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Influence of Nitrogen and Phosphorus Levels on Yield and Chemical Composition of Soybean to Improve Their Efficiency in Animal Feed

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Abstract

A field experiment was conducted to evaluate the effects of nitrogen and phosphate fertilization levels on growth, yield components, and chemical composition of soybean under desert conditions to enhance its value in animal feed. Two trials were conducted during the 2022 and 2023 summer growing seasons at the experimental farm of the Environmental Studies and Research Institute, University of Sadat City, Menofiya Governorate, Egypt. A split-plot arrangement in a randomized complete block design with three replications was used. Main plots received nitrogen at 20, 30 and 40 kg N fed^{-1}, while sub-plots received phosphate at 30, 40, and 50 kg P_2O_5 fed^{-1}. Applying 40 kg N fed^{-1} significantly improved growth rate, chlorophyll content and leaf number, while phosphate affected only plant height at 50 kg P_2O_5 fed^{-1}. Nitrogen influenced most yield traits except seeds per pod, harvest index and shelling percentage. The highest pod number per plant was recorded with 30 kg N fed^{-1}, while 40 kg N fed^{-1} increased 100-seed weight, pod weight, seed number and total yield per fed. Phosphate at 50 kg P_2O_5 fed^{-1} also improved yield traits. Interaction between nitrogen and phosphate levels was significant for most traits, with 40 kg N fed^{-1} and 50 kg P_2O_5 fed^{-1} treatment producing the highest seed yield. Nitrogen significantly affected protein and oil content; 40 kg N fed^{-1} gave the highest protein, while 20 kg N fed^{-1} gave the highest oil. Phosphate influenced protein, oil, and fiber; 30 kg P_2O_5 fed^{-1} gave the highest protein, while 50 kg P_2O_5 fed^{-1} increased oil and fiber. The combined treatment enhanced soybean yield and quality under desert conditions.

Keywords: Nitrogen and phosphorus levels, Seed yield, chemical composition of soybean and animal feed.

Introduction

Soybean meal is a key ingredient in poultry nutrition, recognized as the primary protein source in commercial poultry diets. Its high protein content, which typically ranges from 44% to 48%, combined with an excellent amino acid profile, makes it essential for supporting optimal growth, egg production, and overall health in poultry (**Yang *et al.*, 2023**). The rich nutritional value of soybean meal helps meet the dietary requirements of poultry and contributes significantly to their production efficiency (**Koutsou *et al.*, 2022**).

The total soybean production in Egypt for the marketing year 2023/2024 is estimated at 29 thousand metric tons, cultivated over 13 thousand hectares, with an average yield of approximately 2.23 MT/ha (**United States Department of Agriculture, Foreign Agricultural Service, 2024**). One of the main advantages of soybean meal in poultry diets is its complementary role with corn. While corn is an excellent energy source, it lacks some essential amino acids, particularly lysine and methionine, which are crucial for poultry growth. Soybean meal compensates for this amino acid deficiency, ensuring a balanced and efficient feed formulation that supports poultry performance (**Diao *et al.,* 2023**).

Recent studies have highlighted the positive effects of incorporating soybean meal in poultry diets, including improved feed conversion ratios and better nutrient utilization. For example, the high digestibility of soybean meal allows poultry to efficiently absorb nutrients, which helps maximize growth potential and feed efficiency (**Xu *et al.,* 2021**). This makes it a valuable resource in poultry farming, particularly in intensive systems where feed efficiency is crucial (**Wu *et al.,* 2023**).

In addition, ongoing research has focused on enhancing the nutritional value of soybean meal by improving its protein and amino acid composition. Genetic advancements in soybean varieties, such as higher sulfur amino acid content, are expected to further enhance the productivity and sustainability of poultry production (**Zhang *et al.,* 2022**). These developments could play a pivotal role in meeting the increasing global demand for poultry products (**Sharma *et al.,* 2024**).

Providing nitrogen to soybean plants at the stage of peak seed development can help supplement internal nitrogen levels, potentially reducing early plant aging and contributing to improved seed yields (Freeborn et al., 2001). As a key macronutrient, nitrogen plays a vital role in promoting vegetative growth and the internal distribution of assimilates. It is a fundamental element in the synthesis of amino acids, proteins, chlorophyll, and various enzymes essential for photosynthesis and overall plant functioning. Moreover, nitrogen is involved in carbohydrate metabolism, enhances root system development, and supports the absorption of other nutrients. Given these functions, soybean has a substantial nitrogen demand during seed formation, and its productivity can be significantly influenced by nitrogen application following the flowering phase (Kinugasa et al., 2012).

Several studies have demonstrated the significant impact of nitrogen application on plant growth and productivity. Jahangir et al. (2009) reported that applying 40 kg N ha^{-1} resulted in the highest plant height and pod number per plant. Similarly, Sohrabi et al. (2012) observed a positive association between nitrogen availability and protein synthesis in plants. In the case of French beans, Lad et al. (2014) found that higher nitrogen (150 kg ha^{-1}) and phosphorus (75 kg ha^{-1}) inputs led to considerable increases in both grain and straw yields; however, they concluded that an economically optimal yield was achieved with 100 kg N and 50 kg P_2O_5 ha^{-1}. Córdova et al. (2020) also highlighted that nitrogen application rates up to 135 kg N ha^{-1} positively influenced soybean yield and yield components. They noted a 17% increase in seed and aboveground biomass dry weight compared to the no-nitrogen treatment. Furthermore, Wysokinski et al. (2024) found that varying nitrogen levels significantly affected the dry weights of roots, nodules, stems, seeds, and total plant biomass. Notably, seed yield was greater with 120 kg N ha^{-1} compared to the 180 kg N ha^{-1} application.

Phosphorus is a vital macronutrient involved in a wide range of physiological and biochemical functions in plants, especially in processes related to energy transfer, storage, and utilization (Epstein and Bloom, 2005). It ranks as the second most important nutrient after nitrogen for both plant growth and microbial activity in the soil. Efficient phosphorus uptake is essential for proper nodule formation in leguminous crops and plays a significant role in enhancing both yield quantity and crop quality (Anonymous, 2004). Moreover, phosphorus contributes to root system development and is a key component of phospholipids, phosphoproteins, and energy-related molecules such as ATP and ADP. It also facilitates early crop maturation, lowers grain moisture levels, and improves the overall quality of the harvested product (Malakooti, 2000). Ibrahim (2014) found that increasing phosphorus application up to 31 kg P_2O_5 per feddan led to progressive improvements in growth and yield traits, including number of branches and pods per plant, seed weight, plant height and both seed and straw yields.

Likewise, AL-Dawdi and Al-Jobouri (2014) demonstrated that higher phosphate application significantly enhanced pod number, seed weight, and seed yield. Al-Jobouri and Al-Dawdi (2015) observed similar improvements in branching and yield traits with 80 kg P_2O_5 ha^{-1} in Mosul and 40 kg P_2O_5 ha^{-1} in Tuzkhurmatu. Runia (2018) found that applying 25% more phosphorus than the recommended dose (P_3 level) led to the highest soybean yield (3613.00 kg ha^{-1}), along with improvements in plant height, branching, biomass, nodulation, pod and seed development, stover yield, shelling percentage, and harvest index.

In addition, Nget et al. (2022) emphasized that phosphorus demand is highest in soybean during pod and seed development stages, where over 60% of the absorbed phosphorus is allocated. Phosphorus is essential for photosynthesis, energy transfer, nutrient transport, carbohydrate metabolism, and biological nitrogen fixation. More recently, Amanullah and Yasir (2025) reported that the application of 90 kg P ha^{-1} resulted in the maximum grain yield (3222 kg ha^{-1}), as well as the highest protein (823 kg ha^{-1}) and oil yield (588 kg ha^{-1}).

Material and Methods

Field experiments

This research was carried out during the two consecutive summer seasons of 2022 and 2023 at the Experimental Farm of the Environmental Studies and Research Institute, Sadat City University, located in Sadat City, Menoufia Governorate. The study aimed to evaluate the impact of different nitrogen and phosphorus fertilization levels on the growth, yield, yield components, and chemical composition of soybean (Glycine max Merr.), with the goal of enhancing its technological properties for use in animal feed. The chemical and physical characteristics of the experimental soil are detailed in Table 1, while the properties of the irrigation water are shown in Table 2.

Treatments and experimental design

The experimental layout followed a split-plot design with three replications. Nitrogen fertilizer treatments (20, 30, and 40 kg N fed^{-1}) were allocated to the main plots, whereas phosphorus levels (30, 40, and 50 kg P_2O_5 fed^{-1}) were assigned to the sub-plots. Each plot measured 3.5 meters in length and 3 meters in width and consisted of five rows spaced 0.6 meters apart. Nitrogen was supplied in the form of ammonium nitrate (NH_4NO_3) containing 33.5% N, while phosphorus was applied as single superphosphate [$Ca(H_2PO_4)_2 \cdot H_2O$] containing 15.5% P_2O_5. Both fertilizers were applied in three equal portions, starting 21 days after sowing.

Table 1. Physical and chemical properties of the experimental soil samples collected during both seasons the study.

Soil physical properties													
Season	**Sand**			**Silt**			**Clay**		**Texture**				
2022 season	75.33			6.4			18.27		**Sandy Loam**				
2023 season	75.30			5.2			19.50		**Sandy Loam**				
Soil chemical analysis													
Season	**ECe (dsm^{-1})**	**PH**	**$CaCO_3$ (%)**	**meq/1**									
				Ca^{++}	**Mg^{+}**	**Na^{+}**	**K^{+}**	**$SO_4^{=}$**	**CO_3**	**HCO_3**	**CI**		
2022 season	**1.87**	7.5	**17.63**	**3.6**	**3.7**	**14.4**	**0.4**	**0.61**	**0.0**	**3.80**	**6.4**		
2023 season	**1.68**	7.4	**16.90**	**2.9**	**3.6**	**14.8**	**0.3**	**0.46**	**0.0**	**4.13**	**7.2**		
2023 season													

Table 2. Irrigation water properties of the experimental soil samples collected during both seasons the study.

Season	**pH**	**EC (dS/**	**Ca^{2+}**	**Mg^{2+} (meq/**	**Na^{+} (meq**	**K^{+} (meq**	**CO_3^{2-}**	**HCO_3^{-}**	**Cl^{-} (meq/**	**SO_4^{2-} (meq/**	**SAR**	**TDS (mg/**	**Fe (pp**	**Zn (pp**	**Mn (ppm)**	**Cu (ppm)**
2022 season	**7.98**	**1.26**	**4.20**	**2.60**	**6.50**	**0.20**	**0.00**	**4.00**	**7.00**	**2.50**	**3.50**	**896.00**	**0.11**	**0.18**	**<0.01**	**<0.01**
2023 season	**7.85**	**1.37**	**4.10**	**2.70**	**6.60**	**0.08**	**0.00**	**3.78**	**5.00**	**3.63**	**4.11**	**967.00**	**0.18**	**0.31**	**0.13**	**0.06**

Soybean seeds were planted at a depth of 5 cm with an intra-row spacing of 20 cm on June 20 in the first season and June 23 in the second season. All recommended agronomic practices for soybean cultivation in the region were properly implemented throughout the study period.

Data Collection

Plant samples were taken at 60 and 80 days after planting, subsequent to the application of fertilizers. Five plants were randomly selected from each plot for evaluation the dry weight to calculate the crop growth rate as following:

Crop growth rate (CGR) $mg/m^2.d^{-1}$,: $CGR = \frac{1}{A} \times \frac{W_2 - W_1}{T_2 - T_1}$

Where: A: Land area occupied by the plant sample cm^2 -W_2: Dry weight of the plant sample at time T_2 - W_1: weight of the plant sample at time T_1

Fully matured crop was harvested on Oct. 17 and 20, 120 days after planting for the two successive seasons, respectively.

Ten plants were harvested at random from each plot to record the following data:

Growth characteristics: crop growth rate (gm/day), chlorophyll (%), leaves number, plant height (cm) and number of branches.

Yield and it's components: No. pods plant^{-1}, weight of 100 seeds (gm), No. seeds pod^{-1}, harvest index (%), shelling percentage (%), weight of pods plant^{-1} (gm), No. seeds plant^{-1}, seed yield plant^{-1} (gm) and seed yield kg fed^{-1}.

Chemical Measurements: Protein and Oil in seeds (%): Nitrogen Percentage according to **A.O.A.C (2012)**, Oil in seeds (%) was determined by **A.O.A.C. (1975)**. Ash, crude fiber and carbohydrate in soybean seeds percentages according to **Dubois *et al*., (1956).**

Statistical analysis: A split-plot design with three replications was employed to conduct the experiment. The collected data were analyzed statistically using analysis of variance (ANOVA) in accordance with the method described by Snedecor and Cochran (1980). Prior to performing the combined analysis across seasons, a test for the homogeneity of error variances was conducted. The means were compared using the Least Significant Difference (LSD) test at the 5% level of significance.

Results and discussion

The effect of nitrogen, phosphate levels and their interaction on growth characters of soybean

Application of nitrogen fertilization levels had significant effects on all growth characters except number of branches per plant which was insignificant. Application of the highest level of nitrogen fertilizer (40 kg N fed^{-1}) led to produce the highest values of crop growth rate (3.45 gm/day), chlorophyll content (16.81%), plant height (79.06 cm) and number of leaves per plant (25.00). On the other hand, application of the lowest level of nitrogen fertilizer (20 kg N/fed) led to produce less values of crop growth rate (3.16 gm/day), chlorophyll content (15.53 %), plant height (74.72 cm) and the number of leaves per plant (22.22) are presented in Table 3. This is because nitrogen provides vital nutrients for chlorophyll, resulting in increased energy for development.

Enhanced photosynthesis boosts glucose production, allowing plants to produce more leaves and grow higher. As a result, increased photosynthetic ability and chlorophyll content improve light absorption and carbon fixation, resulting in increased biomass accumulation. This encourages better crop growth rate (CGR) and dry matter (DM) yields, as seen in nitrogen-treated soybeans. **Jahangir *et al.*, (2009), Sohrabi *et al.*, (2012**), **Lad *et al.*, (2014**) and **Wysokinski *et al.*, (2024**) mentioned that different nitrogen fertilizer application rates significantly influenced on growth characters of soybean plants.

Phosphate fertilization levels had insignificant effects on all growth characters except plant height which was significant. Application of the highest level of phosphate fertilizer (50 kg P_2O_5 fed^{-1}) led to produce the highest values of plant height (80.11 cm). While, application of the lowest level of phosphate fertilizer (30 kg P_2O_5 fed^{-1}) led to produce less values of plant height (72.56 cm) (Table 3). **Alabdalsayid and Al-Freeh (2021)** mentioned that phosphorus enhances root development and branching, improving nutrient uptake, which in turn supports overall growth.

The interaction between nitrogen and phosphorus fertilization showed significant effects on several growth parameters, with the exception of crop growth rate and chlorophyll content, which

Table 3. Effect of nitrogen and phosphate levels and their interaction on growth characters of soybean over two seasons

	Number of branches				**plant height (cm)**				**leaves number**				**Chlorophyll (%)**				**Crop growth rate (gm/day)**			
	N1	**N2**	**N3**	**Mean**	**N1**	**N2**	**N3**	**Mean**	**N1**	**N2**	**N3**	**Mean**	**N1**	**N2**	**N3**	**Mean**	**N1**	**N2**	**N3**	**Mean**
P1	3.42	2.75	3.50	**3.22**	14.79	16.26	16.08	**15.71**	16.67	21.67	25.67	**21.34**	74.67	72.67	70.33	**72.56**	2.45	2.78	2.72	**2.65**
P2	3.00	3.37	3.38	**3.25**	15.92	16.59	16.78	**16.43**	23.67	24.00	23.00	**23.56**	73.17	74.00	84.17	**77.11**	2.43	2.73	2.72	**2.63**
P3	3.07	3.38	3.47	**3.31**	15.88	16.82	17.56	**16.75**	26.33	22.00	26.33	**24.89**	76.33	81.33	82.67	**80.11**	2.78	2.70	2.88	**2.79**
Mean	**3.16**	**3.17**	**3.45**	**3.26**	**15.53**	**16.56**	**16.81**	**16.30**	**22.22**	**22.56**	**25.00**	**23.26**	**74.72**	**76.00**	**79.06**	**76.59**	**2.56**	**2.74**	**2.77**	**2.69**
L.S.D at 5% level																				
	N= 0.27 P=N.S NP=N.S				**N= 0.32 P=N.S NP= N.S**				**N= 0.62 P= N.S NP= 1.23**				**N= 3.26 P= 2.37 NP= 3.11**				**N=N.S P=N.S NP= 0.26**			

were not significantly affected according to the combined data (Table 3). The combination of 40 kg N/fed with 50 kg P_2O_5/fed, as well as 20 kg N/fed with 50 kg P_2O_5/fed, resulted in the highest recorded number of leaves (26.33). Moreover, the treatment combining 40 kg N/fed with 40 kg P_2O_5/fed produced the tallest plants, reaching an average height of 84.17 cm. Similarly, the combination of 40 kg N/fed with 50 kg P_2O_5/fed yielded the greatest number of branches per plant (2.88). These findings are in agreement with Begum et al. (2015), who reported that applying 25 kg of nitrogen along with 54 kg of phosphorus per hectare significantly improved both plant height and number of branches. Likewise, Tekulu et al. (2020) found that the combined application of nitrogen and phosphorus fertilizers significantly enhanced plant height in groundnut.

The effect of nitrogen, phosphate levels and their interaction on yield and its components of soybean

Nitrogen fertilization levels had significant effects on some yield and its components except number of seeds of soybean per pod, harvest index and shelling percentage which was insignificant are presented in Table 4. Application of nitrogen fertilizer at the rate (30 kg N fed^{-1}) led to produce the highest values of number of pods of soybean per plant at harvest (71.78). As well as, application of the highest level of nitrogen fertilizer (40 kg N fed^{-1}) led to produce the highest values of weight of 100 seeds (13.51 gm), weight of pods of soybean per plant (44.00 gm), number of seeds plant^{-1} (215 seed), seed yield plant^{-1} (29.31 gm) and seed yield fed (1172.3 kg), the escalation in nitrogen fertilization rates applied to soybean seed yield fed^{-1} demonstrates a notable increase.

Specifically, an increase from 20 kg N fed^{-1} to 30 kg N fed^{-1} resulted in an enhancement of 11.57%, while an increase from 20 kg N fed^{-1} to 40 kg N fed^{-1} yielded a 17.74% improvement. While, application of the lowest level of nitrogen fertilizer (20 kg N fed^{-1}) led to produce less values of number of pods plant^{-1} at harvest (69.05 pod), weight of pods plant^{-1} (43.50 gm), number of seeds plant^{-1} (185.27 seed), seed yield plant^{-1} (24.90 gm) and seed yield fed^{-1} (995.9 kg). In addition, application of level of nitrogen fertilizer (30 kg N fed^{-1}) led to produce less values of weight of 100 seeds (12.91 gm). In this concern, nitrogen stimulates vegetative growth, resulting in more nodes and flowers, which in turn produce more pods and seeds.

Improved photosynthesis and food availability (due to nitrogen's function in chlorophyll and enzymes) promote seed production and filling, resulting in higher pod and seed weight. However, **Xu *et al.*, (2024**) associate seed production with pod quantity and seed number. **Chiluwal *et al.*, (2022) and Poudel *et al.*, (2024**) explain seed weight in terms of nutritional availability, which nitrogen may alter via increasing photosynthesis. These data are in agreement with (**Begum *et al.*, 2015**, **Ahmed *et al.*, 2018 and Abdel-Wahab *et al.*, 2024**) showed that the mineral N fertilizer rates had a significant effect on 100-seed weight , pod weight/plant, seed yield/plant. and seed yield/ha. The application nitrogen resulted in the highest observed values for number of pods per plant. Application of nitrogen, significantly increased number of seeds per plant.

Phosphate fertilization levels had significant effects on all yield and its components are presented in Table 4. Application of the highest level of phosphate fertilizer (50 kg P_2O_5 fed^{-1}) led to produce the highest values of number of pods plant^{-1} (74.17 pod), weight of 100 seeds (13.76 gm), number of seeds pod^{-1} (3.37 seed), harvest index (32.83%), shelling percentage (0.79%), weight of pods plant^{-1} (44.17 gm), number of seeds plant^{-1} (251.48 seed), seed yield plant (34.60 gm), and seed yield fed (1384.0 kg), the escalation in phosphate fertilization rates applied to soybean seed yield per feddan demonstrates a notable increase.

Specifically, an increase from 30 kg P_2O_5 fed^{-1} to 40 kg P_2O_5 fed^{-1} resulted in an enhancement of 26.01%, while an increase from 30 kg P_2O_5 fed^{-1} to 50 kg P_2O_5 fed^{-1} yielded a 65.05% improvement. While, application of the lowest level of phosphate fertilizer (30 kg P_2O_5 fed^{-1}) led to produce less values of number of pods plant (68.83 pod), weight of 100 seeds (12.55 gm), number of seeds pod (2.43 seed), harvest index (29.64%), shelling percentage (0.49%), weight of pods plant (43.50 gm), number of seeds plant (167.39 seed), seed yield plant (20.96 gm), and seed yield fed (838.5 kg). This result may be due to phosphorus fertilization plays a crucial role in enhancing root development and branching, thereby improving nutrient uptake and supporting overall plant growth (**Alabdalsayid and Al-Freeh 2021**).

The highest seed output observed at 50 kg P_2O_5/fed may result from the combined effects of increased seeds per pod, seeds per plant, and total seed weight per plant. The present results support the reports of **(Ibrahim 2014**) revealed that increasing phosphorus fertilization rate up to 31 kg P_2O_5/fad, increased gradually seed yield (ton / fad) and 100–seed weight and seed yield and number of pods and number of seeds per plant. These result were inharmony with those obtained by **Al-Jobouri and AL-Dawdi (2015**), **Runia 2018** and **Amanullah and Yasir (2025)**.

Interaction between nitrogen and phosphate had significant effects on some yield and its components except number of seeds per pod which was insignificant (Table 4). Combine (30 kg N fed^{-1} with 50 kg P_2O_5 fed^{-1}) led to produce the highest values of number of pods plant (76.00 pod), combine (20 kg N fed^{-1} with 40 kg P_2O_5 fed^{-1}) led to produce the highest values of weight of 100 seeds (14.45 gm), combine (30 kg N fed^{-1} with 40 kg P_2O_5 fed^{-1}) led to produce the highest values of harvest index (35.53%), weight of pods plant (45.83 gm), combine (40 kg N fed^{-1} with 50 kg P_2O_5 fed^{-1}) led to produce the highest values of shelling percentage (0.90%), number of seeds plant (287.55 seed), seed yield plant (40.75 gm) and seed yield fed (1629.8 kg). Nitrogen prolongs the reproductive phase, increasing pod retention, while phosphorus ensures efficient sugar transport and energy supply for seed filling. **Gai *et al.,* (2017), Córdova *et al.,* (2020), Kakabouki *et al.,* (2022**) and **Epie *et al.,* 2023**) studies show that N fertilization reduces pod abscission. And P enhances metabolic processes that maintain seed weight under resource-limited conditions (**Caliskan *et al.,* 2008; Qiang *et al.,* 2025**). The result obtained is in agreement with the findings of **Begum *et al.,* (2015**) and **Tekulu *et al.,* (2020**) found that significantly affects were found by combined application of N and P fertilizers.

The effect of nitrogen, phosphate levels and their interaction on the chemical composition of soybean seeds

Nitrogen fertilization levels significantly influenced most chemical composition traits, with the exception of ash, crude fiber, and carbohydrate content, which were not significantly affected (Table 5). The application of the highest nitrogen rate (40 kg N/fed) resulted in the greatest protein concentration (39.88%). Conversely, the highest oil content (21.71%) was recorded under the lowest nitrogen rate (20 kg N/fed). In contrast, applying 20 kg N/fed led to the lowest protein content

Table 4. Effect of nitrogen and phosphate levels and their interaction on yield and its components of soybean over two seasons.

	No. pods plant^{-1}				100-seed weight (g)				No. seeds pod^{-1}				Harvest index (%)				Shelling percentage (%)			
	N1	**N2**	**N3**	**Mean**	**N1**	**N2**	**N3**	**Mean**	**N1**	**N2**	**N3**	**Mean**	**N1**	**N2**	**N3**	**Mean**	**N1**	**N2**	**N3**	**Mean**
P1	72.00	66.33	68.17	**68.83**	12.12	12.35	13.19	**12.55**	2.66	2.33	2.29	**2.43**	30.35	31.56	27.00	**29.64**	0.56	0.44	0.46	**0.49**
P2	64.33	73.00	70.83	**69.39**	14.45	13.08	13.17	**13.57**	2.80	2.79	2.85	**2.81**	29.10	35.53	28.08	**30.90**	0.59	0.58	0.64	**0.60**
P3	70.83	76.00	75.67	**74.17**	13.82	13.30	14.17	**13.76**	2.60	3.72	3.80	**3.37**	34.41	31.82	32.27	**32.83**	0.57	0.89	0.90	**0.79**
Mean	**69.05**	**71.78**	**71.56**	**70.80**	**13.46**	**12.91**	**13.51**	**13.29**	**2.69**	**2.95**	**2.98**	**2.87**	**31.29**	**32.97**	**29.12**	**31.12**	**0.57**	**0.64**	**0.67**	**0.63**
L.S.D at 5% level																				
	N=2.61 P=3.15 NP=4.3				**N=0.26 P=0.43 NP=1.08**				**N=N.S P=0.82 NP=N.S**				**N=N.S P=1.23 NP=1.63**				**N=N.S P=0.14 NP=0.09**			

	Weight of pods plant^{-1} (g)				No. seeds plant^{-1}				Seed yield plant^{-1} (g)				Seed yield fed^{-1} (kg)			
	N1	**N2**	**N3**	**Mean**	**N1**	**N2**	**N3**	**Mean**	**N1**	**N2**	**N3**	**Mean**	**N1**	**N2**	**N3**	**Mean**
P1	41.67	43.83	45.00	**43.50**	191.52	154.55	156.11	**167.39**	23.21	19.09	20.59	**20.96**	928.5	763.5	823.6	**838.5**
P2	43.83	45.83	41.67	**43.78**	180.12	203.67	201.87	**195.22**	26.03	26.64	26.59	**26.42**	1041.1	1065.6	1063.4	**1056.7**
P3	45.00	42.17	45.33	**44.17**	184.16	282.72	287.55	**251.48**	25.45	37.60	40.75	**34.60**	1018.0	1504.1	1629.8	**1384.0**
Mean	**43.50**	**43.94**	**44.00**	**43.81**	**185.27**	**213.65**	**215.18**	**204.70**	**24.90**	**27.78**	**29.31**	**27.33**	**995.9**	**1111.1**	**1172.3**	**1093.1**
L.S.D at 5% level																
	N=1.03 P=1.36 NP=1.06				**N=5.67 P=15.32 NP=32.17**				**N=3.02 P=7.37 NP=8.24**				**N=93.1 P=103.22 NP=74.36**			

(37.01%), while 40 kg N/fed resulted in reduced oil content (20.14%). These findings can be attributed to the central role of nitrogen in protein synthesis.

When nitrogen availability is sufficient, plants utilize carbon skeletons from photosynthesis to form amino acids and proteins. However, under nitrogen-deficient conditions, the plant diverts more carbon towards lipid synthesis, leading to increased oil accumulation. This inverse relationship between seed protein and oil content has been previously reported by Loubser and Grimbeek (1986) and Steer et al. (1986), who noted that increasing nitrogen supply enhances protein content while reducing oil levels. Similarly, Weilenmann and Luquez (1999) found that protein content exhibited greater variability than oil and confirmed the negative correlation between the two. These results are consistent with the findings of Nuttall et al. (1989), Morshed et al. (2008), and Sharifi et al. (2016), who also observed significant effects of nitrogen fertilization on soybean seed protein content.

Phosphate fertilization levels had significant effects on some chemical composition except ash, carbohydrate which was insignificant are presented in Table 5. Application of level of phosphate fertilizer (30 kg P_2O_5 fed^{-1}) led to produce the highest values of protein content (39.65%). As well as, application of the highest level of phosphate fertilizer (50 kg P_2O_5 fed^{-1}) led to produce the highest values of oil content (21.53%), crude fiber (6.52%). While, application of level of phosphate fertilizer (50 kg P_2O_5 fed^{-1}) led to produce less values of protein content (38.20%). As well as, application of the lowest level of phosphate fertilizer (30 kg P_2O_5 fed^{-1}) led to produce less values of oil content (20.08%), crude fiber (4.68%). This is due to low-phytate soybeans under high P show improved zinc and iron bioavailability, which are cofactors for enzymes in both oil and protein pathways. However, protein synthesis is more sensitive to micronutrient limitations under P stress (**Taliman *et al.,* 2019 and Jiang *et al.,* 2021**). Additionally, improved phosphorus increases the creation of sugar, which raises the crude fiber content of soybeans. Therefore, Phosphorus fertilization promotes cell wall formation, improves metabolic processes, and facilitates nutrient interactions; it has a considerable influence on the crude fiber content of soybean plants.

Interaction between nitrogen and phosphate had significant effects on all chemical composition (Table 5). Combine (30 kg N fed^{-1} with 30 kg P_2O_5 fed^{-1}) led to produce the highest values of protein content (42.70%), combine (20 kg N fed^{-1} with 30 kg P_2O_5 fed^{-1}) led to produce the highest values of oil content (22.82%), combine (40 kg N fed^{-1} with 40 kg P_2O_5 fed^{-1}) led to produce the highest values of ash content (5.66%), combine (40 kg N fed^{-1} with 50 kg P_2O_5 fed^{-1}) led to produce the highest values of crude fiber content (6.77%), combine (20 kg N fed^{-1} with 30 kg P_2O_5 fed^{-1}) led to produce the highest values of carbohydrate content (33.80%). This is due to N fertilization typically boosts protein content, excessive N without adequate P may disrupt root-shoot balance, reducing carbohydrate partitioning to seeds and potentially lowering oil or fiber fractions (**Dzida and Pitura 2008, Raharivololoniaina *et al.,* 2021**).

Balanced N&P fertilization likely mitigates such antagonisms, ensuring optimal allocation of resources to both nitrogen-rich (protein) and carbon-based (oil, carbohydrates) components (**Wood *et al.,* 1993, Leite *et al.,* 2021**).

Table 5. Effect of nitrogen and phosphate levels and their interaction chemical composition of soybean seeds over two seasons.

	Protein %				**Oil %**				**Ash %**				**Crude fiber %**				**Carbohydrate %**			
	N1	**N2**	**N3**	**Mean**	**N1**	**N2**	**N3**	**Mean**	**N1**	**N2**	**N3**	**Mean**	**N1**	**N2**	**N3**	**Mean**	**N1**	**N2**	**N3**	**Mean**
P1	35.83	42.70	40.42	**39.65**	20.57	20.23	19.44	**20.08**	5.40	5.36	5.14	**5.30**	4.40	5.13	4.52	**4.68**	33.80	26.58	30.48	**30.29**
P2	37.49	37.06	40.20	**38.25**	22.82	20.24	19.78	**20.95**	5.50	5.05	5.66	**5.40**	5.92	5.08	5.72	**5.57**	28.27	32.57	28.64	**29.83**
P3	37.72	37.86	39.01	**38.20**	21.73	21.66	21.20	**21.53**	5.38	5.40	5.65	**5.48**	6.26	6.53	6.77	**6.52**	28.91	28.55	27.37	**28.28**
Mean	**37.01**	**39.21**	**39.88**	**38.70**	**21.71**	**20.71**	**20.14**	**20.85**	**5.43**	**5.27**	**5.48**	**5.39**	**5.53**	**5.58**	**5.67**	**5.59**	**30.33**	**29.23**	**28.83**	**29.46**
L.S.D at 5% level																				
	N =1.74 P =1.16 NP=3.11				**N =1.14 P = 0.76 NP=0.85**				**N = NS P =NS NP= 0.64**				**N = NS P =0.72 NP=0.17**				**N =NS P =NS NP= 1.14**			

Conclusion

This research highlights the strategic importance of soybean for global food security due to its nutritional value and diverse uses. The study found that the combined application of 40 kg N fed^{-1} and 50 kg P2O5 fed^{-1} significantly enhances soybean yield and quality. These findings are crucial for improving cultivation in challenging environments like newly reclaimed lands and supporting sustainable agricultural development to reduce import dependency.

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