Effect of Nitrogen Source on Nitrogen Use Efficiency and Physicochemical Parameters in Wheat Bean Intercropping

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Abstract

Intercropping is an important practice to reduce nitrogen (N) losses and to improve nitrogen use efficiency (NUE). Intercropping improves N uptake and minimizes N losses. Nitrogen sources have a significant impact on NUE, especially in the presence of leguminous species. A pot experiment was carried out to investigate the effect of nitrogen sources such as ammonium nitrate NH4 and NO3 on NUE and the growth of wheat and beans grown alone, as well as intercropping. The experiments were designed with a completely randomized design (CRD). Recommended doses of N, P and K were applied. The results indicated that there was a significant increase in plant biomass (49 ± 0.5g) and shoot fresh (13.68 ± 0.4) and plant dry weights (9 ± 0.5), root fresh weight (2.3 ± 0.09), number of spikes (14 ± 0.6) under ammonium nitrate application. Chlorophyll a, b, chlorophyll a + b and carotenoid contents increased in wheat grown by ammonium nitrate application. Wheat spike length was found to be maximum in intercropping by ammonium nitrate. Grains N contents increased (2.77 % ± 0.07) in intercropping because intercropping may help to improve the nitrogen use efficiency. A significant increase in N was observed in intercropping relative to crops grown separately. Intercropping and N sources had a substantial impact on the phosphorus contents of grains, shoots, and roots. The study concluded that plant growth parameters and nutrient contents improved by intercropping under ammonium nitrate application.

Keywords: Intercropping, Nitrogen Use Efficiency, Ammonium Nitrate, Phosphorus Contents, Nitrogen Sources, Leguminous Species

Introduction

The global population is steadily growing, and the demand for food is also increasing. However, agricultural land is diminishing as it is being converted for residential or commercial use. (Gao *et al.*, 2010). Therefore, there is a need to use better practices to improve the growth. Nitrogen plays a crucial role in the plant's metabolic processes, as it is a key component in the synthesis of proteins and chlorophyll (Botelho & Muller, 2020). Inadequate Nitrogen management is known to be a significant factor that can decrease wheat grain production (Haidri et al., 2023; Hussain et al., 2024).

Agricultural soils in Pakistan exhibit low nitrogen content (Shah *et al.*, 2003). Nitrogen depletion primarily occurs due to NH_3 volatilization and climatic conditions (Khan *et al.*, 2013). The excessive application of nitrogen-based fertilizers not only degrades soil quality but also leads to the emission of greenhouse gases like nitrogen dioxide (NO_2), nitrous oxide (N_2O), and nitric oxide (NO) (Mosier *et al.*, 2013). Inappropriate nitrogen management practices can exert adverse impacts on both soil health and the surrounding environment. The use of chemical fertilizers has the potential to disrupt ecosystems and contribute to environmental pollution (Sanz-Cobena *et al.*, 2017).

Intercropping is the best solution to this problem; it can help to increase the crop yield. It can increase yields of leguminous crops by from 20% to 47% when compared to single-cropping methods. Furthermore, intercropping also offers the significant advantage of saving up to 38% of farming land (Workayehu, 2014). Intercropping contributes to enhanced nitrogen status, improved soil health, increased water-holding capacity, and a reduction in soil erosion. (Lithourgidis *et al.*, 2011).

Intercropping cereal and legumes can enhance nitrogen supply (Hauggaard-Nielsen *et al.*, 2008). Meanwhile, legumes play a crucial role in mitigating greenhouse gas emissions through their nitrogen fixation capabilities.(Jensen *et al.*, 2012; Jeuffroy *et al.*, 2013), Legumes offer numerous ecosystem benefits, including biological control, pollination, carbon sequestration, and nutrient cycling (Doring *et al.*, 2012; Gaba *et al.*, 2015). Furthermore, it is noteworthy that grain-legume crops can boost subsequent cereal yields by an average of 29% (Cernay *et al.*, 2018). Intercropping of legumes with non-legumes, such as cereals, presents a promising avenue to increase overall yield. (Raseduzzaman and Jensen, 2017).

Intercropping in agricultural systems offers numerous benefits, primarily attributed to its enhanced resource utilization efficiency (Matusso *et al.*, 2014). The overall yield in intercropping is attributed to the distinctive characteristics of its components, including improved phosphorus availability (Li *et al.*, 2005). Intercropping has the potential to boost both legume symbiotic nitrogen fixation and cereal soil nitrogen acquisition. (Hauggaard-Nielsen *et al.*, 2001; Bedoussac *et al.*, 2015).

To minimize these losses from soil, intercropping wheat with beans is an important practice that reduces nitrogen losses and minimizes the usage of chemical fertilizers (Inal *et al.*, 2007). The most important aspect of intercropping involves assessing its impact by employing various nitrogen sources. In this context, the intercropping system is most beneficial when it favors crops with higher Nitrogen Use Efficiency (NUE), thereby reducing nitrogen losses. Cereal crops, owing to their deep root systems, typically absorb more mineral nitrogen than legumes. Integrating legumes with cereals enhances nitrogen availability for the cereals, ultimately boosting the overall value of the cereal-legume intercropping system.

When excessive nitrate source is used by cereal, then N fixation by legumes is improved (Tang & Rengel, 2003). Intercropping is an important strategy to improve root zone activities. It is an effective technique for the utilization of natural resources and to minimize dependence on chemical fertilizer. The component crop with high yield advantages and strong competitive potential to improve production is immensely needed. When it comes to intercropping cereal and legumes, they both utilize similar resources, albeit in different ways. Cereals absorb nitrogen in the form of nitrate, while legumes acquire nitrogen as molecular N2, which is fixed by root-dwelling bacteria; thus, competition for N is reduced (Szumigalski & Van Acker, 2006). Cereals intercropped with legumes have deeper and stronger roots for penetrating more N from the soil than sole cropping

Intercropping and the effect of N sources on NUE seem important. Therefore, there is a need to investigate this issue. Considering all the facts mentioned above, a pot experiment was planned to investigate the effect of nitrogen sources such as ammonium nitrate and calcium nitrate on NUE and plant growth in wheat-chickpea intercropping.

Material and methods

Soil sampling and preparation

An experimental pot study was conducted using soil samples collected from the institute's field, which were subsequently transferred to a controlled environment, the wirehouse. The collected soil samples were subjected to air-drying, and then ground and any unwanted debris was removed by passing the material through a 2 mm sieve. A subsample was selected for the analysis of various physical and chemical parameters from these prepared samples. Soil texture was assessed using the hydrometer method. (Gee and Bauder, 1986).

Table 1. Soil basic characteristics

Soil Characteristics	**Values**
Sand	43%
Silt	26%
Clay	35%
Texture	Sandy clay loam
Water holding capacity	42%
Saturation percentage	22%
pHs	7.33
EC_e	2.45dsm^{-1}

Soil organic matter	0.89%
Total soil N	0.48%
Extractable P	7.70 mg Kg^{-1}
Extractable K	164.20 $mgKg^{-1}$

Experimental design and growth conditions treatment plan

Seeds of wheat and beans were initially germinated on moist filter paper in the absence of light, and then they were transplanted into pots. In each pot, a total of four plants were maintained. A total of 36 pots were used. In 24 pots, wheat and bean were grown separately, and the remaining 12 pots were used for wheat and bean intercropping. The recommended amounts of phosphorus (250 mg kg-1) and potassium (60 mg kg-1) were applied as fertilizers. The interaction between nitrogen sources and intercropping was evaluated by administering the recommended doses of nitrogen in the form of NH4NO3 (171.25 mg kg-1) and Ca(NO3)2 (2506.25 mg kg-1). All the fertilizers were applied at the time of sowing.

After three weeks of plant growth, the chlorophyll content was measured on a weekly basis. Prior to harvesting, various plant growth parameters, such as the number of tillers, the number of spikes, plant height, and spike length, were meticulously recorded. Plant height was measured from the base of the plants to their tips. Upon reaching crop maturity, the harvest was conducted, and post-harvest growth parameters, including fresh and dry weights of shoots and roots, grain weight, and grain and straw yields, were carefully determined.

Plant nutrient analysis

For full recovery of nutrients, all samples of shoots, grains, and roots underwent a wet-digestion process, as per the guidelines established by (Rashid, 1986). The total nitrogen content in the digested plant samples was quantified using the Kjeldahl method. The phosphorus levels in the digested shoot, grain, and root samples were assessed utilizing the vanadate-molybdate method, commonly referred to as the yellow color method, employing a UV-visible spectrophotometer (Shimadzu UV-1201) (Chapman, 1961). Potassium concentration in the digested plant samples was determined through flame photometry. (Jenway PFP-7).

Statistical Analysis

All the agronomic and physiological parameters related to growth and yields were collected and analyzed statistically through the analysis of the variance method of Fisher (Steel and Torrie, 1980) using the software statistics-8.1. By using a level of significance of 5%, means were tested by LSD test. Differences consider significance with $P<0.05$.

RESULTS

Plant growth parameters

The maximum total wheat biomass was observed with the application of N sources (49 +0.5 g) as compared to the control (39 +0.6 g). The N source had no significant effect on the total biomass of beans. In intercropping wheat, plant biomass was significantly higher when grown under a nitrogen source relative to intercropped wheat biomass. Intercropped wheat had increased biomass than beans under similar N sources.

Intercropped wheat had increased plant height in intercropping under ammonium nitrate relative to intercropped wheat grown in control (63.5 ±0.5 cm). Ammonium nitrate application had maximum results in wheat intercropping (78 +0.5 cm) compared to calcium nitrate. Wheat plant attained maximum height (73 ±0.5 cm) by the application of ammonium nitrate relative to control. There were no significant effects of calcium nitrate on bean plant height while under ammonium nitrate application; beans had maximum height (55 ±1.7 cm) relative to control and calcium nitrate. Beans intercropped with wheat had maximum shoot length under ammonium nitrate application.

A maximum number of spikes in wheat (14 +0.6) was recorded when grown under ammonium nitrate application, while average spike numbers were found under calcium nitrate (12 ±0.3) and in control (11 ±0.5) conditions. In the case of intercropping, there was a maximum number of spikes in intercropped wheat (9.5 ±0.7) by applying the nitrogen source as compared to control (8 ±0.9) and calcium nitrate.

Maximum spike length (11.5 ±0.6) was recorded in wheat under ammonium nitrate application, while average spike length was recorded under calcium nitrate (10.03 +0.4) and in control (8.6 +0.5) conditions. However, in intercropping, the spike length is maximum when the nitrogen source is applied (13 ±0.5) in contrast to control (9.3 ±0.9) and calcium nitrate.

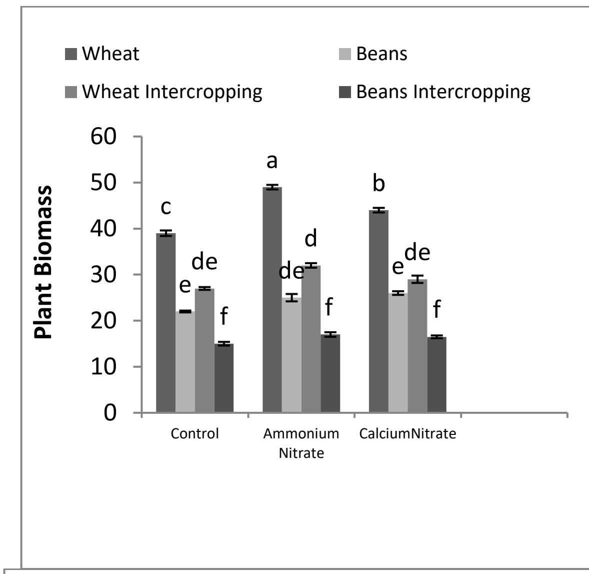
Wheat had the maximum fresh weight (13.68 +0.4g) when grown alone by application of ammonium nitrate compared to the control (10.37 +0.6 g). In intercropping, wheat had the maximum shoot weight (11.18 +0. 5 g). Beans also had the maximum fresh weight when grown alone under nitrogen sources (9.99 +0.5 g) compared to the control.

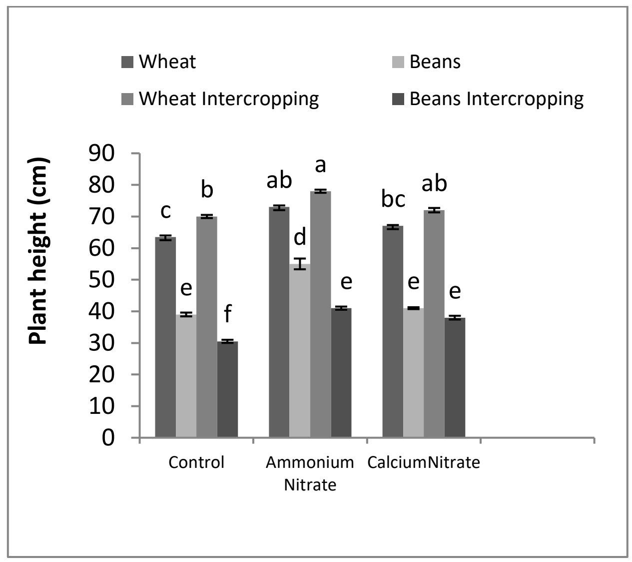
Wheat obtained maximum grain weight (4.54 ±0.5g) by the application of nitrogen relative to control (3.91 ±0.3g). Under ammonium nitrate application, wheat grains had (4.54 ±0.5 g) maximum weight when grown alone. In intercropping, wheat had maximum grain weight (4.03 +0.3 g) under ammonium nitrate application relative to all other sources of N.

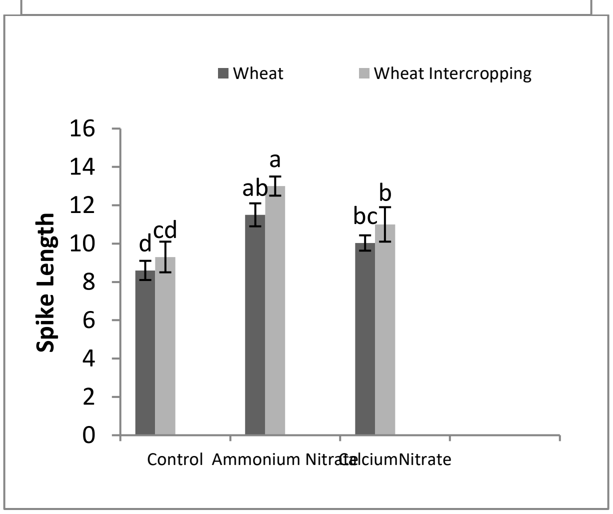
Maximum plant dry weight (8.7 ± 0.5 g) in wheat was observed with the application of ammonium nitrate relative to control (8.1 ±0.5 g) and receiving calcium nitrate treatment. Wheat dry weight decreased by the application of calcium nitrate compared to ammonium nitrate. Beans had maximum dry weight (4.9 ±0.06 g) under calcium nitrate application relative to control (3.3 ±0.5 g). Wheat had increased dry weight in intercropping. The lowest weight in intercropping was observed in control, where no source of N was applied.

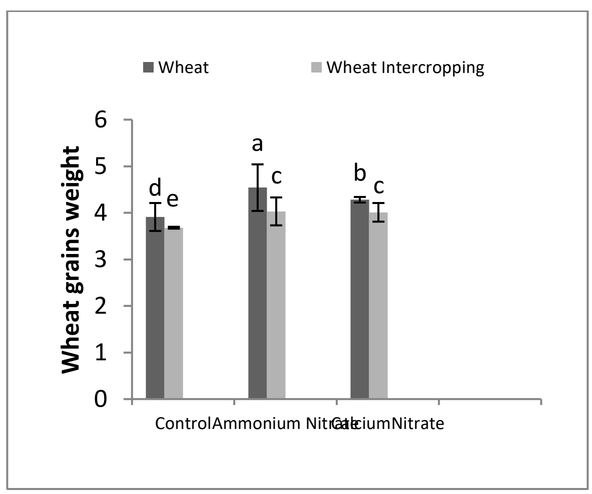
Beans had higher seed weight (9.9 ±0.2 g) when grown alone under ammonium nitrate application relative to the control (7.5 +0.4 g). Under ammonium nitrate application, intercropped beans' seeds attained maximum weight (3.95 +0.5 g) relative to the control. A decrease in seed yield was observed in the control, where no N source was applied. Thus, intercropping has maximum seed weight under nitrogen sources relative to the control.

Wheat roots had maximum dry weight (2.3±0.09 g) in intercropping under ammonium nitrate relative to control (1.5 ±0.05 g). In beans, The maximum dry weight was recorded (0.68 + 0.06 g) when grown alone with ammonium nitrate application compared to the control. The application of ammonium nitrate maximum root dry weight (2.0 +0.03 g) was recorded in wheat alone, as compared to the control. Under calcium nitrate application, roots had maximum dry weight (1.90 +0.06 g) in intercropping, while roots had maximum dry weight (1.5 ±0.04g) when grown alone.









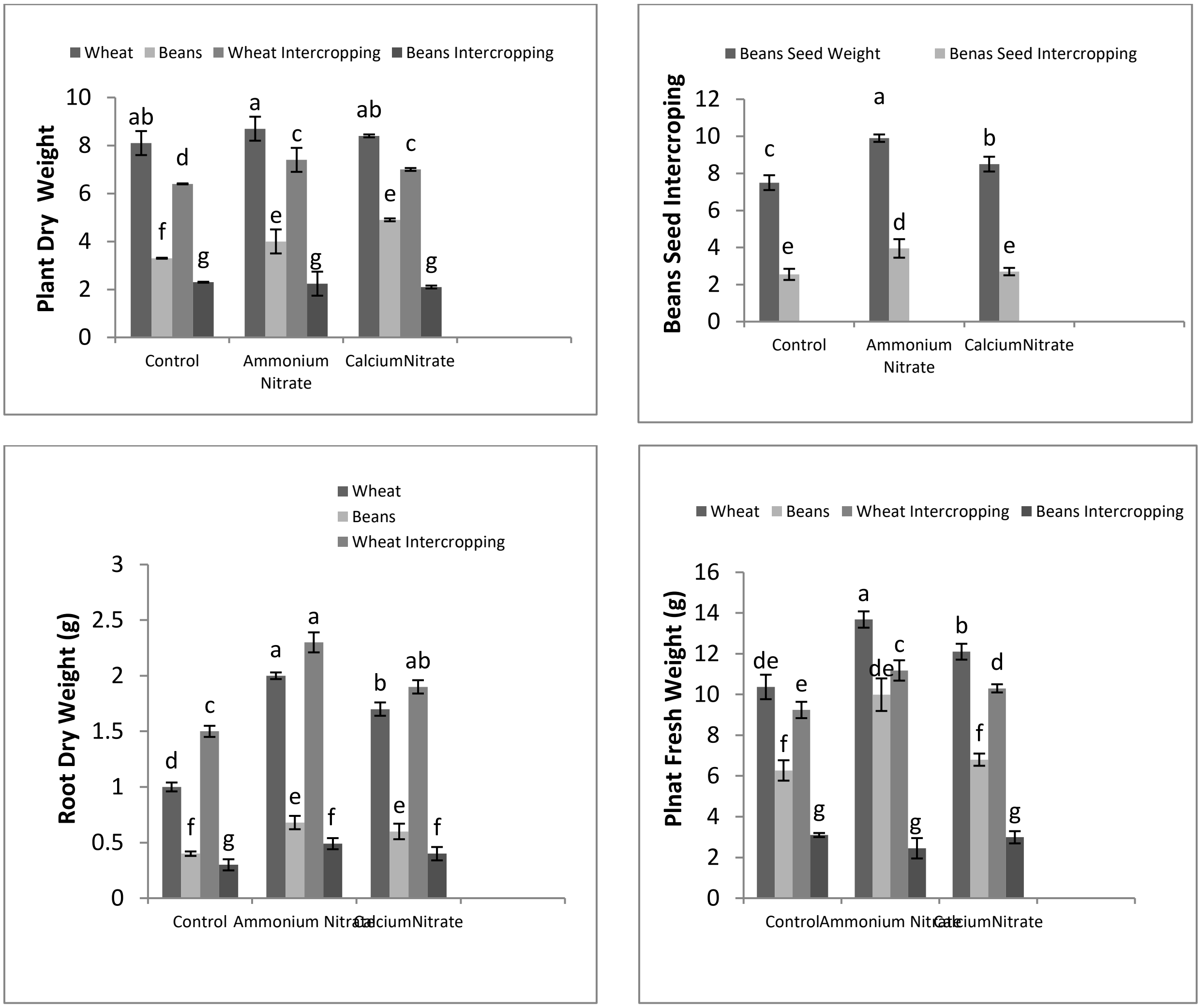


Figure 1. Effect of Nitrogen Source under individual and intercropping of wheat and beans on plant growth parameters. Data are represented as mean ± standard error (S.E.) (n=4).

Physiological parameters

Chlorophyll a contents

Chlorophyll contents were significantly higher in wheat (62 + 0.8) under ammonium nitrate application when grown alone, while wheat had decreased chlorophyll contents (45 ± 0.6) under calcium nitrate application. Maximum chlorophyll contents in intercropped wheat were observed (54 ± 0.5) under ammonium nitrate application relative to control (43 ± 0.5), and other sources of N. Beans had no significant effect on chlorophyll contents when grown alone. In contrast, intercropped beans had increased chlorophyll contents a by application of ammonium sulfate. Wheat had maximum chlorophyll contents when grown alone.

Carotenoid contents were significantly higher in wheat (53 + 0.5) under ammonium nitrate application when grown alone, while wheat had decreased carotenoid contents (43 ± 0.06) under calcium nitrate application. Maximum carotenoid contents in intercropped wheat were observed (48 + 0.5) under ammonium nitrate application relative to control (42 +0.31), and other sources of N. Beans had no significant effect on carotenoid contents when grown alone. In contrast, intercropped beans had increased carotenoid contents by application of ammonium sulfate. Wheat had maximum carotenoid contents when grown alone.

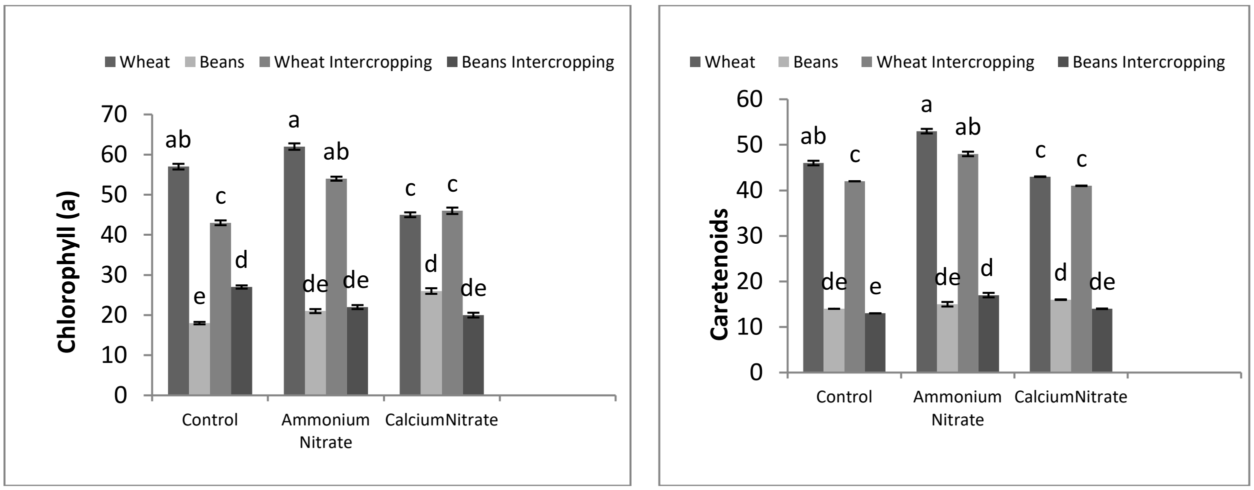


Figure 2. Effect of different sources of N under individual as well as intercropping of wheat and bean on Chlorophyll content. Data represented as mean ± standard error (S.E.) (n=4)

Chemical parameters

The maximum N contents in shoots (1.7±0.09%) were observed in intercropped wheat by application of ammonium nitrate compared to control (1.3±0.06%) and calcium nitrate. Beans shoots had maximum N contents (1.32 ±0.09%) under ammonium nitrate application relative to control (1.19 ±0.02%) and other N sources. Wheat shoots have no significant impact on Ammonium nitrate when grown separately. N contents increased in intercropped wheat under ammonium nitrate, but there was no significant impact of N sources on wheat shoots when grown separately.

Wheat grains had the highest N content in intercropping (2.77 + 0.09%) under ammonium nitrate application relative to the control (2.3 + 0.02%) and calcium nitrate. Beans intercropped grains contained the highest N content (2.57 + 0.003%) when grown alone with ammonium nitrate application as an N source relative to the control and calcium nitrate. The Lowest N contents in wheat grains were observed under calcium nitrate application compared to the control (2.07 ±0.12).

Intercropped wheat roots had the maximum N content (1.99+0.01%) relative to control (1.7+0.02%) and calcium nitrate under ammonium nitrate application in intercropping. There was a significant increase in N contents in bean roots observed (1.7±0.09%) when grown alone under ammonium nitrate. Wheat roots have no significant impact on N sources when grown alone. A significant increase in N contents was observed in intercropping under ammonium nitrate application.

The application of ammonium nitrate increased the potassium content of wheat shoots (0.79+0.03%) compared to the control (0.58+0.01%) and calcium nitrate. Bean shoots also contained the maximum potassium content (0.87±0.05%) with the application of ammonium nitrate compared to the control (0.85±0.02%). Potassium contents increased in wheat intercropping (1.01±0.03%) with the application of calcium nitrate.

The maximum potassium percentage in wheat grains (0.29±0.003%) was observed with the application of ammonium nitrate compared to control (0.265±0.01%). Beans contain maximum potassium percentage (0.298±0.01%) in grains with the application of calcium nitrate compared to control (0.259±0.02%). In the intercropping of wheat, the maximum potassium percentage (0.276+0.03%) was recorded with the application of ammonium nitrate as a nitrogen source compared to the control (0.249±0.03%). By comparing potassium contents in wheat, the maximum potassium percentage of beans intercropping was observed in wheat grown separately.

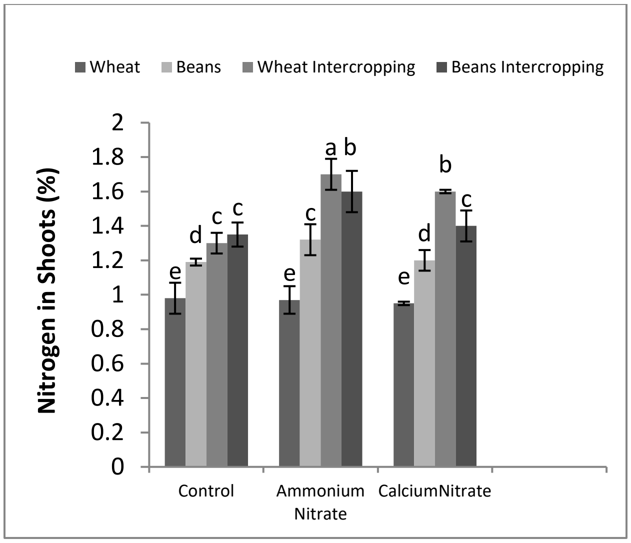
Potassium contents in wheat roots increased significantly (0.53+0.03%) with the application of ammonium nitrate as a source of nitrogen relative to the control (0.453+0.01%). Bean roots had maximum potassium content (0.50+0.01%) with the application of calcium nitrate compared to the control (0.41+0.02%). Beans intercropping had a higher potassium percentage (0.54±0.03%) with the application of calcium nitrate.

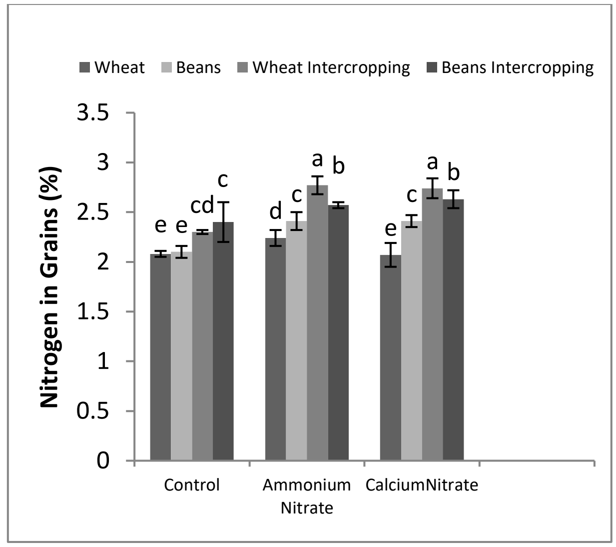
Phosphorus contents in shoots increased significantly (0.0196±0.0002%) in wheat intercropping by application of ammonium nitrate compared to wheat (0.0122+ 0.0002%) and beans (0.0124+ 0.0003%). By application of calcium nitrate, P contents in intercropping wheat were (0.0172+0.0012%) compared to wheat (0.01±0.0005%) and bean (0.0128±0.0001%), respectively. A similar trend was observed in treatment where ammonium nitrate was applied.

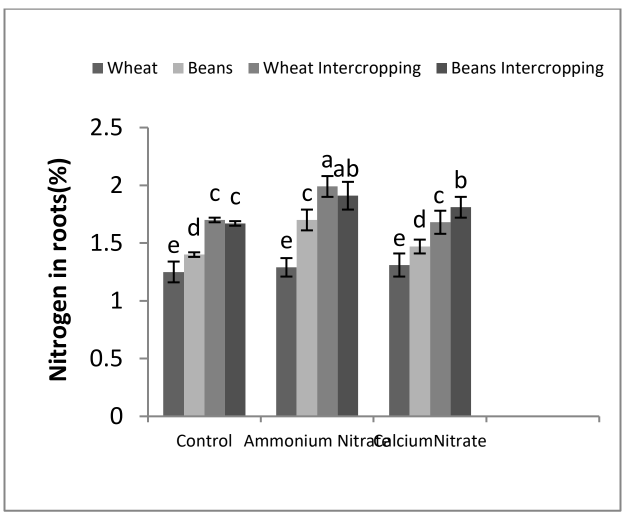
Phosphorus content increased significantly in grains of beans intercropping (0.0184±0.002%), where ammonium nitrate was applied as compared to wheat (0.014±0.001%) and beans (0.016±0.0003%), respectively. By the application of calcium nitrate, P content increased significantly in bean intercropping (0.0199 ±0.002%) as compared to wheat (0.015 and 0.002 %) and bean (0.017 ±0.0001 %). In bean grains, P content increased significantly (0.016±0.0003%), whereas ammonium nitrate was applied, whereas wheat content increased significantly (0.014±0.001%).

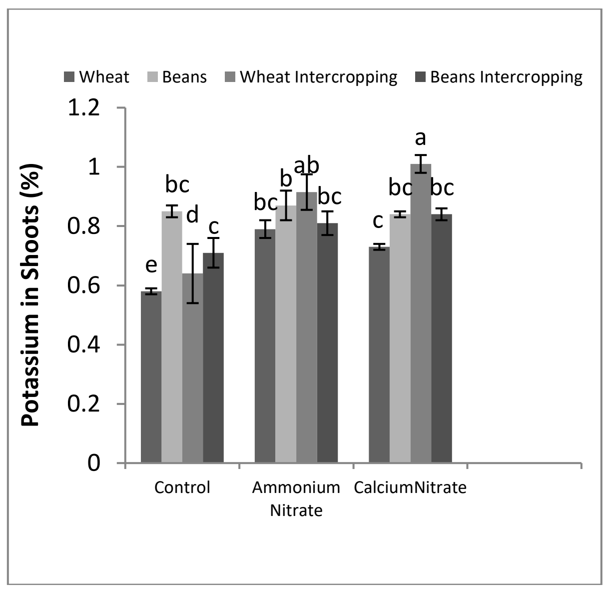
Wheat roots have higher phosphorus contents (0.0157±0.0002%) by the application of ammonium nitrate as a source of nitrogen compared to bean and wheat intercropping (0.0135 and 0.0156%), respectively. In intercropping, P contents significantly increased (0.0191± 0.0002%), where the applied source was calcium nitrate, compared to wheat and bean (0.017 and

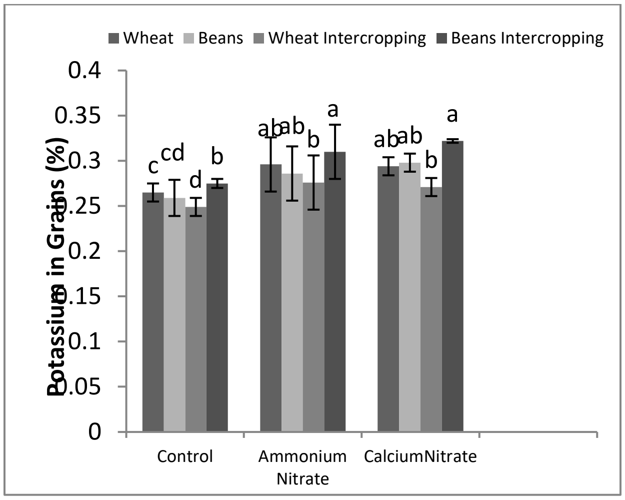
0.0159%), respectively. Maximum P content in roots was observed in wheat bean intercropping (0.0191 ± 0.0002%) where calcium nitrate was applied as compared to control and other treatments.

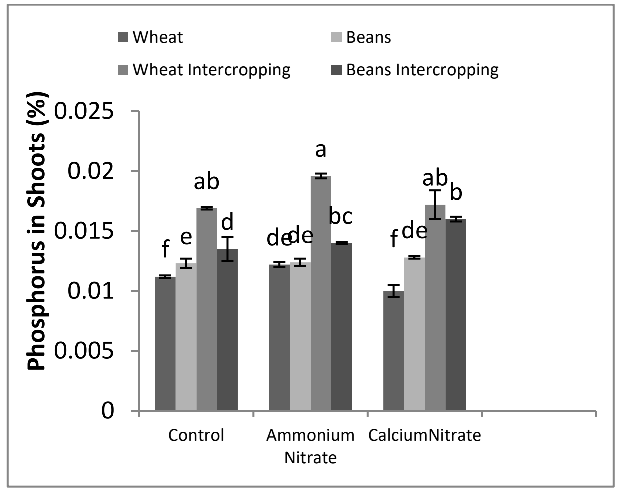


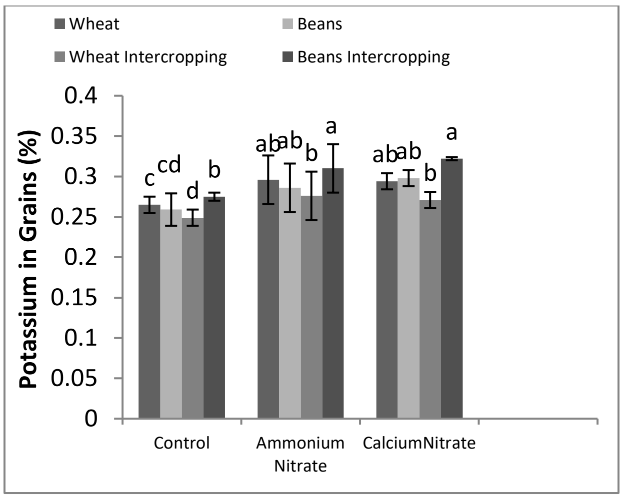


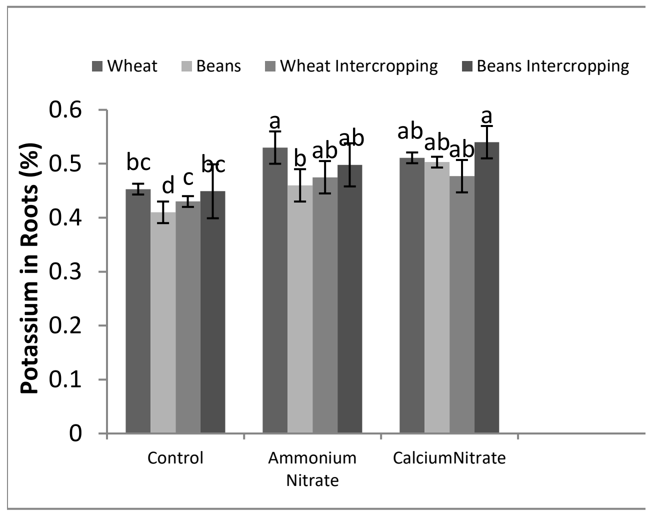


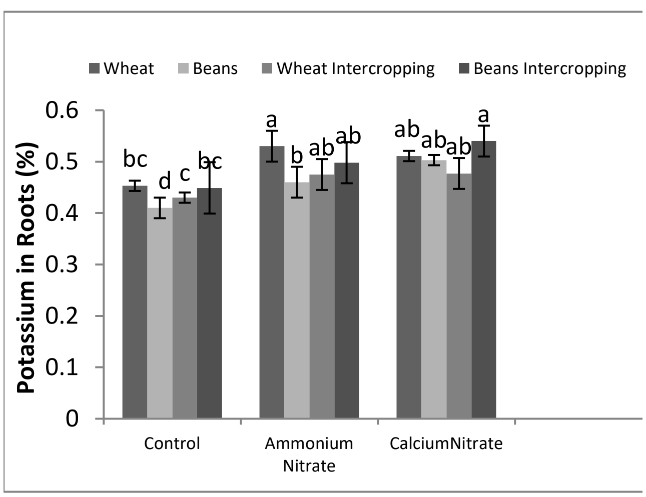



Wheat
Beans
Wheat Intercropping
Beans Intercropping
Potassium in Grains (%)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
c cd d b
ab ab b a
ab ab b a
Control
Ammonium Nitrate
CalciumNitrate


Wheat
Beans
Wheat Intercropping
Beans Intercropping
Phosphorus in Shoots (%)
0.025
0.02
0.015
0.01
0.005
0
f e ab d
de de a bc
f de ab b
Control
Ammonium Nitrate
CalciumNitrate


Wheat
Beans
Wheat Intercropping
Beans Intercropping
Potassium in Grains (%)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
c cd d b
ab ab b a
ab ab b a
Control
Ammonium Nitrate
CalciumNitrate


Wheat
Beans
Wheat Intercropping
Beans Intercropping
Potassium in Roots (%)
0.6
0.5
0.4
0.3
0.2
0.1
0
bc d c bc
a b ab ab
ab ab ab a
Control
Ammonium Nitrate
CalciumNitrate


Wheat
Beans
Wheat Intercropping
Beans Intercropping
Potassium in Roots (%)
0.6
0.5
0.4
0.3
0.2
0.1
0
bc d c bc
a b ab ab
ab ab ab a
Control
Ammonium Nitrate
CalciumNitrate

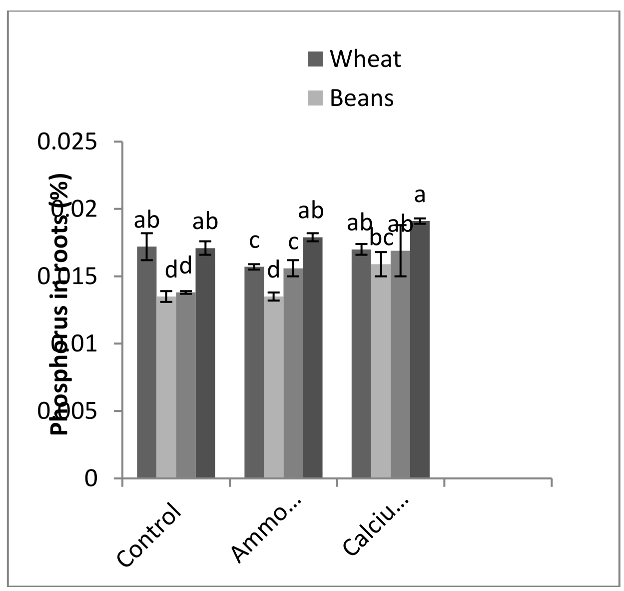

Wheat
Beans
Phosphorus in roots (%)
0.025
0.02
0.015
0.01
0.005
0
ab d d ab
c d c ab
ab bc ab a
Control
Ammo...
Calciu...

Figure 3. The effect of different sources of N under individual and intercropping of wheat and bean on chemical parameters. Data represented as mean ± standard error (S.E.) (n=4)

Discussion

Plant growth parameters

Nitrogen application by using different sources has a significant impact on wheat-bean biomass production. In wheat, maximum biomass was observed, and nitrogen was applied in the form of ammonium nitrate. Nitrogen is a basic need of every plant, and it is available in two forms (NO_3^{-1} and NH_4^+). In the current study, the maximum biomass production is observed under ammonium nitrate application. Ammonium has an antagonistic effect with cationic nutrients like K and Ca, which limits the availability of cationic nutrients, which results in low biomass production of the wheat crop because all essential nutrients are equally important in crop growth and production. Our results are in line with (Kismanyoky & Lehoczky, 2007), who observed the positive effect of nitrogen in nitrate form on wheat biomass production.

Wheat had a maximum shoot and roots fresh and dry weight when wheat was grown alone under ammonium nitrate application. Plants uptake nitrogen in two forms: ammonium and nitrate. Under ammonium nitrate application, nitrogen was available to plants in two forms. That is why the nitrogen concentration was higher under ammonium nitrate application as compared to other nitrogen sources. By comparing wheat and bean relation in intercropping, maximum plant biomass, grains, and root weight was present in wheat relative to chickpea because intercropping has a positive effect on wheat root and shoot weight while chickpea has an inhibitory effect due to the allelopathic effects of wheat root exudates(Rizvi *et al.*, 1992; Bezuidenhout & Laing, 2006). Cereals are more efficient in cereal–legume intercropping for obtaining better root structure and growth (Gill *et al.*, 2009; Ullah et al., 2024).

Plant height increased in intercropped wheat compared to wheat grown separately under ammonium nitrate application. Our results are supported by the findings of (Nargis et al., 2004 Ullah, 2007; and Das et al., 2011), who reported an increase in plant height in wheat intercropped with beans because in intercropping chickpea plants fix nitrogen to the soil, and it easily available for the wheat plant. Cereals take N in nitrate form while beans can fix N, so they have no competition for nutrients, and Wheat easily takes up N, but wheat grown separately has greater competition for nutrients and light(Mandal *et al.*, 1985; Das *et al.*, 2011).

An increase in spike length (11.5cm) was observed intercropping relative to wheat grown separately (12cm) under ammonium nitrate application. Our results are in accordance with the findings of Malik and Aziz (2002), who reported that spike length in wheat increased under intercropping relative to wheat grown separately.

Wheat yield increased significantly under ammonium sulfate application. This increase might be due to the fact that ammonium sulfate contains 24% S, which might decrease the pH of calcareous soil. Our soils are alkaline(Ummer et al., 2023; Waseem et al., 2023). By applying ammonium sulfate, pH decreases, and the availability of micronutrients increases (Ozturk, 2010). For this reason, ammonium sulfate has a high NUE.

Chlorophyll contents (SPAD value) were observed to be the maximum in wheat grown separately relative to chickpea and intercropping under ammonium nitrate application. This increase in chlorophyll contents is due to the availability of N in both ammonium and nitrate forms. N is the structural component of most of the protein that influences the contents of chlorophyll and chloroplast (Fatima et al., 2024; Haidri et al., 2024). Chlorophyll contents increased with increasing trends of nitrogen supply, which also increased photosynthetic activity (Loreto *et al.*, 2004).

Plant nutrient contents

There was a significant increase in N contents of intercropped wheat and bean grains relative to wheat, and bean shoots and roots grew separately under ammonium nitrate. The increase in N contents in grains may be due to the mobilization of nutrients to grain at grain filling stage(Arduini *et al.*, 2006).wheat and chickpea intercropping under ammonium nitrate application might have sufficient availability of N to utilize for growth and easily translocate to grain(Hauggaard-Nielsen *et al.*, 2001b; Das *et al.*, 2011). by application of ammonium nitrate, there is an extra availability of S that reduces the pH of calcareous soil, and there is easy uptake of micronutrients and translocation of nutrients towards grain at the grain filling stage (Shah, 2010). Our results are supported by the findings of(Zhang & Li, 2003; and Iqbal et al., 2013), who observed that during the intercropping system, N contents were highest in both legume and non-legume grains due to biological nitrogen fixation and a significant reduction in nitrogen losses.

N contents in roots were observed to be the maximum in intercropping under ammonium nitrate application. This increase in N contents might be because, during cereal legumes intercropping, cereal crops facilitate legumes for nodule formation and growth(Santalla *et al.*, 2001). This increase in nodulation may facilitate N contents in the roots of legumes in intercropping.

K uptake

This data shows that the maximum potassium uptake in grains and roots was observed under calcium nitrate application. NH_4 has an antagonistic effect on potassium(Li *et al.*, 2014). The other sources provide nitrogen in the form of ammonium, which competes with potassium and reduces its uptake. Plant roots absorb nutrients from the soil solution and transport them to other parts of the plant. Bean is a leguminous crop that fixes nitrogen from the air in the form of ammonium. Ammonium added from double resources causes a reduction in the uptake of potassium.

P uptake

The bioavailability of phosphorous is influenced by the pH of the soil (Bambara & Ndakidemi, 2010) and the type of exudates that are released by the roots of the legume plant (Raynaud *et al.*, 2008). Phosphorus is uptaken in the form of orthophosphates. These forms are highly sensitive to soil pH and have high reactivity, which results in a reduced availability of phosphorous by plants(Saharan & Nehra, 2011). In the current study, the maximum phosphorous concentration in roots is observed under Ammonium nitrate application. Ammonium nitrate can lead to a decrease in pH. Pakistani soils have high pH, which affects the availability of P. As the pH of soil lowers, the availability of P increases, which is why maximum phosphorous concentration calcium nitrate sources. Bean is a leguminous crop that has high microbial activity in the rhizosphere. High microbial activity in the rhizosphere lowers rhizosphere pH, which results in more uptake of P (Zhang *et al.*, 2001).

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