Effects of Tillage Methods and Phosphorus Fertilizer Rates on the Growth, Yield and Nutritional Qualities of Onion (Allium Cepa L.) in Ogbomoso South Western Nigeria

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ABSTRACT

Field experiment was conducted at Ladoke Akintola University of Technology, Ogbomoso, Oyo State, Southwest Nigeria, to investigate the effects of tillage methods and phosphorus fertilizer rates on the growth, yield and Nutritional Qualities of onion (Allium cepa L.). The experiment was conducted using a split-plot arrangement in a randomized complete block design with three replicates. Tillage methods (plough, plough + bed, and plough + ridging) constituted the main plots, while phosphorus rates (0, 15, 30, 45, and 60 kg P_2O_5 ha^{-1}) formed the subplots. A recommended combined application of N and K fertilizers (60Kg N/ha x 120Kg K2O/ha) inform of Urea and Muriate of Potash (MOP) was applied at 2 weeks after transplanting. Results showed that tillage methods significantly influenced early growth parameters, with plough + ridging producing higher plant height and leaf number at early stages. Phosphorus application significantly improved growth and yield, with 30 kg P_2O_5 ha^{-1} consistently producing optimal plant height, leaf number, bulb diameter, and bulb weight. Interaction effects revealed that plough + ridging combined with 30 kg P_2O_5 ha^{-1} produced superior growth and yield performance. Nutritional analysis indicated that both tillage and phosphorus significantly affected mineral composition, proximate contents, and phytonutrients, with highest values generally obtained under plough + ridging combined with 15 kg P_2O_5 ha^{-1}.The study concludes that plough + ridging integrated with 30 kg P_2O_5 ha^{-1} optimizes onion growth and yield, while lower phosphorus rates (15 kg P_2O_5 ha^{-1}) enhance nutritional quality.

KEYWORDS

Onion, Tillage methods, Phosphorus fertilizer, Onion yield, Mineral elements, Proximate and Phytonutrient compositions, LAUTECH

I. INTRODUCTION

Tillage is a critical agronomic practice that influences soil structure, water infiltration, aeration, and nutrient availability, thereby affecting crop productivity. Conventional tillage systems such as ploughing and ridging enhance root penetration and nutrient uptake, whereas conservation tillage systems improve soil organic matter, soil aggregation, and moisture retention, leading to improved soil health and sustainable crop production. Phosphorus is an essential macronutrient required for root development, energy transfer, photosynthesis, and bulb formation in onion. However, phosphorus availability is often limited in tropical soils due to fixation by iron and aluminum oxides, making efficient fertilizer management crucial for optimum onion growth and yield. Adequate phosphorus nutrition has been reported to enhance bulb size, dry matter accumulation, and overall marketable yield of onion under varying agro ecological conditions. Although previous studies have examined the independent effects of tillage and nutrient management, there is limited information on their combined influence on onion growth, yield, and nutritional quality under tropical conditions. Recent findings suggest that integrating suitable tillage practices with balanced phosphorus fertilization can improve nutrient use efficiency, soil fertility, and crop productivity while minimizing environmental degradation. Therefore, this study aimed to determine the optimal combination of tillage method and phosphorus fertilizer rate for improved onion performance.

II. OBJECTIVES

The objectives of this experiment were as follows: (1) to examine the suitable tillage method for onion production in the study area (2) to study the optimum phosphorus rate suitable for onion production (3) to examine the maximum growth, yield and nutritional qualities as related to the treatment tested.

III. MATERIALS AND METHODS

A. Research Design

Field experiment was conducted at Teaching and Research Farm Ladoke Akintola University of Technology, Ogbomoso (80 10′N and 40 10′E), a location in the Southern Guunea Savannah zone of South-western Nigeria in 2021. The experiment was split-plot with tillage methods as main factor and phosphorus fertilizer rates as sub-plot factor laid out in a Randomized Complete Block Design (RCBD) with three replicates. The 3 x 5 factorial combination of the two factors and their levels gave 15 treatment combinations. The experimental site was manually cleared, stumping, ploughing, and ridging depending on the tillage method. The plot was 2m x 2m (4m2) with the spacing of 1m within replicate and 2m between replicates. The total area of the experimental plot was 44m x 10m (440m2) and this was divided into three replicates each dimensioned 44m x 2m (88m2). Each replicate consists of 15 plots. Texas Grano onion variety was sourced for at National Institute of Horticultural Research (NIHORT), Ibadan and used as test crop.

B. Field Establishment and Crop Management

Land preparation was carried out according to the tillage methods, the seedlings were carefully removed early in the morning from where it was sown and transplanted to the designated plots for each of the tillage methods, watering was done immediately after transplanting. Weeding was done by hoeing as required in all plots to ensure weed free conditions throughout the experimental periods. Recommended combined basal application of N and K fertilizers (60Kg N/ha x 120Kg K2O/ha) inform of Urea and Muriate of Potash (MOP) respectively was applied at 4 weeks after transplanting. Cypermetrin applied at the rate of 10ml to 10 litres of water was used to control insect pest. The treatments were three tillage methods (Plough, Plough +Bed, Plough +Ridging) and five Phosphorus rates (0, 15, 30, 45 and 60 kg k2O5ha-1) with their various combinations.

C. Soil analysis of the experimental site

Soil samples were collected from the experimental plots prior to planting at depths 0 – 15cm. These was air-dried at room temperature, crushed and sieved through wire mesh of 0.02 mm sieve, to remove debris and other materials and kept in plastic containers with covers for routine analysis according to Anderson and Ingram (1993) procedure. Soil pH was measured in a 1:1 soil-water suspension using glass electrode pH meter. Exchange acidity (Al3+, H+) was extracted with KCL and determined by titration with 0.05 NaOH, using phenolphthalein as indicator. Organic carbon was determined by wet dichromate acid oxidation method. Total nitrogen was determined by the micro-kjeldahl method. Available phosphorus was extracted with Bray-P1 solution and measured by the molybdenum blue method and read in the technical auto analyzer. Exchangeable cations (Ca, Mg, Na and K) was extracted with 1N NH4OAc. (pH 7.0), K and Na was read in a flame emission photometer while Ca and Mg was determined with atomic absorption spectrometer. Effective cation exchange capacity (ECEC) was calculated by the summation of exchangeable bases and exchange acidity. Particle size distribution was determined by the hydrometer method. The soils were dispersed with sodium hexamethaphosphate solution. Bulk density was determined according to the method of Anderson and Ingram (1993). Particle density was determined by the expulsion of trapped air in the air-dried soil sample, using a graduated cylinder, and distilled water aggregate stability was determined by the wet sieving method, using a 0.02 mm sieve and distilled water in a bowl.

IV. DATA COLLECTION

Data collection commenced two weeks after transplanting (2WAT) and continues monthly till plant maturity. Early growth of onion plant was determined by assessing plant height and number of leaves while the yield parameters (Bulb weight, Leaf weight, Bulb Length, Bulb diameter) were taken as well.

A. Proximate analysis

Onion bulbs and leaves were collected from three selected plants in each treatment. The selected samples were air dried and analysed in the laboratory to determine the following chemical properties of onion as affected by treatments viz: Mineral elements i.e Phosphorus, Potassium, Calcium, Magnesium, Proximate elements i.e Crude protein, Crude fibre, Moisture content and Phytonutrients i.e Quercetin, Vitamin A, Vitamin C. Samples were analyzed according to the official method of analysis described by the Association of Official Chemist.

B. Statistical analysis

Data collected was analyzed using Standard Analysis System (SAS, 1990) for analysis of variance (ANOVA). Difference among treatments means was computed using least significance differences (LSD) at 0.05 probability level. Physico-chemical properties of soil before sowing of Onion: the physico-chemical properties of composite soil sample are given (table 1).

V. RESULTS AND DISCUSSIONS

A. Effects of tillage methods on the growth parameters of Onion plants

The plant height of onion recorded its highest value (6.69cm) at 8weeks after transplanting (WAT) with plough + ridging method of tillage followed by plough +bed method which gave the value of 6.65cm while plough gave the least value of 5.83cm. At 12WAT, the tallest height (8.16cm) was obtained from plough + bed tillage method, closely followed by plough + ridging valued as 8.08cm while the least (7.75cm) was obtained from plough method but there was no significant difference observed in all the three tillage methods used. At 16WAT, plough recorded the tallest height of 9.76cm, closely followed by plough +bed with the value of 9.68cm while plough + ridging recorded the least value of 9.58 cm but there was no significant difference observed in the three tillage methods used.

For the number of leaves/plant, at 8WAT, plough + ridging tillage method recorded the highest number of leaves of 6.87, this was followed by plough + bed tillage method with the mean value of 6.07 while the least value of 5.47 was obtained from plough. At 16WAT, plough +ridging method recorded the highest value of 9.47, this was followed by plough+ bed tillage method which gave 8.67 while the least value of 7.8 was obtained from plough.

B. Effects of tillage methods on the yield parameters of Onion

The bulb diameter of onion recorded its highest value (49.73mm) from plough +bed tillage methods closely followed by and not significantly different from the value obtained from plough (49.61mm) while plough + ridge recorded the least value of 45.53mm. For bulb length, there were no significant difference observed from the three tillage methods but the highest value (7.39cm) was obtained from plough. In the case of bulb and leaf weight, there were no significant differences observed from the values obtained from the three tillage methods used meanwhile plough recorded the highest values of 81.65g/plant and 60.42g/plant for bulb and leaf respectively.

C. Effect of phosphorus rate on the height (cm) and number of leaves of Onion plants:

The phosphorus rates applied to onion plants show significant influence in the values obtained for the height and number of leaves respectively. The tallest height of 7.22cm was recorded at 8weeks after transplanting (8WAT) with 30kg/ha application rate but there were no significant differences observed from the values obtained at 30, 45 and 60kg/ha application rate while control recorded the least value of 5.3cm. At 12 weeks, the tallest height of 8.70cm was obtained from 30kg/ha application rate and the value obtained was not significantly different from the values obtained from 45kg/ha and 60kg/ha application rate, while control recorded the least value of 7.08cm. At 16 weeks, the tallest height of 10.36cm was recorded from 30kg/ha of SSP fertilizer application rate, this was slightly different from the values obtained from 45kg/ha and 60kg/ha (10.02cm and 9.98cm) respectively while control recorded the least value of 8.66cm as shown in Table 13.

The effect of phosphorus rates on the number of leaves of onion plants indicated a significant ($P = 0.05$) effects. The values obtained at 12 and 16 WAT showed that the highest number of leaves (9.77) were obtained from the Phosphorus application rate of 30kg/ha, this was closely followed by the value obtained from 60kg/ha (9.00) application rate while control recorded the least value of 7.33.

D. Effect of phosphorus rate on the bulb and leaf yields of Onion plants

The effect of SSP fertilizer application rates on bulb and leaf yields of onion which were bulb diameter (BDM), Bulb length (BLT), Bulb weight (BWT), and leaf weight (LWT) of Onion is presented in figure 9. The highest bulb diameter (54.25mm) was obtained with 30kg/ha SSP application, this was closely followed by 50.55mm obtained by application of 60kg/ha SSP rate while control recorded the least value of 40.66mm. The bulb length of onion recorded the highest value (7.63cm) at 30kg/ha SSP rate, but there was no significance difference among the values obtained from all the rates tested except control which was slightly lower and recorded least value of 6.65cm

The bulb weight of onion recorded it highest value of 91.54kg/ha at 30kg/ha SSP application rate, the value obtained from all others were not significantly difference from one other, except for control which recorded the least value of 48.74kg/ha The leaf weight of onion recorded its highest value of 67.23kg/ha with Phosphorus rate of 60kg/ha. These was closely followed by 30kg/ha and 45kg/ha application rate respectively with the value of 65.14kg/ha and 59.02kg/ha respectively while control recorded the least value of 42.43kg/ha.

E. Interactive effects of tillage methods and Phosphorus rates on the growth parameter of onion:

The plant height of onion at 8WAP recorded its highest value (8.10cm) when plough +bed tillage method interacted with 30kg/ha SSP rate while the interaction of plough tillage method at control recorded the least height of 4.83cm. The interaction of tillage methods used with SSP rate were significantly different from one another. At 12WAP plough +ridge at 30kg/ha SSP application rate recorded the highest height of 9.27cm. This was closely followed by the interaction of plough +bed at 30kg/ha SSP rate which gave the value of 9.03cm while plough +bed at control recorded the least value of 7.00cm. At 16WAP, the highest height of onion plant (10.77cm) was obtained from the interaction of plough + ridge at 30kg/ha SSP fertilizer application rate, this was closely followed by the interaction of plough +bed at 45kg/ha SSP fertilizer rates which gave the value of 10.53cm while the least value of 8.27cm was obtained from plough + bed at control.

For the number of leaves at 8WAP, the interaction of plough+ ridge at 30kg/ha SSP fertilizer application rate recorded the highest mean number of leaf (7.67), this was closely followed by the interaction of plough + bed recorded the least mean value of 4.67 both at control. At 12WAP, the highest mean number of leaves was recorded from the interaction of plough + ridge at 30kg/ha SSP fertilizer application rate which gave the mean value of 9.67 and was not significantly different with the value obtained from the interaction of plough + bed tillage method at control. At 16WAP, the interaction of plough + ridge at 30kg/h SSP rate recorded the highest (10.67) number of leaves, closely followed by the interaction of plough +bed at 45kg/ha SSP rate with the mean value of 10.00 while plough +bed tillage method at control recorded the least mean value of 6.67.

F. Interactive effects of tillage methods and Phosphorus rates on the yield of onion:

The onion bulb diameter shows significant differences with interaction of tillage methods and Phosphorus rates. The highest bulb diameter valued 59.02mm was obtained from the interaction of plough +bed tillage method at 45kg/ha Phosphorus fertilizer application rate, closely followed by the interaction of plough + ridging at 30kg/ha Phosphorus rate which gave the value of 57.81mm while the least value of 38.30mm was obtained from plough + bed tillage method at no fertilizer application.

The highest bulb length of onion was obtained from the interaction of plough + ridging tillage method at 30kg/ha Phosphorus rate with the value of 8.07cm while the least value of 6.07 cm was obtained from plough + ridge tillage method at 45kg/ha Phosphorus rate. The bulb weight of onion was at the highest value of 121.01kg/ha when plough interacted with 15kg/ha Phosphorus rate, followed by the interaction of plough + ridging tillage method at 30kg/ha SSP rate which gave the value of 103.2kg/ha while plough + ridging at no application recorded the least value of 40.1kg/ha.

G. Effect of tillage methods on the physicochemical properties of Onion bulb and leaves:

The tillage methods used shows a significant effect in the physicochemical properties of Onion bulb and leaves. The highest values were obtained from plough + ridging tillage method for all the parameters tested, this was followed by plough + bed tillage method while plough method recorded the least values for all the tested parameters for both onion bulb and leaves.

H. Effect of Phosphorus fertilizer rates on the physicochemical properties of onion:

The phosphorus fertilizer rates had a significant effect on the physicochemical properties of onion bulb and leaves with the highest values obtained at 15kg/ha application rate for both bulb and leaf, this was followed by 60kg/ha while 30kg/ha application rate recorded the least values for both the bulb and leaves. Interactive effect of tillage methods and phosphorus rates on the physicochemical properties of onion leaves: The highest Phosphorus value of 69.50 was obtained from the interaction of plough +ridging with 45kg/ha SSP rate, this was followed by the interaction of plough +bed at 15kg/ha SSP application rate with the value of 68.50 while the interaction of plough tillage method with 30kg/ha SSP rate recorded the least value of 46.35. For the potassium, the highest value was obtained from the interaction of plough +ridging tillage method with 45kg/ha SSP rate which gave the value of 153.20 while the interaction of plough with 30kg/ha SSP rate recorded the least value of 126.40.

The interaction of plough + ridging tillage method with 45kg/ha recorded the highest Calcium value of 49.75, this was not significantly different from the value obtained from the interaction of plough +ridging with 15kg/ha SSP rate which gave 49.40 while the least value was obtained from the interaction of plough with 30kg/ha SSP rate. The magnesium contents of onion leaf recorded its highest value (264.4g/l) with plough ridging tillage combined with 15kg/ha SSP application rate. This was followed by plough +ridging with 45kg/ha SSP fertilizer (258.6 g/l) while plough +bed plus 0kg/ha SSP recorded the least value of 226.7 g/l. The crude protein content of onion leaf recorded its highest value of

0.168 when plough+ridging tillage method interact with 45kg/ha SSP rate followed by the interaction of plough + ridging with 15kg/ha SSP rate while the interaction of plough +bed at 30kg/ha recorded the least value of 0.114. The crude fibre, Iron, moisture, Quecertin, Vitamin A and C contents had highest values with the combination of plough+ridging tillage method and 45kg/ha SSP application rate. This was followed by the interaction of plough +ridging tillage method with 15kg/ha SSP rate while plough +bed at 30kg/ha recorded the least values respectively. Interactive effects of tillage methods and Phosphorus rates on the physicochemical properties of Onion bulb The interaction of tillage methods and SSP fertilizer application rates shows significant effects on the mineral, proximate and Phytonutrients contents of onion bulb and leaf. The highest values for the Phosphorus, Potassium, Calcium, Magnesium, Crude Protein, Crude fibre, Moisture content, Quecertin, Vitamin A and C contents were obtained from the combination of plough +ridging tillage method with 45kg/ha SSP application rate. This was followed by the combination of plough +ridging tillage with 15kg/ha SSP rate while plough +bed at 30kg/ha recorded the least values respectively.

Table 1: Chemical and Physical properties of the soil of the experimental site

Parameters	**Values**
pH (H_20)	5.8
Organic carbon (g/kg)	2.53
Total N (mg/kg)	0.26
Available P (mg/kg)	6.00
Fe (mg/kg)	11.40
Cu (mg/kg)	2.70
Zn (mg/kg)	1.96
Exchangeable K (C mol/kg)	0.31
Exchangeable Na (C mol/kg)	0.26
Exchangeable Ca (C mol/kg)	3.42
Exchangeable Mg (C mol/kg)	0.70
Exchangeable acidity (C mol/kg)	0.32
Sand (%)	78
Silt (%)	20
Clay (%)	2
Textural class	Sandy loam

Table 2: Main effect of tillage methods on the growth parameters of onion

	Weeks after transplanting		
Tillage method	8	12	16
	Plant height (cm)		
Plough	5.83^{b}	7.75^{a}	9.76^{a}
Plough+Bed	6.65^{a}	8.16^{a}	9.68^{a}
Plough+Ridging	6.69^{a}	8.08^{a}	9.58^{a}
	Number of leaves/plant		
Plough	5.47^{c}	6.73^{b}	7.80^{c}

	Plough+Bed	6.07[b]	7.53[a]	8.67[b]	
	Plough+Ridging	6.87[a]	7.73[a]	9.47[a]	

Means in the same row sharing the same letters are not significantly different, while those without common letters differ significantly at 0.05% probability level ($P<0.05$).

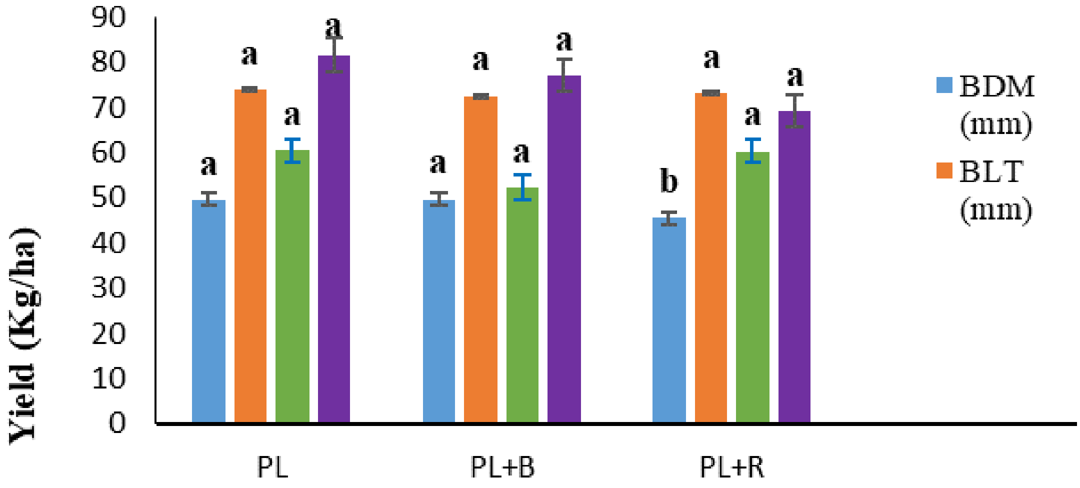

Figure 1: Effect of tillage methods on the bulb and leaf yields of onion

Means sharing the same letters are not significantly different, while those without common letters differ significantly at 0.05% probability level ($P<0.05$).

Table 3: Effects of phosphorus rate on the height and number of leaves of Onion

Weeks after transplanting				
Phosphorus rate (kg/ha)	8	12	16	
Plant height (cm)				
0	5.30[b]	7.08[b]	8.66[c]	
15	5.60[b]	7.42[b]	9.33[b]	
30	7.22[a]	8.70[a]	10.36[a]	
45	7.11[a]	8.44[a]	10.02[a]	
60	6.71[a]	8.32[a]	9.98[a]	
Number of leaves				
0	5.11[b]	6.22[c]	7.33[d]	
15	6.00[a]	7.00[b]	8.22[c]	
30	6.44[a]	8.22[a]	9.77[a]	
45	6.44[a]	7.55[ab]	8.88[bc]	
60	6.69[a]	7.66[ab]	9.000[b]	

Means in the same row sharing the same letters are not significantly different, while those without common letters differ significantly at 0.05% probability level ($P<0.05$).

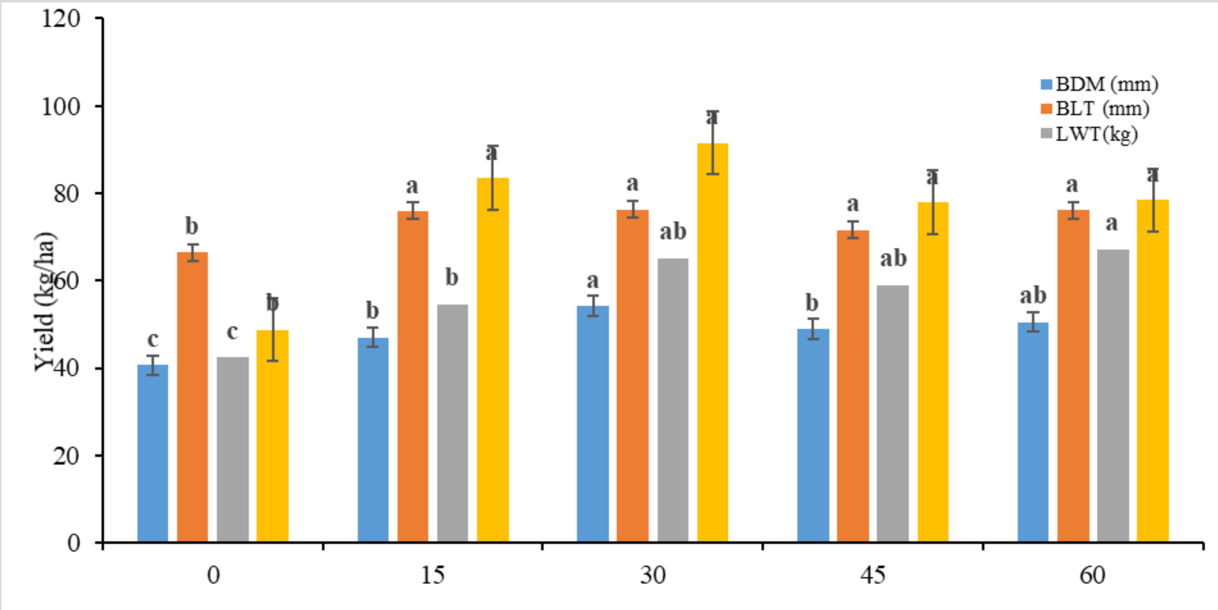

Figure 2: Effects of Phosphorus rates on the bulb and leaf yields of onion plants

Means in the same row sharing the same letters are not significantly different, while those without common letters differ significantly at 0.05% probability level ($P<0.05$).

Table 4: Interactive effect of Tillage Phosphorus rates on the height (cm) and number of leaves of onion

	Phosphorus Rates (kg/ha)				
Tillage method	0	15	30	45	60
Plough	4.83^{f}	5.37^{def}	5.80^{cdef}	6.90^{abcd}	6.23^{bcdef}
Plough+Bed	5.27^{ef}	5.20^{ef}	8.10^{a}	7.80^{ab}	6.90^{abcd}
Plough+Ridging	5.80^{cdef}	6.23^{bcdef}	7.77^{ab}	6.63^{abcde}	7.00^{abc}
Plough	7.03^{e}	7.33^{cde}	7.80^{bcde}	8.53^{abcd}	8.03^{abcde}
Plough+Bed	7.00^{e}	7.27^{cde}	9.03^{ab}	8.87^{ab}	8.63^{abc}
Plough+Ridging	5.80^{cdef}	$6.23b^{cdef}$	7.77^{ab}	6.63^{abcde}	7.00^{abc}
Plant height at 16WAT					
Plough	9.13^{fghi}	9.60^{cdefg}	$9.90^{abcdefg}$	10.23^{abcd}	9.73^{abcdef}
Plough+Bed	8.27^{i}	9.00^{ghi}	10.40^{abc}	10.53^{ab}	10.20^{abcde}
Plough+Ridging	8.60^{hi}	9.40^{defgh}	10.77^{a}	9.30^{efgh}	9.83^{bcdefg}
Number of Leaves at 8WAT					
Plough	4.67^{e}	5.67^{cde}	5.67^{cde}	5.67^{cde}	5.67^{cde}
Plough+Bed	4.67^{e}	5.33^{de}	6.00^{bcde}	7.33^{ab}	7.00^{abc}
Plough+Ridging	6.00^{bcde}	7.00^{abc}	7.67^{a}	6.33^{abcd}	7.33^{ab}
Number of Leaves at 12WAT					
Plough	6.00^{d}	6.67^{cd}	7.67^{abc}	6.67^{cd}	6.67^{cd}

Plough+Bed	5.67^{d}	6.67^{cd}	8.33^{ab}	9.00^{a}	8.00^{abc}	
Plough+Ridging	7.00^{bcd}	7.67^{abc}	9.67^{a}	7.00^{bcd}	8.33^{ab}	
Number of Leaves at 16WAT						
Plough	7.00^{e}	7.67^{de}	9.00^{bc}	7.67^{de}	7.67^{de}	
Plough+Bed	6.67^{e}	7.67^{de}	9.67^{ab}	10.00^{ab}	9.33^{bc}	
Plough+Ridging	8.33^{cd}	9.33^{bc}	10.67^{a}	9.00^{bc}	10.00^{ab}	

Means in the same row sharing the same letters are not significantly different, while those without common letters differ significantly at 0.05% probability level ($P<0.05$).

WAT= Weeks after transplanting

Table 5: Interactive effects of tillage and Phosphorus rates on bulb and leaf yields of Onion

	Phosphorus Rates (kg/ha)						
	Tillage method	0	15	30	45	60	
Bulb Diameter (cm)							
	Plough	46.04^{cd}	51.78^{abc}	52.05^{abc}	49.07^{bc}	49.13^{bc}	
	Plough+Bed	38.30^{d}	45.52^{cd}	52.90^{abc}	59.02^{a}	52.91^{abc}	
	Plough+Ridging	37.65^{d}	43.81^{cd}	57.81^{ab}	38.80^{d}	49.60^{abc}	
	Bulb Length (cm)						
	Plough	7.26^{ab}	7.51^{ab}	7.28^{ab}	7.51^{ab}	7.44^{ab}	
	Plough+Bed	6.09^{c}	7.21^{ab}	7.54^{ab}	7.91^{a}	7.56^{ab}	
	Plough+Ridging	6.60^{bc}	8.03^{a}	8.07^{a}	6.07^{c}	7.83^{a}	
	Bulb weight (kg/ha)						
	Plough	60.34^{def}	121.02^{a}	80.61^{bcd}	71.66b^{cdef}	74.64^{bcde}	
	Plough+Bed	45.82^{ef}	62.00^{def}	90.78^{abcd}	100.20^{abc}	87.08^{bcd}	
	Plough+Ridging	40.07^{f}	67.52^{cdef}	103.23^{ab}	61.97d^{ef}	73.63^{bcdef}	
	Leaf weight (kg/ha)						
	Plough	53.30^{bc}	67.26^{ab}	55.98^{bc}	64.31^{ab}	61.26^{ab}	
	Plough+Bed	37.40^{c}	47.61^{bc}	57.72^{bc}	60.70^{ab}	58.08^{bc}	
	Plough+Ridging	36.60^{c}	48.99^{bc}	81.73^{a}	52.03^{bc}	82.37^{a}	

Means in the same row sharing the same letters are not significantly different, while those without common letters differ significantly at 0.05% probability level ($P<0.05$).

Table 6: Effect of tillage methods on the Mineral elements compositions of Onion leaf and bulb

Tillage Method	**Mineral elements (kg/ha)**				
	P	K	Ca	Mg	
Onion bulb (kg/ha)					
Plough	62.09^{c}	157.81^{c}	59.96^{c}	252.15^{c}	
Plough+Bed	67.75^{b}	164.46^{b}	62.82^{b}	262.70^{b}	

Plough+Ridging	71.35^{a}	169.60^{a}	66.09^{a}	268.15^{a}	
Onion leaf (kg/ha)					
Plough	52.78^{c}	135.11^{c}	37.17^{c}	237.49^{c}	
Plough+Bed	58.38^{b}	139.14^{b}	38.50^{b}	243.90^{b}	
Plough+Ridging	60.56^{a}	143.45^{a}	44.02^{a}	249.28^{a}	

Means in the same row sharing the same letters are not significantly different, while those without common letters differ significantly at 0.05% probability level ($P<0.05$).

Table 7: Effect of tillage methods on the Proximate compositions of Onion leaf and bulb

Tillage Method	**Proximate composition**			
	CP	CF	Fe	MC
Onion bulb (kg/ha)				
Plough	0.07^{c}	1.85^{c}	0.40^{c}	7.78^{c}
Plough+Bed	0.08^{b}	1.89^{b}	0.46^{b}	8.80^{b}
Plough+Ridging	0.09^{a}	1.98^{a}	0.47^{a}	10.13^{a}
Onion Leaf (kg/ha)				
Plough	0.13^{c}	0.65^{c}	0.77^{c}	49.54^{c}
Plough+Bed	0.14^{b}	0.67^{b}	0.82^{b}	54.46^{b}
Plough+Ridging	0.16^{a}	0.69^{a}	0.85^{a}	58.76^{a}

Means in the same row sharing the same letters are not significantly different, while those without common letters differ significantly at 0.05% probability level ($P<0.05$).

Table 8: Effect of tillage methods on the Phytonutrients contents of Onion bulb and leaf

Tillage Method	**Quecetin (mg)**	**Vitamin A (mcg)**	**Vitamin C (mg)**
	Onion bulb		
Plough	14.86^{c}	0.45^{c}	7.68^{c}
Plough+Bed	16.98^{b}	0.48^{b}	8.42^{b}
Plough+Ridging	21.24^{a}	0.49^{a}	9.68^{a}
	Onion leaf		
Plough	3.90^{c}	0.27c	5.35^{c}
Plough+Bed	4.08^{b}	0.33b	5.63^{b}
Plough+Ridging	4.36^{a}	0.34a	6.26^{a}

Means in the same row sharing the same letters are not significantly different, while those without common letters differ significantly at 0.05% probability level ($P<0.05$).

Table 9: Effect of Phosphorus rates on the Mineral elements of Onion bulb and leaf

Phosphorus rate (kg/ha)	**P**	**K**	**Ca**	**Mg**
	Onion bulb			
0	63.82^{c}	158.74^{d}	59.96^{d}	254.53^{d}

15	74.60[a]	174.32[a]	70.33[a]	273.18[a]
30	59.01[d]	154.57[e]	54.93[e]	247.02[e]
45	68.69[b]	165.20[c]	63.91[c]	263.72[c]
60	69.20[b]	166.90[b]	65.65[b]	266.55[b]
	Onion leaf			
0	54.52[d]	136.13[d]	37.59[d]	238.13[d]
15	65.97[a]	146.77[a]	43.87[a]	258.30[a]
30	49.97[e]	130.91[e]	35.41[e]	231.66[e]
45	57.22[c]	140.15[c]	40.76[c]	243.33[c]
60	58.93[b]	142.19[b]	41.85[b]	246.37[b]

Means in the same row sharing the same letters are not significantly different, while those without common letters differ significantly at 0.05% probability level (P<0.05).

Table 10: Effect of Phosphorus rates on the proximate composition of Onion bulb and leaf

Phosphorus rate(kg/ha)	**CP (%)**	**CF (%)**	**Fe(mcg/dL)**	**MC (%)**
Onion bulb				
0	0.074[d]	1.84[c]	0.40[d]	7.92[d]
15	0.098[a]	2.08[a]	0.59[a]	10.59[a]
30	0.070[e]	1.75[d]	0.26[e]	7.46[e]
45	0.080[c]	1.94[b]	0.46[c]	9.25[b]
60	0.083[b]	1.92[b]	0.50[b]	8.93[c]
Onion Leaf				
0	0.140[d]	0.64[d]	0.78[c]	51.15[d]
15	0.149[c]	0.74[a]	0.90[a]	60.86[a]
30	0.132[e]	0.60[e]	0.74[d]	48.84[e]
45	0.152[a]	0.68[c]	0.81[bc]	54.90[c]
60	0.151[b]	0.70[b]	0.83[b]	5.52[b]

Means in the same row sharing the same letters are not significantly different, while those without common letters differ significantly at 0.05% probability level (P<0.05).

Table 11: Effect of Phosphorus rates on the phytonutrients of Onion bulb and leaf

Prate (kg/ha)	**Quercetin (mg)**	**Vitamin A (mcg)**	**Vitamin C (mg)**	
Onion bulb				
0	15.03[d]	0.45[d]	7.63[d]	
15	22.91[a]	0.58[a]	10.76[a]	
30	12.55[e]	0.39[e]	6.35[e]	
45	19.35[b]	0.46[c]	9.05[c]	
60	18.54[c]	0.48[b]	9.16[b]	
Onion Leaf				
0	3.79[d]	0.29[d]	5.42[d]	
15	4.84[a]	0.36[a]	6.29[a]	
30	3.56[e]	0.25[e]	5.20[e]	

45	4.30^{b}	0.31^{c}	6.11^{b}	
60	4.08^{c}	0.34^{b}	5.71^{c}	

Means in the same row sharing the same letters are not significantly different, while those without common letters differ significantly at 0.05% probability level ($P<0.05$).

Table 12: Interactive effect of tillage and Phosphorus rates on mineral elements of Onion.

Phosphorus rates (kg/ha)					
Tillage method	0	15	30	45	60
	Bulb Phosphorus				
Plough	63.35^{f}	68.80^{d}	54.35^{i}	59.59^{h}	62.35^{g}
Plough+Bed	69.65^{d}	76.50^{b}	55.13^{i}	65.63^{ef}	71.85^{c}
Plough+Ridging	56.45^{i}	78.50^{b}	67.55^{de}	80.85^{a}	73.40^{c}
	Bulb Potassium				
Plough	160.70^{i}	168.30^{f}	149.50^{l}	152.4^{k}	158.30^{j}
Plough+Bed	167.30^{g}	176.20^{c}	147.70^{m}	161.00^{i}	170.10^{e}
Plough+Ridging	148.20^{m}	178.50^{b}	166.6^{h}	182.30^{a}	172.50^{d}
	Bulb Calcium				
Plough	64.17^{g}	67.35^{f}	51.35^{l}	56.80^{k}	60.13^{i}
Plough+Bed	64.21^{g}	71.50^{c}	50.75^{m}	58.55^{j}	69.11^{d}
Plough+Ridging	51.50^{l}	72.13^{b}	62.70^{h}	76.40^{a}	67.70^{e}
	Bulb Magnessium				
Plough	258.50^{i}	262.40^{g}	238.30^{l}	244.20^{k}	257.40^{j}
Plough+Bed	267.80^{e}	277.50^{c}	236.30^{m}	260.80^{h}	271.20^{d}
Plough+Ridging	237.40^{m}	279.70^{b}	266.50^{f}	286.20^{a}	271.10^{d}
Mineral Elements of Onion Leaves					
	Leaf Phosphorus				
Plough	57.20^{h}	60.95^{f}	46.35^{l}	48.55^{k}	50.85^{j}
Plough+Bed	59.50^{g}	68.50^{b}	46.80^{l}	53.60^{i}	63.50^{d}
Plough+Ridging	46.85^{l}	67.25^{c}	56.75^{h}	69.50^{a}	62.45^{e}
	Leaf Potassium				
Plough	139.50^{h}	141.40^{f}	126.40^{o}	131.50^{l}	136.80^{j}
Plough+Bed	140.50^{g}	147.70^{c}	127.70^{n}	135.70^{k}	144.10^{e}
Plough+Ridging	128.50^{m}	151.10^{b}	138.6^{i}	153.20^{a}	145.70^{d}
	Leaf Calcium				
Plough	39.43^{e}	39.42^{e}	34.14^{k}	35.72^{i}	37.13^{h}
Plough+Bed	38.50^{f}	42.80^{c}	34.28^{k}	36.81^{h}	40.12^{d}
Plough+Ridging	34.83^{j}	49.40^{a}	37.80^{g}	49.75^{a}	48.30^{b}
	Leaf Magnessium				
Plough	241.4^{f}	248.3^{d}	227.1^{i}	234.4^{a}	236.3^{g}
Plough+Bed	246.4^{e}	258.2^{b}	226.8^{i}	237.1^{g}	251.1^{c}
Plough+Ridging	226.7^{i}	264.4^{a}	241.1^{f}	258.6^{b}	251.8^{c}

Means in the same row sharing the same letters are not significantly different, while those without common letters differ significantly at 0.05% probability level (P<0.05).

Table 13: Interactive effect of tillage Phosphorus rates on the Proximate elements of Onion.

Phosphorus rates (kg/ha)					
Tillage method	0	15	30	45	60
	Bulb Crude protein				
Plough	0.075^{g}	0.077^{f}	0.069^{j}	0.072^{i}	0.074^{gh}
Plough+Bed	0.079^{e}	0.095^{b}	0.068^{j}	0.073^{h}	0.093^{c}
Plough+Ridging	0.069^{j}	0.095^{b}	0.075^{g}	0.098^{a}	0.082^{d}
	Bulb Crude fibre				
Plough	1.92^{cde}	1.96^{c}	1.69^{h}	1.81^{g}	1.85^{fg}
Plough+Bed	1.90^{def}	2.12^{b}	1.67^{h}	1.81^{g}	1.97^{c}
Plough+Ridging	1.71^{h}	2.16^{ab}	1.87^{ef}	2.21^{a}	1.93^{cd}
	Bulb Moisture content				
Plough	8.31^{h}	9.43^{e}	6.83^{k}	6.91^{j}	7.43^{i}
Plough+Bed	8.62^{g}	11.65^{c}	6.81^{k}	7.44^{i}	9.47^{e}
Plough+Ridging	6.82^{k}	11.78^{b}	8.74^{f}	13.41^{a}	9.91^{d}
	Leaf Crude Protein				
Plough	0.141^{h}	0.143^{g}	0.126^{k}	0.138^{j}	0.140^{i}
Plough+Bed	0.154^{e}	0.143^{g}	0.114^{l}	0.150^{f}	0.155^{d}
Plough+Ridging	0.126^{k}	0.162^{b}	0.159^{c}	0.168^{a}	0.159^{c}
	Leaf Crude fibre				
Plough	0.685^{e}	0.720^{cd}	0.575^{h}	0.625^{g}	0.655^{f}
Plough+Bed	0.655^{f}	0.755^{b}	0.545^{i}	0.640^{fg}	0.735^{bc}
Plough+Ridging	0.565^{h}	0.740^{bc}	0.660^{f}	0.775^{a}	0.705^{d}
	Leaf Moisture content				
Plough	52.60^{h}	56.40^{g}	44.40^{kl}	47.15^{j}	47.15^{j}
Plough+Bed	56.30^{g}	61.65^{c}	44.30^{l}	51.38^{i}	58.65^{e}
Plough+Ridging	44.55^{k}	64.52^{b}	57.81^{f}	66.16^{a}	60.77^{d}

Means in the same row sharing the same letters are not significantly different, while those without common letters differ significantly at 0.05% probability level (P<0.05).

Table 14: Interactive effect of tillage methods and Phosphorus rates on the Phytonutrients of Onion

Phosphorus rates (kg/ha)					
Tillage method	0	15	30	45	60
	Bulb quecertin				
Plough	16.90^{g}	19.38^{e}	10.43^{j}	12.73^{i}	14.83^{h}
Plough+Bed	17.83^{f}	22.55^{c}	10.31^{j}	14.81^{h}	19.39^{e}
Plough+Ridging	10.34^{j}	26.80^{b}	16.90^{g}	30.76^{a}	21.39^{d}
	Bulb Vitamin A				
Plough	0.527^{f}	0.568^{d}	0.377^{l}	0.395^{k}	0.411^{j}
Plough+Bed	0.452^{h}	0.585^{b}	0.373^{m}	0.410^{j}	0.563^{e}
Plough+Ridging	0.374^{m}	0.581^{c}	0.440^{i}	0.558^{a}	0.462^{g}

	Bulb Vitamin C				
Plough	8.85^{f}	9.47^{e}	5.85^{m}	6.41^{k}	7.81^{h}
Plough+Bed	8.11^{g}	11.39^{c}	5.81^{n}	6.95^{j}	9.83^{d}
Plough+Ridging	5.93^{l}	11.44^{b}	7.41^{i}	13.79^{a}	9.85^{d}
	Leaf Quecertin				
Plough	4.11^{d}	4.67^{c}	3.41^{i}	3.5^{gh}	3.74^{fg}
Plough+Bed	3.85^{ef}	4.93^{b}	3.41^{i}	3.63^{gh}	4.61^{c}
Plough+Ridging	3.44^{i}	4.91^{b}	3.86^{ef}	5.70^{a}	3.91^{e}
	Leaf Vitamin A				
Plough	0.285^{g}	0.294^{f}	0.232^{l}	0.256^{j}	0.272^{h}
Plough+Bed	0.371^{e}	0.384^{c}	0.233^{l}	0.263^{i}	0.375^{d}
Plough+Ridging	0.235^{k}	0.390^{b}	0.272^{h}	0.424^{a}	0.385^{c}
	Leaf Vitamin C				
Plough	5.74^{e}	5.93^{d}	4.85^{j}	4.97^{i}	5.26^{h}
Plough+Bed	5.69^{f}	6.23^{c}	4.84^{j}	5.51^{g}	5.91^{d}
Plough+Ridging	4.85^{j}	6.74^{b}	6.74^{b}	7.85^{a}	5.95^{d}

Means in the same row sharing the same letters are not significantly different, while those without common letters differ significantly at 0.05% probability level ($P<0.05$).

VI. DISCUSSION

Influence of Tillage methods on Growth and Yield: Tillage significantly influenced growth parameters, particularly through its effects on soil structure and root development. This investigation examined the impacts of tillage methods and phosphorus application rates on onion growth, yield, and nutritional profiles. Results suggest that any of the evaluated tillage approaches ploughing, plough+bed, or plough+ridging can support viable onion production in the study region, with plough+ridging excelling in bulb diameter and plough alone in leaf and bulb weight, improved growth under plough + ridging can be attributed to enhanced soil aeration and moisture retention. Similar findings have been reported where conventional tillage improved root growth and nutrient uptake in vegetable crops (Bationo et al., 2023), though overall yields showed no marked differences. Recent advancements in conservation tillage, such as minimum tillage, have demonstrated superior soil health benefits, reducing water footprints by up to 15% and enhancing bulb yields through improved nutrient retention and reduced erosion (Rahman et al., 2024).

Effect of Phosphorus Fertilizer rates: Phosphorus fertilization significantly modulated onion growth and yield, the highest growth values at 30 kg P/ha indicate that adequate phosphorus enhances root development and nutrient uptake. The absence of significant differences beyond this rate suggests diminishing returns, which is consistent with recent studies reporting that onion yield responds to phosphorus up to an optimum threshold (Li et al., 2024). Maximum bulb yield at 30 kg P/ha confirms the optimum phosphorus requirement under the study conditions. Similar findings have been reported where moderate phosphorus rates maximized onion yield and nutrient use efficiency (FAO, 2022). With 30 kg/ha single superphosphate (SSP) yielding peak plant height and bulb metrics, though leaf number varied distinctly, higher rates (60 kg/ha) favored leaf weight, indicating dose-dependent responses. Recent analyses confirm that balanced phosphorus enhances mineral uptake and proximate composition, with optimal rates (e.g., 92-138 kg P_2O_5/ha) maximizing yields when integrated with organics, improving soil fertility and bulb quality (Gupta et al., 2025; Gelaye et al., 2025).

Interaction of Tillage and Phosphorus: The interaction between tillage and phosphorus demonstrates that nutrient efficiency is strongly influenced by soil physical conditions. Interactions between tillage and phosphorus were notable, with plough+ridging at 30 kg/ha SSP optimizing height and leaf count, and other combinations peaking specific yield traits without significant disparities. Enhanced yield under plough + ridging combined with phosphorus application is consistent with findings that improved soil structure enhances fertilizer use efficiency (Bationo et al., 2023). For nutritional content, plough+ridging elevated minerals (P, K, Ca, Mg, Fe), Proximates (protein, fiber, moisture), and Phytonutrients (quercetin, vitamins A and C). Phosphorus at 15 kg/ha maximized these, with interactions like plough+bed at 45 kg/ha yielding the highest values. These synergistic effects align with studies showing integrated nutrient management sustains high yields (up to 57.84 t ha^{-1}) and quality in hybrids (Getaneh et al., 2025). Both tillage and phosphorus significantly influenced mineral and phytochemical composition. The observation that moderate phosphorus (15 kg/ha) improved phytochemical content supports the theory that mild nutrient stress can stimulate secondary metabolite synthesis (Ali et al., 2025; Banik et al., 2024).

VII. CONCLUSION

The three tillage methods tested can be used for onion production in the study area, but plough+ridging tillage method performed better than the other two. Also, application of phosphorus fertilizer at the rate of 30kg/ha gave higher result in terms of growth and yield parameters. The interaction of plough+ridging tillage method with 30kg/ha phosphorus fertilizer recorded higher growth and yield parameters. Whereas, 15kg/ha phosphorus rate gave higher values for the mineral elements, proximate elements and phytonutrients (Physicochemical properties) tested. The interaction of plough+ridging with 45kg/ha phosphorus rate recorded the highest physicochemical properties compared to other interactions. Plough + ridging combined with 30 kg P_2O_5 ha^{-1} is recommended for optimal onion growth and yield. However, for improved nutritional quality, 45 kg P_2O_5 ha^{-1} is more effective.

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