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## **Effect of Nitrogen and Phosphorus Fertilizer Combinations on Nutrient Use Efficiency and Wheat Yield in Calcareous Soils**

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### **ABSTRACT**

The deficiency of most essential plant nutrients is prevalent due to low organic matter, high alkalinity and calcareousness in Pakistan. The mix of low nutrient availability and climate change eventually affects the productivity of crops. Nitrogen and phosphorus are the essential elements for plant metabolism hence the optimal supply of phosphorus and nitrogen are very crucial for plant growth. This is the necessity to implement certain practices to boost nutrients use efficiency and production of crops. A field study was carried out at the research area of the Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad to assess the effect of different combinations of nitrogenous and phosphatic fertilizers on nutrients use efficiency and wheat yield. The sources of P used in the experiment were nitrophos (NP) and Di-ammonium phosphate (DAP), while sources of N were urea and calcium ammonium nitrate (CAN). Sulfate of



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potash (SoP) fertilizer was used to fulfill the requirement of potassium. There were total five treatments including control and each treatment was replicated three times. At the time of sowing full dose of phosphorus and potassium were applied while nitrogen application was done at sowing, tillering, and booting (flower initiation) stages. Four different combinations of N and P fertilizers were applied according to the treatment plan (i.e. CAN+NP, CAN+DAP, Urea+NP, and Urea+DAP). At the time of harvest, data regarding nutrient uptake, nutrients use efficiency, yield and growth parameters were recorded. Results revealed that a combination of CAN and NP improved all the growth parameters and thus produced more yield as compare to other combinations. The estimated impact of NP and CAN combination was 12.7% higher as compared to DAP and urea combination in terms of grain yield. In CAN+NP combination grain yield, 1000-grain weight and number of tillers were increased by 12.7, 9 and 26 %, respectively as compared to urea + DAP combination.

### Chapter 1. Introduction

Wheat (*Triticum aestivum* L.) is a major cereal crop grown worldwide and a primary staple food in Pakistan, where it contributes substantially to national food security. Despite occupying a large proportion of the cultivated area, wheat yields in Pakistan remain below the global average. This persistent yield gap is largely attributed to poor soil fertility, imbalanced nutrient application, and suboptimal crop management practices. Among these constraints, inadequate and inefficient use of nitrogen (N) and phosphorus (P) fertilizers is one of the most critical factors limiting wheat productivity.

Nitrogen is essential for chlorophyll formation, leaf development, biomass accumulation, and grain formation, making it a key determinant of crop performance (Sandhu et al., 2021). However, N fertilizers are often applied in excessive quantities with the assumption that higher inputs will ensure higher yields. Such practices reduce nitrogen use efficiency (NUE) and lead to considerable nutrient losses through volatilization, leaching, and denitrification (Wen et al., 2024). These losses not only diminish crop productivity but also contribute to environmental degradation, including nitrate contamination, eutrophication of water bodies, and increased emission of nitrous oxide (Sabina et al., 2025). Efficient N management therefore requires selecting appropriate fertilizer sources and ensuring synchronized nutrient supply with crop demand.

Phosphorus is the second major nutrient limiting wheat production, especially in calcareous soils that dominate Pakistan's agricultural landscape. High soil pH and elevated calcium carbonate levels promote P fixation, drastically reducing its availability to plants (Zhang et al., 2025). As a result, even when P fertilizers are applied, only a small fraction becomes accessible for uptake. Phosphorus deficiency restricts root development, energy transfer processes, and overall crop growth (Singh et al., 2025). With increasing pressure on global P resources and rising concerns about fertilizer-induced environmental impacts, improving P-use efficiency has become essential for sustaining wheat production (Ren et al., 2025).

In Pakistan, commonly used N and P fertilizers include urea, calcium ammonium nitrate (CAN), nitrophos (NP), and diammonium phosphate (DAP). These fertilizers vary in their chemical composition and behavior in soil, influencing nutrient availability and crop response (Osorio et al., 2025). Urea, although widely used, is highly susceptible to volatilization in alkaline soils. CAN provides a more stable N source along with calcium, while NP offers both N and P in a form relatively suitable for high-pH soils (Saeed et al., 2025). DAP is a popular P source but can temporarily increase soil pH around the seed, potentially affecting early growth in calcareous conditions (Adnan et al., 2025).



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Evaluating these fertilizer sources under field conditions is important for identifying combinations that enhance nutrient uptake, minimize losses, and improve overall nutrient use efficiency (Zaib et al., 2023).

Sustainable wheat production requires nutrient management strategies that optimize fertilizer use while safeguarding soil health and the environment (Zaib et al., 2023). Understanding how different N and P fertilizer sources influence crop performance in calcareous soils will support the development of practical recommendations for farmers (Zaib et al., 2023). Therefore, this study was designed to assess the effects of various nitrogenous and phosphatic fertilizers on nutrient use efficiency and wheat yield, with the aim of improving fertilizer management practices for sustainable crop production. Therefore the objectives of the study were: i) To enhance the use efficiency of nutrients in the wheat crop by using different phosphorus and nitrogen combinations ii) To investigate the comparative effect of NP plus CAN over DAP plus urea on wheat

### Chapter 2. Materials and Methods

#### Experimental site and design

A field experiment was conducted at the research area of the Institute of Soil and Environmental Sciences, University of Agriculture Faisalabad, in collaboration with Fatima Fertilizer Company Limited, to evaluate the effects of different nitrogen and phosphorus fertilizer sources on wheat performance. The experiment was laid out in a randomized complete block design (RCBD). The field was prepared using a rotavator, followed by cultivation and leveling with a sohaga to ensure a uniform seedbed. Wheat variety FSD-2008 (*Triticum aestivum* L.) was sown on 22 November 2018 at a seed rate of 123.5 kg ha<sup>-1</sup>, with each experimental plot measuring 25 × 25 ft<sup>2</sup>, and the crop was harvested on 22 April 2019. Recommended doses of nitrogen, phosphorus, and potassium (120–90–60 kg N–P–K ha<sup>-1</sup>) were applied to all fertilized treatments, while the control plot received no amendments. Nitrogen was supplied through urea and calcium ammonium nitrate (CAN), phosphorus through di-ammonium phosphate (DAP) and nitrophos (NP), and potassium through sulfate of potash in all fertilized plots. In the urea + DAP treatment, the entire phosphorus dose was applied at sowing, whereas in the CAN + NP treatment, half of the phosphorus was applied at sowing and the remaining half after germination/first irrigation. Nitrogen was split into three equal applications at sowing, tillering, and flowering to match the crop's nutrient demand. The crop received five irrigations using canal water. Soil samples were collected before sowing and after harvest to analyze physicochemical properties. Five treatments were evaluated: T1 (control), T2 (urea + DAP), T3 (CAN + DAP), T4 (urea + NP), and T5 (CAN + NP), each receiving 120 kg N ha<sup>-1</sup> and 90 kg P ha<sup>-1</sup> except the control, to assess their impact on nutrient use efficiency and wheat productivity.

**Table 1. Soil physicochemical properties**

Properties	Readings	Units
Silt	27.40	%
Sand	49.03	%
Clay	23.57	%
Taxonomic class	Typic haplocambids	



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Texture	Sandy loam soil	
Saturation percentage	30.0	%
pHs	7.87	-
CEC	13.5	cmol <sub>c</sub> kg <sup>-1</sup>
Ece	1.94	dS m <sup>-1</sup>
Soluble Potassium	0.04	me L <sup>-1</sup>
Soluble CO <sub>3</sub> <sup>2-</sup>	0.31	me L <sup>-1</sup>
Soluble HCO <sub>3</sub> <sup>-</sup>	2.49	me L <sup>-1</sup>
Ca <sup>2+</sup> +Mg <sup>2+</sup>	10.11	me L <sup>-1</sup>
SO <sub>4</sub> <sup>2-</sup>	9.86	me L <sup>-1</sup>
Cl <sup>-</sup>	12.70	me L <sup>-1</sup>
Organic matter	0.78	%
Soluble Sodium	16.86	me L <sup>-1</sup>
Total Nitrogen	0.025	%
Available Phosphorus	6.10	mg kg <sup>-1</sup> soil

**Chapter 3. RESULTS**

Most essential plant nutrients deficiency is prevalent due to low organic matter, high alkalinity and calcareousness in Pakistan. The mix of low nutrient availability and climate change eventually affects the productivity of crops. Nitrogen and phosphorus are the essential elements for plant metabolism hence the optimal supply of phosphorus and nitrogen are very crucial for plant growth. In our country, most of the farmer applies the heavy doses of fertilizer to obtain a higher yield without considering its losses and impacts on the environment. This approach is costly as well as the wastage of the non-renewable resources. There is a need to implement certain practices to boost nutrients use efficiency and production of crops. The application of nutrients with correct sources may improve the nutrient use efficiency as well as the losses could also be minimized. For this purpose, a field trial was conducted to study the impact of nitrogenous and phosphatic fertilizer combinations on nutrient use efficiency and wheat production. The obtained results of this study are discussed below:

**Chlorophyll contents (SPAD)**

The chlorophyll content is a vital yield affecting parameter. If the chlorophyll contents are more then it will lead towards the higher photosynthesis and more production. Chlorophyll contents were significantly different among the treatments as shown in Figure 3.1 showed that the CAN and nitrophos combination performed better as compared to the urea and DAP combination. The highest value of the chlorophyll was observed in T<sub>5</sub> where the CAN and nitrophos fertilizer combination was used (52.73)



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followed by the T<sub>4</sub> (urea and nitrophos), T<sub>3</sub> (CAN and DAP), T<sub>2</sub> (urea and DAP) and T<sub>1</sub> (control) with chlorophyll content value 45.6, 42.6, 37.47 and 26.13 respectively. Minimum chlorophyll contents were observed in the control treatment (26.13).

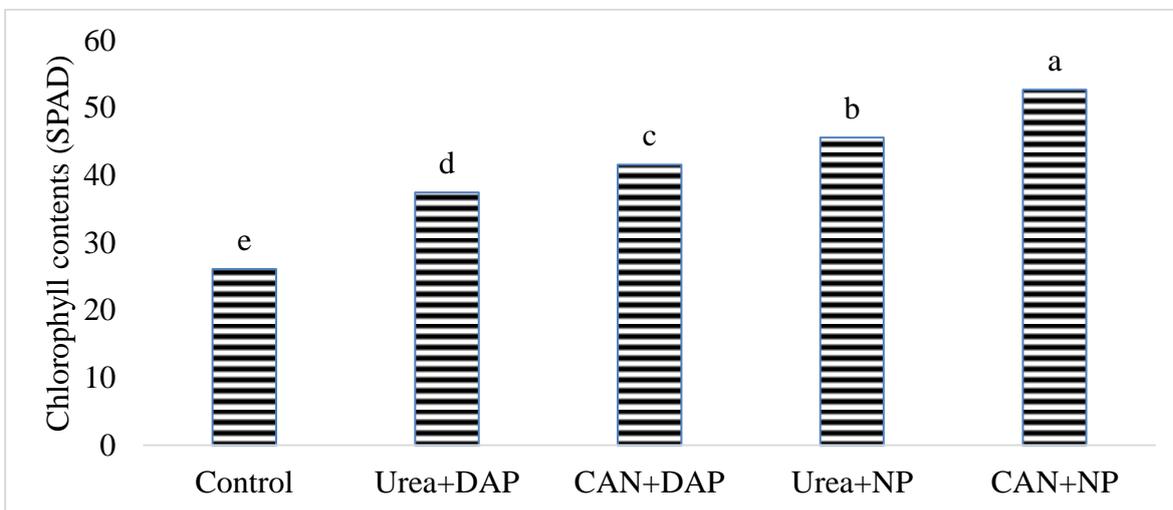


Figure 3.1. Effect of different combinations of nitrogenous and phosphatic fertilizers on chlorophyll content (SPAD) of wheat

Plant height (cm)

Crop performance can be assessed by the plant height. Plant height was significantly different among the treatments as shown Figure 3.2 showed that plant height was reaching maximum value in T<sub>5</sub> where the CAN and nitrophos fertilizer combination was used. In urea and nitrophos (NP) combination (T<sub>4</sub>) the plant height (63.63cm) was more as compare to T<sub>3</sub> (60.40cm) where CAN and DAP were used. In urea and DAP combination (T<sub>2</sub>) plant height (52.30cm) was more as compare to control (33.93 cm).

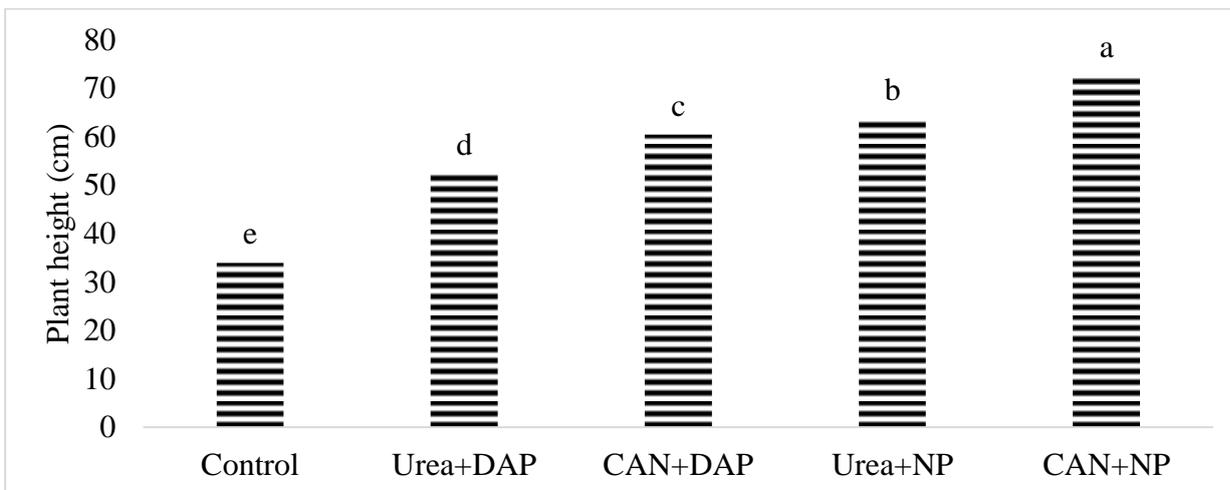


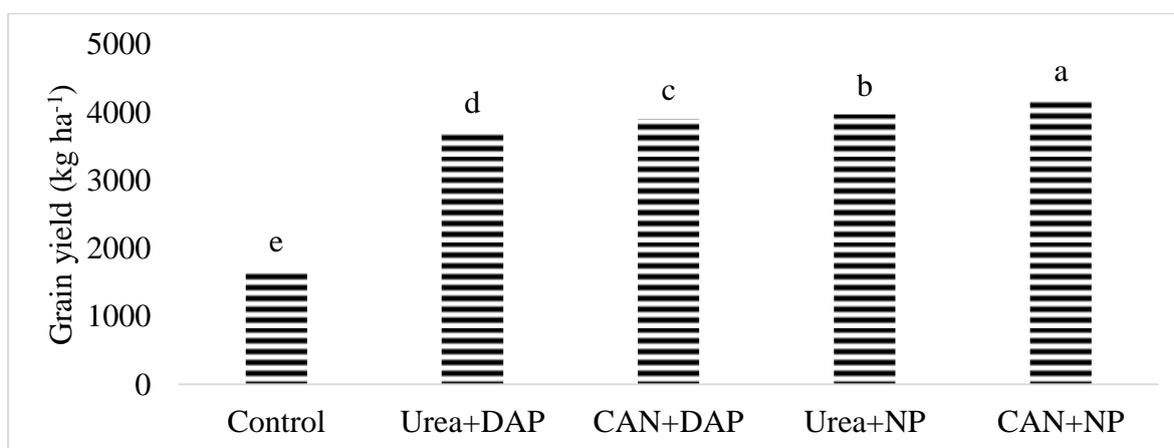
Figure 3.2. Effect of different combinations of nitrogenous and phosphatic fertilizers on plant height (cm) of wheat



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**Grain yield (kg ha<sup>-1</sup>)**

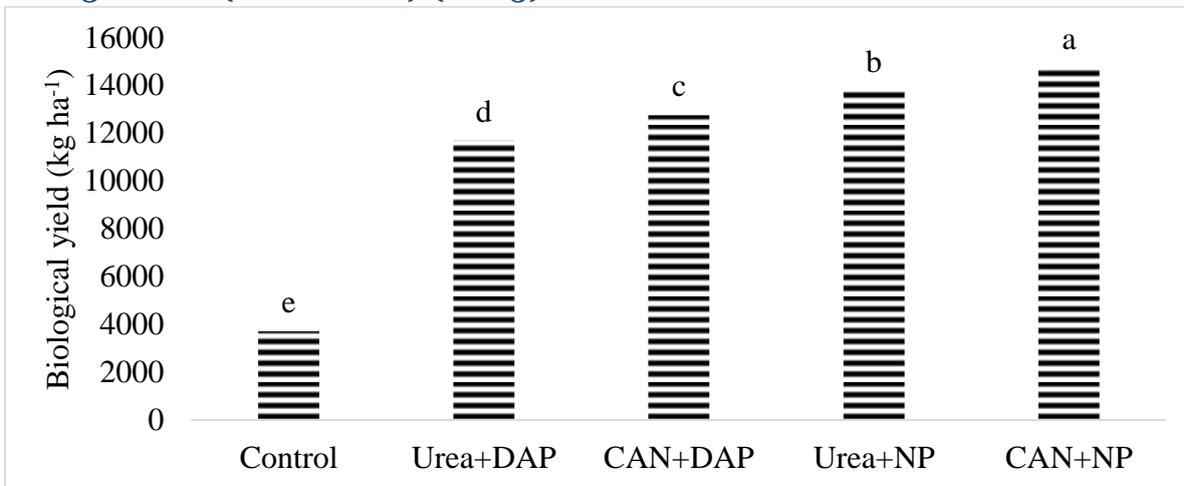
Grain yield is a chief factor among yield contributing factors, especially for cereal crops. In the cereal crops, grains are the monetary part of the crop. Figure 3.3 showed that the CAN and nitrophos combination performed better as compared to the urea and DAP combination. The grain yield obtained from the T<sub>4</sub> (urea and nitrophos) i.e. 3971 kg ha<sup>-1</sup> was higher as compared to the T<sub>3</sub> (CAN and DAP) i.e. 3906 kg ha<sup>-1</sup> but it was lower as compared to the T<sub>5</sub> (CAN and nitrophos) that produced 4187 kg ha<sup>-1</sup> grain yield. In T<sub>2</sub> (urea and DAP) 3716 kg ha<sup>-1</sup> grain yield was obtained which was higher as compared to control (1683 kg ha<sup>-1</sup>) but it was lower as compared to the all other treatments. Control treatment showed the least grain yield (1683 kg ha<sup>-1</sup>).



**Figure 3.3. Effect of different combinations of nitrogenous and phosphatic fertilizers on grain yield (kg ha<sup>-1</sup>) of wheat**

**Biological yield (kg ha<sup>-1</sup>)**

Among the contributing factors of yield, the biological yield is a big contributor to the grain yield. Figure 3.4. showed that urea and DAP combination presented less biological yield as compared to the CAN and nitrophos combination. The lowest value of the biological yield (3716 kg ha<sup>-1</sup>) was observed in T<sub>1</sub> while highest in T<sub>5</sub> (14734 kg ha<sup>-1</sup>) where CAN and nitrophos fertilizers combination was used. While the combination of urea and DAP presented the lesser biological yield (11703 kg ha<sup>-1</sup>) as compared to CAN and nitrophos combination (14734 kg ha<sup>-1</sup>). In the treatment where the urea and NP combination was used higher biological yield (13773 kg ha<sup>-1</sup>) was observed as compared to the CAN and DAP combination (12758 kg ha<sup>-1</sup>).

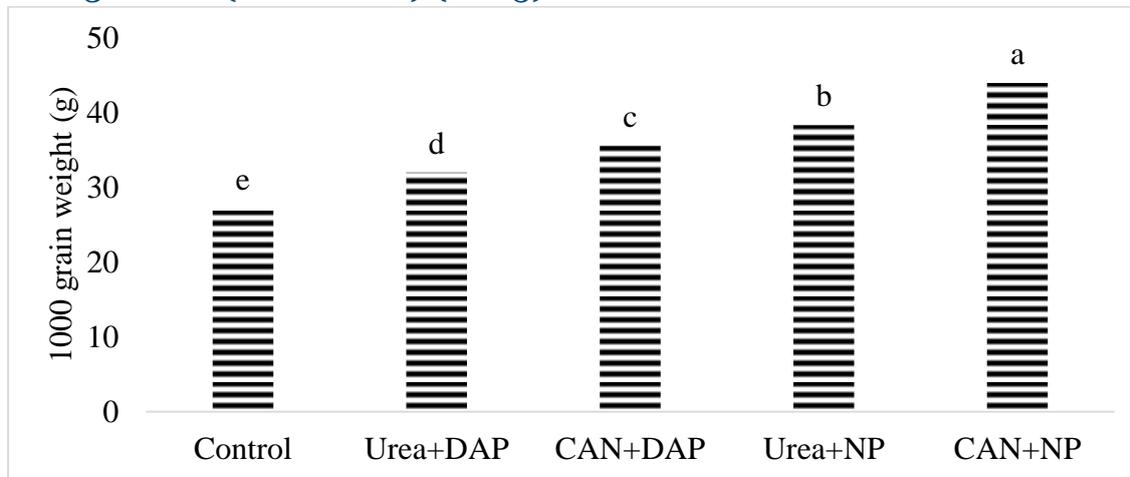


**Figure 3.4. Effect of different combinations of nitrogenous and phosphatic fertilizers on biological yield (kg ha<sup>-1</sup>) of wheat**

**3.5.**

**1000 grain weight (g)**

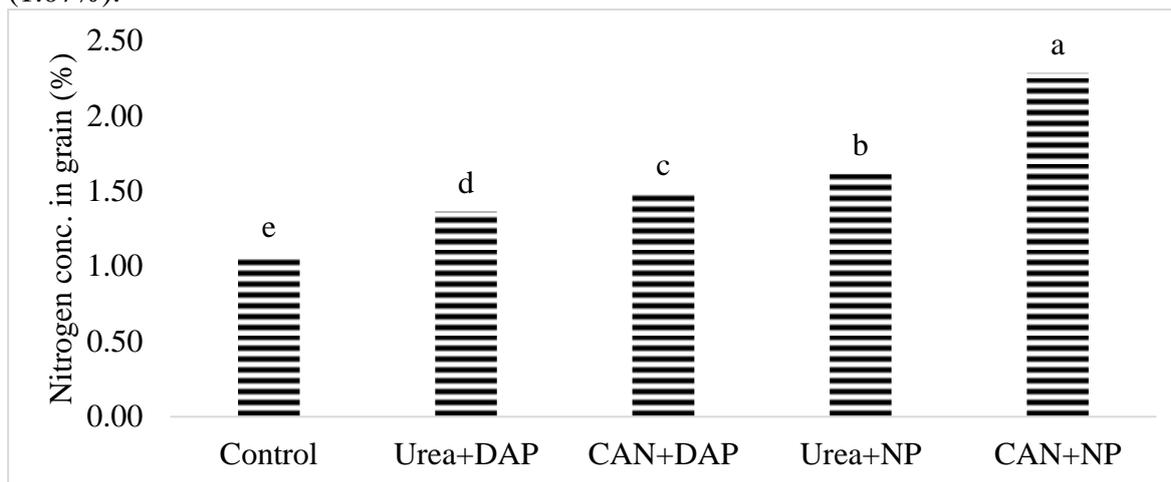
Figure 3.5. show that the CAN and nitrophos combination performed better as compared to the urea and DAP combination. The maximum value of the 1000 grain weight was observed in T<sub>5</sub> where the CAN and nitrophos fertilizer combination was used (43.97 g) followed by the T<sub>4</sub> (urea and nitrophos), T<sub>3</sub> (CAN and DAP), T<sub>2</sub> (urea and DAP) and T<sub>1</sub> (control) with 1000 grain weight value 38.30, 35.57, 32.00 and 27.13 g, respectively.



**Figure 3.5. Effect of different combinations of nitrogenous and phosphatic fertilizers on 1000 grain weight (g) of wheat**

**Nitrogen concentration in grain (%)**

Nitrogen concentration is indicating the performance of fertilizer as well as the crop efficiency to uptake the nutrients. These results indicated the performance of fertilizer to readily available to the plants and contribute to the yield performance of the crop. Figure 3.6 shows that urea and DAP combination produce a lower nitrogen concentration in grain (1.36%) as compared to the CAN and nitrophos combination (2.28%). The highest value of the nitrogen concentration was observed in T<sub>5</sub> where the CAN and nitrophos fertilizer combination was used (2.28%). But the CAN and DAP combination decreased the nitrogen concentration (1.48%) as compared to the urea and nitrophos combination (1.61%). Minimum nitrogen concentration was observed in the control treatment (1.07%).



**Figure 3.6. Effect of different combinations of nitrogenous and phosphatic fertilizers on nitrogen concentration in grain (%) of wheat**

**Nitrogen concentration in straw (%)**

Figure 3.7 showed that the CAN and nitrophos combination performed better as compared to the urea and DAP combination. In the T<sub>5</sub> (CAN and nitrophos) the highest value of the nitrogen concentration in straw (2.53%) was observed among all the treatments Among the T<sub>3</sub> (CAN and DAP) and T<sub>2</sub> (urea and DAP), the T<sub>3</sub> showed the higher value of nitrogen concentration as compared to the T<sub>4</sub> with nitrogen concentration



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1.71 and 1.49% respectively. While among the T<sub>4</sub> (urea and nitrophos) and T<sub>3</sub> (CAN and DAP), the T<sub>4</sub> showed higher value of nitrogen concentration as compared to the T<sub>3</sub> (1.95 and 1.71% respectively). Control treatment showed a minimum nitrogen concentration in straw (0.93%).

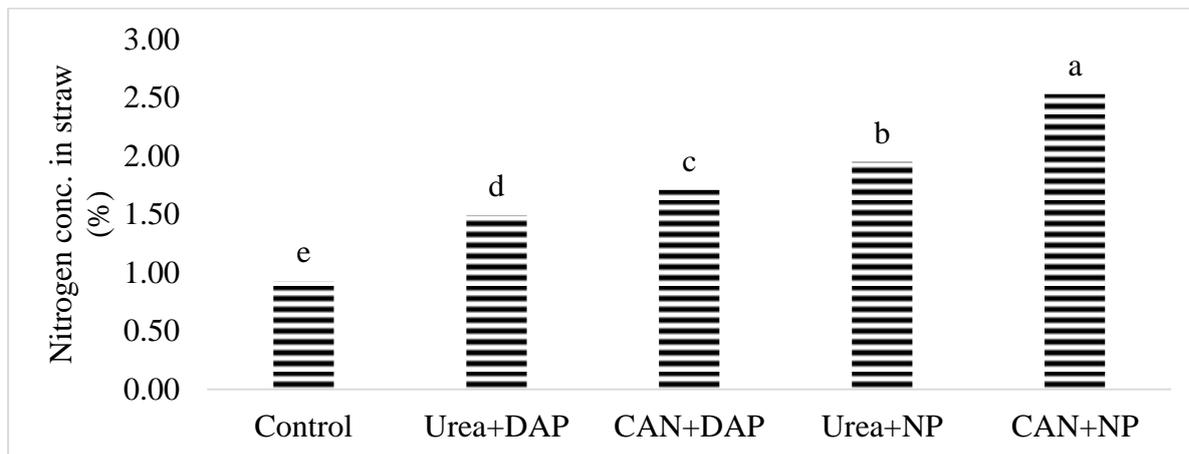


Figure 3.7. Effect of different combinations of nitrogenous and phosphatic fertilizers on nitrogen concentration in straw (%) of wheat

Phosphorus concentration in grain (%)

Phosphorus is an important macronutrient and used for many biological reactions and it is a part of biological energy currency in the plants. Its concentration indicates the performance of fertilizers as well as the plant. The higher concentration will be an indication of the good growth of the crop. In urea and nitrophos (T<sub>4</sub>) the phosphorus concentration in grain (0.32%) was more as compared to T<sub>3</sub> (0.26) where CAN and DAP were used. The highest value of the phosphorus concentration in grain was observed in T<sub>5</sub> (0.38%). In T<sub>2</sub> phosphorus concentration in grain (0.19%) was higher as compared to control (0.11%). As shown in the figure 3.8.

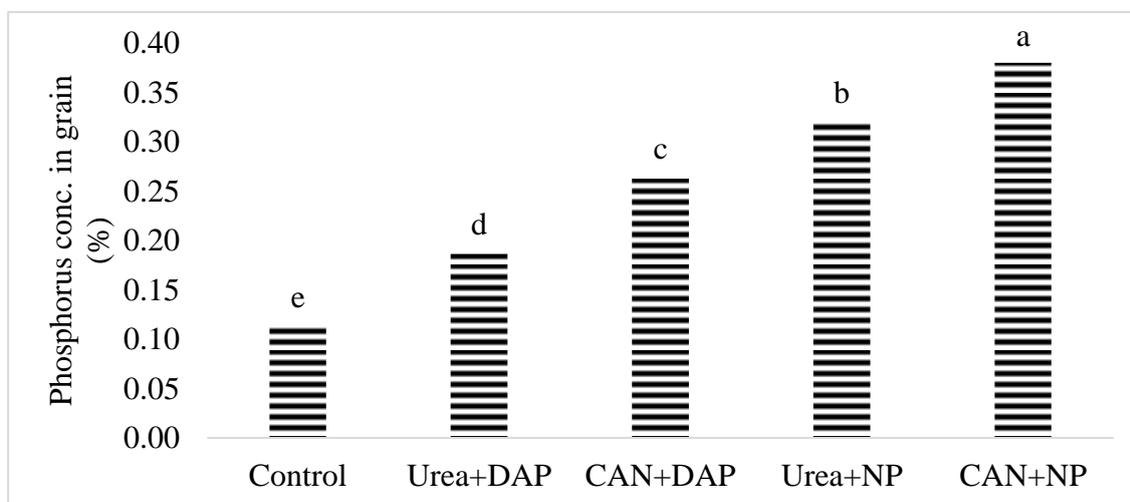


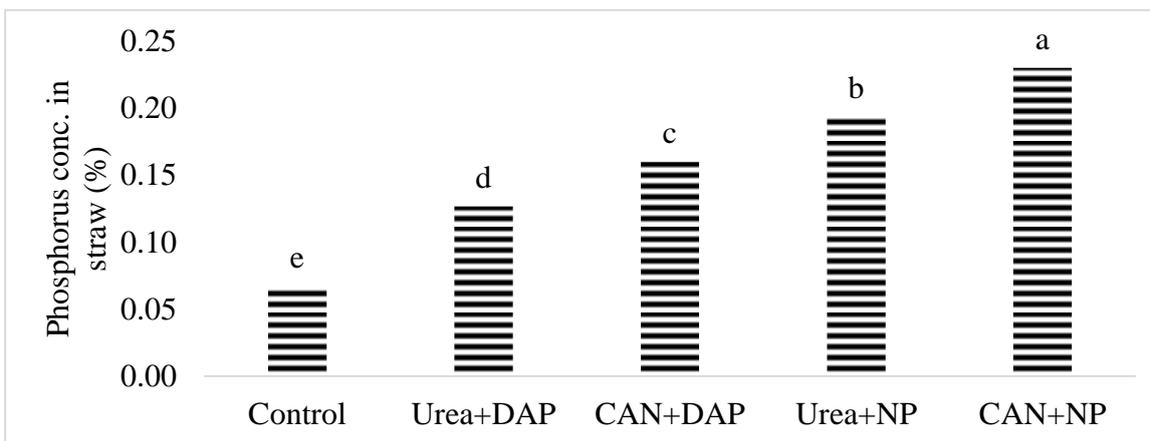
Figure 3.8. Effect of different combinations of nitrogenous and phosphatic fertilizers on phosphorus concentration in grain (%) of wheat



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**Phosphorus concentration in straw (%)**

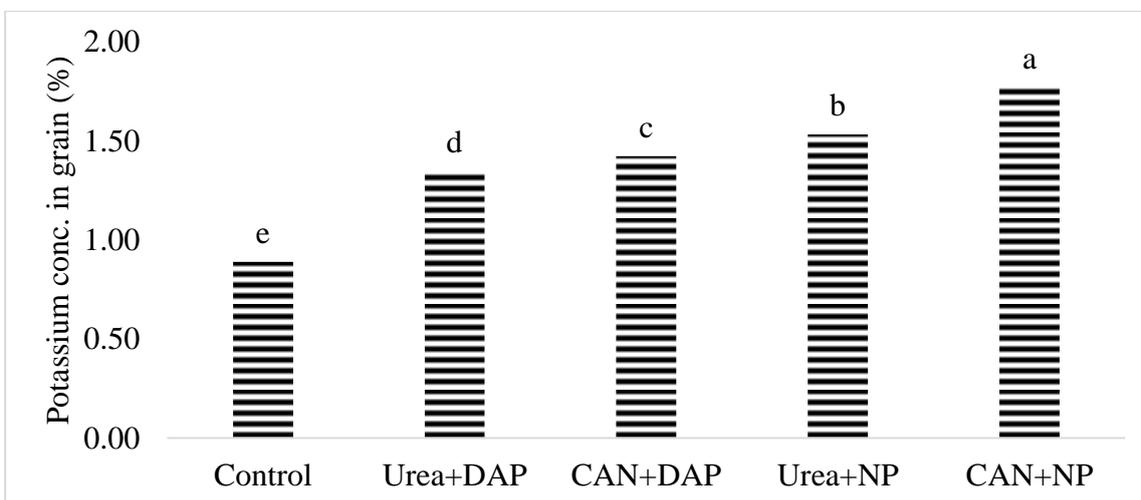
Figure 3.9. showed that urea and DAP combination produced lower phosphorus concentration in straw (0.13%) as compared to the CAN and nitrophos combination (1.07%). The highest value of the phosphorus concentration in straw was observed in T<sub>5</sub> where the CAN and nitrophos fertilizer combination was used (1.07%). But the CAN and DAP combination presented lower phosphorus concentration (0.16%) as compared to the urea and nitrophos combination (0.19%). Control treatment showed minimum phosphorus concentration in straw (0.07%).



**Figure.3.9. Effect of different combinations of nitrogenous and phosphatic fertilizers on phosphorus concentration in straw (%) of wheat**

**Potassium concentration in grain (%)**

Potassium is the third most important macronutrient. Figure 3.10 showed that all the treatments enhanced the potassium concentration in grain as compared to the control. CAN and nitrophos combination exhibited better results as compared to the urea and DAP combination. In the T<sub>5</sub> where the CAN and nitrophos fertilizer combination was used showed the maximum value of potassium concentration in grain (1.77%) was observed followed by the T<sub>4</sub> (urea and nitrophos), T<sub>3</sub> (CAN and DAP), T<sub>2</sub> (urea and DAP) and T<sub>1</sub> (control) with potassium concentration in grain 1.53, 1.42, 1.35 and 0.89% respectively.



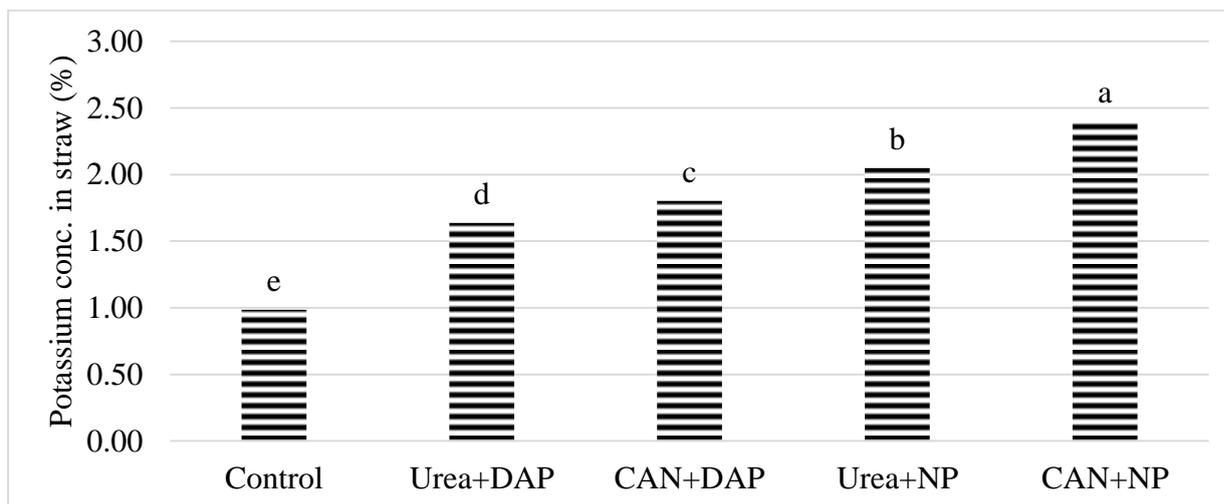


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**Figure 3.10. Effect of different combinations of nitrogenous and phosphatic fertilizers on potassium concentration in grain (%) of wheat**

**Potassium concentration in straw (%)**

Figure 3.11 showed that T<sub>4</sub> (urea and nitrophos) presented the higher potassium concentration in straw (2.05%) as compared to the T<sub>3</sub> (CAN and DAP) (1.80%). But T<sub>2</sub> (urea and DAP) showed the lower concentration of potassium in straw (1.64%) as compared to the T<sub>3</sub> (CAN and DAP) (1.80%). When T<sub>3</sub> (CAN and DAP) and T<sub>2</sub> (urea and DAP) were compared then the higher concentration was observed in T<sub>3</sub> (CAN and DAP) with potassium concentration 1.80 and 1.64%, respectively. Among the T<sub>2</sub> (urea and DAP) and T<sub>5</sub> (CAN and nitrophos), the higher concentration of potassium was obtained in T<sub>5</sub> (2.40%) as compared to the T<sub>2</sub> (1.64%). Overall, the urea and DAP combination is not a better combination of fertilizer as compared to CAN and nitrophos. As shown in Table and Figure 4.21.



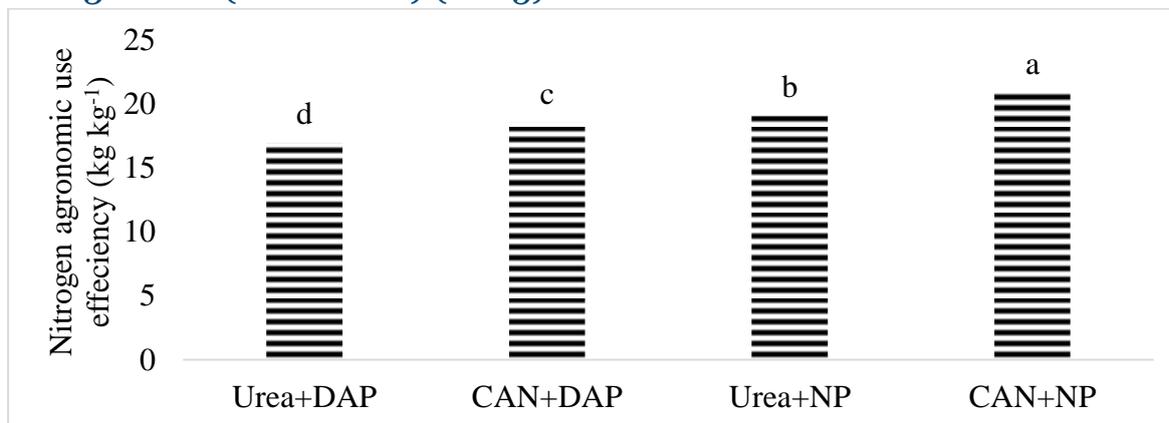
**Figure 3.11. Effect of different combinations of nitrogenous and phosphatic fertilizers on potassium concentration in straw (%) of wheat**

**Nitrogen agronomic use efficiency (kg kg<sup>-1</sup>)**

Figure 3.12 showed that different combinations of nitrogen and phosphatic fertilizers significantly improved the nitrogen agronomic use efficiency. The nitrogen agronomic use efficiency was higher in T<sub>5</sub> (CAN and nitrophos) (20.86 kg kg<sup>-1</sup>) as compared to the T<sub>4</sub> (urea and nitrophos) (19.07 kg kg<sup>-1</sup>). Among the T<sub>3</sub> (CAN and DAP) and T<sub>5</sub> (CAN and nitrophos), the T<sub>3</sub> showed lower agronomic use efficiency of nitrogen (18.53 kg kg<sup>-1</sup>) as compared to the T<sub>5</sub> (20.86 kg kg<sup>-1</sup>). While T<sub>3</sub> (CAN and DAP) showed the higher agronomic use efficiency of nitrogen (18.53 kg kg<sup>-1</sup>) as compared to the T<sub>2</sub> (urea and DAP) (16.94 kg kg<sup>-1</sup>). Minimum nitrogen agronomic use efficiency was observed in urea and DAP combination (16.94 kg kg<sup>-1</sup>).



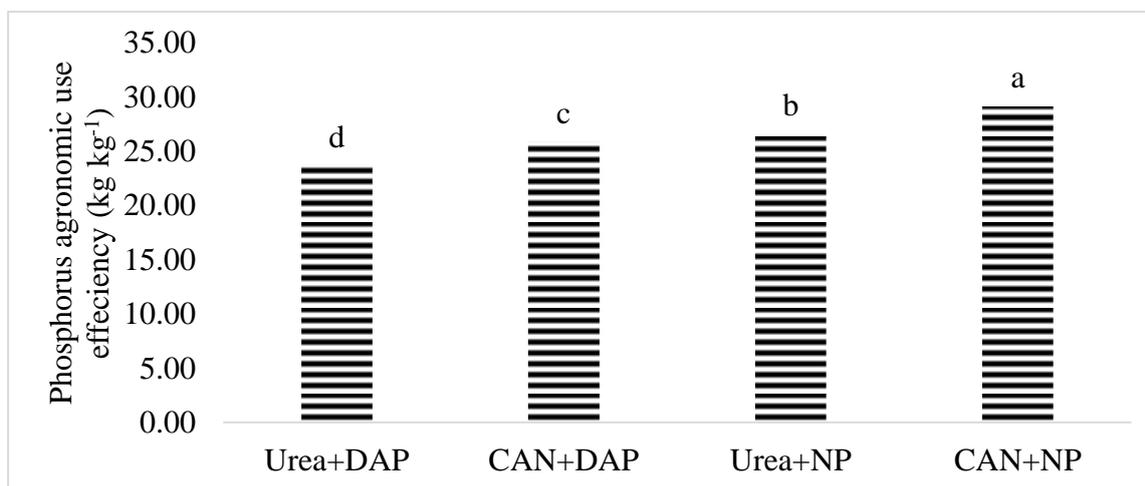
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**Figure 3.12. Effect of different combinations of nitrogenous and phosphatic fertilizers on nitrogen agronomic use efficiency (kg kg<sup>-1</sup>) of wheat**

#### Phosphorus agronomic use efficiency (kg kg<sup>-1</sup>)

Figure 3.13 showed that the CAN and nitrophos combination performed better as compared to the urea and DAP combination. The maximum percentage of the P agronomic use efficiency was observed in T<sub>5</sub> where the CAN and nitrophos fertilizer combination was used (29.11 kg kg<sup>-1</sup>). In urea and nitrophos (NP) combination (T<sub>4</sub>) the phosphorus agronomic use efficiency (26.61 kg kg<sup>-1</sup>) was more as compared to T<sub>3</sub> (25.85 kg kg<sup>-1</sup>) where CAN and DAP were used. In T<sub>2</sub> (urea and DAP) the phosphorus agronomic use efficiency (23.64 kg kg<sup>-1</sup>) was lower as compared to T<sub>5</sub> (CAN and nitrophos) (29.11 kg kg<sup>-1</sup>).



**Figure 3.13. Effect of different combinations of nitrogenous and phosphatic fertilizers on phosphorus agronomic use efficiency (kg kg<sup>-1</sup>) of wheat**

#### Chapter 4. Discussion

The results of this study clearly show that the selection of appropriate nitrogen and phosphorus fertilizer sources has a significant influence on wheat growth, nutrient uptake, and overall productivity in calcareous soils. Among all treatments, the CAN + NP combination consistently performed the best, indicating that this pairing offers a more favorable nutrient supply mechanism under alkaline soil conditions. The superior performance of CAN + NP can be attributed to several complementary factors. The



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nitrate–ammonium balance in CAN likely enhanced nitrogen uptake and minimized nitrogen losses, while the slightly acidic nature of NP helped reduce phosphorus fixation, thereby improving P availability in soils characterized by high pH and CaCO<sub>3</sub> levels.

Improvements in chlorophyll content, plant height, grain yield, and 1000-grain weight under CAN + NP support the idea that synchronized nutrient supply encourages stronger vegetative growth and more efficient grain formation. The higher concentrations of N, P, and K in both grain and straw under this treatment further confirm that nutrient availability and uptake were substantially increased. Enhanced nutrient concentrations directly translated into higher agronomic use efficiencies for all three nutrients, indicating that plants used applied fertilizers more effectively when supplied through CAN + NP than through urea + DAP.

Comparatively, the urea + DAP combination performed the weakest among the fertilized treatments. This may be linked to high ammonia losses from urea in alkaline soils and the temporary pH increase caused by DAP, both of which can reduce nutrient availability at early stages of crop growth. Although the combinations of urea + NP and CAN + DAP showed intermediate improvements, neither matched the consistent advantages provided by CAN + NP.

Overall, the findings highlight that fertilizer source selection is critical for optimizing nutrient use efficiency in calcareous soils. The CAN + NP combination proved substantially more effective than the commonly used urea + DAP, offering improvements not only in yield but also in nutrient uptake and fertilizer-use efficiency. These results reinforce the need for fertilizer strategies that align with soil chemical properties, particularly in regions where alkalinity and phosphorus fixation limit crop productivity. Further long-term studies across different climatic conditions would help validate the stability of these findings and support broader recommendations for sustainable wheat production in similar soil environments.

### Conclusion

The present study demonstrated that selecting appropriate nitrogen and phosphorus fertilizer sources plays a crucial role in improving nutrient use efficiency and wheat productivity in calcareous soils. Among all fertilizer combinations evaluated, the integration of calcium ammonium nitrate (CAN) and nitrophos (NP) consistently outperformed urea and DAP across all growth, yield, and nutrient-uptake parameters. This combination enhanced chlorophyll content, plant height, grain yield, biological yield, and 1000-grain weight, while also improving N, P, and K concentrations in both grain and straw. Furthermore, CAN + NP markedly increased agronomic use efficiencies of nitrogen, phosphorus, and potassium, indicating more effective nutrient utilization by the crop. The acidic nature of NP and the balanced nitrogen forms in CAN together contributed to greater nutrient availability under alkaline soil conditions. Overall, the study concludes that CAN + NP is a superior fertilizer strategy for maximizing wheat yield and nutrient efficiency in calcareous soils of Pakistan. However, further research is recommended to assess long-term soil impacts and performance under varying climatic conditions.

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