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Role of Organic and Phosphate Fertilizer on Growth and Yield of Groundnut

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Abstract

Efforts to increase groundnut productivity can be achieved by fertilizing with organic and phosphate fertilizers. This research aims to investigate the impact of organic and phosphate fertilizers on the growth and yield of groundnuts. The study was conducted at the Faculty of Agriculture, UNS Jumantono, in the EMPT (Ecology and Plant Production Management) Laboratory and the Soil Chemistry and Fertility Laboratory from December 2024 to March 2025. The research employed a Randomized Complete Block Design (RCBD) with two factors, each repeated three times. The first factor is the dose of organic cow manure fertilizer (0, 10, 20, 30 ton.ha^{-1}), and the second factor is the dose of phosphate fertilizer (0, 75, 150, 225 kg.ha^{-1}). The observed variables include initial soil analysis, growth, yield, plant tissue analysis, and nutrient uptake analysis. Observational data were analyzed using analysis of variance (ANOVA) at a 95% confidence level, Duncan Multiple Range Test (DMRT) at a 95% confidence level, regression tests, and Pearson correlation tests. The results showed that cow manure fertilizer, with an optimum dose of 25.67 tons ha^{-1}, combined with 225 kg ha^{-1} of phosphate fertilizer, resulted in early flowering, at 24.97 days after planting. Organic cow manure fertilizer 10 ton.ha^{-1} was able to increase the number of leaves, leaf area index, fresh weight of stover, number of pods, dry weight of pods, number of seeds per plant, and seed weight per plant of groundnut compared to those without organic cow manure fertilizer. Phosphate fertilizer 75 kg.ha^{-1} was able to increase the number of pods, dry weight of pods, and number of seeds per plant compared to those without phosphate fertilizer.

Keywords: Alfisol; cow manure; Leguminoceae; macronutrient; pod.

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Introduction

Groundnut (*Arachis hypogaea* L.) is a primary source of vegetable protein. Groundnut seeds contain approximately 25-30% protein, 12% carbohydrates, 40- 50% vegetable oil, vitamins (A, B, C, D, E, K), and minerals including iron, magnesium, phosphorus, potassium, and sulfur (1). Groundnut demand increases annually, but production declines. Groundnut production in Indonesia decreased from 420.099 tons in 2019 to 418.414 tons in 2020 and again to 390.465 tons in 2021 (Directorate General of Food Crops, 2022). The decline in groundnut production in Indonesia can be caused by several factors, one of which is low soil fertility. Poor soil fertility is the primary factor contributing to the decline in groundnut production (2).

Efforts to increase groundnut productivity were carried out through fertilization using organic and phosphate fertilizers. The organic fertilizer used is cow manure. Cow manure is an organic fertilizer with a high cellulose content, providing macro- and micronutrients for plants, and improving water absorption and soil nutrient availability (3). The application of cow manure can increase soil fertility and impact plant growth and yield. The addition of cow manure significantly increases soil organic carbon, total nitrogen, available phosphorus, and available potassium (4).

Phosphate fertilizers contain phosphorus (P), an essential nutrient required by plants in relatively large amounts. Phosphorus requirements in legumes are higher because phosphorus plays a role in physiological processes and influences plant production (5). Phosphorus (P) is a significant component of ATP (adenosine triphosphate), which functions as an energy source in biochemical processes, including respiration and photosynthesis (6). P is required for growth, flowering, and seed formation in groundnuts. The application of phosphate fertilizer significantly increased soybean production, the number of productive branches, seed production per plot, and the dry weight of 100 seeds (7). Based on the description above, the application of cow manure and phosphate fertilizers has a positive effect on plant growth and yield. Therefore, this research aims to examine the role of organic fertilizers and phosphate on the development and yield of groundnut.

Materials and Methods

The research was conducted at the Agricultural Laboratory of Sebelas Maret University, Jumantono, the EMPT Laboratory, and the Soil Chemistry and Fertility Laboratory, Faculty of Agriculture, Sebelas Maret University, from December 2024 to March 2025. The materials used in this study included Kancil variety groundnut seeds, cow manure as an organic fertilizer, phosphate fertilizer (SP-36), urea, and potassium chloride (KCl). The tools used in this study were 48 experimental units by 40 x 40 cm polybags, a scale, and an electric oven.

This research used a factorial Randomized Complete Block Design (RCBD) with two factors. The first factor was the dose of organic cow manure fertilizer (0, 10, 20, and 30 ton.ha^{-1}). The second factor was the dose of phosphate fertilizer (0, 75, 150, and 225 kg.ha^{-1}). There were 16 treatment combinations repeated three times, resulting in 48 experimental units.

The research implementation included preparation of planting media, fertilization (fertilization was carried out once; cow manure was applied one week before planting, and phosphate fertilizer was applied before planting), planting, maintenance, and harvesting. The observed variables included initial soil analysis, growth (plant height, number of leaves, leaf area index, flowering age, fresh weight of the stover, dry weight of the stover), yield (number of pods, dry weight of the pods, number of seeds per pod, number of seeds per plant, seed weight per plant, weight of 100 seeds), tissue NP and K analysis, and nutrient uptake analysis. The observation data were analyzed using analysis of variance (ANOVA) with a significance level of 95%, followed by Duncan's Multiple Range Test (DMRT) with a significance level of 95% if there were significant differences, regression tests if there was an interaction, and Pearson correlation tests to determine the relationship between observation variables.

Results and Discussions

General Environmental Conditions

The average temperature at the research location was 28°C, and the air humidity was 84%. Groundnuts can grow optimally at temperatures of around 28-32°C and a humidity level of 65-75% (8). The minimum light duration was 12.5%, the maximum was 100%, and the average was 58%. The average rainfall at the research site was 276 mm/month. This rainfall tends to be higher than the requirements for groundnut growth, which range from 800 to 1300 mm/year (9).

The soil at the research site is an Alfisol. It has a pH of 6.85, which is considered neutral. The soil acidity (pH) suitable for groundnuts is around 6.5-7 (10). The soil has a very low organic carbon content of 0.14%. Organic carbon plays a crucial role in determining soil quality; the higher the organic carbon content, the higher the quality or level of soil fertility (11). The total nitrogen (N) content of the soil was 0.70% (high), soil P_2O_5 was 6 ppm (low), and total potassium (K) was 157 ppm (high).

The organic fertilizer used was cow manure. Cow manure contains 1,24% N, 1,41% P2O5, 1,56% K2O, 21,12% organic C, a C/N ratio of 17,03%, and a pH of 6,56. The cow manure used met the quality standards for organic fertilizer in terms of macronutrient content (N, P_2O_5, K_2O), organic carbon, C/N ratio, and pH.

Plant Height (cm)

The results of the analysis of variance showed that there was no interaction between the doses of organic cow manure and phosphate fertilizer. The dose of cow manure fertilizer had a highly significant effect, while the dose of phosphate fertilizer had no significant effect on plant height 5 weeks after planting (Table 1).

Table 1. The role of organic and phosphate fertilizers on the growth of groundnut

Treatment	PH 5 WAP (cm)	NL 5 WAP (Blade)	LAI	FA (DAP)	FWS (g)	DWS (g)
Organic Cow Manure Fertilizer (ton.ha^{-1})						
0	24,85±2,39c	22,56±3,63b	1,17±0,32b	27,83±1,03c	48,96±6,53b	13,95±2,14bc
10	29,90±2,27b	30,39±3,78a	1,82±0,39a	26,67±0,89b	59,69±6,57a	15,65±3,16b
20	32,07±1,91a	31,36±2,63a	1,98±0,21a	26,58±1,24a	64,19±7,90a	17,34±1,97ab
30	31,88±2,09a	31,14±3,69a	1,78±0,42a	25,75±0,75a	62,79±13,08a	18,26±3,25a
Sig.	36,31	17,31	13,26	13,75	9,84	5,00
Phosphate Fertilizer (kg.ha^{-1})						
0	29,25±2,40	27,86±4,45	1,65±0,49	27,33±0,98b	58,67±11,51	15,77±2,89
75	30,25±3,78	30,53±5,06	1,75±0,42	26,75±1,14ab	57,56±12,47	16,41±3,33
150	30,00±4,49	28,69±5,67	1,69±0,50	26,58±1,00a	59,61±10,70	16,59±3,90
225	29,19±3,84	28,36±4,95	1,66±0,46	26,17±1,53a	59,79±8,32	16,43±3,40
Sig.	0,91	1,31	0,24	4,38	0,22	0,18
Interaction	-	-	-	+	-	-
Sig. interaction	1,91	0,89	0,41	2,27	1,25	0,56
KK (%)	6,52	12,19	19,92	3,0	12,93	18,11

Remarks: Numbers followed by the same letter in the same column indicate no significant difference according to DMRT at the 95% significance level. (+)= an interaction. (-) = no interaction. PH plant height. NL number of leaves, LAI leaf area index, FA flowering age, FWS fresh weight of the stover, DWS dry weight of the stover, DAP day after planting. Sig. : Significance. KK: Coefficient of Variation.

Plant height can be influenced by nutrient availability, particularly nitrogen. According to Sarwanidas and Setyowati (12), nitrogen is needed during the vegetative phase because it plays a role in increasing plant height, protein (amino acid) content, and plant quality for leaf production. The application of cow manure can increase nutrient availability in the soil so that it can be absorbed by plants, including nitrogen, which is needed to stimulate vegetative growth of groundnut plants (13).

Number of Leaves (blade)

The results of the analysis of variance showed no interaction between the doses of cow manure and phosphate fertilizer; the dose of cow manure fertilizer had a very significant effect, and the dose of phosphate fertilizer had no significant impact on the number of leaves 5 weeks after planting. A 10 ton ha^{-1} cow manure fertilizer was able to increase the number of leaves compared to a dose of 0 tons.ha^{-1} (Table 1). Kasman (14) stated that the increase in the number of leaves was due to the mineralization of nitrogen from cow manure fertilizer, so that the roots easily absorbed it. The availability of sufficient nitrogen (N) will help plants in the process of leaf formation, allowing the number of leaves to increase.

Leaf Area Index (LAI)

The results of the analysis of variance showed no interaction between the doses of cow manure and phosphate fertilizer; the dose of cow manure fertilizer had a very significant effect, and the dose of phosphate fertilizer had no significant impact on the groundnut LAI. Cow manure fertilizer of 10 ton.ha^{-1} was able to increase the LAI compared to a dose of 0 ton.ha^{-1} (Table 1). Cow manure fertilizer contains macro and micro nutrients as well as organic matter that can improve soil fertility. Ramlan and Ayuningsi (15) stated that the presence of organic matter helps increase the availability of nutrients in the soil so that they can be absorbed by plants. The application of organic fertilizer helps supply nutrients, ensures nutrient balance, and facilitates access to nutrient absorption for plants (16). The availability of sufficient nutrients, especially nitrogen, can stimulate the growth of leaf area, resulting in increased LAI (17).

Flowering Age (Day After Planting)

The results of the analysis of variance showed that there was an interaction between the dose of organic cow manure and phosphate fertilizers on the flowering age of groundnuts. Cow manure fertilizer with an optimum dose of 25,67 ton.ha^{-1}, combined with 225 kg.ha^{-1} of phosphate fertilizer, resulted in a flowering age of 24,97 days after planting. This is stated in the regression equation UB3 = 0.005K2-0.2567K+28.267 with R2 = 0,99 (Figure 1). Karim et al. (18) noted that the application of cow manure fertilizer can provide macro- and micro-nutrients to meet nutrient needs, thereby encouraging plant development and the formation of branches that can produce flowers. The P element plays a vital role in the formation of flowers and fruits because it is one of the compound components that are useful in the process of energy transfer and plant biochemical processes (19).

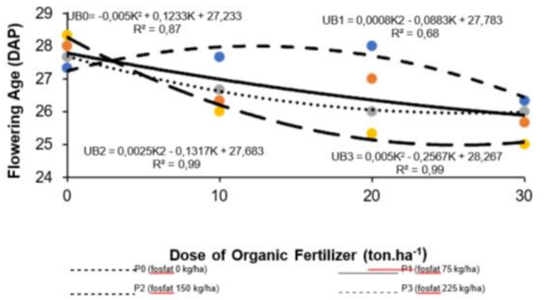

Figure 1. Flowering age of groundnut with organic cow manure and phosphate fertilizer

Fresh Weight of Stover (g)

The results of the analysis of variance showed no interaction between the doses of cow manure and phosphate fertilizer; the dose of cow manure fertilizer had a very significant effect, and the dose of phosphate fertilizer had no significant impact on the fresh weight of groundnut stover. 10 ton.ha^{-1} of cow manure fertilizer was able to increase the fresh weight of stover compared to a dose of 0 ton.ha^{-1} (Table 1). The fresh weight of stover is influenced by plant vegetative growth and optimal nutrient absorption by plants. Pangaribuan et al. (20) argue that plant growth is driven by sufficient nutrient availability and results in an increase in fresh weight. Application of cow manure fertilizer can increase the availability of macro and micro nutrients that support plant vegetative growth, so that it will affect the fresh weight of stover.

Dry Weight of Stover (g)

The results of the analysis of variance showed that there was no interaction between the doses of cow manure and phosphate fertilizer; the dose of cow manure fertilizer had a very significant effect, and the dose of phosphate fertilizer had no significant impact on the dry weight of groundnut stover. According to Ritonga and Anhar (21), dry weight is plant biomass, which is the result of the accumulation of photosynthates from photosynthesis carried out by plants. Gatot and Hasnelly (22) stated that nitrogen and micronutrients play a role in chlorophyll formation, which facilitates photosynthesis. Cow manure fertilizer can increase organic matter in the soil and provide macro and micronutrients needed by plants. The application of organic matter from organic fertilizer can increase the dry weight of stover (23).

Number of Pods per Plant

The results of the analysis of variance showed that there was no interaction between the doses of organic cow manure and phosphate fertilizers; the dose of cow manure fertilizer had a very significant effect, and the dose of phosphate fertilizer had a substantial impact on the number of groundnut pods. Cow manure fertilizer at a dose of 10 tons.ha-1 was able to increase the number of groundnut pods compared to a dose of 0 tons.ha^{-1} (Table 2). Ayu et al (24) stated that cow manure fertilizer can improve soil structure and increase nutrient availability, which can increase plant growth and production. Good soil structure facilitates the penetration of the gynophore into the soil and the formation of groundnut pods. Phosphate fertilizer at 75 kg.ha^{-1} or higher dose is able to increase the number of pods significantly compared to a dose of 0 kg.ha^{-1} (Table 2). This is in line with the opinion of Asante et al. (25) that phosphorus affects the number of groundnut pods. El-Khouly et al. (26) stated that phosphorus is an essential nutrient needed by groundnuts in the formation of pods, seeds, oil, and protein in pod filling.

Table 2. The role of organic and phosphate fertilizers on the yield of groundnut

Treatment	NP	DWP (g)	NSP	NSPl	SWPl (g)	W100 (g)
Organic Cow Manure Fertilizer (ton.ha^{-1})						
0	11,47±2,77b	10,23±2,29b	1,84±0,05	21,03±4,87b	6,20±1,49b	29,64±1,54b
10	15,53±3,36a	14,06±3,49a	1,83±0,09	28,25±6,24a	9,19±2,65a	31,71±3,72ab
20	14,69±2,67a	13,52±2,52a	1,89±0,04	27,78±5,35a	9,19±2,28a	32,93±5,15a
30	16,25±2,27a	14,78±2,48a	1,89±0,06	30,67±4,49a	10,38±2,26a	33,56±4,26a
Sig. Anova	9,23	10,49	2,48	10,66	10,64	2,93
Phosphate Fertilizer (kg.ha^{-1})						
0	12,53±3,30b	11,15±2,98b	1,85±0,09	23,08±5,76b	7,39±2,76b	31,21±4,63
75	14,75±4,00a	13,17±3,85a	1,85±0,06	27,25±7,68a	8,88±3,28ab	31,66±4,91
150	15,03±2,83a	13,84±2,73a	1,86±0,06	28,08±5,41a	8,92±2,15ab	31,57±2,41
225	15,64±2,21a	14,43±2,32a	1,88±0,06	29,31±4,70a	9,76±1,94a	33,40±4,02
Sig. Anova	3,83	5,27	0,50	4,55	3,23	0,94
Interaction	-	-	-	-	-	-
Sig. Interaction	1,22	1,35	0,92	1,10	1,37	2,12
KK (%)	16,59	16,39	3,58	16,29	21,68	10,95

Remarks: Numbers followed by the same letter in the same column indicate no significant difference according to DMRT at the 95% significance level. (+)= an interaction. (-) = no interaction. NP Number of Pods. DWP=Dry Weight of Pods. NSP Number Seed per Pod. NSPl Number Seed per Plant. SWPl Seed Weight per Plant. W100 Weight of 100 seeds. Sig. : Significance. KK: Coefficient of Variation.

Dry Weight of Pods (g)

The results of the analysis of variance showed that there was no interaction between the doses of organic cow manure and phosphate fertilizer; the dose of cow manure fertilizer had a very significant effect, and the dose of phosphate fertilizer had a very substantial impact on the dry weight of groundnut pods. 10 ton.ha^{-1} of cow manure fertilizer was able to increase the dry weight of pods compared to a dose of 0 ton.ha^{-1} (Table 2). Cow manure fertilizer can increase the availability of nutrients for plants. The availability of sufficient nutrients helps the plant biosynthesis process so that it produces more carbohydrates, which are then stored as food reserves that can increase the dry weight of pods (27). The application of organic fertilizer will improve soil conditions that support the development of the root system, so that nutrient absorption from the soil is better and produces better pods (28). A dose of Phosphate fertilizer 75 kg.ha^{-1} was able to increase the dry weight of pods compared to a dose of 0 kg.ha^{-1} (control) (Table 2). Phosphorus is an essential nutrient for groundnuts to increase pod filling (29). When phosphorus requirements are met, metabolic activity increases, thereby enhancing the translocation of organic materials to the pods (30).

Number of Seeds per Pod

The results of the analysis of variance showed that there was no interaction between the doses of cow manure and phosphate fertilizer, the dose of cow manure fertilizer had no significant effect, and the dose of phosphate fertilizer had no significant impact on the number of seeds per groundnut pod. According to Widiastuti et al. (31), the number of seeds per groundnut pod is influenced by genetic factors. The number of seeds per pod of the Kancil variety of groundnut is in accordance with the variety description, which is 1-2 seeds per pod.

Number of Seeds per Plant

The results of the analysis of variance showed that there was no interaction between the doses of cow manure and phosphate fertilizer; the dose of cow manure fertilizer had a very significant effect, and the dose of phosphate fertilizer had a very substantial impact on the number of seeds per groundnut plant. A dose of 10 ton.ha^{-1} of cow manure fertilizer was able to increase the number of seeds per plant compared to a dose of 0 ton.ha^{-1} (Table 2). Yunanda et al. (32) stated that the addition of organic materials such as manure can improve the chemical, physical, and aggregation properties of the soil so that it becomes fertile soil and facilitates nutrient absorption by the roots. Good soil conditions and optimal nutrient absorption will help the plant growth process, including the formation of pods and seeds. A dose of 75 kg.ha^{-1} of phosphate fertilizer was able to increase the number of seeds per plant compared to a dose of 0 kg.ha^{-1} (Table 2). Ijaz et al. (33) stated that phosphorus is the primary and essential macronutrient for plant production and plays a vital role in plant growth processes, such as photosynthesis, flowering, and seed formation.

Seed Weight per Plant

The results of the analysis of variance showed that there was no interaction between the doses of cow manure and phosphate fertilizer; the dose of cow manure fertilizer had a very significant effect, and the dose of phosphate fertilizer had a significant impact on seed weight per groundnut plant. Zebua et al. (34) stated that organic fertilizer can increase nutrient availability and improve soil properties that support the development of the root system so that it can absorb water and nutrients better. Plants require more nutrients during seed formation; nutrient deficiencies cause the seed initiation process to run incompletely, so that the results are not optimal (35). Optimal phosphorus absorption by plants will help the photosynthesis process, and the results are used to form seeds properly so that seed weight will increase (36).

Weight of 100 Seeds (g)

The results of the analysis of variance showed no interaction between the doses of cow manure and phosphate fertilizer; the dose of cow manure fertilizer had a significant effect, and the dose of phosphate fertilizer did not significantly affect the weight of 100 groundnut seeds. Organic fertilizer can help increase the availability of nutrients in plants, such as N, P, and K nutrients, which play an essential role in photosynthesis to produce photosynthates that affect seed yield. According to Kadekoh and Made (37), potassium plays a role in the translocation of photosynthates to the seed. This is thought to increase the weight of 100 groundnut seeds because optimal photosynthates will produce better or fuller seeds.

Tissue N, P, K Analysis

Plant tissue analysis was conducted to determine the nutrient content of plants. The highest N content in plant tissue was found at 1,17% with an organic fertilizer dose of 30 ton.ha^{-1}, and the lowest at 0 ton.ha^{-1} at 0,80% (Figure 2). Cow manure contains organic matter that can improve soil structure, increase water retention capacity, and support the development of soil microorganisms that play a role in the nutrient cycle (38). The P content in plant tissue tends to be lower than the N and K content in plant tissue (Figure 2). This is in line with the opinion of Amelia et al. (39), the P element in plant tissue is generally lower than the N and K levels, but phosphorus plays a vital role in plant growth. Other components cannot replace it.

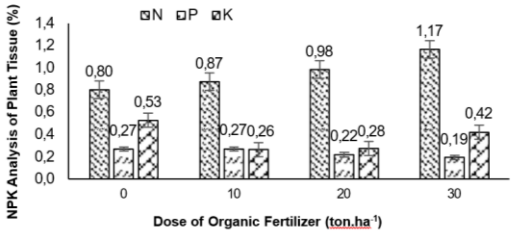

Figure 2. Result of N, P, K analysis of plant tissue in organic fertilizer treatment

The application of phosphate fertilizer aims to increase the availability of P nutrients needed in the plant growth process, so that in the phosphate fertilizer treatment, the P content in plant tissue was analyzed. Based on the analysis results (Figure 3), it was known that phosphate fertilization with a dose of 225 kg.ha^{-1} produced the highest P content, namely 0,31%.

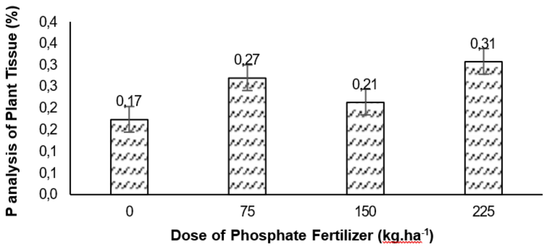

Figure 3. Result of P analysis of plant tissue in phosphate fertilizer treatment

N, P, K Nutrient Uptake

Plant nutrient uptake analysis was conducted to determine the amount of nutrients absorbed by plants from the soil or planting medium. Based on the results of the nutrient uptake analysis (Figure 4), the highest N nutrient uptake was found in the application of an organic fertilizer dose of 30 ton.ha^{-1}, namely 17,24 g; the highest P nutrient uptake was at a fertilizer dose of 20 ton.ha^{-1}, namely 3,20 g; and the highest K uptake was at an organic fertilizer dose of 30 ton.ha^{-1}, namely 6,21 g. The application of organic fertilizer can improve soil properties and increase organic matter, which plays a role in providing nutrients, thus affecting nutrient absorption by plants. Organic matter in the soil can improve soil properties and soil aggregation, thereby facilitating the movement or mobility of P elements in the soil (40).

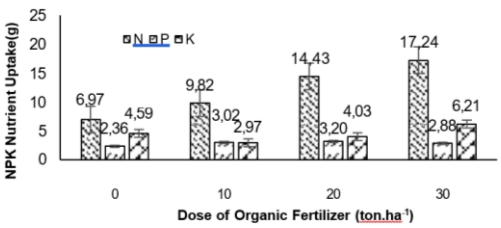

Figure 4. Result of NPK nutrient uptake analysis with organic fertilizer

The results of the nutrient uptake analysis (Figure 5) show that the highest P nutrient uptake was found in the application phosphate fertilizer at a dose of 225 kg.ha^{-1}, namely 3,65 g and the lowest P uptake was at an phosphate fertilizer dose of 0 kg.ha^{-1}, namely 1,91 g. Zulputra and Nelvia (41) stated that the application of phosphate fertilizer can increase the availability of soil P so that it is more easily absorbed by plants.

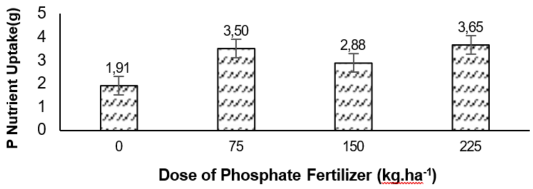

Figure 5. Result of P nutrient uptake analysis with phosphate fertilizer

Correlation Test

Results of this correlation test showed that the height of the groundnut plant was strongly correlated with the number of leaves (*r=0.949), leaf area index (r=0.915), fresh weight of the stover (r=0.845), and dry weight of the stover (r=0.879*). This correlation indicates that the higher the plant, the higher the number of leaves, leaf area index, fresh weight of the stover, and dry weight of the stover. This is in line with the opinion of Hartanti and Yumadela (42), the number and size of the canopy affect the weight of the stover; the higher the plant and the more leaves, the greater the stover weight. The number of pods per plant correlated strongly with pod dry weight (*r=0.976), seed number per plant (r=0.990), and seed weight per plant (r=0.943*). These results indicate that the greater the number of pods, the higher the pod dry weight, seed number per plant, and seed weight per plant. This is in line with the opinion of Poniman et al. (43), who stated that seed weight per plant is related to the number of pods per plant; the greater the number of pods, the heavier the seed weight per plant.

Conclusions

There is an interaction between the dose of organic fertilizer and phosphate on the flowering age of groundnut. Cow manure fertilizer with an optimum dose of 25,67 ton.ha^{-1} combined with phosphate fertilizer at 225 kg.ha^{-1} resulted in the earliest flowering age, namely 24.97 days after planting. Organic cow manure fertilizer at a dose of 10 ton.ha^{-1} tends to increase the number of leaves, leaf area index, fresh weight of the stover, and the number of pods, dry weight of pods, number of seeds per plant, and seed weight per groundnut plant compared to without organic cow manure fertilizer. Phosphate fertilizer at a dose of 75 kg.ha^{-1} tends to increase the number of pods, dry weight of pods, and number of seeds per plant compared to without phosphate fertilizer.

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