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Response of Different Phosphorus Levels on Growth and Productivity of Wheat (*Triticum aestivum L.*), Under Agro-Climatic Conditions in Kabul

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Abstract: Agriculture is a major contributor to the national economy and food security of developing countries especially in Afghanistan. Wheat is a crucial crop for ensuring food security. It is among the most significant crops grown in Afghanistan. It is the leading source of carbohydrates for humans. To fine the effect of fertilizer especially (P) on enhancing this crop productivity, the study was conducted at the agricultural research farm of agriculture faculty of Kabul University over two years (March 17, 2020, and March 4, 2021). The experimental design was a simple randomized complete block (RCB) design with three replications and five phosphorus levels (0, 30, 60, 90, and 120 kg P ha^{-1}) and a constant dose of 120 kg N ha^{-1}. Each sub-plot measured 3m x 2m. The row spacing was maintained at 30 cm, and the Maqawim-09 wheat variety was sown at a seed rate of 140 kg ha^{-1}. Di-ammonium phosphate (DAP) was used as the phosphorus source and urea for nitrogen. Agronomical practices were uniform across all plots. Data were collected on various parameters during the study, including plant height (cm), stem number per m^2, leaf number per plant, spike number per m^2, spike length (cm), grain number per spike, spikelet number per spike, grain number per spikelet, grain yield (ton/ha), thousand grain weight, and dry matter (ton/ha). The results indicated that applying phosphorus in the form of DAP at a rate of 90 kg ha^{-1}, along with 120 kg ha^{-1} of nitrogen, significantly improved the growth and productivity of the Maqawim-09 wheat variety. All parameters were significantly affected by the phosphorus rates. Thus, it is recommended that phosphorus in the form of DAP at a rate of 90 kg ha^{-1} and nitrogen in the form of urea at a rate of 120 kg ha^{-1} should be applied to maximize wheat crop yield.

Keywords: Wheat, Phosphorus sources, rate of application, Growth and yield.

1. Introduction

Wheat (*Triticum aestivum* L.) is one of the world's most important cereal crops, cultivated on 224.8 million hectares and producing 732.9 million metric tons (Obaid et al., 2019). It is grown globally and was one of the earliest domesticated crops, around ten thousand years ago. Although wheat does not thrive in tropical climates, it is extensively grown in temperate regions, representing 17% of global cropland. It is the primary food source for 40% of the world's population (Shams et al., 2018). Wheat meets most nutritional needs, providing about 73% of the calories and protein in the average

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diet. A decline in wheat production significantly impacts people's well-being and the national economy (Bashir et al., 2015). In Afghanistan, wheat is a major food grain, heavily consumed by the population. The wheat grain is used in human diets, while the straw serves as animal feed. Afghanistan's climate is well-suited for wheat cultivation, which occurs annually (Obaid et al., 2019). In 2020, the rainfed and irrigated wheat areas totaled 2.6682 million hectares, producing 5.1846 million tons across all provinces, whereas the total wheat requirement was 6.496 million tons (NSIA, 2020-2021, MAIL). Projected wheat demand in Afghanistan is expected to range from 7.51 to 8.03 million tons in 2016, 8.69 to 9.56 million tons in 2020, 9.34 to 10.42 million tons by 2025, and 10.73 to 12.04 million tons by 2030 (MAIL & FAO, 2013). Agriculture is a crucial part of Afghanistan's economy, contributing 26% to the GDP and employing 43% of the workforce. Arable land covers 12% of the country, forests cover 2.7%, permanent pastures cover 46.4%, and communities, mountains, and rivers account for 38.9% (FAO & MAIL, 2021).

Applying fertilizers or nutrients at the appropriate time, using the correct method, and in balanced proportions significantly enhances crop growth and productivity (Islam et al., 2017). The contact ratio between roots and fertilizer is crucial for nutrient availability; more root contact with phosphorus-rich soil increases the phosphorus supply to the plant (Bashir et al., 2015). Nitrogen and phosphorus are essential nutrients for plants, yet many soils are deficient in these minerals. The importance of phosphatic fertilizer for improving wheat yield per hectare cannot be overstated. Increasing phosphorus fertilizer improves grain output, the number of tillers per plant, plant height, and the number of grains per spike. Phosphorus is also involved in various metabolic activities; low soil phosphorus reduces the crop's response to nitrogen (Majeed et al., 2014). Phosphorus plays several roles in plant physiology, including photosynthesis, flowering, seed development, energy transfer, and maturation. It is necessary for plant metabolism and is present in coenzymes, phosphoproteins, phospholipids, and nucleic acids (Khan et al., 2010). Phosphorus is vital for many physiological activities, including ATP and ADP synthesis, which are crucial for plant energy and metabolism. Plants cannot complete their life cycle without adequate phosphorus. Higher phosphorus application rates increase grain size and weight (Mumtaz et al., 2014). Thus, sufficient phosphorus is particularly crucial during the early stages of crop growth. Insufficient phosphorus supply, even if initially adequate, can have irreversible consequences (Mubeen et al., 2021). Phosphate fertilizer moves only 3-5 cm in the soil upon application (Bashir et al., 2015). It significantly increases crop straw and grain yields (Bashir et al., 2015). Phosphorus is the second most critical element for crop productivity after nitrogen, and phosphorus fertilizer is necessary to achieve optimal yields due to its deficiency in most soils worldwide.

In Afghanistan, poor fertilizer management, particularly phosphorus, has resulted in low wheat yields. Improving phosphorus management is crucial for maximizing wheat productivity, resource efficiency, and profitability (Bairwa et al., 2020). Phosphorus deficiency is often noticeable in young plants as it is mobile within the plant and moves from older to newer growth. Deficient leaves are dark green, turning purplish or reddish as the deficiency progresses, especially in older leaves. Proper application of phosphorus fertilizer is key to enhancing crop productivity and sustainability. Applying 90 kg ha-1 of phosphorus has shown the best results in wheat growth and production (Islam et al., 2017). An application rate of 60 kg P2O5 ha–1 is cost-effective and yields an intermediate increase in grain production (Obaid et al., 2019). Applying 100 kg ha-1 of phosphorus through double band placement increased plant height, productive tillers per m2, grains per spike, 1000 grain weight, biological yield, grain yield, and harvest index (Bashir et al., 2015). A significant increase in grain yield was observed up to 60 kg P2O5 ha-1 (Shams, 2018). Phosphorus application at 80 kg P ha-1 as single super phosphate (SSP) produced superior growth and productivity in wheat compared to triple super phosphate (TSP), nitrophos (NP), and di-ammonium phosphate (DAP) (Khan et al., 2010). Higher phosphorus rates can mitigate water stress effects, with 120 kg ha-1 yielding better outcomes under such conditions (Mumtaz et al., 2014). The Maqawim-09 wheat variety is more productive and responsive to phosphorus up to 60 kg P2O5 ha-1, making it a recommended choice for the studied area (Shams et al., 2018). For maximum benefit, phosphorus in the form of DAP at 90 kg ha-1 should be used (Majeed et al., 2014). Cultivar productivity varied, with clear responses to DAP fertilizer, particularly at 200 kg ha-1, providing essential nitrogen and phosphorus for growth and production (Fahdawi et al., 2020). Some people particularly most growers are unaware that DAP fertilizer have the amount of 46% phosphorus and which dose of phosphorus is most significant for higher yield, hence, the following objectives are consisted in my investigation.

1. To analyses the amount of phosphorus level on growth and Productivity of Wheat.
2. To find out the efficiency of different phosphorus levels on wheat (Maqawim-09) variety under Kabul Climate condition.
3. To find out the Efficiency of DAP fertilizer on growth and productivity of wheat (Maqawim-09) variety under Kabul climate condition of Afghanistan.
4. To find the best amount of phosphorus for wheat growth and production and to introduce them to the Afghan growers so they produce more yield per ha^{-1} of their lands

2. Materials and Method

The current study was, "Effect of Different Phosphorus Levels on Growth and Productivity of Wheat (*Triticum aestivum L.*), testing variety was (Maqawim-09) Under Agro – Climatic Condition in Kabul" that was carried out during the spring of 2020–21. The following provides more information on the climatic and ecological conditions that the current research was conducted, the experimental materials utilized, the methodology used, and the criteria for evaluating treatments throughout the investigation.

2.1. Experimental Site & Location

Experiment was conducted at the agriculture research farm of Kabul University during spring-summer season in 2020 and 2021. The experimental site was located between Latitude: 34° 51' 2.39" N and Longitude: 69° 07' 24.60" E. based on GPS technology.

2.2. Weather and Climate

Afghanistan experiences a continental climate with cold winters and dry, hot, dusty summers (Fig. 1 and Fig. 2). The transition to spring occurs rapidly in April and May. Kabul, situated at an altitude of 1791 meters, is surrounded by mountains that rise up to 5000 meters. The wind patterns in Kabul are unique, with winds generally less than 5 km/h and no prevailing direction. Daily temperatures show little variation, closely aligning with climatological averages, though there is significant variation throughout the day. Maximum temperatures gradually increase from winter to summer. Kabul's daytime temperatures are slightly lower than those of surrounding areas. In August, Kabul's maximum temperatures typically range from 33-36°C, while other regions in Afghanistan report 36-42°C.

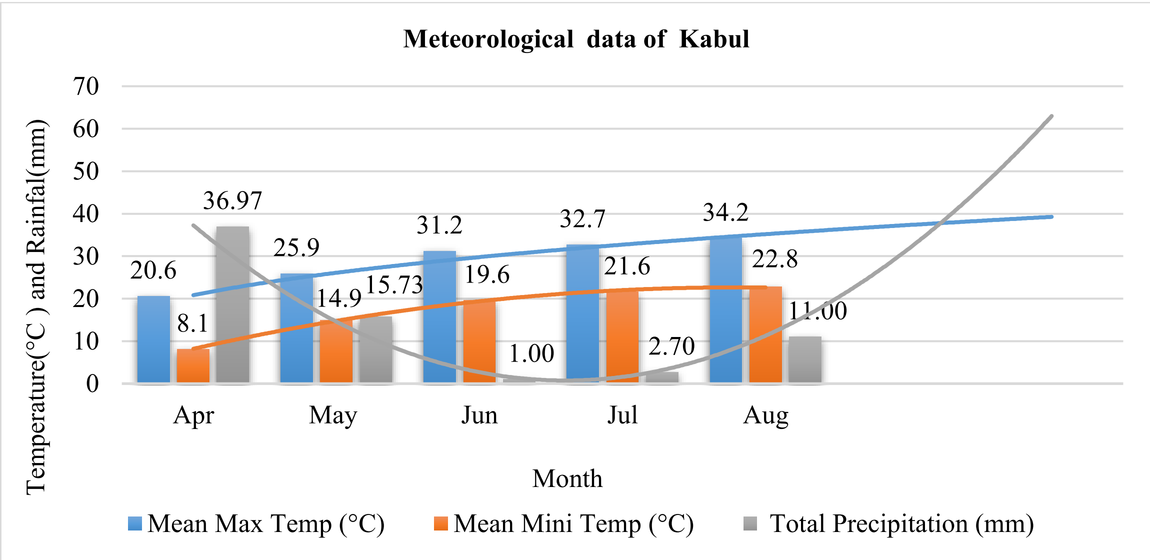

Fig. 1: Seasonal meteorological data of temperature (°C) and rainfall (mm) of Kabul, Afghanistan during the growing seasons of spring wheat in (2020 – 2021)

Meteorological data was collected from, Ministry of Agriculture, Irrigation and Livestock (MAIL) & Afghanistan Meteorological Department.

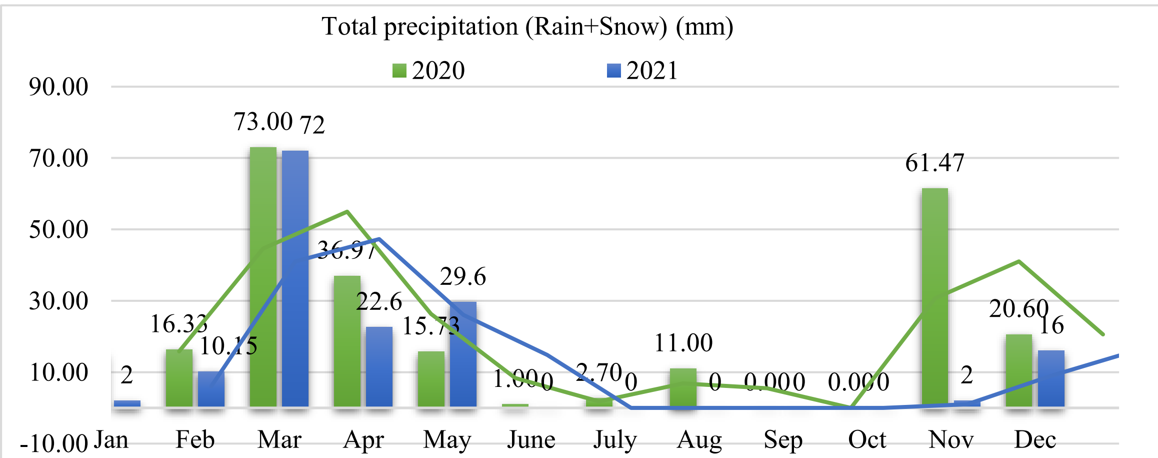

Fig. 2: Two annual meteorological data of precipitation (Rain Snow) (mm) in Kabul, Afghanistan, during the growing seasons of spring wheat in (2020 – 2021)

2.3. Soil Sampling and Analysis

Soil samples were randomly selected from the entire field, ranging in depth from (0 - 20 cm,) the samples were combined from every location, to create a composite sample for mechanical and chemical examination, in order to evaluate the physical and chemical characteristics of the experimental field (Table 1). Prior to conducting the experiment, the soil in the experimental field were underwent for mechanical investigation (020 cm depth).

Table 1. The soil physical and chemical property were studied before and after wheat crop was planted in experimental fields.

Experimental Site	Soil Analysis											Remark
		EC	Elements						Soil Texture			
	PH	Ms/cm	T-N	P2O5 (PPM)	K (PPM)	Na (PPM)	CaCo3 (%)	OM (%)	Sand (%)	Silt (%)	Clay (%)	
KUAF	8.3	0.175	0.17	9.5	24	14	12.5	1	50.9	38	11.0	Sandy loam

Source of soil analyzes: Agriculture Research Institute Soil laboratory directorate of Afghanistan (ARIA)

2.4. Experiment Design

An experiment was conducted at the same location on the agricultural research farm of Kabul University during the spring seasons of 2020 and 2021. The study followed a simple randomized complete block (RCB) design with three replications and five treatments. Each sub-plot measured 3m x 2m, and the row spacing was maintained at 30 cm. The Maqawim-09 wheat variety was sown at a seed rate of 140 kg ha^{-1}. Di-ammonium phosphate was used as the phosphorus source and urea for nitrogen. Agronomical practices were uniform across all plots. The treatments included five different phosphorus levels, all with a constant dose of 120 kg N ha^{-1}. The layout plan of experiment for both years are presented in Fig. 3.

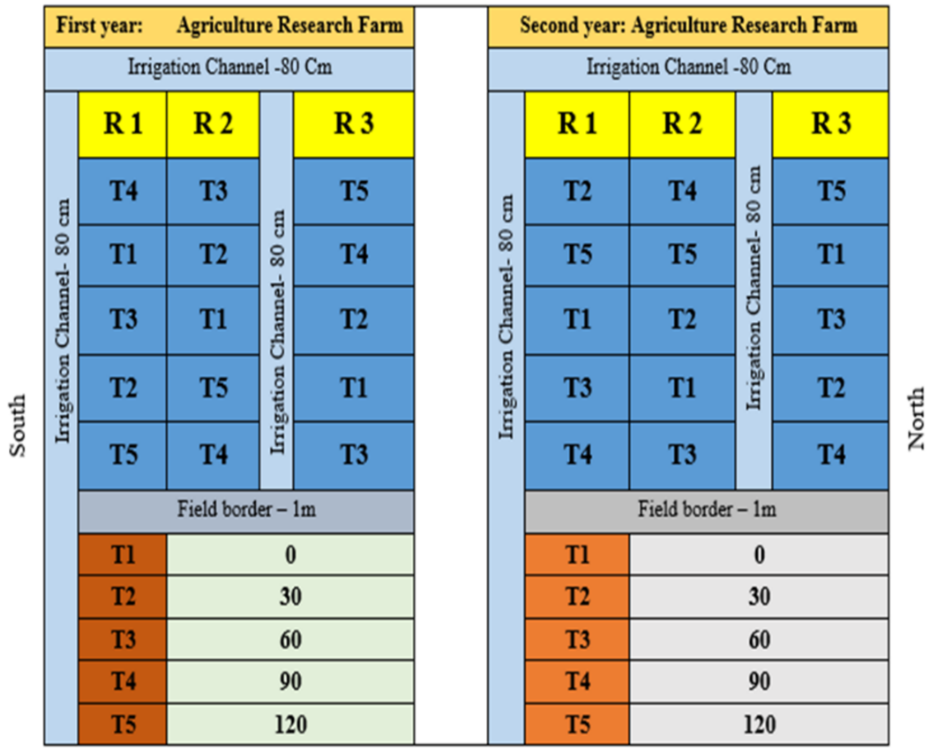

Fig. 3: Project design (RCBD)

2.5. Cultural Practices

2.5.1 Field Preparation

After the clearing of weed flora, the land was first irrigated at 2020/3/1/ after that, it was plowed twice by a small plow and harrow to soften the soil and remove weed seeds and debris which is under the soil surface and make the soil hard, friable and level to ensure appropriate germination of seeds.

2.5.2 Seed Rate and Sowing

Wheat seed was received in Agriculture Research Institute of Afghanistan (ARIA); after land preparation the seed was calculate for each plot. sowing seed rate was 140 kg/hectare. The sowing time was done manually on 17, March, in 2020 and 4, March, 2021. The crop was sown as the method of row.

2.5.3 Fertilizer Application

Nitrogen was applied at a rate of 120 kg N ha^{-1}, divided into three equal splits. The first portion was applied at sowing, the second during the first irrigation, and the remaining nitrogen was top-dressed in two equal parts after the second irrigation and at full bloom. Phosphorus was applied using DAP (Di ammonium Phosphate), which contains 18% nitrogen and 46% P2O5. The phosphorus levels in the treatments were calculated based on the 46% P2O5 content, comprising five different levels.

P1- Control P2O5
P2- 30 kg P2O5 per hectare through DAP as a basal dressing.
P3- 60 kg P2O5 per hectare through DAP as a basal dress
P4- 90 kg P2O5 per hectare through DAP as a basal dressing.
P5-120 kg P2O5 per hectare through DAP as a basal dressing.

2.5.4 Weed Control

All of the weeds from the previous year were removed when the field was chosen for the research. The weeds were manually eradicated three to four times during the growing period. Throughout the growing season, hand hoeing was used to eradicate weeds from the row of the field. Different weed was existing in research area include (*Chenopodium album, Cyperus rotundus, Phalaris minore* and *Avena fatua*).

2.5.5 Irrigation

Water is vital for all living organisms, that include animals and plants, and the inexistence of their, living organisms cannot survive for long terms because it's Participates for some functions of organisms. Afghanistan has one of the highest water consumption rates in the world, with irrigated agriculture using about 93 percent of the country's total water use. The discovery of historical sites near to Kandahar shows that Afghanistan has used irrigation for agriculture for at least 5000 years, even now, land and water allocations are still strongly tied to the traditions and customs of the sedentary population, and maintaining irrigation systems is an established activity on farmers' seasonal calendars, so there are two types of irrigation systems in Afghanistan, traditional irrigation systems and modern irrigation systems. Surface irrigation system was applied in this research, first irrigation was applied 6 days after sowing of wheat crops (23/3/2020) the second was done (5/4/2020), third was (17/4/2020), fourth was applied (30/4/2020), fifth was (16/5/2020), sixth was applied (24/5/2020) seven irrigation was applied at the booting stage (12/6/2020), eight irrigations was done (17/6/2020) nine irrigation was applied (30/6/2020) at the flowering stage and last irrigation was applied 10 days before harvesting. Total were used ten irrigations for wheat crop production in this research.

2.5.6 Harvesting

The crop was harvested on July/25/2020 first year and July/10/2021in second year. First, for the purpose of laboratory analysis, the crop was harvested 30 cm from each experimental plot, then placed in to plastic bags. Secondly, the crops were harvested with $1m^2$ from each experimental plots and placed in to plastic bags. After harvesting the crops, 30cm plastic bags were transferred to the Laboratory of Kabul University's Department of Agronomy for analysis to determine the amount of yield and the harvested material of each $1m^2$ plots were carried out to the threshing floors for threshing operation.

2.6. Observation Recorded

In order to secure the effect of different phosphorus levels on growth and productivity of wheat crop the following treatments were adopted for observations recorded, such as plant height, stem number/m^2, leaf age/m^2, spike number/m^2, spike length, grain number $spike^{-1}$, spikelet number $spike^{-1}$, grain number $spikelet^{-1}$, yield number/m^2, 1000 grain weight and dry weight. after the collection of data from both years (2020 and 2021 in Agriculture Research Farm of Kabul University), the data were separately and combined analyzed, the result of all parameter is explained below.

3. Result

Result of the first year 2019 – 2020 after statistical analysis of (Plant height, Dry matter and leaf number/plant^{-1}) had been shown, that P fertilizers significantly affected all parameters of wheat. Because the plots which were treated with the (90 kg P ha^{-1}) produced the tallest plants (85.33 cm) and maximum dry matter (3.93 ton/ha^{-1}) While the most leaf number/plant^{-1} (5.14) was recorded from the plots that's were applied (120 kg P ha $^{-1}$). for more information, indicated in Table 2.

Table 2: Effect of different levels of phosphorus on plant growth indices of wheat at the time of 2020 in agriculture research farm

Treatment (phosphorus levels)	Plant height (cm)	Dry matter (ton/ha^{-1}	Leaf number/plant^{-1}
P1 = 0	71.33 c	2.21556 d	4.21 bc
P2 = 30	75.33 c	2.66778 cd	4.59 bc
P3 = 60	79.67 b	2.99444 c	4.66 b
P4 = 90	85.33 a	3.93444 a	4.80 ab
P5 = 120	83.67 a	3.31444 b	5.14 a
CV	2.71	7.99	6
SE	2.14	241.76	0.28
LSD (0.05 %)	4.05	455.98	0.53

Data analysis of tiller/m^2, drain no/spike^{-1}, spike length, spike no/m^2, spikelet no/spike^{-1}, grain no/spikelet^{-1}, grain yield and 1000 grain weight indicated that phosphorus has significant for all growth stage and yield attributes of wheat. Because the most stem number per square meter was recorded from the fourth treatment (190 tiller/m^2), maximum number of grains /spike^{-1} (38.96), highest spike length (9.27 cm), maximum number of spike /m^2 (190), most spikelet no/spike^{-1} (13.44), maximum grain no/spikelet^{-1} (2.9), maximum grain yield (2802.95 kg/ha^{-1}) and maximum thousand grains weight (37.87g) were obtained from the plots which were applied 90 kg P ha^{-1}. For more details, see Table 3.

Table 3: Effect of different levels of phosphorus on growth stages and yield attributes of wheat at the time of 2020 in agriculture research farm

Treatment (phosphorus levels)	Tiller/m^2	Grain number /spike^{-1}	Spike length (cm)	Spike number /m^2	Spikelet number /spike^{-1}	Grain numbe r/Spike let^{-1}	Grain yield (kg/ha^{-1})	1000 Grain Weight (g)
P1 = 0	125.56 c	25.11 d	7.73 c	125.56 c	11.57 c	2.17 bc	1105.66 d	35.13 e
P2 = 30	151.11 b	30.24 c	8.70 b	151.11 b	12.60 ab	2.40 bc	1627.06 c	35.60 d
P3 = 60	173.89 ab	34.34 b	8.87 ab	173.89 ab	13.20 a	2.60 b	2167.33 b	36.40 c
P4 = 90	190.00 a	38.96 a	9.27 a	190.00 a	13.44 a	2.90 a	2802.95 a	37.87 a
P5 = 120	174.44 ab	37.25 ab	9.15 a	174.44 ab	12.78 ab	2.73 ab	2251.50 b	37.07 b
CV	6.21	4.69	4.71	6.21	3.53	4.73	6.19	0.67
SE	10.13	1.56	0.41	10.13	0.45	0.12	123.15	0.25
LSD (0.05 %)	19.1	2.93	0.78	19.1	0.85	0.23	232.27	0.46

Result of the second year (2020 – 2021) was also positive and after data collocation of all parameter of wheat growth stages and yield component, data was analyzed. The result shown that phosphorus has most crucial for every stage of wheat. Because Highest plant height (82.00 cm), highest dry matter (2.60 ton/ha^{-1}) and maximum Leaf number/plant^{-1} were recorded from the plots, that were treated with 90 kg P ha^{-1}. For more information, described Table 4.

Table 4: Effect of different levels of phosphorus on plant growth traits of wheat at the time of 2021 in agriculture research farm

Treatment	Plant height (cm)	Dry matter (ton/ha^{-1}	Leaf number/plant^{-1}
P1 = 0	64.33 c	1.81444 c	4.77 bc
P2 = 30	73.67 b	2.14011 bc	4.93 b
P3 = 60	79.00 ab	2365.56 b	5.17 a
P4 = 90	82.00 a	2.60578 a	5.30 a
P5 = 120	81.00 a	2.76700 a	5.03 ab
CV	3.28	8.27	2.97
SE	2.49	193.43	0.15
LSD (0.05 %)	4.7	364.83	0.28

Data of the second year (2020 – 2021) was also analysis for tiller/m^2, drain no/spike^{-1}, spike length, spike no/m^2, spikelet no/spike^{-1}, grain no/spikelet^{-1}, grain yield and 1000 grain weight of wheat. After analysis of data indicated that phosphorus has effective element for growth stage and yield attributes of wheat. Because the maximum Tiller/m^2 (193.33), most Grain number/spike^1 (48.22), highest spike length (11.94 cm), highest spike number/m^2 (193.33), maximum spikelet no/spike^{-1} (15.69), most grain no/spikelet^{-1} (3.10), maximum grain yield (3859.70 kg/ha^{-1}) and maximum 1000 grains weight (39.07 g) were observed from the plots which were applied 90 kg P ha^{-1}. For more details, see Table 5.

Table 5: Effect of different levels of phosphorus on yield attributes and productivity's of wheat at the time of 2021 in Kabul University Agriculture Research Farm

Treatment (phosphorus levels)	Tiller/m^2	Grain number /spike^1	Spike length (cm)	Spike number/ m^2	Spikelet number/ spike^1	Grain numbe r/Spike let^{-1}	Grain yield Kg/ha^{-1}	1000 Grain Weight (g)
P1 = 0	158.89 c	30.17 d	7.99 d	158.89 c	12.38 b	2.43 c	885.04 d	34.30 cd
P2 = 30	170.0 bc	37.31 c	9.73 c	170.0 bc	13.32 b	2.87 ab	1614.4 cd	35.57 c
P3 = 60	180.0 b	41.93 b	10.50 b	180.00 b	13.95 ab	3.00 a	2424.9 bc	37.57 b
P4 = 90	193.33 a	48.22 a	11.94 a	193.33 a	15.69 a	3.10 a	3859.70 a	39.07 a
P5 = 120	182.22 ab	46.64 a	11.82 a	175.56 b	14.89 a	3.07 a	3111. 5 ab	38.87 a
CV	3.42	4.69	2.94	3.26	3.53	7.91	27.36	2.11
SE	6.06	1.56	0.31	5.73	0.45	0.23	650.82	0.78
LSD (0.05 %)	11.42	2.93	0.58	10.8	0.85	0.43	1227.51	1.48

After composition of data from both years, data was reanalyzed and the result of (Plant height, Dry matter and leaf number/plant^{-1}) was obtained. Result indicated that P fertilizers has significantly affected of wheat crop. Because the tallest plants (83.67) and maximum dry matter (3.27 ton/ha^{-1}) were produced from 90 Kg P ha^{-1} While the most leaf number/plant^{-1} (5.09) was recorded from the plots that's were applied (120 kg P ha $^{-1}$). for more details, indicated in Table 6.

Table 6: Effect of different levels of phosphorus on growth parameters of wheat (2-year pooled data)

Treatment	Plant height (cm)	Dry matter (ton/ha^{-1}	Leaf no/plant^{-1}
P1 = 0	67.83 d	2.01500 d	4.49 bc
P2 = 30	74.50 c	2.40394 c	4.76 b
P3 = 60	79.33 b	2.67999 b	4.91 ab
P4 = 90	83.67 a	3.27011 a	5.05 a
P5 = 120	82.33 a	3.04070 ab	5.09 a
CV	2.31	5.37	3.78
SE	1.79	143.97	0.18
LSD (0.05 %)	3.38	271.55	0.35

Result of combine data for tiller/m^2, drain no/spike^{-1}, spike length, spike no/m^2, spikelet no/spike^{-1}, grain no/spikelet^{-1}, grain yield and 1000 grain weight of wheat, indicated that phosphorus is one of the most crucial element for growth stage and yield attributes of wheat. Therefore, the maximum Tiller/m^2 (189.99), maximum Grain number/spike^1 (43.59), highest spike length (10.61 cm), most spike number/m^2 (191.67), maximum spikelet no/spike^{-1} (14.57), most grain no/spikelet^{-1} (3.00), maximum grain yield (3331.33 kg/ha^{-1}) and maximum 1000 grains weight (38.47 g) were observed from the plots which were applied 90 kg P ha^{-1}. For more details, see Table 7.

Table 7: Effect of different levels of phosphorus on yield attributes and productivity's of wheat (2-year pooled data)

Treatment (phosphorus levels)	Tiller/m^2	Grain number/ spike	Spike length (cm)	Spike number/ m^2	Spikelet number/ spike^{-1}	Grain number/ Spikelet^1	Grain yield	1000 Grain Weight (g)
P1 = 0	142.22 d	27.64 d	7.86 c	142.20 d	11.98 bc	2.30 b	995.35 d	34.72 d
P2 = 30	160.55 c	33.77 c	9.22 bc	160.55 c	12.96 b	2.63 ab	1620.75 c	35.58 c
P3 = 60	176.94 b	38.13 b	9.68 b	176.93 b	13.58 ab	2.80 a	2296.13 bc	36.98 b
P4 = 90	189.99 a	43.59 a	10.61 a	191.67 a	14.57 a	3.00 a	3331.33 a	38.47 a
P5 = 120	179.93 ab	41.94 a	10.49 a	175.02 b	13.83 ab	2.90 a	2681.27 b	37.97 ab
CV	3.49	5.12	2.99	2.76	5.19	4.81	13.77	1.03
SE	5.93	1.9	0.29	4.67	0.69	0.13	300.19	0.38
LSD (0.05 %)	11.19	3.58	0.54	8.81	1.31	0.25	567.55	0.72

4. Discussions

The study found that phosphorus significantly and effectively influenced wheat growth and yield. According to our findings, P fertilizer substantially affected all growth, yield, and yield-contributing characteristics of wheat, which will be detailed individually. Statistical analysis revealed that plots receiving 120 kg P ha^{-1} produced plants with a height of 82.33 cm, while those with 90 kg P ha^{-1} had the tallest plants at 83.67 cm. Treatments 5, 3, and 2 resulted in plant heights of 82.33 cm, 79.33 cm, and 74.50 cm, respectively. The shortest plants, at 67.83 cm, were recorded in the control plots. These results align with the findings of Islam et al. (2017), who confirmed that various phosphorus levels (0, 45, 60, 75, and 90 kg ha^{-1}) significantly affected all growth and yield parameters of wheat. It is concluded that the application of phosphorus at 90 kg/ha yielded the best performance.

The number of stems per square meter is directly linked to the yield of the wheat crop. Data analysis showed that phosphorus fertilizer significantly affected stem density. In this study, the stem count per square meter was measured in each plot and compared across treatments. The highest stem count per square meter (189.99) was recorded in plots treated with 90 kg P ha^{-1}, while plots receiving 120 kg P ha^{-1} produced 179.93 stems per square meter. Treatments 3 and 2 resulted in 176.94 and 160.55 stems per square meter, respectively. The lowest stem count (142.22) was observed in the control plots. These findings are consistent with Majeed et al. (2014), who recommended using 90 kg P ha^{-1} as DAP for optimal wheat yield. Similarly, Mumtaz et al. (2014) found that applying 120 kg P ha^{-1} yielded better results under water stress conditions compared to other phosphorus levels.

The highest number of leaves per plant (5.09) was recorded in plots treated with 120 kg P ha^{-1}. Treatments 4, 3, and 2 produced 5.05, 4.91, and 4.76 leaves per plant, respectively, while the control plots had the fewest leaves (4.49 per plant). These results align with Anwar et al. (2017), who reported that the Pirsabak 2013 wheat variety produced more tillers per square meter, greater leaf area per tiller, and a higher leaf area index with 100% phosphorus from DAP. Shams et al. (2018) also noted that phosphorus levels significantly increased plant height, dry matter accumulation, leaf area index, tiller count, spike length, grain number per spike, grain weight per spike, 1000-grain weight, grain yield, straw yield, and biological yield up to 60 kg P_2O_5 ha^{-1}. Similarly, Ahmed et al. (2010) found that applying phosphorus at 90 kg ha^{-1} was optimal for maximizing leaf area index and biological output in wheat.

Data on the effect of various phosphorus levels revealed that the highest spike number per square meter (191.67 spikes/m²) in wheat was observed in plots treated with 90 kg P ha^{-1}. In contrast, the highest phosphorus level (120 kg P ha^{-1}) resulted in lower spike numbers of 175.02, 176.93, and 160.55 spikes/m² for treatments 5, 3, and 2, respectively. The control plots had the fewest spikes (142.20 spikes/m²). These findings align with those of Suleiman et al. (2014), who noted a significant increase in spike number per square meter with phosphorus levels up to 60 kg P2O5 ha^{-1}, peaking at 80 kg P2O5 ha^{-1} with 278.8 spikes/m², similar to the results reported by Shams et al. (2018). There was no observed interaction between wheat varieties and phosphorus levels in terms of spike density, with the maqawim-09 variety showing the highest productivity and responsiveness up to 60 kg P2O5 ha^{-1}.

Phosphorus levels significantly affected spike length, with data from 2020 and 2021 showing the longest spikes (10.61 cm) at 90 kg P ha^{-1} (treatment 4), compared to 10.49 cm at 120 kg P ha^{-1} (treatment 5). Treatments 3 and 2 produced spike lengths of 9.68 cm and 9.22 cm, respectively, while the control plots had the shortest spikes (7.86 cm). These results are consistent with findings by Noonari et al. (2016), who reported higher values for yield traits such as plant height, tillers per plant, spike length, grains per spike, 1000-grain weight, and grain yield with 90 kg P2O5 ha^{-1} compared to other treatments. Singh et al. (2018) similarly found that the yield components, including spike number per square meter, spike length, grains per spike, grain yield, straw yield, and phosphorus uptake, were maximized at 90 kg P2O5 ha^{-1}, with variety DBW-14 performing comparably to NW2036.

Grain number per spike is a crucial determinant of wheat crop yield potential. Data indicated that the highest grain number per spike (43.59) was recorded in plots treated with 90 kg P ha^{-1}, which was statistically similar to plots treated with 120 kg P ha^{-1} (41.94 grains per spike). Treatments 3 and 2 produced 38.13 and 33.77 grains per spike, respectively, while the control plots had the lowest number (27.64 grains per spike). These findings are consistent with Ali et al. (2020). Significant variations in grain number per spike were observed with different phosphorus levels, with 90 kg P ha^{-1} yielding the most grains per spike, similar to the results reported by Bashir and Anwar (2015).

The highest number of spikelets per spike (14.57) was recorded in plots treated with 90 kg P ha^{-1}, compared to 13.83, 13.58, and 12.96 spikelets per spike in treatments 5, 3, and 2, respectively. The control plots had the fewest spikelets (11.98 per spike). These results align with Alam and Jahan (2013), who found that different phosphorus levels significantly affected wheat yield and its components, with spike length and spikelet number enhanced at 90 kg P ha^{-1} and 120 kg P ha^{-1}. Anum et al. (2020) also reported that 120 kg ha^{-1} is the recommended phosphorus dose for maximum grain yield.

For grains per spikelet, the maximum number (3.00) was recorded in plots treated with 90 kg P ha^{-1}, compared to 2.90, 2.80, and 2.63 grains per spikelet in treatments 5, 3, and 2, respectively. The control plots had the lowest number (2.30 grains per spikelet). These findings are supported by Majeed et al. (2014), who noted that phosphorus application at 90 kg ha^{-1} significantly increased the number of spikelets per spike and grains per spikelet. Phosphorus application significantly increased dry matter accumulation in wheat. The highest dry matter (3.27 tons/ha) was observed with 90 kg P ha^{-1}, similar to the 3.04 tons/ha produced by the highest phosphorus level (120 kg P ha^{-1}). Treatments 3 and 2 yielded 2.68 and 2.40 tons/ha, respectively, while the control plots had the least dry matter (2.015 tons/ha). These results are consistent with Irfan et al. (2019), who found that phosphorus and boron interactions significantly affected growth, nutrient accumulation, and grain yield in wheat.

The highest grain yield (3.33-ton ha^{-1} a) was recorded in plots treated with 90 kg P ha^{-1}, compared to 2.68 tons ha^{-1} for the highest phosphorus level (120 kg P ha^{-1}). Treatments 3 and 2 produced 2.296 and 1.62-ton ha^{-1}, respectively, while the control plots had the lowest grain yield (0.99 tons/ha). These results align with Ali et al. (2020), who found that 90 kg P ha^{-1} is optimal for wheat productivity in Sargodha, Pakistan. Aatif et al. (2017) also noted that applying 120 kg P ha^{-1} combined with 9 tons/ha FYM improved wheat grain yield and yield components.

Statistical analysis showed that phosphorus significantly affects the weight of a thousand grains. The highest weight (38.47 g) was obtained from plots treated with 90 kg P ha^{-1}, while plots receiving 120 kg P ha^{-1} produced grains weighing 37.97 g. Treatments 3 and 2 yielded grains weighing 36.98 and 35.58 g, respectively, and the control plots had the lowest weight (34.72 g). These results confirm the findings of Noonari et al. (2016), who reported that higher phosphorus doses contributed to maximum dry matter, grain number per spike, thousand-grain weight, and overall wheat yield.

5. Conclusion

It was concluded that applying phosphorus as DAP at 90 kg ha^{-1} and nitrogen at 120 kg ha^{-1} is optimal for enhancing the growth and productivity of the wheat variety Maqawim-09 under Kabul climate conditions. All measured parameters were significantly influenced by phosphorus rates. Data analysis showed that the tallest plants (83.67 cm), highest stem number per square meter (189.99), most spike number per square meter (191.67), longest spike length (10.61 cm), greatest grain number per spike (43.59), highest spikelet number per spike (14.57), most grains per spikelet (3.00), highest dry matter accumulation (3.27 tons/ha), maximum grain yield (3.33 tons/ha), and greatest thousand-grain weight (38.47 g) were all recorded in plots treated with 90 kg P ha^{-1} and a constant nitrogen dose of 120 kg N ha^{-1}. Additionally, the highest leaf number per plant (5.09) was observed in plots receiving 120 kg P ha^{-1}. Therefore, it is recommended that phosphorus as DAP at 90 kg ha^{-1} and nitrogen as Urea at 120 kg ha^{-1} be applied to achieve maximum wheat crop benefits.

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Conflict of Interest

The authors declare no conflicts of interest.

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