{-3}
12	73.54	80.83	270.13	275.13	31.04	31.54	28.88	32.86	2536.96	2973.88	8419.79	9667.49	29.77	30.69	5.24	7.23
24	78.29	84.83	289.71	294.46	33.33	32.67	32.18	35.68	3192.42	3535.20	9266.51	10886.24	34.38	32.39	13.52	16.59
36	83.58	90.54	302.46	306.96	35.71	35.04	33.19	37.15	3672.62	4101.81	9885.34	11227.71	36.96	36.23	15.58	18.43
l.s.d.	1.183**	3.374**	3.48**	6.26**	3.24*	ns	2.856*	ns	356.9**	827*	1089*	1217.6*	ns	ns	0.649**	0.385**
Biofertilizer (B)																
Without B	76.22	82.75	275.06	279.64	32.22	31.61	29.75	33.72	2747.05	3113.53	8486.96	9902.25	32.12	31.32	10.34	13.40
With B1	80.72	88.06	299.81	304.72	34.5	34.56	33.07	36.74	3520.94	3960.40	9894.14	11285.37	35.28	34.89	12.56	14.77
l.s.d.	2.921**	3.905*	2.29**	3.72**	2.109*	2.778*	1.72**	2.238*	336.2**	453.7**	1390.3*	1298.5*	ns	ns	0.280**	0.304**
N fertilizer kg ha^{-1}																
0	74.11	80.94	247	251.06	29.56	29.72	28.41	32.40	2150.56	2532.29	8169.5	9399.05	26.06	26.68	10.54	12.47
50	77.22	85.67	275.17	279.94	32.61	31.78	31.29	35.00	2894.95	3220.05	8932.96	10436.13	32.36	30.99	10.87	14.04
100	79.78	86.89	315.72	320.67	35.56	34.78	32.18	35.63	3675.93	4033.04	9341.16	10885.92	39.43	37.32	11.45	14.73
150	82.78	88.11	311.83	317.06	35.72	36.06	33.78	37.89	3814.55	4362.48	10318.56	11654.16	36.97	37.44	12.93	15.10
l.s.d.	1.774**	2.766**	6.94**	7.39**	1.786**	2.723**	1.568**	1.947**	260.3**	379.3**	846.8**	1021.7**	3.841**	4.809**	0.633**	0.772**

* * significantly different at probability levels 0.05 and 0.01, respectively ns: not significant.

317.06 spikes m^{-2} at the TL and QL location respectively). Whereas the lowest values were 247.000 and 251.06 spikes m^{-2} at the TL and QL location respectively for the control treatment.

The interaction effects of tillage depth and biofertilizer were significantly impacted by the spike number m^{-2} of wheat (Table 5). In general, the large number of inoculated plant treatments at each tillage depth level was higher than the uninoculated plants at the same tillage depth level. Inoculated plants with a tillage depth of 36 cm registered the highest value of the spike number. At both growing sites the lowest spike number was observed in the uninoculated plants at the tillage depth of 12 cm.

In the same direction, the tillage depth×N fertilization was also significant (Table 6). The 36 cm×150 kg N ha^{-1} interaction gave the highest number of spike m^{-2} of 326 and 330.67 at the TL and QL location respectively compared with the lowest number of 212.17 and 215.83 spike m^{-2} at the TL and QL location for 12 cm×0 kg N ha^{-1}.

The triple interaction was also significant (Table 8). 36 cm×B1×100 kg N ha^{-1} gave the highest number of spike 336.333 and 340 spike m^{-2} at the TL and QL location respectively, while 12 cm×B0×0 kg N ha^{-1} gave the lowest value at both locations of 201.333 and 204 spike m^{-2}, respectively.

3.4 Grain number per spike

Data analysis of variances showed that depth of tillage, inoculation of biofertilizers and fertilization of nitrogen had statistically significant effects on the number of grains per spike. Highest grain number per spike at the TL location were observed in the 36 and 24 cm tillage depths (35.708 and 33.333 grains per spike respectively) without significant differences between them. The 36 and 24 cm tillage depths resulted in 15.034 and 7.383 % respectively more number of grains per spike than 12 cm tillage depth (Table 4). The increase in tillage depth include changes in the moisture and physical properties of soil, resulted in decreased soil bulk density and increasing porosity and plant-available water (Table 3), which facilitates root penetration and proliferation and increases nutrient movement across soil profile.

Statistically, inoculated wheat plants had more grains per spike than non - inoculated ones. Biofertilizer inoculation increased this trait at the TL and QL

Table 5: Effect of the interaction between tillage depth and biofertilizer.

Treatments	Plant height		Spikes m^{-2}		Kernels $spike^{-1}$		1000-grains weight		Grain yield		Biological yield		Harvest index		Root mass density	
	TL	QL	TL	QL	TL	QL	TL	QL	TL	QL	TL	QL	TL	QL	TL	QL
Tillage depth × Biofertilizer(B)	cm	cm	No.	No.	No.	No.	g	g	kg ha^{-1}	kg ha^{-1}	kg ha^{-1}	kg ha^{-1}	%	%	mg cm^{-3}	mg cm^{-3}
12×B	71.83	79.00	253.67	257.75	29.58	29.83	27.56	31.79	2159.75	2553.94	7436.35	8564.41	29.02	30.25	4.15	6.49
12×B1	75.25	82.67	286.58	292.50	32.5	33.25	30.19	33.93	2914.18	3393.83	9403.24	10770.58	30.52	31.13	6.33	7.98
24×B	76.42	82.33	283.92	289.33	31.92	30.92	30.23	33.13	2815.1	3060.29	8637.61	10340.04	32.71	29.86	12.29	15.63
24×B1	80.17	87.33	295.5	299.58	34.75	34.42	34.13	38.23	3569.73	4010.12	9895.4	11432.44	36.05	34.92	14.75	17.56
36×B	80.42	86.92	287.58	291.83	35.17	34.08	31.48	36.23	3266.31	3726.38	9386.9	10802.31	34.64	33.85	14.58	18.10
36×B1	86.75	94.17	317.33	322.08	36.25	36.00	34.9	38.07	4078.93	4477.24	10383.77	11653.10	39.28	38.61	16.59	18.77
l.s.d.	ns	ns	3.83**	6.66**	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	0.649*	ns

*, ** Significantly different at 0.05 and 0.01 probability levels, respectively ns: not significant.

Table 6: Effect of the interaction between tillage depth and N fertilizer levels.

Treatments	Plant height		Spikes m^{2}		Kernels $spike^{-1}$		1000-grains weight		Grain yield		Biological yield		Harvest index		Root mass density	
Tillage depth × N fertilizer	TL	QL	TL	QL	TL	QL	TL	QL	TL	QL	TL	QL	TL	QL	TL	QL
	cm	cm	No.	No.	No.	No.	g	g	kg ha^{-1}	kg ha^{-1}	kg ha^{-1}	kg ha^{-1}	%	%	mg cm^{-3}	mg cm^{-3}
12×0	70.17	76.17	212.17	215.83	27.17	28.33	26.36	29.60	1559.56	1861.33	7297.35	8484.35	21.34	21.90	4.38	5.75
12×50	72.5	82.17	260.67	264.83	29.17	28.33	28.85	31.99	2250.98	2447.49	8201.25	9453.15	28.12	27.26	4.51	6.88
12×100	75	82.00	308	313.00	33.67	34.00	29.69	35.11	3137.48	3772.29	8670.44	10154.36	36.11	37.62	5.13	7.72
12×150	76.5	83.00	299.67	306.83	34.17	35.50	30.6	34.74	3199.84	3814.43	9510.14	10578.11	33.51	35.98	6.94	8.58
24×0	73.83	79.33	256.5	260.83	27.5	27.17	29.75	32.71	2153.04	2423.14	8249.6	9679.61	26.35	25.48	12.34	14.70
24×50	76.83	84.50	276.33	282.17	33.67	32.33	32.54	37.24	3047.17	3394.64	8989.87	10694.18	34.04	32.50	13.05	16.60
24×100	79.33	86.00	316.17	321.17	35.33	34.00	32.28	33.94	3659.06	3780.71	9247.58	11129.33	39.9	33.53	13.72	17.46
24×150	83.17	89.50	309.83	313.67	36.83	37.17	34.13	38.82	3910.39	4542.33	10578.98	12041.84	37.24	38.05	14.98	17.61
36×0	78.33	87.33	272.33	276.50	34	33.67	29.11	34.91	2739.09	3312.39	8961.55	10033.19	30.48	32.65	14.91	16.96
36×50	82.33	90.33	288.5	292.83	35	34.67	32.48	35.75	3386.72	3818.04	9607.77	11161.05	34.93	33.19	15.04	18.64
36×100	85	92.67	323	327.83	37.67	36.33	34.56	37.83	4231.26	4546.12	10105.46	11374.07	42.27	40.80	15.51	19.01
36×150	88.67	91.83	326	330.67	36.17	35.50	36.6	40.11	4333.41	4730.69	10866.57	12342.52	40.16	38.28	16.88	19.12
l.s.d.	ns	ns	10.69**	11.96**	3.71*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

* * * significantly different at probability levels 0.05 and 0.01, respectively ns: not significant.

locations by 7,076 and 9,332 percent, respectively compared to plants not treated with inoculum (Table 4). Bacterial inoculation has been reported by many researchers to increase the number of grains per spike compared to non-inoculated and non-fertilized control [Sood *et al*. (2018)].

The grain number per spike increased with each increment of nitrogen rate, the highest number of grains per spike (35.722 and 36.06 at the TL and QL location respectively) 150 kg N ha^{-1} application was registered. In the control treatment the least number of this trait was obtained (29.556 and 29.72 at the TL and QL location, respectively). The 150 kg N ha^{-1}, in turn, did not differ significantly from 100 kg N ha^{-1} that it gave 35.556 and 34.78 grains per spike. Application of 150 kg N ha^{-1} increased the number of grains per spike about 20.839 and 21.332% at the TL and QL location respectively compared to control treatment (Table 4). Similar trends were reported by Piccinin *et al*. (2013). The increased amount of grains per spike may be attributed to a better diet due to the optimum crop stand. Better nutrition increased the ability of source to better fill the sink.

Interaction effects at the TL location of tillage depth ×N fertilizer the number of grains per spike was found substantial (Table 6). For wheat, the highest number of grains was recorded per spike for 36 cm×100 kg N ha^{-1} interaction treatment of 37.67 grains per spike. The least value of 27.17 grains per spike was obtained from 12 cm×0 kg N ha^{-1}.

3.5 1000 Grains weight

1000-grains weight was significantly affected by tillage depth, biofertilizer inoculation and nitrogen fertilization. The maximum 1000-grains weight at the TL location was recorded in the 36 and 24 cm tillage depths (33.187 and 32.176 g respectively) without significant differences between them. The 36 and 24 cm tillage depths increased 1000-grains weight about

14.927 and 11.427% compared to 12 cm tillage treatment (Table 4). Wozniak (2020) also found similar results. He conducted field experiments and studied wheat yield components under different tillage systems. Highest 1000 grain weight of 42 g was obtained by conventional tillage (20-25 cm) compared to shallow ploughing (33.3 g) at a depth of 10-12 cm. Greater tillage depth reduced soil bulk density (Table 3). This facilitated the growth of roots and their horizontal and vertical spread. The improvement of the physical conditions of the soil has led to a gradual improvement in crop components as a result of providing the plant needs of the basic elements of growth.

Inoculated plants showed about 11.160 and 8.956%, at the TL and QL location, respectively, higher 1000-grains weight than non-inoculated plants (Table 4). Grain weight increment under the impact of the biofertilizer might be due to stimulating the uptake ability of the roots for nutrients and improving the root system through a source-sink relationship to the reproductive part [Sood *et al*. (2018)]. Their field study reported that bacterial applications were effective in increasing the weight of a thousand grains.

Moreover, the increase of the nitrogen application rate increased the weight of 1000-grains in wheat significantly. The highest 1000-grains weight (33.78 and 37.89 g at the TL and QL location respectively) was recorded in the application of 150 kg N ha^{-1}. In comparison, the lowest values of this trait (28.41 and 32.4 g at the TL and QL location respectively) Unfertilized plants were obtained from this. 150 kg N ha^{-1} applied increased the weight of 1000 grains by 18.902 and 16.944% at the TL and QL location respectively compared to control treatment (Table 4).

3.6 Grain Yield

The data presented showed that all of the studied experimental factors (tillage depth, biofertilizer inoculation and N fertilization) had significant effects on grain yield of wheat. The 36 cm tillage depth treatment showed the maximum grain yield. It increased grain yield by 44.765 and 37.928% at the TL and QL location respectively and 15.042 and 16.028% at the TL and QL location respectively, compared to 12 and 24 cm tillage depth (Table 4). Higher grain yield (by 52.82%) were also determined in conventional tillage (20-25 cm) than shallow ploughing at a depth of 10-12 cm [Wozniak (2020)]. These yield increases could be ascribed to more prolific root growth and more excellent distribution in the soil profile and increased water infiltration and storage in the soil. Subsequently, lower bulk density with increasing tillage depth (Table 3), conspicuously large yield increases with deep tillage compared with the control treatments were observed.

Inoculated plants have also indicated a higher yield of grain than non-inoculated plants. Biofertilizer inoculation increased grain yields at the TL and QL locations by about 28.172 and 27.200 percent compared to treatment controls (Table 4) respectively. Higher grain yields in the inoculated plants could be due to *Azotobacter* sp. exuding plant growth regulators, such as auxins and gibberellin and cytokinin. And as for *Azospirillum* sp. increase in nutrient availability aside [Vessey (2003)]. When plants were grown with a combination of chemical N and biofertilizer inoculation, Piccinin *et al* (2013) found an improvement in grain yield of wheat.

Grain yields continuously increased with N application rise; however, this wheat trait increased until 100 kg N ha^{-1} and a further increase in N rates resulted in no significant increase in grain yields. Application of 100 kg N ha^{-1} increased grain yield per unit of the area by 70.929 and 59.265% at the TL and QL location respectively, compared to the least application of N fertilizer (control) (Table 4).

3.7 Biological yield

Biological yield steadily increased with increasing tillage depth, the greatest tillage depth of 36 cm showed the greatest biological yield (9885.34 and 11227.71 kg ha^{-1} at the TL and QL location, respectively). However, this depth of tillage was statistically at par with 24 cm tillage depth (9266.51 and 10886.24 kg ha^{-1} at the TL and QL location, respectively). The 36 and 24 cm tillage depths increased biological yield about 17.406 and 10.056% respectively at the TL location, and 16.139 and 12.607% at the QL location compared to 12 cm tillage depth. The 12 cm tillage depths in turns, did not differ significantly from 24 cm tillage depth at the TL location (Table 4). Greater tillage depth breaks up high-density soil layers, increasing soil porosity and permeability, therefore, facilitating the growth and spread of roots, utilizing of moisture and nutrients available, subsequently, plant growth and development.

In fact, wheat plants treated with biofertilizer had higher biomass than untreated plants with that inoculum.

Biofertilizer inoculation increased biological yield from around 16.580 and 13.968% at the TL and QL location, respectively compared to control treatment (Table 4). The observed benefits on wheat by biofertilizer inoculation seem to be due to the supply of N to the crop [Rana *et al*. (2012)]. Those organisms were also producing growth-promoting substances (phytohormones). Phytohormones are known to play a key role in regulating plant growth, as secondary metabolites. They promote seed germination, root elongation, and leaf expansion stimulation also, great root growth and plant proliferation in response to biofertilizer activities, i.e. *Azotobacter* sp. and *Azospirillum* sp., boost water and nutrient absorption. Many researchers have reported in previous studies that chemical fertilization and bacterial inoculation give control-based increases in biological yields [Sood *et al*. (2018)].

As shown in Table 4, the highest biomass was obtained from the application of 150 kg N ha^{-1} (10318.56 and 11654.16 kg ha^{-1} respectively at the TL and QL sites); however, there was no significant difference between the application of 150 and 100 kg N ha^{-1} in biological yield at QL. Use of 150 kg N ha^{-1} increased the biological yield, compared to control, by 26.306 and 23.993 percent at the TL and QL sites, respectively. Nitrogen is known to be an essential nutrient for plant growth and development that involves vital plant functions such as photosynthesis, DNA synthesis, protein formation and respiration [Rana *et al*. (2012)]. An increase in the production of biomass could be attributed to the increased population of plants due to better application of nitrogen.

3.8 Harvest Index

Harvest index is described as plant capacity to allocate biomass (assimilates) into the formed reproductive parts. Harvest index of wheat as influenced by tillage depths, biofertilizer inoculant and N levels application treatments are presented in Table 4.

The analysis of variance showed that N application has significant impacts on the wheat harvest index. The highest harvest index at the TL location of 39.43% The use of 100 kg N ha^{-1} was found to be statistically equal to the use of 150 kg N ha^{-1} which it recorded 36.97%. While it was 26.06% for the control treatment. However, in the QL location, the 150 kg N ha^{-1} recorded

Table 7: Effect of the interaction between biofertilizer and N fertilizer levels..

Treatments	Plant height		Spikes m^{-2}		Kernels spike^{-1}		1000-grains weight		Grain yield		Biological yield		Harvest index		Root mass density	
	TL	QL	TL	QL	TL	QL	TL	QL	TL	QL	TL	QL	TL	QL	TL	QL
Biofertilizer × N fertilizer	cm	cm	No.	No.	No.	No.	g	g	kg ha^{-1}	kg ha^{-1}	kg ha^{-1}	kg ha^{-1}	%	%	mg cm^{-3}	mg cm^{-3}
B×0	71.56	77.78	234.56	239.00	28.56	28.33	26.47	29.84	1844.95	2147.34	7576.66	8942.61	24.05	23.78	9.35	11.66
B×50	75.33	82.89	257.33	261.33	31.44	30.33	29.29	32.86	2422.34	2664.16	8027.57	9437.92	30.59	29.11	9.86	13.51
B×100	77.33	83.33	307.00	312.11	34.22	32.78	30.29	34.37	3218.76	3539.16	8509.83	10054.59	38.28	35.85	10.35	14.02
B×150	80.67	87.00	301.33	306.11	34.67	35.00	32.96	37.78	3502.17	4103.47	9833.76	11173.89	35.57	36.55	11.80	14.42
B1×0	76.67	84.11	259.44	263.11	30.56	31.11	30.34	34.96	2456.18	2917.23	8762.33	9855.49	28.06	29.57	11.74	13.28
B1×50	79.11	88.44	293.00	298.56	33.78	33.22	33.29	37.13	3367.57	3775.94	9838.35	11434.33	34.14	32.87	11.87	14.57
B1×100	82.22	90.44	324.44	329.22	36.89	36.78	34.06	36.88	4133.11	4526.92	10172.50	11717.25	40.57	38.79	12.55	15.44
B1×150	84.89	89.22	322.33	328.00	36.78	37.11	34.60	38.00	4126.92	4621.49	10803.37	12134.42	38.37	38.32	14.06	15.79
l.s.d.	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

* * * significantly different at probability levels 0.05 and 0.01, respectively ns: not significant.

Table 8: Effect of the interaction among tillage depths, biofertilizer and N fertilizer levels.

	Plant height		Spikes m^{-2}		Kernels $spike^{-1}$		1000-grains weight		Grain yield		Biological yield		Harvest index		Root mass density	
Treatments	**TL**	**QL**	**TL**	**QL**	**TL**	**QL**	**TL**	**QL**	**TL**	**QL**	**TL**	**QL**	**TL**	**QL**	**TL**	**QL**
Tillage depth × Biofertilizer(B) ×N fertilizer	cm	cm	No.	No.	No.	No.	g	g	kg ha^{-1}	kg ha^{-1}	kg ha^{-1}	kg ha^{-1}	%	%	mg cm^{-3}	mg cm^{-3}
12×B×0	68.67	73.00	201.33	204.00	26.33	27.00	24.92	27.02	1355.46	1529.59	6568.37	7910.13	20.83	19.67	3.48	5.03
12×B×50	71.33	79.33	237.33	240.67	27.67	27.67	27.76	31.05	1876.82	2113.21	6962.01	8240.99	27.92	27.68	3.63	6.31
12×B×100	73	80.67	296	300.00	32	32.33	27.71	34.21	2643.03	3326.95	7469.85	8623.45	35.67	39.17	3.84	6.63
12×B×150	74.33	83.00	280	286.33	32.33	32.33	29.86	34.87	2763.69	3245.99	8745.16	9483.06	31.66	34.50	5.66	7.98
12×B1×0	71.67	79.33	223	227.67	28	29.67	27.8	32.18	1763.66	2193.06	8026.32	9058.56	21.84	24.13	5.28	6.47
12×B1×50	73.67	85.00	284	289.00	30.67	29.00	29.95	32.93	2625.13	2781.76	9440.48	10665.32	28.32	26.85	5.38	7.45
12×B1×100	77	83.33	320	326.00	35.33	35.67	31.67	36.01	3631.93	4217.63	9871.04	11685.28	36.55	36.06	6.41	8.81
12×B1×150	78.67	83.00	319.33	327.33	36	38.67	31.35	34.61	3635.98	4382.86	10275.13	11673.16	35.36	37.46	8.23	9.19
24×B×0	71	75.67	242.33	247.67	26.33	24.00	26.78	27.81	1746.11	1697.85	7713.61	9449.03	22.44	18.21	10.65	13.21
24×B×50	75.33	80.33	273.67	279.67	32.67	31.00	29.61	34.66	2638.46	2959.22	8229.32	9710.37	32.76	32.26	11.96	16.00
24×B×100	78.33	85.00	315.33	320.67	32.67	31.33	30.86	31.21	3183.42	3098.57	8300.84	10278.13	39.65	31.03	12.77	16.53
24×B×150	81	88.33	304.33	309.33	36	37.33	33.66	38.82	3692.42	4485.50	10306.69	11922.66	36.01	37.94	13.76	16.77
24×B1×0	76.67	83.00	270.67	274.00	28.67	30.33	32.73	37.60	2559.97	3148.42	8785.58	9910.20	30.27	32.74	14.02	16.19
24×B1×50	78.33	88.67	279	284.67	34.67	33.67	35.48	39.82	3455.87	3830.06	9750.43	11677.99	35.32	32.75	14.14	17.21
24×B1×100	80.33	87.00	317	321.67	38	36.67	33.7	36.67	4134.7	4462.84	10194.33	11980.53	40.15	36.03	14.67	18.38
24×B1×150	85.33	90.67	315.33	318.00	37.67	37.00	34.6	38.82	4128.36	4599.17	10851.27	12161.03	38.47	38.15	16.19	18.44
36×B×0	75	84.67	260	265.33	33	34.00	27.73	34.70	2433.27	3214.59	8448.01	9468.66	28.9	33.47	13.91	16.75
36×B×50	79.33	89.00	261	263.67	34	32.33	30.51	32.87	2751.72	2920.07	8891.39	10362.42	31.08	27.38	13.99	18.22
36×B×100	80.67	84.33	309.67	315.67	38	34.67	32.31	37.70	3829.82	4191.95	9758.79	11262.20	39.52	37.34	14.44	18.90
36×B×150	86.67	89.67	319.67	322.67	35.67	35.33	35.35	39.66	4050.41	4578.93	10449.43	12115.96	39.05	37.23	15.99	18.52
36×B1×0	81.67	90.00	284.67	287.67	35	33.33	30.49	35.11	3044.91	3410.19	9475.09	10597.72	32.07	31.84	15.91	17.16
36×B1×50	85.33	91.67	316	322.00	36	37.00	34.45	38.63	4021.72	4716.01	10324.15	11959.69	38.77	39.00	16.09	19.06
36×B1×100	89.33	101.00	336.33	340.00	37.33	38.00	36.8	37.96	4632.7	4900.29	10452.12	11485.93	45.02	44.27	16.58	19.13
36×B1×150	90.67	94.00	332.33	338.67	36.67	35.67	37.85	40.57	4616.4	4882.45	11283.72	12569.08	41.27	39.34	17.76	19.73
l.s.d.	ns	ns	15.08*	16.66*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

* * * significantly different at probability levels 0.05 and 0.01, respectively ns: not significant.

the highest harvest index of 37.44% that was statistically at par with 100 kg N ha^{-1} (37.32%). In contrast, the lowest harvest index was 26.68% recorded at control treatment. The application of nitrogen increased the grain yield of the tested cultivar as compared to the control. The increase in yield with increasing N rates might be due to the role of N in increasing the leaf area and promote photosynthesis efficiency that promotes dry matter production and increase harvest index.

3.9 Root Mass Density

The tillage depth significantly affected root mass density across the soil profile at the flowering stage (Table 4). Root mass density under 36 cm tillage depth was higher than that under 24 and 12 cm tillage depths (15.27 and 197.46 % increase for 36 cm compared to 24 and 12 cm at the TL location and 11.10 and 154.81% increase for 36 cm compared to 24 and 12 cm at the QL locations). Root morphology can greatly affect crop efficiencies in water extraction and nutrient uptake, and ultimately yield. The development of a vigorous root system is especially important for better crop production. As roots in the deep soil layers are essential for nutrient and moisture absorption and, therefore, growth and final yield in wheat [Xu *et al*. (2016)].

For the biofertilizer treatment, the highest root mass density recorded at the two locations were at biofertilizer application (12.56 and 14.77 mg cm^{-3} at the TL and QL location respectively). At the same time, it was 10.34 and 13.40 mg cm^{-3} at the TL and QL location, respectively, for the no biofertilizer application treatment (Table 4).

The root mass density among Tillage N fertilizer treatments was significantly varied across the tillage depth profile (Table 4). Highest density of root mass was found at 150 kg N ha^{-1} (12.93 and 15.10 mg cm^{-3} for the TL and QL location, respectively). In contrast, the lowest root mass density was noted at control treatment without N fertilizer (10.54 and 12.47 mg cm^{-3} for the TL a QL location respectively). The 150 and 100 kg N ha^{-1} in turns does not differ significantly from each other at the QL location.

The tillage depth×biofertilizer interaction was also significant (Table 5). The 36 cm×B1 interaction gave the highest root mass density of 16.59 mg cm^{-3} at the TL location compared with the lowest number of 4.15 mg cm^{-3} for 12 cm×B interaction treatment.

The statistical analysis shows that no significant differences existed among biofertilizer×N fertilizer levels interactions for all studied traits (Table 7).

3.10 Modeling and predicting yield using Stepwise regression

Multiple regression analyses are multiple statistical methods which, through a dependent variable like grain yield, can pick the most important variables. All studied variables were entered into the regression model. Based on this method, 1000 grain weight, many grain

Table 9: Result of stepwise regression analysis for grain yield components in wheat at the TL and QL growing location.

Model TL location	Unstandardized coefficient		Standardized coefficient	t	Significance	R^2	Adjusted R^2
	B	Standard error	Beta				
Constant	-5532.350	160.611		-34.446	0.000	0.978	0.977
1000 grain weight	107.789	5.023	0.503	21.459	0.000		
Number of grain $spike^{-1}$	85.792	6.56	0.347	13.078	0.000		
Number of spike	8.413	0.870	0.287	9.674	0.000		
Model QL location	**Unstandardized coefficient**		**Standardized coefficient**	**t**	**Significance**	**R^2**	**Adjusted R^2**
	B	**Standard error**	**Beta**				
Constant	-6179.802	189.163		-32.669	0.000	0.976	0.975
1000 grain weight	102.513	5.286	0.454	19.392	0.000		
Number of grain $spike^{-1}$	97.357	5.710	0.414	17.049	0.000		
Number of spike	9.871	0.843	0.303	11.699	0.000		

spike^{-1} and number of the spike was the most important character and largest variation in grain yield. This model had explained 0.978 and 0.976 alterations in grain yields at the TL and QL locations, respectively (Table 9). Because of their low and non-significant contributions the other variables were not included in the study. Coefficients of regression for the agreed variables are shown in Table 9. The equation for predicting grain yield was calculated as follows, based on the final step of the stepwise regression analysis:

Grain yield = -5532.350 + 107.789 (1000 grain weight) + 85.792 (number of grain spike^{-1}) + 8.413 (number of spike) TL location.

Grain yield = -6179.802 + 102.513 (1000 grain weight) + 97.357 (number of grain spike^{-1}) + 9.871 (number of spike) QL location.

Knowledge of the relationship between plant characters is useful in selecting traits for yield enhancement. From the results of stepwise regression, increasing 1000 grain weight was found to have the greatest effect on increasing grain yield (0.503 and 0.454 Standardized coefficients, at the TL and QL location respectively) (Table 9).

4. Conclusion

In this study, tillage depth, Bio-and mineral fertilizer had a significant effect on growth and yield of wheat. Increasing tillage depth was more effective for increasing yield component and wheat yield, due to mitigating effects of topsoil compaction. They were thereby increasing the space available in the soil for air, water and root development. The results of this study affirmed that tillage depth in the short term allowed more important improvement of Physical soil properties leading to reduced soil bulk density and increased porosity and water content following tillage operations. Bio-fertilization could be used to reduce mineral fertilizer use and to reduce production costs. Bio application of *azotobacter* plays an important role in the production of good crop and higher yields. The obtained results show that bio-nitrogen fertilizers enhanced the vegetative growth, yield component and root mass density. Nitrogen fertilization increased wheat grain yield. The highest grain yield was obtained at 150 kg N ha^{-1}, while the lowest grain yield was produced by control treatment, which suggests the importance of N doses for higher grain production in wheat. A substantial increase in yield was achieved until the 100 kg ha^{-1} nitrogen fertilizer rate; higher rates of nitrogen fertilizer did not significantly increase yield. Nitrogen levels also have a major impact on the values of all the traits studied. The results of this field experiment provide a view of affecting factors under study and may be useful in recommending optimum depth of tillage, source and rate of nitrogen, for wheat production under similar climatic and soil conditions.

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