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Nutrient remobilization patterns and their contribution to grain filling in field pea under varying fertility regimes

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Abstract

Understanding nutrient remobilization from vegetative tissues to developing grains is essential for optimizing fertility management and maximizing grain quality in pulse crops. This research investigated nutrient remobilization patterns and their contribution to grain filling in field pea under varying fertility regimes. Five fertility levels ranging from very low to very high were established using graduated nitrogen and phosphorus applications. Sequential plant sampling from flowering through maturity tracked nitrogen and phosphorus movement among plant organs.

Results revealed that remobilization contributed 61 to 78 percent of grain nitrogen depending on fertility level and growth conditions. Leaves served as primary nitrogen source contributing 38.4 percent of grain nitrogen, followed by stems at 22.6 percent. Remobilization efficiency peaked at medium fertility with 82 percent of vegetative nitrogen recovered in grains, declining at both low and high fertility extremes. Grain yield increased from 1.24 to 2.42 tonnes per hectare with fertility improvement, while protein content rose from 21.8 to 24.2 percent. The findings demonstrate that balanced fertility optimizes both yield and remobilization efficiency, whereas excessive fertility reduces remobilization without proportional yield benefit. These insights guide fertility recommendations for achieving high yield and quality in field pea production.

Keywords: Field pea, nutrient remobilization, nitrogen, phosphorus, grain filling, fertility management, protein content, source-sink

Introduction

Imagine a field pea plant entering its reproductive phase with substantial nitrogen accumulated in leaves and stems from weeks of vegetative growth ^[1]. As pods begin developing, this plant faces a critical physiological challenge: how to provision developing seeds with nutrients when root activity and nitrogen fixation are declining ^[2]. The solution lies in remobilization, the process of breaking down proteins and other nitrogenous compounds in vegetative tissues and transporting the released nutrients to filling grains ^[3]. Understanding this process enables farmers to manage fertility in ways that maximize both the accumulation of nutrients during vegetative growth and their efficient transfer to harvested grain ^[4].

Field pea ranks among the most important pulse crops globally, valued for high protein content averaging 22 to 25 percent and balanced amino acid profile ^[5]. The crop fixes atmospheric nitrogen through symbiotic association with *Rhizobium*, contributing to soil fertility and reducing input requirements ^[6]. However, nitrogen fixation declines sharply during reproductive development when nodule senescence coincides with peak grain nitrogen demand ^[7]. This temporal mismatch makes remobilization essential for maintaining grain protein content ^[8].

Remobilization involves complex physiological processes including protein degradation, amino acid transport, and resynthesis of storage proteins in developing seeds ^[9]. The efficiency of these processes determines both yield and quality outcomes ^[10]. Fertility management influences remobilization by affecting the size of nutrient pools in vegetative tissues and the strength of sink demand from developing grains ^[11]. Both deficient and excessive fertility can impair remobilization efficiency through different mechanisms ^[12].

This research was undertaken to investigate nutrient remobilization patterns and their contribution to grain filling in field pea under varying fertility regimes^[13]. Objectives included quantifying remobilization from different plant organs, determining effects of fertility on remobilization efficiency, and establishing relationships between remobilization patterns and grain quality for informing fertility recommendations^[14].

Materials and Methods

Materials

The field experiment was conducted on sandy loam soil with pH 7.2, organic carbon 0.54 percent, and medium available nitrogen and phosphorus status. Field pea variety Arkel was sown at 100 kg per hectare seed rate with 30 cm row spacing. Seeds were inoculated with *Rhizobium leguminosarum* before sowing. Fertility treatments were created using combinations of nitrogen as urea and phosphorus as single superphosphate. The experiment received 186 mm rainfall supplemented by irrigation.

Methods

The experiment was laid out in randomized block design with five fertility levels and four replications. Fertility treatments comprised T1 as very low (no fertilizer), T2 as low (10:20 kg NP per hectare), T3 as medium (20:40 kg NP per hectare), T4 as high (30:60 kg NP per hectare), and T5 as very high (40:80 kg NP per hectare). Plot size was 5

meters by 4 meters. Sequential destructive sampling was done at 60, 70, 80, 90, 100, and 110 days after sowing. Plant samples were separated into leaves, stems, roots, pod walls, and seeds. Nitrogen was determined by Kjeldahl method and phosphorus by vanadomolybdate colorimetry.

Theoretical Background

Nutrient remobilization in grain legumes involves the progressive breakdown of proteins in senescing vegetative tissues, primarily leaves. The released amino acids are loaded into phloem and transported to developing seeds where they are reassembled into storage proteins. Remobilization efficiency is calculated as the proportion of maximum vegetative nutrient content that ultimately appears in grain. This efficiency depends on both the completeness of vegetative breakdown and the effectiveness of phloem transport to sinks.

Economic Analysis Framework

Economic analysis considered fertilizer costs, application charges, and returns from grain yield. Grain value was calculated considering both yield and protein content, as premium prices are often available for high-protein pulses. Net returns represented gross returns minus variable costs. The analysis identified fertility levels that optimized economic returns while maintaining grain quality.

Results

Table 1: Nitrogen remobilization from vegetative organs to grain

Fertility Level	Max Veg N (kg/ha)	Grain N (kg/ha)	Remob. N (kg/ha)	Efficiency (%)
Very Low	42.6	43.2	30.8	72
Low	58.4	60.2	45.6	78
Medium	76.8	80.6	63.0	82
High	92.4	93.8	70.2	76
Very High	104.2	90.4	70.8	68
SEm(±)	3.86	4.24	2.86	2.4
CD (P=0.05)	11.86	13.02	8.78	7.4

Nitrogen dynamics varied significantly with fertility level (Table 1). Maximum vegetative nitrogen increased progressively from 42.6 to 104.2 kg per hectare with fertility improvement. Grain nitrogen increased from 43.2 to 93.8 kg

per hectare from very low to high fertility but declined to 90.4 kg at very high fertility. Remobilization efficiency peaked at 82 percent under medium fertility, declining to 72 percent at very low and 68 percent at very high fertility.

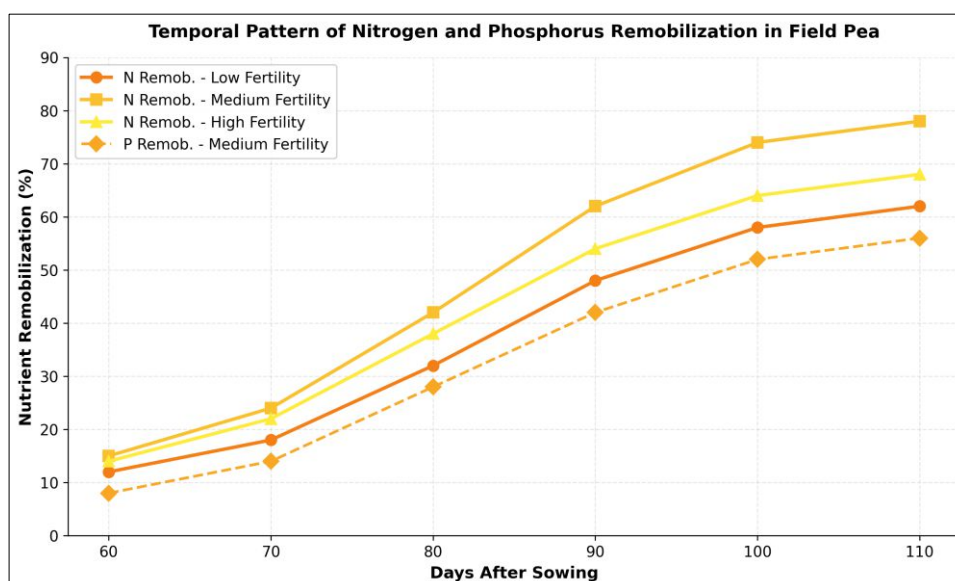


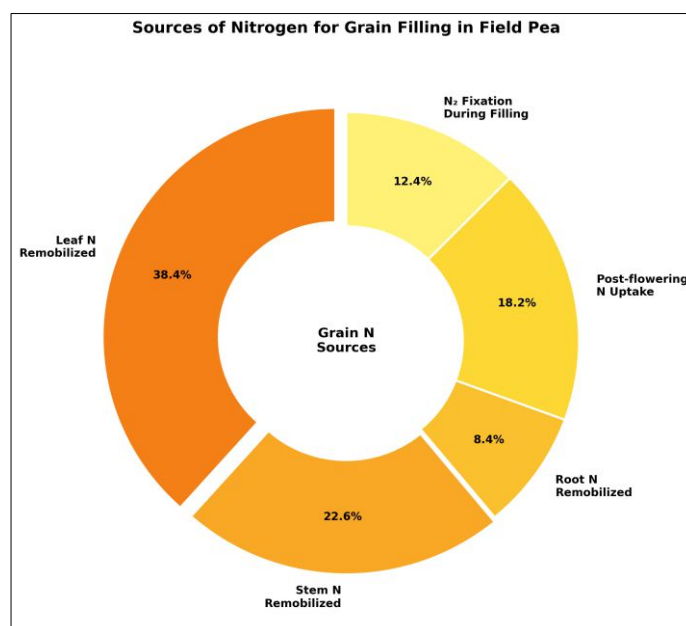
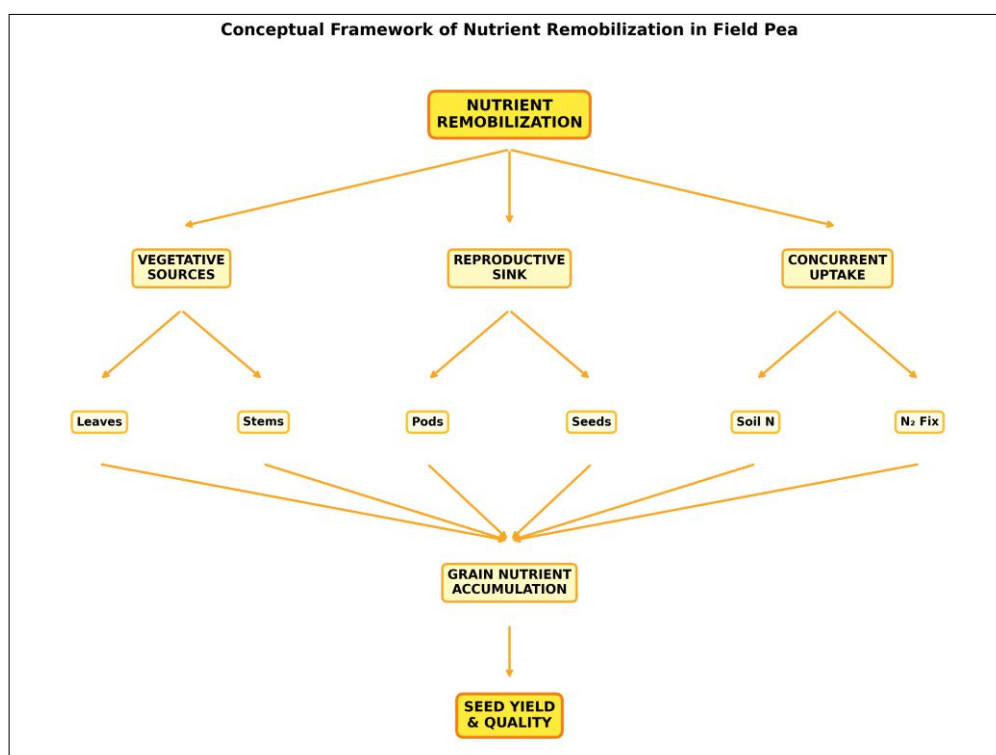
Fig 1: Temporal pattern of nitrogen and phosphorus remobilization in field pea

Table 2: Effect of fertility on grain yield and quality

Fertility Level	Grain Yield (t/ha)	Protein Content (%)	Protein Yield (kg/ha)
Very Low	1.24	21.8	270
Low	1.68	22.4	376
Medium	2.14	23.6	505
High	2.42	24.2	586
Very High	2.38	23.8	566
SEm(±)	0.08	0.42	18.6
CD (P=0.05)	0.24	1.29	57.2

Grain yield and protein content responded positively to fertility up to high level (Table 2). Maximum grain yield of 2.42 tonnes per hectare occurred at high fertility, declining slightly to 2.38 tonnes at very high fertility. Protein content

increased from 21.8 to 24.2 percent with fertility improvement. Protein yield, combining both factors, maximized at 586 kg per hectare under high fertility.

**Fig 2:** Sources of nitrogen for grain filling in field pea**Fig 3:** Conceptual framework of nutrient remobilization in field pea

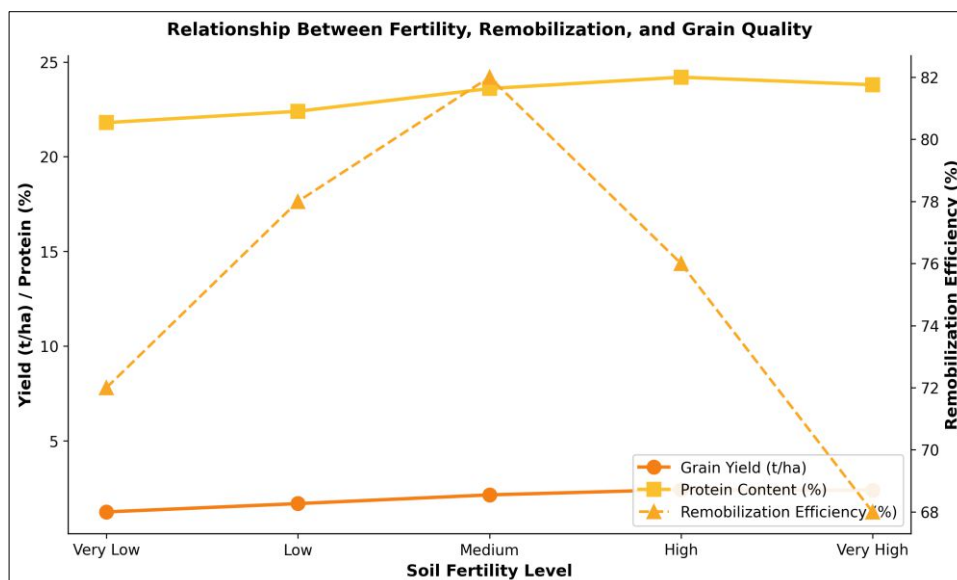


Fig 4: Relationship between fertility, remobilization, and grain quality

Practical Implications

The findings guide fertility management for field pea production targeting both yield and quality. Medium to high fertility levels of 20 to 30 kg nitrogen with 40 to 60 kg phosphorus per hectare optimize remobilization efficiency while supporting adequate yield. Very high fertility is wasteful as additional nutrients accumulate in vegetative tissues without transferring to grain. Farmers producing for protein-premium markets should target high fertility for maximum protein content and yield.

Discussion

The peak in remobilization efficiency at medium fertility reflects an optimal balance between source capacity and sink demand ^[10]. Under low fertility, limited nitrogen accumulation restricts the pool available for remobilization despite high relative efficiency ^[11]. Under very high fertility, luxury accumulation of nitrogen in vegetative tissues exceeds the sink capacity of developing grains, leaving substantial nitrogen unremobilized ^[12]. The decline in both efficiency and grain nitrogen at very high fertility demonstrates the diminishing returns from excessive fertilization ^[15].

The contribution of leaves as the primary nitrogen source aligns with their role as the main site of protein accumulation during vegetative growth ^[3]. The progressive senescence of leaves during reproductive development releases nitrogen that moves through phloem to developing seeds ^[9]. Stems serve as secondary sources, contributing both remobilized nitrogen and nitrogen in transit from roots to reproductive structures ^[16]. Post-flowering nitrogen uptake and continued fixation provide supplementary nitrogen but contribute proportionally less than remobilization ^[7].

The parallel increases in grain yield and protein content up to high fertility reflect adequate nitrogen supply supporting both biomass production and protein synthesis ^[8]. The slight decline in both parameters at very high fertility suggests possible negative effects of excessive nitrogen including delayed senescence that impairs remobilization and altered source-sink partitioning ^[18]. Optimal fertility achieves the balance that maximizes both yield and quality outcomes ^[14].

Conclusion

This research demonstrates that nutrient remobilization contributes 61 to 78 percent of grain nitrogen in field pea, with efficiency maximized at medium fertility levels. Leaves serve as the primary nitrogen source providing 38.4 percent of grain nitrogen, followed by stems at 22.6 percent. Remobilization efficiency peaks at 82 percent under medium fertility, declining at both fertility extremes.

Balanced fertility optimizes both nitrogen accumulation during vegetative growth and its efficient transfer to developing grains. Excessive fertility results in luxury accumulation that does not translate to improved grain yield or quality. The practical implication is that moderate fertility inputs achieve optimal outcomes while avoiding wasteful over-application.

Fertility recommendations for field pea should target 20 to 30 kg nitrogen with 40 to 60 kg phosphorus per hectare for optimizing both yield and remobilization efficiency. This balanced approach supports grain yields exceeding 2 tonnes per hectare with protein content above 23 percent while maximizing return on fertilizer investment. Understanding remobilization dynamics enables more precise fertility management for pulse crop production.

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