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# NUMBER OF SEEDS AND FERTILIZATION AFFECT THE MORPHOPHYSIOLOGICAL CHARACTERS AND PRODUCTION OF COWPEA

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## ABSTRACT

Cowpea, known as a food crop, demonstrates thrive on land with low soil fertility. Albina IPB is a new superior variety of cowpea with a potential yield of 3.88-4.69 t ha$^{-1}$. This study aims to evaluate the productivity of Albina based on differences in the number of seeds and fertilization. Minus one test method was applied to find out which nutrients among N, P, and K had the most influence on the growth and production of cowpea. The results showed that one seed per planting hole gave the best results which were significantly different from others, while the combination of three seeds per planting hole with minus K resulted in the lowest growth in general. Nevertheless, anthocyanin in the combination of three seeds per planting hole with minus K produced the highest value, significantly different from the other treatments. These results indicate that element K is a limiting element in the growth of cowpea. However, neither the fertilization treatment nor the number of seeds was significantly different in the yield and yield components. Plant productivity ranged from 0.82-1.42 t ha$^{-1}$ for all treatments.

**Keywords**: Anthocyanin, minus one test, photosynthesis, plant density, plant nutrition, potassium, yield

## Introduction

Cowpea (*Vigna unguiculata* Walp) which originated in Sub-Saharan Africa, is one of the world's most important legumes (Murdock *et al.* 2018). Cowpea is adapted to suboptimal environments with high temperatures, acid soils, drought, and low soil fertility (Chikoye *et al.* 2014). The global area of cowpea plantations is 15.1 million hectares, with a global productivity of 8.9 million tons (FAO 2022). According to Goncalves *et al.* (2016), cowpea has a high level of vegetable protein (18-35%). Therefore, in Indonesia, cowpea can be used as an alternative food to soybeans, particularly for the basic ingredients used to make popular Indonesian foods such as tempeh and tofu. Indonesia's reliance on soybean imports has reached 78.44% per year and its use as a food ingredient reached 84.6% (Ministry of Agriculture 2020). The use of cowpea as an alternative food to soybeans has the potential to improve Indonesia's food security.

Cowpea productivity in Indonesia remains low, ranging from 1.5 to 2.0 tons ha$^{-1}$ depending on variety, location, planting season, and cultivation method (Wicaksono 2020). Superior varieties are an important factor in crop production efforts and are easily implemented by farmers. Albina IPB Cowpea is one of the new superior varieties developed through plant breeding by IPB University researchers, Indonesia. Cowpea with white seed characteristics has a higher yield potential of 3.88-4.69 t ha$^{-1}$ and a harvest age of 60-69 days after planting (DAP).

To increase the actual yield of the Albina variety to its potential yield, appropriate cultivation techniques such as adjusting the number of seeds per hole and applying fertilization in balanced doses must be evaluated. Plant density is affected by the number of seeds planted per planting hole, which is related to the level of competition for resources such as light, water, space, and nutrients. Fertilization through the minus one test is one method for determining the role of N, P, and K specifically for plants. This method involves applying a combination treatment of N, P, and K fertilizers, then removing one of the three elements to determine which nutrient produces the lowest yield. The treatment consisting of two elements and yielding the lowest production demonstrates that the missing element is a limiting factor for plant growth (Atmaja 2017). Based on this background, it is necessary

to conduct research to increase cowpea productivity by evaluating the number of seeds per planting hole and fertilizing using the minus one test method.

## Material and Methods

**Experimental site and plant material:** The planting material used was cowpea seeds (*Vigna unguiculata*) of the Albina IPB variety with white seed characteristics. This research was conducted at the Cikabayan Experimental Station (6º33'04.4"S, 106º42'54.2"E), Department of Agronomy and Horticulture, IPB University, Dramaga, Bogor, Indonesia. The experiment was carried out in January until May 2022. Analysis of soil was carried out at the Testing Laboratory, Department of Agronomy and Horticulture, IPB University. Analysis of plant pigments and yield components was carried out at the Post Harvest Laboratory, Department of Agronomy and Horticulture, IPB University.

**Experimental design:** This study used a factorial Randomized Block Design (RBD) method with two factors and three replications. The first factor was the number of seeds per planting hole which consisted of three levels; one seed per planting hole (J1), two seeds per planting hole (J2) and three seeds per planting hole (J3). The spacing used was 50 × 20 $cm^2$. The second factor was the fertilization treatment using the minus one test method, by removing one of the nutrients so that it only consisted of two combinations of nutrients. Fertilization was carried out with four treatment levels; complete NPK fertilization (P1), PK minus N fertilization (P2), NK minus P fertilization (P3) and NP minus K fertilization (P4). Thus, there were 36 experimental units from 12 treatment combinations and three replications.

**Minus on Test method of fertilization application**: Fertilization treatment was carried out in accordance with the FERADS application recommendations based on the results of soil analysis before planting. The concept of fertilization is to provide nutrient deficiencies that are not yet available in the soil so that these nutrients are sufficient for plant needs. Fertilization treatment using a single nitrogen fertilizer (urea), phosphorus (SP-36) and potassium (KCl). The following explains the application of fertilization using the minus one test method:

a. Urea fertilization with a dose of 249 kg $ha^{-1}$ was applied in three stages. The urea fertilizer needed for all experimental plots was 10.76 kg. 4.3 kg of urea fertilizer was applied at 1 week after planting (WAP), a second fertilization of 3.2 kg of urea fertilizer was applied at 4 WAP and as much as 3.2 kg was applied at 7 WAP. Urea fertilization was not applied for P2 treatment (minus N).
b. SP-36 fertilization with a dose of 249 kg $ha^{-1}$ was applied 100% at the start of planting. The SP-36 fertilizer needed for all experimental plots was 10.76 kg. SP-36 fertilization was not given for P3 treatment (minus P).
c. KCl fertilization with a dose of 179 kg $ha^{-1}$ was applied in three stages. The KCl fertilizer needed for all experimental plots was 7.75 kg. 3.1 kg of KCl fertilizer was applied at 1 WAP, 2.32 kg of KCl fertilizer was applied at 4 WAP, and 2.32 kg was applied at 8 WAP. KCl fertilization was not applied to P4 treatment (minus K).

**Data collection**: The stages of observation on cowpea adjusted to the growth phase of the legume, phase V for vegetative and phase R for reproductive. The data observed in this study were: (1) soil analysis observed before and after research at the IPB University Testing Laboratory, (2) plant growth (number of leaves, canopy diameter, leaf area, plant biomass). Planting material is taken destructively then counted manually (number of leaves), and observed using a tape measure (canopy diameter). The plant shoots were dried in an oven at 80 ºC for 48 hours, then those were weighed using a digital scale to obtain the plant biomass, (3) plant physiology (greenness of leaves, leaf pigment, relative growth rate (RGR), photosynthetic rate, stomatal conductance). The relative content of chlorophyll was measured using a SPAD-502 chlorophyll meter (Minolta Co. Ltd. Japan). Photosynthesis rate and stomatal conductance were measured using a Li-Cor 6400XT Portable Photosynthesis System. RGR was measured by destructively weighing the dry weight of roots, stems and leaves from two plant holes per plot. Observations of relative growth rates are calculated by the formula as stated by Hoffmann and Poorter (2002), (4) yield and yield components (pod dry weight, seed dry weight, and productivity). Plants that

were suitable for harvest had indicators that the leaves of the plants started to turn yellow or the cowpea pods started to dry out in 50% of the plant population in each experimental plot. Harvesting is carried out three times every week. Harvesting is done by picking dry pods which are marked with brown or black pods.

**Statistical analysis**: The data were analyzed statistically using SAS 9.0 software with two-way ANNOVA at the α level of 5% to determine the real effect of each treatment. If there is a significant effect, then the Duncan Multiple Range Test is carried out at the α level of 5%. The Pearson correlation test was carried out to determine the relationship between the observed variables.

## Results and Discussion

The experimental land had a pH of 4.3 (very acid), C-organic 1.63% (very low), total N 0.23% (moderate), total P 122.24 mg $P_2O_5$ (very high), P-available 3.70 ppm $P_2O_5$ (very low), and K-available 42.87 ppm K (high) (Sulaeman *et al.* 2005). Plants cannot grow in soil that is extremely acidic. Additional organic matter and lime are required on very acidic land with very low C-organic content. Cowpea grows best in soil that has an acid pH of 5.0-6.5 (Karsono 1998). Thus, an additional application of manure and agricultural lime at a rate of 2 t $ha^{-1}$ is made to reduce soil acidity and allow for more optimal cowpea growth.

Soil analysis after the research found that the results of soil chemical parameters were generally better. pH after the study rose to 5.1, and the soil status become acidic. Meanwhile, the nutrient status of C-organic, N-total, K-total and P-available remained unchanged, but the value increased. Before planting P-total nutrient status was extremely high, however, P-available is very low (3.7), so there is an indication that there is a lot of bound P that could not be absorbed by plants. In acid soils, P is usually bound to Al or Fe so it becomes unavailable to plants. After planting, the total P value decreases after planting become low (10.46), this indicated there is a release of phosphorus to become P-available which can be absorbed by plants. These findings found an improvement in chemical soil quality after cowpea planting (Table 1).

Climate data showed an average humidity of 84.87% each month, an average temperature of around 26.15°C and during the experiment, rainfall ranged from 107 to 317 mm $month^{-1}$ (BMKG 2022). These climatic conditions are favorable for cowpea growth, but continuous water stagnation has the potential to reduce cowpea yield (Adisarwanto 1998). In general, the growth of plants was in quite good condition.

**Plant growth parameters:** Observations in plant morphology during the vegetative phase revealed that significant differences in the variables of leaves number, number of branches and plant biomass (Table 2.). The treatment with one seed per planting hole produced the highest value, while the treatment with three seeds per planting was the lowest compared with others. Planting one seed per hole reduces competition among plants, allowing plants to grow faster than planting a larger number of seeds. The density of plants is affected by the number of seeds planted per planting hole. Plant competition is important both above and below ground (Yu *et al.* 2009; Chen *et al.* 2015). This relates to the acquisition of population structure and individual functional acquisition in high density populations, which is the primary goal of cultivation in order to produce high yields (Zhao *et al.* 2006; Chen *et al.* 2010).

**Table 1. Soil analysis results before and after planting**

| Parameter | Method | Before planting | After planting |
|---|---|---|---|
| pH | pH meter | 4.3 (very acid) | 5.1 (acid) |
| C-organik (%) | Spectophotometry | 1.63 (very low) | 1.9 (very low) |
| N-total (%) | Kjeldahl | 0.23 (medium) | 0.26 (medium) |
| P-total (me 100 $g^{-1}$) | Spectophotometry | 122.24 (very high) | 60.49 (very high) |
| P-available (ppm) | Bray | 3.7 (very low) | 10.46 (low) |
| K-total (me 100 $g^{-1}$) | AAS | 42.87 (high) | 63.02 (high) |

The soil status described above is based on Sulaeman *et al.* (2005)

The full NPK fertilization treatment did not differ significantly from the treatment lacking N, P, and K. The combination of three seeds per hole and a minus K showed that leaf number, canopy diameter, and leaf area in R1 produced the lowest results (Table 2.). This is consistent with the findings of Mualim *et al.* (2009), who found that element K is a limiting factor in producing more leaf area in bay leaves. According to the findings of this study, element K is a limiting element in the vegetative phase of plant growth. The function of K element is to promote assimilate translocation from the leaves as a source to the storage organ or sink. Furthermore, K is involved in the process of opening and closing stomata. Stomata open because guard cells absorb water, which occurs due to the influence of $K^+$ ions (Singh *et al.* 2014). Potassium is also vulnerable to luxury consumption when the addition of elemental K input does not correspond to an increase in yield (yield is constant). This result is consistent with the findings of Sukarjo *et al.* (2017), who found that increasing K nutrient inputs increased K uptake in grain but did not increase grain production.

**Plant Physiology:** The Li-Cor 6400XT Portable Photosynthesis System (Li-Cor BioScience, Lincoln, NE, USA) was used to measure photosynthesis rate and leaf temperature. Measurements were taken on the third leaf from the top at 09.00-11.00 a.m., when the weather is sunny and the solar radiation is at its peak. In general, The treatment of one seed per hole resulted in the lowest photosynthetic rate which was significantly different from others (Table 3.). In cowpea with three seeds per planting hole, the plant density is higher so that more leaves overlap each other which eventually results in shading from the leaves above it. This causes the rate of light photosynthesis in plants with high density to be greater than that of low plant density. In the canopy area, light absorption can take place efficiently due to a limited balance of $CO_2$ absorption (Yustianingsih 2019). This finding is consistent with the study by Yang *et al.* (2022) which found that maize planted at higher plant densities has a higher photosynthetic rate, which corresponds to an increase in the number of chloroplasts in the grana. The highest photosynthesis in rice and cowpea plants occurs

**Table 2. Number of leaves at R1, number of branches at R1, canopy diameter at V4 and total biomass of cowpea**

| Treatment combinations | Number of leaves (plant$^{-1}$) | Number of branches (plant$^{-1}$) | Canopy diameter (cm) | Plant biomass (g) |
|---|---|---|---|---|
| | R1 | R1 | V4 | |
| J1P1 | 25.33$^{ab}$ | 28.17$^{ab}$ | 63.00$^{abc}$ | 140.76$^{ab}$ |
| J1P2 | 24.00$^{bc}$ | 27.67$^{ab}$ | 79.00$^{a}$ | 143.88$^{ab}$ |
| J1P3 | 29.00$^{a}$ | 30.33$^{a}$ | 73.66$^{ab}$ | 171.32$^{a}$ |
| J1P4 | 25.67$^{ab}$ | 22.00$^{bc}$ | 50.33$^{cd}$ | 139.68$^{ab}$ |
| J2P1 | 18.33$^{cde}$ | 15.50$^{de}$ | 56.00$^{cd}$ | 102.03$^{bc}$ |
| J2P2 | 17.50$^{de}$ | 16.00$^{cde}$ | 46.33$^{d}$ | 83.82$^{cd}$ |
| J2P3 | 18.17$^{cde}$ | 16.17$^{cde}$ | 54.66$^{cd}$ | 112.50$^{bc}$ |
| J2P4 | 18.00$^{cde}$ | 14.17$^{de}$ | 53.33$^{cd}$ | 87.58$^{cd}$ |
| J3P1 | 16.30$^{de}$ | 11.77$^{e}$ | 48.11$^{cd}$ | 83.82$^{cd}$ |
| J3P2 | 12.30$^{ef}$ | 12.40$^{de}$ | 48.11$^{cd}$ | 72.98$^{d}$ |
| J3P3 | 13.533$^{ef}$ | 13.53$^{e}$ | 56.11$^{bc}$ | 77.50$^{cd}$ |
| J3P4 | 9.633$^{f}$ | 10.10$^{e}$ | 44.88$^{d}$ | 76.62$^{cd}$ |
| Pr>F | <.0001 | <.0001 | 0.0004 | <.0001 |

Means within a column followed by common letter(s) are not significantly different by DMRT posthoc statistic at P < 0.05. J1: 1 seed per planting hole, J2: 2 seeds per planting hole, J3: 3 seeds per planting hole.
P1: NPK, P2: PK (Minus N), P3: NK (Minus P), P4: NP (Minus K).

**Table 3. Photosynthesis and leaf temperature at R1, relative growth rate at R1, R3, R5 on cowpea plants**

| Treatment combinations | Photosynthesis rate (μmol $m^{-2}s^{-1}$) | Leaf temperature (ºC) | Relative Growth Rate (g $day^{-1}$) | |
|---|---|---|---|---|
| | R1 | R1 | R1-R3 | R3-R5 |
| J1P1 | 30.77[b] | 22.76[a] | 0.04[a] | 0.05[a] |
| J1P2 | 30.68[b] | 22.80[a] | 0.03[a] | 0.09[a] |
| J1P3 | 32.60[ab] | 22.62[a] | 0.05[a] | 0.03[a] |
| J1P4 | 30.83[b] | 22.60[a] | 0.07[a] | 0.03[a] |
| J2P1 | 33.92[ab] | 22.60[a] | 0.08[a] | 0.06[a] |
| J2P2 | 33.15[ab] | 22.70[a] | 0.05[a] | 0.05[a] |
| J2P3 | 33.38[ab] | 22.81[a] | 0.09[a] | 0.03[a] |
| J2P4 | 36.24[a] | 22.61[a] | 0.03[a] | 0.05[a] |
| J3P1 | 35.44[a] | 22.47[a] | 0.09[a] | 0.04[a] |
| J3P2 | 34.33[ab] | 22.57[a] | 0.05[a] | 0.03[a] |
| J3P3 | 36.20[a] | 22.55[a] | 0.03[a] | 0.04[a] |
| J3P4 | 34.37[ab] | 22.60[a] | 0.05[a] | 0.08[a] |
| Pr>F | 0.0244 | 0.9852 | 0.0537 | 0.0504 |

Means within a column followed by common letter(s) are not significantly different by DMRT posthoc statistic at P < 0.05. J1: 1 seed per planting hole, J2: 2 seeds per planting hole, J3: 3 seeds per planting hole.
P1: NPK, P2: PK (Minus N), P3: NK (Minus P), P4: NP (Minus K).

during the vegetative period and then decreases with the increasing age of the plant until the lowest photosynthesis occurs in the seed filling (Faza *et al.* 2023, Lubis *at al*. 2013).

The average leaf temperature was 22.63 °C. Temperature and relative growth rate have no significant difference for all treatments. Leaf temperature can affect plant photosynthesis because it influences enzyme activity and plant metabolism, stomatal closure and opening (Wang *et al.* 2020). An increase in leaf temperature increased net assimilation in tillers and internode elongation to some extent, while net assimilation decreased in the reproductive and generative phases. In peanuts exposed to high temperatures ≥36 °C caused a decrease in seed yield despite greater biomass accumulation (Prasad *et al.* 2023). The relative growth rate in every stage has no significant difference for all treatments.

Plants require chlorophyll and other pigments for their photosynthesis. The amounts of chlorophyll a, chlorophyll b, total chlorophyll, and carotene were not significantly different among treatments when these plant pigments were examined. However, the amount of chlorophyll a is higher than chlorophyll b. This phenomenon is closely related to photosynthesis, since chlorophyll can absorb light energy to activate the photosynthetic process. Indirect light hitting plants will promote higher chlorophyll a production because the absorption of the red light spectrum is much higher (Taiz and Zeiger 2010)

Anthocyanins are flavonoid compounds that have antioxidant properties in living things (Ververidis *et al.* 2007). The anthocyanin levels of cowpea leaves with the treatment of three seeds per hole and NP fertilizer (minus K) yielded in the highest value of 0.17 mg $g^{-1}$ BW, which was significantly different from the other treatments (Table 4). Plants under stress, both abiotic and biotic, can produce secondary metabolites in the form of anthocyanins, according to Steyn *et al.* (2002) and Gould (2004). This phenomenon showed that a lack of potassium combined with a high planting density in cowpea can be a limiting factor because stress induces the formation of antioxidants in the form of anthocyanins. This finding is in accordance with Mualim *et al.* (2009), who found that the minus K treatment induced the highest anthocyanin formation in bay leaves as much as 18.90 mol $plant^{-1}$.

**Table 4. Plant pigments at R2 and leaf SPAD values at R1 and R8 on cowpea plants**

| Treatment combinations | Anthocyanin (mg $g^{-1}$) | Carotene (mg $g^{-1}$) | Chlorophyll a (mg $g^{-1}$) | Chlorophyll b (mg $g^{-1}$) | Chlorophyll total (mg $g^{-1}$) | Leaf SPAD value | |
|---|---|---|---|---|---|---|---|
| | R2 | R2 | R2 | R2 | R2 | R1 | R8 |
| J1P1 | 0.09[b] | 0.43[a] | 1.49[a] | 0.54[a] | 2.03[a] | 66.57[a] | 28.20[a] |
| J1P2 | 0.11[b] | 0.49[a] | 1.71[a] | 0.59[a] | 2.30[a] | 54.57[a] | 20.63[a] |
| J1P3 | 0.08[b] | 0.40[a] | 1.35[a] | 0.47[a] | 1.82[a] | 59.43[a] | 24.40[a] |
| J1P4 | 0.10[b] | 0.41[a] | 1.38[a] | 0.49[a] | 1.88[a] | 60.06[a] | 25.43[a] |
| J2P1 | 0.08[b] | 0.49[a] | 1.68[a] | 0.56[a] | 2.24[a] | 60.23[a] | 25.93[a] |
| J2P2 | 0.07[b] | 0.35[a] | 1.11[a] | 0.35[a] | 1.46[a] | 52.46[a] | 22.13[a] |
| J2P3 | 0.08[b] | 0.33[a] | 1.01[a] | 0.38[a] | 1.40[a] | 60.80[a] | 26.13[a] |
| J2P4 | 0.07[b] | 0.45[a] | 1.53[a] | 0.52[a] | 2.04[a] | 61.46[a] | 24.90[a] |
| J3P1 | 0.07[b] | 0.42[a] | 1.34[a] | 0.48[a] | 1.81[a] | 65.03[a] | 30.27[a] |
| J3P2 | 0.09[b] | 0.46[a] | 1.60[a] | 0.59[a] | 2.20[a] | 64.56[a] | 22.96[a] |
| J3P3 | 0.07[b] | 0.41[a] | 1.38[a] | 0.48[a] | 1.86[a] | 64.73[a] | 19.07[a] |
| J3P4 | 0.17[a] | 0.38[a] | 1.18[a] | 0.47[a] | 1.65[a] | 58.63[a] | 30.60[a] |
| Pr>F | 0.0331 | 0.7977 | 0.4937 | 0.9554 | 0.5108 | 0.0849 | 0.4118 |

Means within a column followed by common letter(s) are not significantly different by DMRT posthoc statistic at $P < 0.05$.
J1: 1 seed per planting hole, J2: 2 seeds per planting hole, J3: 3 seeds per planting hole.
P1: NPK, P2: PK (Minus N), P3: NK (Minus P), P4: NP (Minus K).

SPAD is a method for determining the relative chlorophyll content of leaves. SPAD values were measured three times on three different leaves and then averaged. The findings showed that leaf SPAD values were not significantly different for all treatments in both the R1 and R8. The SPAD value in R1 ranged from 52.46 to 66.57 units, while it dropped dramatically to 20.63-30.60 units in vase R8. The greatest decrease in SPAD, according to Olorunwa *et al.* (2023), occurred in R7. The SPAD value of the leaves is high in the R1, indicating that the leaves are very active in photosynthesis. In R8, leaf chlorophyll has been degraded as a result of senescence, causing the leaves to turn yellowish and fall. Nutrient remobilization from old to young leaves occurs during this phase. These findings are in accordance with a study from Khafid (2021) which found that the chlorophyll and carotenoid pigments in bay leaves increase to the peak of the vegetative and then decrease due to senescence. As plants concentrate on grain production, leaf photosynthesis decreases.

**Yield and yield components:** Albina IPB cowpea begin to bloom around 37-40 days after planting. Harvesting was carried out on the tiles of each plot when 50% of the pods' color began to dry, as indicated by a change in color from green to brown. Harvesting was done three times. High rainfall also caused incomplete seed filling so not all pods contain seeds. Rainfall can affect growth and yield, it is the primary controller in cowpea cultivation. The cowpea harvest is less than ideal when there is a lot of rain. Olorunwa *et al.* (2022) also mentioned how standing water for 10 consecutive days stunted root growth in cowpea.

Data on yield components were obtained from each experimental plot's area per square meter and then converted into $ha^{-1}$ to obtain the yield (productivity). Although the plant growth variables were significantly different, the results of the analysis of variance on the yield and yield components of the cowpea yield showed no significant effect for all treatments (Table 5.). This case can occur due to the relatively high rainfall during the study period, low soil fertility, and plants adapting to different light intensities. In this study, the productivity of the Albina cowpea variety ranged from 0.82-1.43 t $ha^{-1}$, which was lower than the yield potential of 3.88-4.69 t $ha^{-1}$.

High rainfall, particularly during the R2 (when plants are fully bloomed), is considered to be to blame for the decrease in yields. R2 is a critical stage in cowpea

**Table 5. Yield and yield components at R8 on cowpea plants**

| Treatment combinations | Number of pods ($m^{-2}$) | Pods dry weight (g $m^{-2}$) | Seeds dry weight (g $m^{-2}$) | Productivity (t $ha^{-1}$) |
|---|---|---|---|---|
| | R8 | R8 | R8 | R8 |
| J1P1 | 71.56[a] | 113.52[a] | 84.26[a] | 0.84[a] |
| J1P2 | 114.44[a] | 163.96[a] | 120.11[a] | 1.20[a] |
| J1P3 | 114.11[a] | 171.96[a] | 127.10[a] | 1.27[a] |
| J1P4 | 95.76[a] | 131.42[a] | 92.11[a] | 0.92[a] |
| J2P1 | 126.78[a] | 163.14[a] | 123.25[a] | 1.23[a] |
| J2P2 | 105.44[a] | 155.10[a] | 115.38[a] | 1.15[a] |
| J2P3 | 142.11[a] | 195.01[a] | 143.13[a] | 1.43[a] |
| J2P4 | 102.33[a] | 149.31[a] | 104.80[a] | 1.05[a] |
| J3P1 | 100.88[a] | 148.08[a] | 105.90[a] | 1.06[a] |
| J3P2 | 95.89[a] | 255.37[a] | 107.57[a] | 1.07[a] |
| J3P3 | 120.67[a] | 192.43[a] | 142.47[a] | 1.42[a] |
| J3P4 | 96.33[a] | 122.84[a] | 82.53[a] | 0.82[a] |
| Pr>F | 0.597 | 0.725 | 0.753 | 0.713 |

Means within a column followed by common letter(s) are not significantly different by DMRT posthoc statistic at $P < 0.05$.
J1: 1 seed per planting hole, J2: 2 seeds per planting hole, J3: 3 seeds per planting hole.
P1: NPK, P2: PK (Minus N), P3: NK (Minus P), P4: NP (Minus K).

growth because it requires a high nutrient input, after which resources are diverted to the reproductive phase in preparation for pod formation (Olorunwa *et al.* 2023). Excessive waterlogging during this phase will disrupt plant morphology and physiology, resulting in a decrease in yield (Noori *et al.* 2017). Because of the high rainfall, mobile nutrients such as nitrogen and potassium are easily leached. Stagnant water in cowpea can cause anaerobic conditions that inhibit the absorption of important nutrients such as N, P, and K, potentially reducing crop yields (Kaur *et al.* 2020). In addition, high rainfall causes the intensity of light received by plants to decrease, thereby reducing plant photosynthesis, which in turn reduces yields.

The level of poisoning of Mn, Zn, and Al elements increased in research lands with very acidic soil status (pH 4.3), then decreased in soils with a pH less than 5.5 (Siswanto 2018). Low pH had a direct impact on the availability of nutrients such as N, K, Ca, Mg, and S, which tended to decrease as pH decreased. Because elemental P availability was dependent on the formation of less soluble compounds with Al, Fe, Mn, and Ca, the effect of pH on elemental P was indirect. As a result, there was a lot of P-total in the soil, but only a little of it could be absorbed by plants (P-available) because Al metal binds a lot of it in acid soils. Excessive Al content could harm plants by inhibiting root elongation and decreasing root biomass (Pintro *et al.* 1995), causing obstacles to nutrient uptake. High Al levels also inhibited $CO_2$ assimilation in plants, potentially reducing crop yields.

## Conclusion

The plant growth parameters exhibited by one seed per planting hole treatment were the highest with significant differences in the variables of leaf number, canopy diameter, and plant biomass. Nevertheless, the rate of plant photosynthesis was generally lowest in one seed per planting hole. The combination treatment of three seeds per planting hole and NP fertilizer (minus K) showed the lowest growth compared with other treatments. Anthocyanin pigments in three seeds and minus K treatment produced the highest amount of anthocyanin. Cowpea yield and yield components did not differ significantly across treatments. The Pearson correlation test revealed a link between photosynthesis and cowpea yield components. The productivity of Albina IPB cowpea in this study (0.82-1.42 t $ha^{-1}$) was lower than Albina IPB potential yields in the variety description (3.88-4.69 t $ha^{-1}$).

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