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# Major nutrient uptake, their partitioning, and harvest index of peanut under organic farming practice in tropical highlands

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**Abstract** The partitioning of major plant nutrients determines the harvest index of each nutrient, which is closely related to crop yield. The purpose of this study was to determine the major nutrient uptakes, partitioning, and harvest index of peanut when vermicompost was combined with a liquid organic fertilizer in organic farming practice. Results indicated that peanut fertilized with vermicompost at a rate of 25 Mg ha$^{-1}$ combined with LOF absorbed the highest amount of N, P, and K and had the highest kernel. The study demonstrated that the appropriate time for greater availability of nutrients for peanut growth was during pod and seed formation. Supplementation of LOF to the application of vermicompost provided higher availability of N, P, and K, mainly after the flowering stage of peanut development. Lower N availability leaded to a higher harvest index. The findings supported the importance of LOF supplementation over solid organic fertilizer in organic farming practices for higher peanut productivity.

**Keywords:** Nutrient harvest index, Nutrient partitioning, Nutrient uptake, Peanut, Vermicompost

## Introduction

Peanut (*Arachis hypogea* L.) is a popular food legume that contributes to human nutrition and is used in a variety of food industries (Akram *et al.*, 2018; Alasalvar *et al.*, 2020). This cash crop provides 20–40% of protein and 40–50% of oil (Htoon *et al.*, 2014). Fertilization is an important aspect of increasing peanut productivity. The use of synthetic fertilizer has increased crop yield; yet, the long-term effect of fertilization leads to soil fertility loss (Fang *et al.*, 2012; Coolon *et al.*, 2013; Tetteh, 2015). Organic fertilization is an attempt to enhance the fertility of degraded soil.

Vermicompost is a high-quality organic fertilizer that is frequently utilized in organic farming practices and has been shown to improve crop

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growth and yields (Muktamar *et al.,* 2017; Huerta *et al.,* 2010; Wang *et al.,* 2010). The main drawback of organic fertilizer is its slower nutrient release. Nitrogen and phosphorus availability require two weeks for vermicompost to decompose (Muktamar *et al.*, 2020; 2022). Crop nutrient uptake may differ depending on species or agricultural practices. Organic fertilizer's gradual release of nutrients may result in different crop growth, particularly at an early stage of crop growth, than synthetic fertilizer. Muktamar *et al.* (2017), on the other hand, demonstrated that adding organic fertilizer with liquid organic fertilizer increased sweet corn nutrient uptake.

Nutrient partitioning will assist in describing the composition of nutrient uptake at various plant organs. Crusciol *et al.* (2021) reported in a study on peanut that higher availability of nutrients in soil was required at 70–84 days after emergence, as represented by nutrient accumulation in different parts of the plant. According to Xie *et al*. (2020), nutrient uptake would increase linearly with increasing peanut pod yield until reaching 60–70% of the potential yield. Silva *et al.* (2017) discovered that nutrient uptake increased 110 days after emergence, when peanut growth reached its maximum. Zhao *et al.* (2021) showed that peanut pod yield was positively correlated with N, P, and K absorption. These studies illustrated that nutrient uptake patterns fluctuate depending on farming practices. The goal of this study was to evaluate the major nutrient uptakes, partitioning, and harvest index of peanut following the application of vermicompost combined with a liquid organic fertilizer in organic farming practice.

## Materials and methods

### *Experimental site and design*

The research was carried out at the CAPS (Closed Agricultural Production System) Research Station in Air Duku Village, Selupu Rejang Subdistrict, Rejang Lebong District, Bengkulu Province, Indonesia. The trial site was 1054 meters above sea level. The soil was classified as Andept, in the order of Inceptisols, according to USDA soil classification. Since 2009, the experimental plot has been a long-term organic farming practice. The site was established as a long-term study field for the organic farming experiment in early 2016, with crop rotation patterns of corn, corn, and legumes.

The experiment employed a randomized complete block design with three replications. The treatment consisted of the application of vermicompost at a rate of 25 Mg $ha^{-1}$, vermicompost at a rate of 25 Mg $ha^{-1}$ supplemented with liquid organic fertilizer (LOF), and synthetic fertilizer (as a comparison) at a rate of 50 kg $ha^{-1}$ urea, 100 kg $ha^{-1}$ TSP, and 100 kg $ha^{-1}$ KCl.

### *Preparation of vermicompost and liquid organic fertilizer*

Vermicompost has been produced using a method described by Muktamar *et al.* (2017). In a 4x4x2 m roofing cement block, 5 kg of the *Peryonic exavatus* earthworm was carefully mixed with 250 kg of dairy cattle feces before being incubated for eight weeks. After being harvested, vermicompost was passed through a 2 mm screen sieve before being used. In addition, a liquid organic fertilizer was produced by digesting a mixture of cow faces, cow urine, EM4, Thitonia leaves, and water under blue plastic for four weeks (Fahrurrozi *et al.*, 2016). The solution was screened with a white cloth before use.

### *Land preparation and cropping management*

Before planting, the land was cleared of weeds and tilled with a hand tractor to a depth of 25 cm. Then, nine 5 x 5 m experimental plots were made. The plot was homogeneously fertilized with vermicompost corresponding to the treatment. Peanut seedlings were planted in the soil at a 25 x 25 cm spacing. Weeds were manually controlled every two weeks. LOF was treated at 7, 15, 21, 28, and 35 days after planting and at flower emergence by dispensing it around the plant in amounts of 50, 100, 200, 250, 200, and 200 ml per plant, respectively. Plant fragments (stem, leaves, peg/pod, seed) were sampled at R1 (flowering), R2 (pegging), R4 (full pod), and R6 (full seed/harvest). The sample was dried in the oven at a temperature of 60–70 $^{o}$C for shoot dry weight and analyzed for nitrogen, phosphorous, and potassium content using the wet destruction method. Nutrient uptake was calculated by multiplying the respective concentration by the dry weight. Nutrient Harvest Index (HI) is the ratio of seed nutrient uptake to total nutrient uptake. Data were descriptively compared among treatments.

## Results

### *Biomass recovery and nutrient uptake*

This study showed that the dry biomass of plant fragments (stem, leaves, peg/pod, and kernel) increased with time, as indicated in Figure 1. The dry weight of peanut leaves treated with vermicompost combined with LOF was 4.2 fold higher at full pod (R4) than at pegging (R2), then slightly lower at full seed (R6) (Figure 1b). The dry weight of the stem had a pattern similar to that of leaves; it increased significantly at R4. A noticeable dry peg/pod increase was observed at R6 compared to R4. Different treatments essentially had a similar dry weight of peanut fragments (Figures 1a, b, and c). At flowering (R1), the dry weight of the stem and leaves tended to be higher in the treatment with synthetic fertilizer than in the others. However, as maturation progressed, the dry weight of both vermicompost fragments approached that of synthetic fertilizer treatment, with vermicompost combined with LOF having the highest dry weight.

Result showed that the weight of the pod and kernel was greatest in the vermicompost mixed with LOF treatment, whereas the other two treatments were roughly comparable (Figure 1).

The study discovered that N absorption by peanut fragments varied during the stages of development (Figure 2). Nitrogen uptake by leaves and stem increased significantly from flowering (R1) to full pod (R4); however, it declined to the end of the plant's development (harvest). At treatment with vermicompost combined with LOF, nitrogen uptake in leaves increased almost 13.6 fold higher in R1 than R4 and declined by 27% in R6. A similar trend was observed in the N absorption of the stem.

Treatments affected the N contribution at each stage of peanut growth and development. At flowering (R1), N uptake in leaves and stems was lowest in the treatment of vermicompost alone and the highest in synthetic fertilizer. At R2, however, N uptake by leaves and stems in vermicompost combined with LOF aligned and at R4 exceeded that in synthetic fertilizer. Also, the vermicompost treatment alone could be similar to the uptake of N at R4 in synthetic fertilizer. At R6, N uptake by pod and kernel was the highest in the treatment of vermicompost combined with LOF, while that of vermicompost alone was the lowest.

The study revealed that P absorption by leaves and peanut stem increased during plant growth and development (Figure 3). Phosphorous uptake in leaves and stem enlarged by 14.5 and 6.2 times in R4 than R1, respectively, at the treatment of vermicompost combined with LOF, then continuously higher at R6 (Figure 3b). The P absorption by pod was also higher at R6 than at R4. Phosphorous uptake was the highest by the kernel, reaching 11.9, 13.7, and 9.6 kg $ha^{-1}$ for vermicompost, vermicompost with LOF, and synthetic fertilizer, respectively.

The study also found that the combination of vermicompost and LOF had similar P uptakes by leaves and stems at all stages to the synthetic fertilizer treatment, but were higher than those of vermicompost alone (Figure 3a, b, c). Phosphorous uptake by pegs and pods was greatest in vermicompost treated with LOF and lowest in vermicompost alone. Similarly, the treatment of vermicompost with LOF resulted in the maximum P uptake by the kernel, while synthetic fertilizer resulted in the lowest.

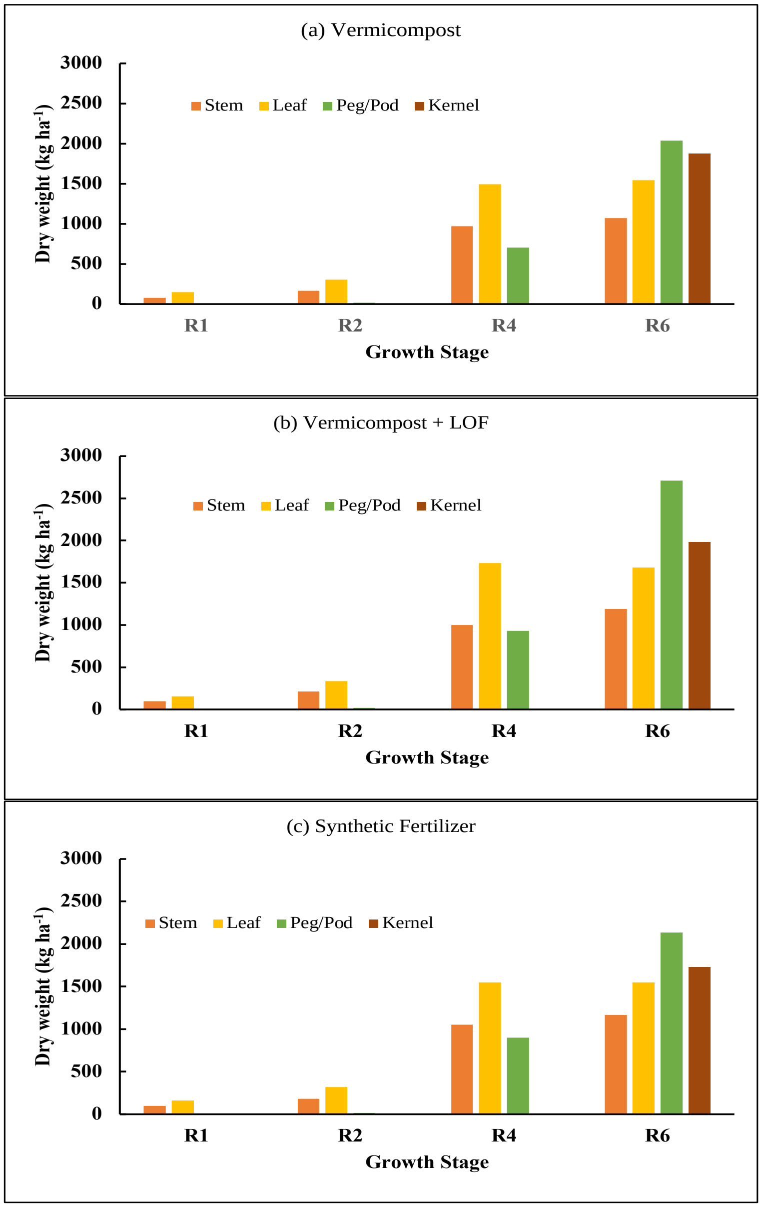


**Figure 1.** Shoot dry weight of peanut during growth stages (R1=flowering, R2=pegging, R4=full pod, and R6=full seed/harvest) under different applications of vermicompost and synthetic fertilizer

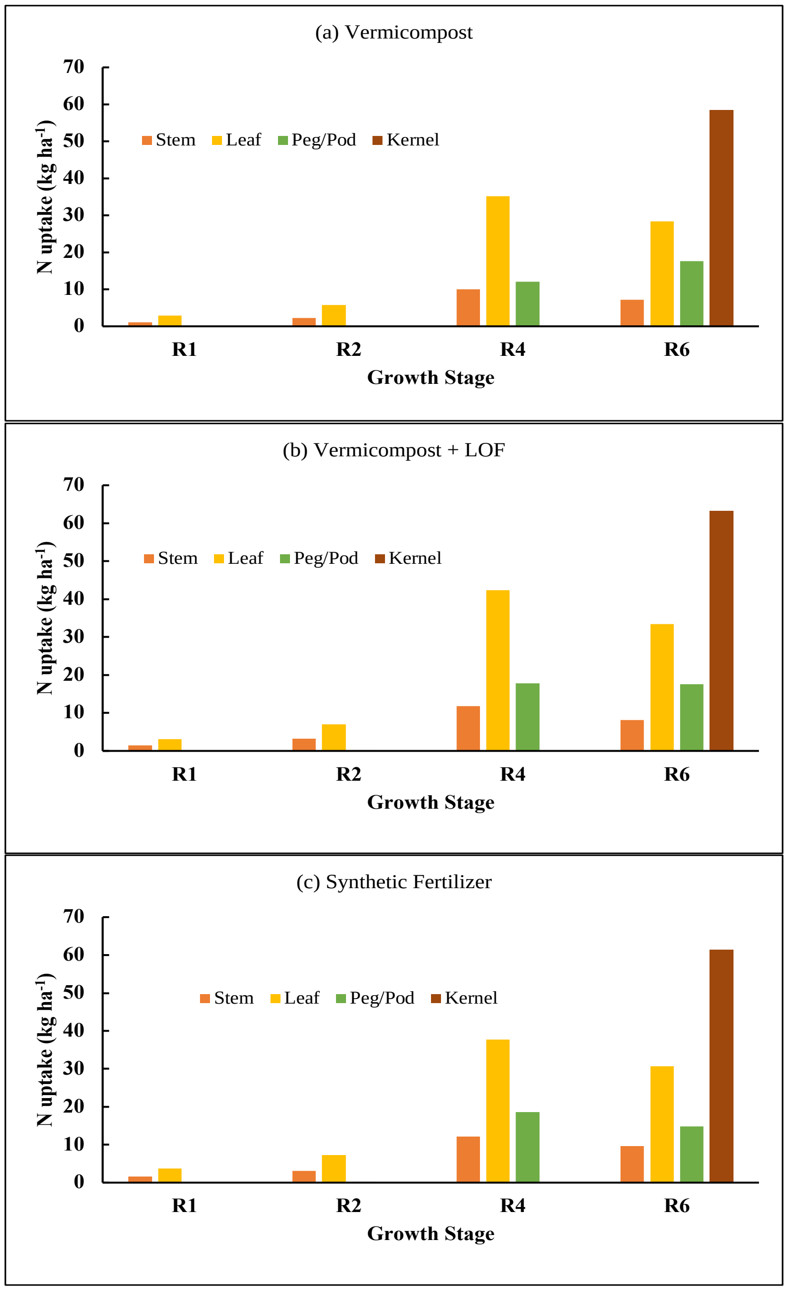


**Figure 2.** Nitrogen uptake at different growth stages (R1=flowering, R2=pegging, R4=full pod, and R6=full seed/harvest) of peanut under different applications of vermicompost and synthetic fertilizer

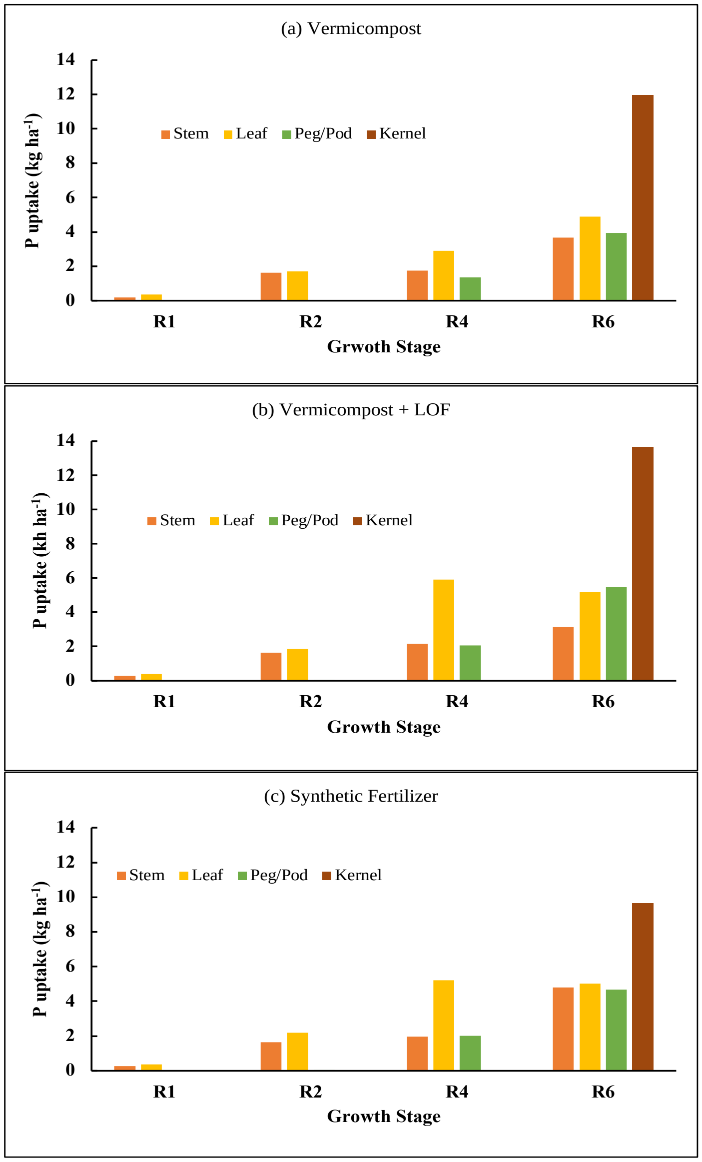


**Figure 3.** Phosphorous uptake at different growth stages (R1=flowering, R2=pegging, R4=full pod, and R6=full seed/harvest) of peanut under different applications of vermicompost and synthetic fertilizer

The study showed a prominent increase in potassium uptake at seed filling until the full seed (R6) (Figure 4). Peanut fertilized with vermicompost combined with LOF exhibited the highest K uptake for all fragments, followed by synthetic fertilizer and vermicompost alone. Resukt showed that potassium absorption by leaves and stems is increased in the treatment of vermicompost with LOF inflated by 41.5 and 44.5 folds at R1 and R4, respectively, compared to vermicompost alone (Figure 4b).

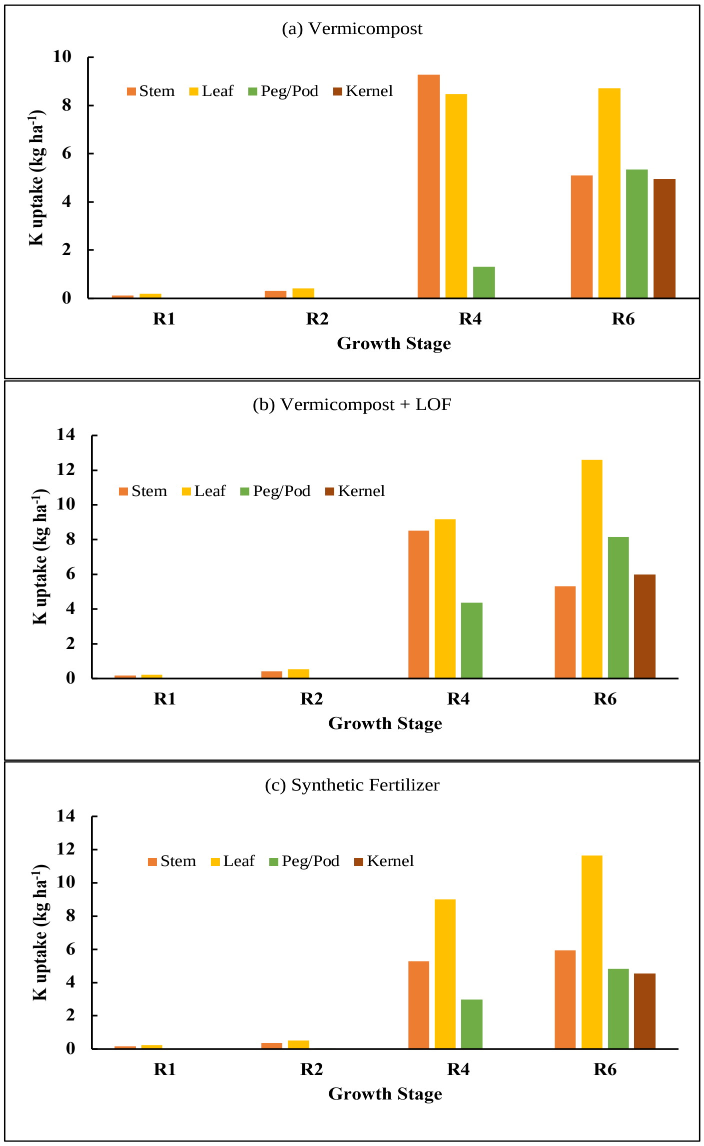


**Figure 4.** Potassium uptake at different growth stages (R1=flowering, R2=pegging, R4=full pod, and R6=full seed/harvest) of peanut under different applications of vermicompost and synthetic fertilizer

The uptake of K by leaves continuously increased at R6 but was lowered by the stem. At R6 (full seed; at harvesting), potassium absorption by the kernel was lower than that by the pod. The study also demonstrated that K uptake by leaves and stem at R1 and R2 was principally similar among treatments. However, at R4 and R6, the treatment of vermicompost with LOF had the greatest K uptake, followed by synthetic fertilizer and vermicompost alone (Figure 4a, b, c). Also, the treatment of vermicompost with LOF was superior in K uptake by pod and kernel compared to the other treatments. Pods and kernels had similar K absorption at R6.

Nutrient uptakes by the whole plant at flowering, pegging, full pod, and full seed, as influenced by vermicompost and synthetic fertilizer, are presented in Table 1. Total N uptake increased steadily throughout the plant's life cycle (from flowering to full seed). These nutrient uptake at R1 was the highest in the treatment of synthetic fertilizer. However, as plant growth proceeded, the superiority of treatments changed. At R2, vermicompost with LOF had similar total N uptake to synthetic fertilizer, while vermicompost alone had the least. At R4 and later plant development, vermicompost with LOF exhibited the highest total N uptake, followed by synthetic fertilizer and vermicompost alone.

**Table 1.** Nitrogen, P, and K uptakes by peanut during the growth stages as affected by vermicompost and synthetic fertilizer

| **Nutrient (kg ha-1)** | **R1** | **R2** | **R4** | **R6** |
|---|---|---|---|---|
| Vermicomppost | | | | |
| N (kg ha-1) | 4.0 | 8.1 | 57.2 | 111.6 |
| P (kg ha-1) | 0.5 | 3.4 | 6.0 | 24.5 |
| K (kg ha-1) | 0.3 | 0.7 | 19.1 | 24.1 |
| Vermicompost+LOF | | | | |
| N (kg ha-1) | 4.5 | 10.4 | 71.9 | 122.5 |
| P (kg ha-1) | 0.7 | 3.6 | 10.1 | 27.5 |
| K (kg ha-1) | 0.7 | 3.6 | 22.1 | 27.5 |
| Synthetic Fertilizer | | | | |
| N (kg ha-1) | 5.3 | 10.6 | 68.5 | 116.7 |
| P (kg ha-1) | 0.6 | 3.9 | 9.2 | 24.1 |
| K (kg ha-1) | 0.4 | 0.9 | 17.3 | 27.0 |

Similar to N, total P absorption constantly increased during the plant's growth, as presented in Table 1. Peanuts fertilized with vermicompost and LOF had the highest total P uptake during flowering compared to the other treatments. At pegging (R2), the treatment of vermicompost with LOF had similar total P uptake to synthetic fertilizer. The treatment of vermicompost with LOF at full pod (R4) and full seed (R6) had the most significant total P uptake, followed by synthetic fertilizer and vermicompost alone. Table 1 also revealed that total K uptake increased steadily throughout the plant growth stages.Treatment of vermicompost with LOF consistently had the highest total K uptake from R1, R2, R4, and R6. Total K uptake in synthetic fertilizer treatment was slightly higher at R1 and R3 than in vermicompost alone.

***Nutrient harvest index and yield of peanut***

In this study, the harvest N index ranged from 66–81%, depending on the treatments. This study showed that the N harvest index was highest in the treatment of vermicompost alone, while vermicompost with LOF and synthetic fertilizer was not significantly different (Figure 5). The nitrogen harvest index in vermicompost treatment is 22.7% and 24.6% higher than in vermicompost with LOF and synthetic fertilizer, respectively. The N harvest index in vermicompost with LOF and synthetic fertilizer were similar. A different trend was observed in the P harvest index, where treatments were similar in number. The K harvest index followed suit. The phosphorus harvest index ranged between 65-75%, while the K harvest index was 42-44%.

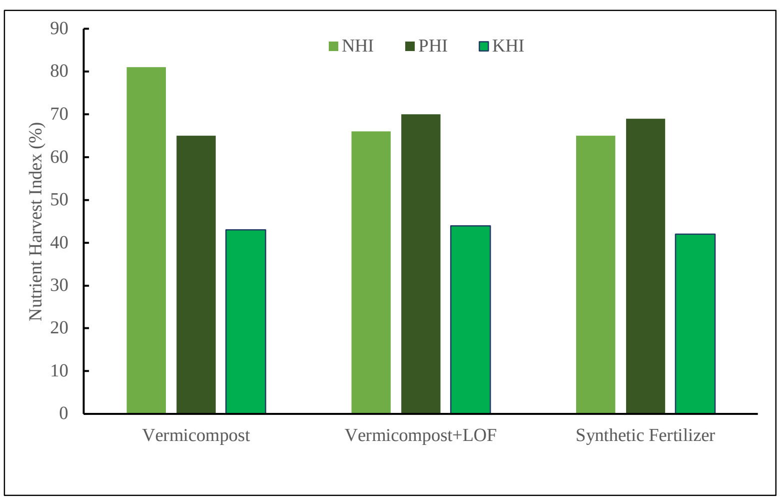


**Figure 5.** Harvest index of N, P, and K as affected by vermicompost and synthetic fertilizer

This study indicates that higher absorption of nutrients is highly related to peanut yield and kernel dry weight. Figure 6 shows that the treatment of vermicompost combined with LOF had the highest yield (pod and kernel) and dry weight of kernel. The dry weight of the kernel in the treatment of vermicompost with LOF is 27.3% and 34.7% higher than in the treatment of vermicompost alone and with synthetic fertilizer, respectively.

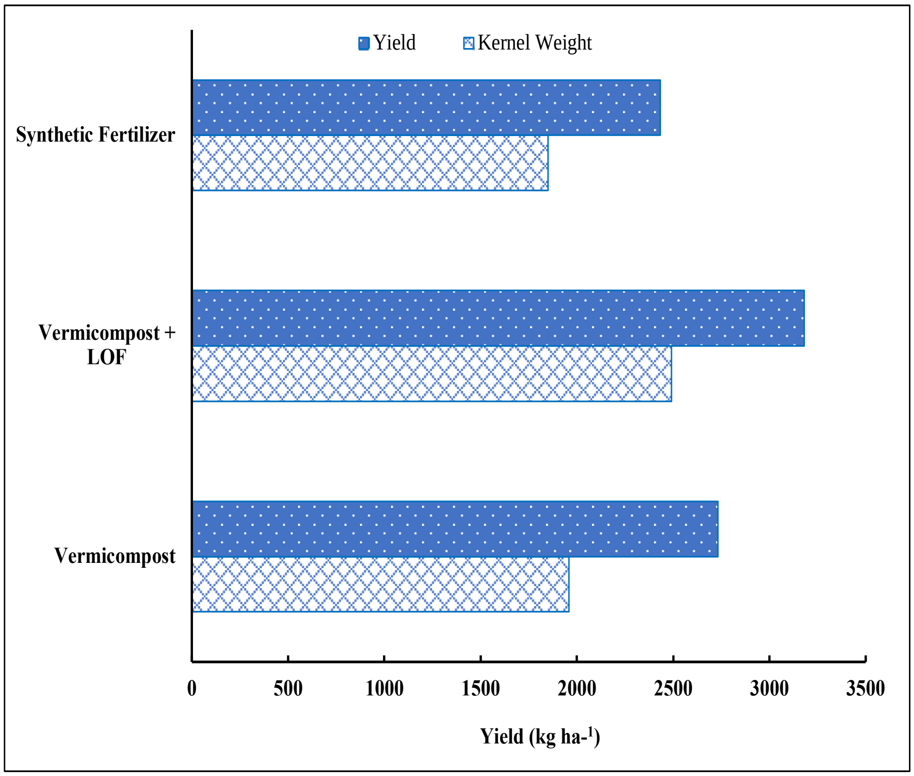


**Figure 6.** Yield and kernel dry weight of peanut under vermicompost and synthetic fertilizer application

## Discussion

Nitrogen, P, and K have different distribution roles in each peanut growth and development stage. Leaves and stem require more N at an earlier stage of development (R1 to R4); afterward, pod and kernel need more N, indicating that most N is mobilized for seed formation. Nitrogen is required for protein synthesis and nucleic acid synthesis (Purbajanti *et al.*, 2018). Most N is mobilized from vegetative organs during grain filling (Suprayogi *et al.*, 2011).

According to Silva *et al.* (2017), the N absorption rate was highest at stages R1-R4, averaging 55 g $day^{-1}$. During the development stage, the peanut absorbs more phosphorus. The kernel achieves the greatest P absorption, demonstrating its vital role in seed development. According to Lott *et al*. (2017), the role of phytin and phytic acid is in controlling inorganic phosphate homeostasis in developing seeds. A different pattern of K uptake was observed where leaves and stem absorbed higher K at R4 and R6, while kernels had lower K uptake, exhibiting lower K during seed development.

Nutrient absorption by peanuts depends on their availability in soil. Nitrogen from synthetic fertilizer (urea) is readily available at an early stage of development since this fertilizer is very soluble, leading to higher uptake at R1 than vermicompost, which releases nutrients slowly. However, at R2, vermicompost combined with LOF aligned with synthetic fertilizer N absorption, even exceeding it at R4 and later development. Likewise, the application of vermicompost alone needs a longer time to align N absorption by synthetic fertilizer (R4). Phosphorous uptake by peanuts fertilized with vermicompost and LOF was the highest after pegging (R2). However, there were no differences between those fertilized with vermicompost alone and those fertilized with synthetic fertilizer. This study also observed that K absorption followed a similar pattern. These results indicate that LOF can supplement the availability of N, P, and K for the plant. Liquid organic fertilizer eventually provides faster nutrient availability to plants. According to Hartz *et al*. (2010), N from liquid organic fertilizer is available up to 93% within 1 week of the application. Muktamar *et al*. (2017) confirmed that supplementation of LOF to vermicompost increased N, P, and K uptakes by organically managed sweet corn in the highlands. Higher N, P, and K uptakes by peanuts fertilized with the combination of vermicompost and LOF lead to the greatest biomass (leaves, stems, pods, and kernels). The total peanut biomass in the treatment of vermicompost with LOF was 7561 kg $ha^{-1}$, higher than in vermicompost alone and with synthetic fertilizer.

The nutrient harvest index is a ratio of nutrient uptake by the kernel to the total plant uptake of nutrients. This index measures the re-translocation efficiency of absorbed nutrients from vegetative plant fragments to the kernel. This index is vital in determining nutrient partitioning in the crop, which indicates how efficiently the plant utilizes nutrient absorption for kernel production. According to Bender *et al*. (2013), grain nutrient content increases after nutrient remobilization from the leaf, stem, and pod. In this study, the harvest N index ranges from 66% to 81% (average: 71%), depending on the treatments. Bender *et al*. (2015) found a much lower N harvest index for soybean (46%). A high N harvest index suggests increasing nitrogen partitioning in the seed (Bulman and Smith, 1994). Nitrogen assimilated by the plant is highly correlated with seed yield, as suggested by Ohyama *et al*. (2013). The nitrogen harvest index in the treatment of vermicompost alone is the highest compared to other treatments, indicating very efficient nitrogen transport from vegetative fragments to the kernel. Peanut fertilized with vermicompost alone has a lower N uptake, forcing it to transfer the nutrient for seed formation.

The phosphorus harvest index ranges between 65-75% (average of 68%), slightly lower than that of N. However, the K harvest index is lower than those of N and P (an average of 43%). Despite its lower harvest index, the translocation of K from vegetative fragments is still indispensable since a large quantity of K was remobilized from leaves and stem. A study by Bender *et al*. (2015) suggested that plant stems can temporarily store particular nutrients. The study also indicates that the application of synthetic or organic fertilizer does not influence the P and K harvest indices. A similar result was reported by Xie *et al*. (2020), where the N, P, and K indices were 72%, 69%, and 39%, respectively.

The application of vermicompost combined with LOF had the greatest kernel production compared to other fertilizers. This result might have been related to the greater removal of N, P, and K during seed formation. Also, the release of micronutrients, including boron (B), from vermicompost and LOF will accelerate seed formation. According to Meena *et al*. (2007), boron is essential in seed setting and the quality of peanut seed, along with assisting the acquisition of N.

In conclusion, N, P, and K acquisition increased from the flowering stage to the full seed stage of peanut growth and development. At full seed (R6), the average N requirement is 116.9 kg $ha^{-1}$, while P and K requirements are 25.4 and 26.2 kg $ha^{-1}$, respectively. During pod and seed formation, nutrient availability is crucial for the formation of pod and seed (R4–R6). Application of vermicompost combined with LOF aligned the N, P, and K absorption by synthetic fertilizer at R2 and was higher at later stages, while vermicompost alone was at R4 but never surged afterward. On average, the N, P, and K harvest indices for peanut were 71%, 68%, and 43%, respectively. The application of vermicompost alone had the highest N harvest index, while the P and K indices were not different among the treatments. When compared to no LOF or synthetic fertilizer, the application of vermicompost with LOF resulted in the highest kernel yield. This finding supports the management of fertilization for peanut production in organic farming practices.

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