The Effect of Ammonium Nitrate Ratio and Support Types on the NPK Uptake and Growth of Black Pepper (*Piper nigrum* L.) in Field Conditions

Učinak omjera amonijeva nitrata i tipova potpore na unos NPK i uzgoj crnoga papra (*Piper nigrum* L.) u poljskim uvjetima

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THE EFFECT OF AMMONIUM NITRATE RATIO AND SUPPORT TYPES ON THE NPK UPTAKE AND GROWTH OF BLACK PEPPER (*Piper nigrum* L.) IN FIELD CONDITIONS

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Preliminary communication
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SUMMARY

The study's objective was to determine the effect of the NO_3^-: NH_4^+ratio and types of support on NPK uptake and pepper plant growth in field conditions. The study used a completely randomized block design with three replications. The first factor was the type of support, being the deadwood and living supports in the form of* Gliricidia sp. *and* Ceiba pentandra*. The second factor was the ratio of N fertilizer forms, which were 100% NO_3^-, 100% NH_4^+, 50% NO_3^-:50% NH_4^+, 75% NO_3^-:25% NH_4^+ and 25% NO_3^-:75% NH_4^+. The results have demonstrated that the uptake of N, P, and K, as well as the plant growth, were not affected by the interaction of the N fertilizer form ratio with the types of support. In field conditions, the black pepper prefers the N fertilizer in the form of 50% NO_3^-:50% NH_4^+. The pepper plants that were given N fertilizer in a combination of 50% NO_3^-:50% NH_4^+ have demonstrated an N, P, and K uptake, and morphology and plant dry weight were higher than the ratio of other forms of N fertilizers.

Keywords: black pepper growth, N fertilizer form, NPK uptake, supports

INTRODUCTION

Nitrogen (N) is an essential plant macronutrient. The N content in plant dry matter ranges from 1.5 – 5% (Haynes, 2012). Nitrogen plays a role in various physiological, metabolic, and structural activities of plants such as cell building, protein building, cytoplasm, nucleic acids, and chlorophyll (Mengel et al., 2001). The important role of N for plants is often followed by the application of large amounts in cultivation practices, therefore the efficiency of using N fertilizer is low (Malhi et al., 2001). Furthermore, the use of inappropriate N fertilizers can cause environmental pollution (Fageria and Baligar, 2005). The selection of the use of N fertilizer forms can be one of the considerations for the efficiency of N fertilizer use (Wang et al., 2016). These are the most used forms of N in fertilizers and taken up by plants are ammonium (NH_4^+) and nitrate (NO_3^-). NH_4^+ and NO_3^- ions are the most widely absorbed forms of N by plants. The uptake of NH_4^+ or NO_3^- ions is influenced by internal plant factors such as species, cultivar, growth phase and environmental factors such as pH, concentrations of NH_4^+ and NO_3^- (Xu et al., 2001). The species that grow adaptively in low pH soil or flooded land such as lowland rice prefer N in the form of NH_4^+. Such plants are generally tolerant of NH_4^+ poisoning (Britto and Kronzucker, 2002). In aerobic soils, high pH or dry land, adaptive growth of plants such as tobacco, corn and wheat prefer N in the form of NO_3^- (Shi-Wei et al., 2007).

The use of NH_4^+ and NO_3^- as a source of N fertilizer has so far only considered economic aspects, in that the two forms of N have different effects on plant growth and yield (Li et al., 2013). Plant preference for NH_4^+ and NO_3^- can be individually (alone) or a combination of both. Walch-Liu et al. (2000) stated that tobacco plants that were applied to N in the form of NO_3^- resulted in higher

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wet biomass weight, leaf area, and leaf growth rate than those applied to N in the form of NH_4^+. Wheat crops obtained the best results if N fertilizer was given in the form of NO_3^- (Wang et al., 2015). In tomato plants, the combination of NH_4^+ and NO_3^- (75: 25) showed higher root and shoot biomass and N uptake compared to the individual NH_4^+ and NO_3^- applications (Dong et al., 2012). The form of N fertilizer also causes competition for uptake of cations and anions of plants including the uptake of phosphorus (P) and potassium (K) nutrients (Marshcner, 1995). P uptake is higher when applied to N in the form of NH_4^+ compared to NO_3^- (Hoffmann et al., 1994) while K uptake is higher in N in the form of NO_3^- (Zhang et al., 2010).

Black pepper is a climbing perennial plant responsive to fertilization, especially N. Black pepper using living support require higher N fertilizer than plants using non-living support (deadwood). The majority of black pepper farmers in Indonesia uses wooden pole. Zaubin et al. (1990) explained that growth and yield of pepper plants using living support were lower than plants using non-living support. Nutrient competition with live tree support is one of the factors that causes the growth and yield of plants using living support to be lower than non-living support (Wahid, 1984). It has an impact on the adoption of the use of living support by black pepper farmers in Indonesia is lower. Preference for the form of N fertilizer can reduce the level of competition between plants. Plants that have the same preference for the form of N fertilizer compete more strongly and vice versa compete less if they have different preferences. From the description above, it is very interesting to study related to the preference of N fertilizer for black pepper and live tree support which until now have not been known. The objective of the study was to determine the effect of the ratio of NO_3^-: NH_4^+ and types of support on NPK uptake and black pepper growth in field conditions.

MATERIAL AND METHODS

The study was conducted in the KemujaVillage, MendobaratDistrict, Bangka District, Bangka Belitung Islands Province, from February to October 2018. The study used a factorial randomized complete block design with three replications. The factors tested were the types of support and the ratio of N fertilizer forms. The types of support tested were wooden pole, *Gliricidia* sp., and *Ceiba pentandra*. The ratios of N fertilizers tested were 100% NO_3^-, 100% NH_4^+, 50% NO_3^- + 50% NH_4^+, 75% NO_3^- + 25% NH_4^+, and 25% NO_3^- + 75% NH_4^+. Source of NO_3^- fertilizer was KNO_3, NH_4^+ was ZA (ammonium sulphate) fertilizer and 50% NO_3^- + 50% NH_4^+ is calcium ammonium nitrate. *Gliricidia* sp., and *C. pentandra* tree support with a length of 150 cm were planted six months before the pepper plants were planted. Planting distance of support 2 x 2m, planting hole measuring 40x40x40 cm. The distance of the black pepper plant from the support is about 15 cm. Two weeks before planting, 2,500g of chicken manure was applied and then mixed evenly in the planting hole. The 5-month-old Nyelungkup variety seeds were planted in the field with a population of 16 plants per treatment unit. Black pepper plants were fertilized according to Wahid (1984) at 300g of NPK (12:12:17) per plant per year which was divided into three applications every two months. NPK fertilizer (12:12:17) was converted into NH_4^+ and NO_3^- (source ofN according to treatment), SP-36 and KCl. The first application of fertilization is 1/6 dose, the second 2/6 dose and the third 3/6 dose of the total amount of fertilizer given per plant per year. Observations of morphology, plant growth, levels and nutrient uptake ofN, P, and K were conducted at the end of the study, which was plants aged 8 months after planting. Leaf area and root length were observed using an area meter. The roots were cut 2-4 cm long then put into a plastic bag measuring 12 x 20 cm, the bag was filled with enough water then the roots are spread by shaking. Water was removed slowly by cutting the two corners of the closed bag. In order to spread the roots more evenly assisted by hand, the water was set until no more drips. The root length was read with the meter area at the "length" button position. Furthermore, the root length was converted using a predetermined standard. The standard size used copper wire with a diameter adjusted to the size of the root (Indradewa, 2002). For this observation, a wire with a diameter of pepper root and a length of 0.5–5 m was used. Readings were conducted starting from the smallest diameter of the shortest length to the largest diameter of the longest length. Wires of different diameters but of the same length should read nearly the same length. The actual wire length relationship curve is made as the X axis with the long reading as the Y axis. The result of the length reading for the roots was entered in the curve to get the actual root length. Root surface area per plant sample, after measuring the sample root length, read the root projection area at the "area" button position assuming the root, which is cylindrical, then the root projection area = 2RP, where R is the radius, P is the root length. From this calculation, the value of R is obtained. The root surface area is the area of the cylindrical skin without a cap at both ends of the root, that is the circumference times the length of the root = 2ϖ RP. The root diameter is calculated by observing the root surface area to obtain a root diameter of 2R (Indradewa, 2001). The dry weight of leaves, stems, and branches, as well as that of the roots, was obtained by exposure in an oven at 65°C for 48 hours and then weighed using a digital scale until the weight was constant. The content of N, as well as that of P and K in the tissue, was analyzed using Kjeldahl and Morgan-Wolf methods following the procedures of the Institute for Soil Research, Indonesian Agency for Agricultural Research and Development, Ministry of Agriculture (Eviati and Sulaeman, 2009). Nitrogen, phosphorus and potassium uptake in the plant were obtained from the multiplication of N, P and K content with plant dry weight. Analysis of crop growth included:

Specific leaf area (SLA) was the leaf area in every leaf dry weight:

$$SLA = \frac{La}{Lw}\ cm^2\ g^{-1}$$

Net assimilation rate (NAR) (g dm^{-2} $week^{-1}$) according to Gardner et al. (1991):

$$NAR = \frac{(W2\text{-}W1)}{(T2\text{-}T1)} \times \frac{\ln La2\text{-}\ln La1}{(La2\text{-}La1)}$$

Crop growth rate (CGR) (g m^{-2} $week^{-1}$):

$$CGR = \frac{1}{Ga} \times \frac{(W2\text{-}W1)}{(T2\text{-}T1)}$$

where: La– plant leaf area (cm^2), Lw–leaf weight (g), W1–plant dry weight at first observation (g); W_2–plant dry weight at second observation (g); La1– leaf area at first observation (dm^2); La2– leaf area of second observation (dm^2); T1– first observation time (week); T2– second observation time (week), Ga– land area (m^2).

Data were statistically analyzed by an analysis of covariance (ANCOVA) to assess the interaction of two treatment factors and followed by the Tukey HSD test at a five–percent level if there was a significant difference among the treatments. The used covariance variables were calcium (Ca) and sulfur (S). All the analyses were performed using the General Linear Model Procedure (PROC GIM) (SAS Institute Inc., 1990).

RESULTS AND DISCUSSION

The results have demonstrated that there was no interaction between types of support and the ratio of N fertilizer forms to black pepper plants aged eight months after planting. The uptake of N, P, K, morphological characteristics and plant growth were significantly influenced by the type of support, while the type of ratio of the N shape did not give a significant effect.

The effect of N fertilizer form ratio on the N, P, and K uptake and the black pepper growth

Most of the nutrients needed by plants are absorbed from the roots. Plants with a good root system have optimal ability to absorb nutrients. The results showed that the length, diameter, and surface area of the roots when given N in the form of a combination of NH_4^+ with NO_3^- were greater than that given in the form of NH_4^+ or NO_3^- alone. However, the length, diameter and surface area of the roots showed no significant difference between the treatments for the ratio of the N fertilizers (Table 1).

Table 1. Root length (cm), root diameter (cm), and root surface area (cm^2) of black pepper on the types of supports and N fertilizer forms

Tablica 1. Duljina korijena (cm), promjer korijena (cm) i površina korijena (cm^2) crnoga papra na tipovima potpornja i oblicima N gnojiva

Treatment / *Tretman*	Root length / *Duljina korijena*	Root diameter / *Promjer korijena*	Root surface area / *Površina korijena*
Type of supports / *Vrsta potpornja*			
Deadwood / *Mrtvo drvo*	54.94a	0.75a	2,407.17a
Gliricidia sp.	22.08b	0.72a	998.29b
Ceiba pentandra	38.34b	0.72a	1,616.99b
Form of N fertilizers / *Oblik N gnojiva*			
NH_4^+ 100%	27.26a	0.68a	1,097.49a
NH_4^+ 75%: NO_3^- 25%	39.09a	0.70a	1,461.39a
NH_4^+ 50%: NO_3^- 50%	47.29a	0.80a	2,366.94a
NH_4^+ 25%: NO_3^- 75%	39.67a	0.71a	1,917.92a
NO_3^- 100%	38.96a	0.77a	1,527.02a
Interaction / *Međudjelovanje*	(-)	(-)	(-)

Note: The means in columns with different letters are significantly different at a five–percent level using the HSD Tukey test, (-) = no interaction

Opaska: srednje vrijednosti u stupcima s različitim slovima značajno su različite na razini od 5 %, uz korištenje Tukeyeva HSD testa, (-) = nema međudjelovanja

N, P, and K uptake

Nutrient uptake of N, P, and K was only influenced by the ratio of N fertilizer form, which was the differentiating factor. The results have proven that the lowest N nutrient uptake was in the form of 100% N fertilizer. There was a tendency that pepper plants liked the N fertilizer in the form of a combination of NH_4^+ and NO_3^-. It was indicated by a lower N uptake if the plants were fertilized with NH_4^+ or NO_3^- alone, compared to the combination of the two. If plants were fertilized with NH_4^+ or NO_3^- only, the N uptake was higher when fertilized with NH_4^+ than NO_3^-. The highest N uptake when fertilized with NH_4^+ 50%: NO_3^-50%. This result was in line with Mengel and Kirkby's (1987) statement that the rate of N uptake was higher if N fertilizer is given in the form of NH_4^+ and NO_3^- together. However, until the plants were eight months old after planting, the ratio of the forms of N fertilizers did not have a significant effect on the plant's N uptake in the leaves, branches, and roots (Table 2). Contrary to 100% of NH_4^+ fertilizer, the

N uptake in the leaves at 100% NO_3^- was similar to all ratios in the form of N fertilizer.

The form of N fertilizer can stimulate or inhibit the uptake of P and K. The results of P analysis of plant tissue have demonstrated that the P uptake was not significantly different between various ratios of N fertilizer forms. P uptake at the ratio of NH_4^+ 50%: NO_3^-50% was higher than the ratio of other N fertilizer forms, as was a higher K uptake at the ratio of NH_4^+ 50%: NO_3^- 50% (Table 4). K uptake was higher in the N fertilizer in the form of NO_3^- than that of NH_4^+ and, conversely, the K uptake in NH_4^+ fertilizer was lower than the NO_3^-. The K and NH_4^+uptakes compete with each other, different than the NO_3^- facilitated K uptake. The P uptake competes with NO_3^- and reinforces each other with NH_4^+ fertilizers. In addition, according to Marschner (1985), NH_4^+ and NO_3^- affect the cell pH and rhizosphere pH. pH is one of the factors that affect the absorption rate of cations and anions.

Table 2. Nitrogen (g plant^{-1}), phosphorus (g plant^{-1}), and potassium (g plant^{-1}) uptake in root, branches, leaf and total of black pepper on type of supports and form of N fertilizer

Table 2. Unos dušika (g biljka^{-1}), fosfora (g biljka^{-1}) i kalija (g bijlka^{-1}) u korijenu, granama i listu te ukupna količina crnoga papra na tipu potpornja i obliku N gnojiva

Treatment / *Tretman*	Nitrogen uptake / *Unos dušika*			Phosphorus uptake / *Unos fosfora*			Potassium uptake /*Unos kalija*		
	Root /*Korijen*	Branch / *Grana*	Leaf / *List*	Root / *Korijen*	Branch / *Grana*	Leaf / *List*	Root / *Korijen*	Branch / *Grana*	Leaf / *List*
Type of supports / *Vrstapotpornja*									
Deadwood / *Mrtvo drvo*	0.134a	0.748a	0.916a	0.003a	0.048a	0.150a	0.209a	1.414a	0.763a
Gliricidia sp.	0.048b	0.380b	0.457b	0.001a	0.025a	0.062b	0.076b	0.745b	0.375b
Ceiba pentandra	0.072b	0.602b	0.617b	0.001a	0.048a	0.104b	0.112b	1.01b	0.506b
Form of N fertilizers / Oblik N gnojiva									
NH_4^+ 100%	0.047a	0.472a	0.486b	0.001a	0.026a	0.075a	0.082a	0.642a	0.388b
NH_4^+ 75%: NO_3^- 25%	0.076a	0.549a	0.635ab	0.001a	0.034a	0.067a	0.101a	1.015a	0.494ab
NH_4^+ 50%: NO_3^- 50%	0.129a	0.682a	0.877a	0.004a	0.051a	0.134a	0.211a	1.248a	0.681a
NH_4^+ 25%: NO_3^- 75%	0.107a	0.472a	0.679ab	0.002a	0.048a	0.124a	0.155a	1.205a	0.594ab
NO_3^- 100%	0.075a	0.609a	0.641ab	0.002a	0.041a	0.127a	0.116a	1.164a	0.582ab
Interaction / *Međudjelovanje*	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)

Note: The means in columns with different letters are significantly different at a five–percent level using the HSD Tukey test, (-) = no interaction

Opaska: srednje vrijednosti u stupcima s različitim slovima značajno su različite na razini od 5 %, uz korištenje Tukeyeva HSD testa, (-) = nema međudjelovanja

Net assimilation rate (NAR) and crop growth rate (CGR)

The various ratio in the form of N fertilizer did not generate a significant impact on NAR, but it was significantly different on the CGR. A CGR with the ratio of high NH_4^+ was lower than that in the ratio of lower NH_4^+. Therefore, the lowest CGR was recorded at 100% NH_4^+, and it was significantly different. The application of N fertilizer with ratio of 50% NH_4^+:50% NO_3^- produced the highest CGR, but it was not significantly different from that of 25% NH_4^+:75% NO_3^- or 100% NO_3^- (Table 3).

Table 3. Net assimilation rate (NAR) (mg dm^{-2} week^{-1}) and crop growth rate (CGR) (g dm^{-2} week^{-1}) of black pepper on type of supports and form of N fertilizer

Tablica 3. Neto–stopa asimilacije (NAR) (mg dm^{-2} tjedan^{-1}) i stopa rasta biljke (CGR) (g dm^{-2} tjedan^{-1}) crnoga papra na tipu potpornja i obliku N gnojiva

Treatment / *Tretman*	N A R	C G R
Type of supports / *Vrsta potpornja*		
Deadwood / *Mrtvo drvo*	3.45a	6.78a
Gliricidia sp.	2.01b	2.78b
Ceiba pentandra	2.27ab	4.15b
Form of N fertilizers / *Oblik N gnojiva*		
NH_4^+ 100%	2.78a	3.14b
NH_4^+ 75%: NO_3^- 25%	1.62a	3.14b
NH_4^+ 50%: NO_3^- 50%	3.38a	6.69a
NH_4^+ 25%: NO_3^- 75%	2.49a	5.09ab
NO_3^- 100%	2.49a	4.78ab
Interaction / *Međudjelovanje*	(-)	(-)

Note: The means in columns with different letters are significantly different at a five–percent level using the HSD Tukey test, (-) = no interaction

Opaska: srednje vrijednosti u stupcima s različitim slovima značajno su različite na razini od 5 %, uz korištenje Tukeyeva HSD testa, (-) = nema međudjelovanja

Plant morphology

The results showed that the CGR affected leaf formation but had no effect on branch formation (Table 4 and Table 5). The length and number of orthotopic branches and the number and length of plagiotropic branches were not significantly different between the ratio forms of N fertilizer. The same results were also shown in the number of leaves, while the SLW and SLA were not significantly different between the ratio of N fertilizer forms. However, the ratio of N fertilizer forms had a significant effect on the leaf area. The lowest leaf area was found in the NH_4+ treatment of 100%, while the highest leaf area was found in the NH_4+ 50%: NO_3-50% ratio but it was not significantly different from the application of N fertilizer in the form of NH_4+100%. These results inform that 100% NH_4+ can inhibit the cell development, especially in leaves.

Table 4. Length (cm), and number of orthotropic branches and the number and length (cm) of plagiotropic branches of black pepper on the type of supports and the forms of N fertilizers

Tablica 4. Duljina (cm) i broj ortotropskih grana te broj i duljina (cm) plagiotropskih grana crnoga papra na tipu potpornja i obliku N gnojiva

Treatment	Length of orthotropic branches / *Duljina ortotropskih grana*	Number of orthotropic branches / *Broj ortotropskih grana*	Number of plagiotropic branches / *Broj plagiotropskih grana*	Length of plagiotropic branches / *Duljina plagiotropskih grana*
Type of supports / *Vrsta potpornja*				
Deadwood / *Mrtvo drvo*	150.66a	2.26a	20.03a	30.45a
Gliricidia sp.	133.24a	1.99a	14.45b	25.87b
Ceiba pentandra	143.57a	2.31a	17.15b	28.06ab
Form of N fertilizer / *Oblik N gnojiva*				
NH_4^+ 100%	132.54a	2.14a	16.26a	26.78a
NH_4^+ 75%: NO_3^- 25%	138.86a	1.82a	15.82a	28.15a
NH_4^+ 50%: NO_3^- 50%	156.78a	2.28a	19.71a	28.97a
NH_4^+ 25%: NO_3^- 75%	141.37a	2.30a	18.71a	27.46a
NO_3^- 100%	142.89a	2.39a	16.55a	29.28a
Interaction / *Međudjelovanje*	(-)	(-)	(-)	(-)

Note: The means in columns with different letters are significantly different at five-percent level using the HSD Tukey test, (-) = no interaction

Opaska: srednje vrijednosti u stupcima s različitim slovima značajno su različite na razini od 5 %, uz korištenje Tukeyeva HSD testa, (-) = nema međudjelovanja

Table 5. Leaf number, leaf area, specific leaf weight (SLW) (mg cm^{-2}) and specific leaf area (SLA) (cm^2 g^{-1}) of black pepper on type of supports and form of N fertilizers

Tablica 5. Broj listova, površina lista, specifična težina lista (SLW) (mg cm^{-2}) i specifična površina lista (SLA) (cm^2 g^{-1}) crnoga papra na tipu potpornja i obliku N gnojiva

Treatment / *Tretman*	Leaf number/ *Broj listova*	Leaf area/ *Površina lista*	SLW	SLA
Type of supports / *Vrsta potpornja*				
Deadwood / *Mrtvo drvo*	173.72a	4,198.81a	8.92a	114.69a
Gliricidia sp.	95.32b	2,255.42b	8.59a	119.34a
Ceiba pentandra	133.32b	3,040.42b	8.22a	123.85a
Form of N fertilizers / *Oblik N gnojiva*				
NH_4^+ 100%	121.85a	2,432.95b	8.13a	125.89a
NH_4^+ 75%: NO_3^- 25%	125.43a	2,900.43ab	8.35a	125.29a
NH_4^+ 50%: NO_3^- 50%	161.95a	4,107.87a	8.49a	119.92a
NH_4^+ 25%: NO_3^- 75%	124.27a	3,391.95ab	8.71a	115.55a
NO_3^- 100%	126.35a	2,990.71ab	9.23a	109.82a
Interaction / *Međudjelovanje*	(-)	(-)	(-)	(-)

Note: The mean in columns with different letters are significantly different at five-percent level using the HSD Tukey test, (-) = no interaction

Opaska: srednje vrijednosti u stupcima s različitim slovima značajno su različite na razini od 5 %, uz korištenje Tukeyeva HSD testa, (-) = nema međudjelovanja

Plant dry weight

The dry weight of leaf, root branch, and total plant dry weight were significantly affected by the various ratio in the form of N fertilizer. The results revealed that plant dry weight was lower under the higher ratio of NH_4^+ 100%; however, the application of NO_3^- 100% did not produce maximum plant dry weight. The highest plant dry weight was found on the ratio of NH_4^+ 50%: NO_3^- 50%, but it was not significantly different than other ratios in the N form excluding NH_4^+ 100%, indicating a significant difference (Table 6). The plant dry weight under the application of NH_4^+ 100% fertilizer was smaller. This was parallel to the study of Haynes (2012), documenting that a plant with the N fertilizer in the form of NH_4^+ and NO_3^-has produced a higher plant dry weight when compared to that of a separate application of NH_4^+ and NO_3^-. However, the optimum ratio was not similar to each plant species and each plant growth stage (Li et al., 2013).

Table 6. Leaves (g), branches (g), root (g), total dry weight (g) and root shoot ratio of black pepper on type of supports and form of N fertilizers

Tablica 6. Listovi (g), grane (g), korijen (g), ukupna suha masa (g) te omjer korijenskih izdanaka crnoga papra na tipu potpornja i obliku N gnojiva

Treatment / *Tretman*	Leaf / *List*	Branches / *Grane*	Root / *Korijen*	Total / *Ukupno*	Root shoot / *Korijenski izdanci*
Type of supports / *Vrsta potpornja*					
Deadwood / *Mrtvo drvo*	36.73a	47.44a	8.04a	92.21a	0.09a
Gliricidia sp.	18.85b	26.48b	3.14b	48.47b	0.07a
Ceiba pentandra	24.75b	34.69b	5.46ab	64.90b	0.09a
Form of N fertilizers/ *Oblik N gnojiva*					
NH_4^+ 100%	19.11b	24.55b	3.14b	46.79b	0.07a
NH_4^+ 75%: NO_3^- 25%	24.83ab	35.19ab	4.50ab	64.53ab	0.08a
NH_4^+ 50%: NO_3^- 50%	33.24a	44.47a	7.98a	86.69a	0.09a
NH_4^+ 25%: NO_3^- 75%	28.45ab	37.58ab	6.88ab	72.91ab	0.10a
NO_3^- 100%	27.26ab	39.22ab	5.23ab	71.71ab	0.08a
Interaction / *Međudjelovanje*	(-)	(-)	(-)	(-)	(-)

Note: Mean in column with different letters are significantly different at 5% level using HSD Tukey test, (-) = No interaction

Opaska: srednje vrijednosti u stupcima s različitim slovima značajno su različite na razini od 5 %, uz korištenje Tukeyeva HSD testa, (-) = nema međudjelovanja

The effect of support types on N, P, K uptake and growth of black pepper

The growth of plant roots is influenced by biophysical conditions in the soil. The use of living support has inhibited the root growth of black pepper plants. The black pepper plants' root length and root area using living support were smaller and significantly different from the plants using wooden poles. There was no significant difference between the length and root surface area of black pepper plants using *C. pentandra* and *Gliricidia* sp. (Table 1). However, percentual value of a decrease in root growth of black pepper plants using *Gliricidia* sp. on a control (wooden pole), i.e., the black pepper plants using the wooden poles, was higher than in the plants using the *C. pentandra* poles. The percentage reduction in root length and root surface area of pepper plants using *Gliricidia sp.* was 57.99% and 55.74%, respectively, while in the plants using *C. pentandra*it amounted to 32.82% and 38.44%, respectively. The decrease in root length and surface area had an impact on a lower plant nutrient uptake. Therefore, a low nutrient uptake was a limiting factor for the plant growth, signifying smaller root length and surface area.

N, P, and K uptake

The results showed that the accumulation of N, P, and K in roots, branches, leaves and total dry plant weight was as listed in Table 2. The distribution of N in roots, branches, and leaves ranged from 5.0-7.5%, 41.00-46.70% and 47.0-51.50%, respectively. Potassium distribution in roots, branches, and leaves ranged from 1.0-1.50%, 23.0-32.65% and 67.0%-75.12%, respectively, while K ranged from 6.5-8.85%, 59.0-62.4% and 31.0-32.0%. Tree support *Gliricidia* sp. and *C. pentandra* competed to absorb N, P, and K nutrients, indicated by alower total N, P, and K nutrient uptake of black pepper plants when compared to the black pepper plants using wooden poles. A total absorption of N, P, and K nutrients from black pepper plants using *Gliricidia sp.* was not significantly different than the one using the *C. pentandra*. However, the uptake of N, P, and K of black pepper plants using *Gliricidia* sp. decreased greater than that of the *C. pentandra*. The magnitude of the decrease in N, P, and K uptake of black pepper plants using *Gliricidia* sp. amounted to 48.57%, 53.66%, and 47.37%, respectively, while the decline in plants using *C. pentandra* was 33.27%, 31.22%, and 38.53%, respectively. Wahid et al (2004) reported that the N (urea) uptake of black pepper plants using erythrina support was low, ranging from 24-40%, while those where ^{15}N was applied only ranged from 6-12%. It is related to a competition with the live tree support.

Net assimilation rate (NAR) and crop growth rate (CGR)

Plants that absorb more N, P, and K nutrients have a higher NAR and CGR. The use of *Gliricidia sp.* and *C. pentandra* caused a lower N, P, and K uptake when compared to the plants using wooden poles, so that the NAR and CGR of pepper plants using *Gliricidia sp.* and *C. pentandra* were lower than that of the black pepper plants using wooden poles. There was no difference in NAR and CGR between the black pepper plants using *Gliricidia sp.* with *C. pentandra*. However, the NAR and CGR of pepper plants with *Gliricidia sp.* showed a greater percentage of decrease than the black pepper plants with *C. pentandra.* A NAR reduction of black pepper plants using *Gliricidia* sp. amounted to 40.64% and the CGR amounted to 55.68%, while the plants using *C. pentandra* had the percentages of 46.17% and 54.34%, respectively (Table 3). This result is in line with Wahid's (1984) report that the growth of black pepper plants with a living support was lower than that of the plants using wooden poles.

Plant morphology

The results have demonstrated that when the assimilation produced was limited, it was indicated by a low NAR that did not affect the length, number of internodes, internodes length, and the number of black pepper plants' orthotropic branches because there was no significant difference between the plants using living support and the plants using wooden poles. Assimilate differences that occur in black pepper plants using living support affect the diameter of orthotropic branches and the number and length of plagiotropic branches. Black pepper plants using a living support had smaller orthotropic branch diameters and a lower number and length of plagiotropic branches than the black pepper plants using wooden poles (Table 4). The percentage decrease in orthotropic branch diameter, number, and length of black pepper plant plagiotropic branches using *Gliricidia sp.* was 13.40%, 26.24%, and 14.72%, respectively, while a decrease in *C. pentandra* was smaller, amounting to 11.49%, 18.17%, and 9.22%, respectively.

The use of living support inhibits the formation and growth of black pepper plant leaves. According to Yudianto et al (2014), the support tree causes black pepper plants 'deficiency in sunlight intensity. Pruning the support tree branchesincreases the penetration of sunlight to the black pepper. The average irradiation intensity with pruning frequency of one, two, and three times were 30–35%, 50–55%, and 65–70%, respectively (Wahid, 1987). In this study, the support tree branches were pruned three times, so that a sufficientlight for black pepper growth was obtained. The number and area of black pepper plants using a living support were smaller and significantly different than that of the plants using wooden poles. The number of leaves and leaf area were the same between the black pepper plants that used *Gliricidia sp.* and *C. pentandra*. The number and the leaf area of black pepper plants using *Gliricidia sp.* has decreased by 44.32% and 43.93% andby 27.19% and 33.44% while using the *C. pentandra* (Table 5). The types of support did not have a significant effect on the SLA.

Plant dry weight

The dry weight is related to the morphology of the plants formed. Dry weight of leaves, branches, roots, and total black pepper plants using living support of *Gliricidia sp.* and *C. pentandra* were significantly smaller compared to black pepper plants using wooden poles. The dry weight of the black pepper plant was not significantly different between the *Gliricidia sp.* and *C. pentandra*. A total dry weight of black pepper plants using *Gliricidia sp.* decreased by 45.27% while using *C. pentandra* decreased by 35.56% of the total weight of black pepper plants using wooden poles (Table 6). Thus, from the dry weight data, it is shownthat the use of *Gliricidia sp.* Has inhibited the growth of black pepper plants,whereby it was greater than that of *C. pentandra*. From the results of this study, it was found that an underground competition in this case was the root system, and the N, P, K nutrients gave significant inhibition to the growth of black pepper plants when compared to the above-ground competition, which was light. In fact, according to Issukidarsyah et al. (2020), black pepper plants that have usedthe wooden poles with a light intensity ranging from 50-75% had a positive effect on the pepper plant growth. It is indicated by an increase in plant dry weight two to three times concerning the plants that receive a 100% light intensity. These results explain that a nutrient competition has had a greater effect than the light competition. Therefore, a key to the success of black pepper cultivation using a living support is to maximize the black pepper plants' nutrient uptake through the provision of larger fertilizer doses, climbing poles management, and a good tree support management.

CONCLUSION

In the field conditions, black pepper prefersthe N fertilizer in the form of a ratio of NO_3^-50% NH_4^+50%, compared to the ratio of other forms of N fertilizer. Nutrient absorption of pepper plants using living support was lower due to a competition with the tree support. The capability of the main crop in absorbing nutrients was low when growing with a living support, since the length and root surface area of black pepper was smaller, so that the crop growth was lower.

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UČINAK OMJERA AMONIJEVA NITRATA I TIPOVA POTPORE NA UNOS NPK I UZGOJ CRNOGA PAPRA (*Piper nigrum* L.) U POLJSKIM UVJETIMA

SAŽETAK

Svrha ovoga istraživanja bila je utvrditi učinak omjera NO_3^-:NH_4^+ i vrsta potpornja na unos NPK i rast biljke papra u poljskim uvjetima. Istraživanje se koristilo potpuno slučajnim bloknim rasporedom s trima ponavljanjima. Prvi je čimbenik bio vrsta potpornja, koji se odnosio na mrtvo drvo i žive potpornje u obliku drveta **Gliricidia sp.** ***i*** **Ceiba pentandra.** ***Drugi je čimbenik bio omjer oblika N gnojiva, koji je iznosio 100% NO_3^-, 100% NH_4^+, 50% NO_3^-:50% NH_4^+, 75% NO_3^-:25% NH_4^+ te 25% NO_3^-:75% NH_4^+. Rezultati su pokazali da na unos N, P i K, kao i na rast biljke, nije utjecalo međudjelovanje omjera oblika N gnojivai tipa potpornja. U poljskim uvjetima crni papar preferira N gnojivou obliku 50% NO_3^-:50% NH_4^+. Biljke papra kojima je dodavano N gnojivo u kombinaciji 50% NO_3^-:50% NH_4^+ pokazale su unos N, P i K, a morfologija i suha masa biljke bili su viši negoli omjer drugih oblika N gnojiva.***

Ključne riječi: rast crnoga papra, oblik N gnojiva, unos NPK, potpornji

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