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Source and Rate of Nitrogen for Drip Irrigated Polyethylene Mulched Chilli Pepper

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Abstract

Chilli pepper is the one of most important vegetable crops in Indonesia, and nitrogen is an essential macronutrient to support plant growth. This study was conducted to determine the best source of nitrogen (N) and its optimum rate for drip irrigated polyethylene mulched chilli pepper at. The study site is located at Tajur II Experimental Field of Center for Tropical Horticulture Studies Bogor Agricultural University, West Java, Indonesia 250 m above the sea level (-6.6364580S, 106.8231460E) from January to August 2018. The experiments were organized in a factorial split-plot with sources of N fertilizer as the main plots (Urea, NPK, and ZA) and rates of N as a sub-plots (0, 115, 230, 345, and 460 kg.ha^{-1}). The results showed that NPK fertilizer is the best source of N compared to the other N sources. The maximum yield of 9.01 kg per plot, or equivalent to 10.46 t.ha^{-1}, was obtained with N fertilization at 265 to 295 kg N.ha^{-1}.

Keywords: fertigation, maximum yield, nutrient, the optimum rate

Introduction

Chilli pepper is one of the vegetable crops with a significant national and international market and has high economical values. In Indonesia, chilli pepper productivity had showed an increase from 5.70 to 6.88 t.ha^{-1} in 2017 (BPS, 2018). However chilli pepper productivity is considered low when compared to its potential yield of 14.09 t.ha^{-1}. The low national productivity of chilli pepper is caused by various factors, including sub-optimal growing condition, pest and plant disease infestation, and poor crop management. Improvement in crop management is one of the potential areas that can be improved to increase crop production, including fertilizer management. Fertilizers should be applied with the correct formulation at optimal rates, and correct time of application.

Nitrogen (N) is an important macro nutrient for crops; 1-5% of the total plant dry matter is nitrogen. Nitrogen availability is a major determinant of plant growth (Marschner, 2012) for its roles in formation of amino acids, enzymes, nucleic acids, alkaloids, purines, and chlorophyll (Jones, 2012). Nitrogen is the main constituent of chlorophyll which plays an important role in photosynthesis (Bhuvaneswari et al., 2014; Roy et al., 2011).

Polyethylene mulch has been used widely by Indonesian growers, particularly for chilli pepper production. Mulch can inhibit surface flow, erosion rate, suppress weed growth, and soil structure improvement (Heryani et al., 2013). Mulch can also maintain soil moisture, improve yield and quality of bell pepper (Filipovic et al., 2016) and chilli pepper (Ashrafuzzaman et al., 2011). However, fertilization for crop production grown with mulch requires more intensive labor; fertilizers would need to be applied directly into each planting hole.

Nitrogen fertilization in a fertigation system has provided benefits when compared to conventional methods (Pandey et al., 2013). Studies have shown that fertilization through drip irrigation system with polyethylene mulch is an efficient and effective method to regulate water and fertilizer placement to the root zone, reduce labor costs, save water (Pandey et al., 2013), improve the yield of bell pepper (Patil and Das, 2015) and yield of eggplant (Diaz-Perez and Eaton, 2015).

There have been limited published reports on the optimal rates of fertilizer in chilli pepper production. A general recommendation rate of fertilization from The Indonesian Ministry of Agriculture Research Centers are available, i.e. 186 kg N.ha (Muharam, 2005), but the rates are not specifically addressed to drip irrigated polyethylene mulched chilli pepper. The aims of this experiment were to determine the best source of nitrogen fertilizer and its optimal rate to obtain a maximum yield of chilli pepper grown in a drip irrigated polyethylene mulched system.

Materials and Methods

The research was conducted at Tajur II Experimental Field of Center for Tropical Horticulture Studies, Bogor Agricultural University, 250 m above the sea level (-6.6364580S, 106.8231460E) from January to August 2018. The soil type at the research location is inceptisol. Soil N, P, K, cation exchange capacity (CEC) and saturation base (SB) were analyzed at Soil, Plant, Fertilizers, Water Laboratory of Agricultural Research and Development Center, Bogor, West Java, Indonesia.

The experiment was organized in a factorial split-plot design with a randomized complete block design with types of fertilizer as the main plots (Urea, NPK, and ZA), and rates of N fertilizer as sub-plots (0, 115, 230, 345 and 460 kg.N.ha^{-1}). The treatments were replicated four times, totaling 60 experimental units. The collected data were analyzed using ANOVA using SAS 9.4. at a significant level of 5%. Significant differences between treatments were further separated using Duncan Multiple Range Test (DMRT) and orthogonal polynomial tests. Regression curves were used to determine the optimum rate of N fertilizer.

Plant growth parameters measured were plant height at 2 to 10 week after planting, number of days to 50% anthesis at 4 to 6 weeks after planting, number of days to 50% fruit maturity, which occurred at week 10 to 12 after planting. Production parameters measured number of fruits per plant, fruit weight per plant, fruit weight per plot and fruit weight per hectare from week 12 until week 20 on ten sample plants per plot. Leaf N content was analyzed using Total N Kjeldahl method. Analysis of leaf chlorophyll was conducted on of leaves at the maximum vegetative stage, i.e. around 6 weeks after transplanting. Two-hundred grams of fresh young fully expanded leaves from the sample plants was used for analysis according to the method of Sims and Gamon (2002).

The cultivar of chilli pepper used in this research was hybrid “Santika”. The experimental plot consists of beds of 1 x 6 m in size; the plant beds were raised to 30 cm above the ground with 60 cm distance between beds. Four to five-week-old seedlings were transplanted, 24 seedlings per bed, totaling 1440 seedlings for the whole 500 m^2 block. The types of N fertilizer used were Urea (46% N), ZA (21% N), and NPK (16% N-P-K). TSP (46% P_2O_5), KCl (60% K_2O) were applied according to Susila (2006), i.e. 143 kg.P_2O_5.ha^{-1} and 136 kg.K_2O.ha^{-1}; different types of N fertilizer was applied at 230 kg N.ha^{-1}. Time of fertilizer application was based on Locascio et al. (1997), i.e. 40% N, 100% P_2O_5, and 40% K_2O were applied before planting, 60% N and 60% K_2O with 6% irrigation water which was applied 10 times during the growing season. The drip irrigation system installation was prepared by assembling the components in the head unit (reservoir, engine pump, pressure regulator, disc filter, PE line 16 mm) that was connected to the field unit (dripline 16 mm). The crops were staked at 2 weeks after planting. Weed, pests and disease control were conducted when necessary. The first harvest was conducted at 105 days after transplanting (DAT) when the fruits showed signs of maturity, indicated by fruits color that had turned orange to red.

Results and Discussion

Soil Physical and Chemical Properties

The soil type in the study location is inceptisol with clay proportion of 38%, dust of 51%, and sand of 11%, and has a pH of 6.8. According to soil evaluation criteria by Balai Penelitian Tanah (2009) the soil total N-organic matter was 0.15%, which is classified as very low, the total P-content and total K had a very high range of 461 mg/100g and 86 mg/100 g, respectively. Cation exchange capacity (21.20 cmolc/kg) and base saturation (84%) were moderate to high.

Plant Height

The rate of N fertilizer affected plant height quadratically (Table 1). Nitrogen has important roles in stem growth and chlorophyll formation. According to Ayodele et al. (2015) plant growth and development is highly affected by the availability N in the soil and the amount of N fertilizer applied. The high supply of N increases the use of carbohydrates to form protoplasm and new cells, resulting in increases of plant height. Similar studies on nitrogen roles in chilli growth have been reported, e.g. Bhuvaneswari et al. (2013); Khan et al. (2014); Wahocho et al. (2016) and Suman et al. (2015).

Plant height was not affected by the interaction of N sources and its rates (Table 1). Therefore different sources of N have similar effects on plant height.

Total Dry Matter, N Content and Plant N Uptake

Sources of N and N rates did not interact in affecting

Table 1. Chilli pepper plant height at the various N fertilizer sources and rates

Treatment	Plant height (cm)				
	weeks after planting				
	2	4	6	8	10
N sources					
NPK	23.78	42.02	59.44	75.36	74.64
Urea	24.14	42.43	59.08	72.87	69.83
ZA	24.25	42.65	56.93	74.98	73.49
F test	ns	ns	ns	ns	ns
Rate of N (kg $N.ha^{-1}$)					
0	22.58	33.67	50.24	60.96	62.68
115	24.51	44.75	57.48	75.06	74.83
230	24.58	44.70	59.96	77.72	72.94
345	24.47	44.47	63.17	79.45	76.84
460	24.14	44.24	61.55	78.82	75.99
Response	L*Q*	L**Q**	L**Q**	L**Q**	L**Q**
N sources x rates	ns	ns	ns	ns	ns

Note: Values followed by the same letters within the same column are not significantly different according to DMRT at $P<0.05$; n.s.: not significant, **: significant at $P<0.01$, *: significant at $P<0.05$. Response regression by orthogonal polynomial test, L: linear, Q: quadratic.

total dry matter, N content and plant N uptake at 6 and 20 WAT (weeks after transplanting). The sources of N affected the total dry matter at 6 and 20 WAT, and N uptake at 6 WAT (Table 2). NPK had the most significant effects in increasing total dry matter and N uptake (Table 2), possibly because NPK fertilizer contains N in the form of ammonium nitrate (NH_4NO_3), whereas Urea and ZA only contain N in the nitrate (NO_3) form. The ammonium formulation in NPK fertilizer provides better N uptake and N accumulation by plants. According to Pessarakli (2001) N forms (NH_4^+ or NO_3^-) can affect N availability as a result of differences in the mobility of each N form in the soil solution. On the ground, NH_4^+ ions are bound to negatively charged soil particles and are relatively immobile. Conversely, NO_3^- ions are not bound by soil particles, easier to move, and N in the form of NO_3^- are most available for plants.

Fertilization at the different rates of N affected the total dry matter, N content and N uptake at 6 and 20 WAT quadratically (Table 2). Nitrogen fertilization increased total dry matter, N content and plant N uptake, which is in line with Yasuor et al. (2013), Iqbal et al. (2013), and Chalkoo et al. (2014) that N fertilization can increase N uptake, accumulation of N content, and total dry matter of chilli pepper. The increase in the total dry matter was due to the accumulation of organic compounds and photosynthate. Similar results were reported by Aminifard et al. (2012) Magdatena (2003), and Iqbal et al. (2015).

Leaf Chlorophyll Content

The rates of N fertilizer increased leaf chlorophyll content (Table 3) as N is one of the major constituents of the chlorophyll. The result of this study confers with Suharja and Sutarno (2009) in red chilli, Iqbal et al. (2013) in chilli pepper, and Bhuvaneswari et al. (2014) in bell pepper. Nitrogen fertilization affects photosynthesis and chlorophyll content through the formation of photosynthetic enzymes and chlorophyllase enzyme. Nitrogen was applied in the form of ammonia and subsequently changes to glutamic acid. Glutamic acid functions as a base material in the biosynthesis of amino acids, nucleic acids, and precursors of porphyrin rings for the chlorophyll formation (Suharja and Sutarno, 2009)

The sources and rates of N fertilizer did not interact in affecting leaf chlorophyll content (Table 3). The sources of N fertilizer had no effect on the content of chlorophyll A, chlorophyll B, and total chlorophyll, whereas rates of N fertilizer had a quadratic effect on the chlorophyll content and total chlorophyll (Table 3). A significant increase in chlorophyll content by N fertilization rates was recorded compared to N fertilizer sources. Therefore, N fertilizer from various sources of N fertilizer can be used to increase leaf chlorophyll content.

Table 2. Chilli pepper total dry matter, N content and N uptake at the various N fertilizer sources and rates

Treatment	Total dry matter (g)	N content (%)	N uptake (g)	Total dry matter (g)	N content (%)	N uptake (g)
	6 WAT			20 WAT		
Source of N						
NPK	26.62 a	3.08	0.84 a	105.62 a	0.93	0.84
Urea	19.85 b	3.08	0.65 b	80.26 b	1.12	0.90
ZA	18.74 b	3.05	0.59 b	79.42 b	1.15	0.95
F test	**	ns	*	**	ns	ns
Rate of N (kg $N.ha^{-1}$)						
0	12.01	2.44	0.29	59.89	0.72	0.43
115	21.30	3.24	0.69	95.94	1.01	0.89
230	24.25	3.31	0.81	94.39	1.34	1.16
345	27.32	3.02	0.84	105.41	1.06	1.05
460	23.80	3.20	0.78	86.52	1.23	0.95
Response[1)]	L**Q**	L**Q*	L**Q**	L**Q**	L**Q*	L**Q**
N sources x rates	ns	ns	ns	ns	ns	ns

Note: Values followed by the same letters within the same column are not significantly different according to DMRT at P<0.05; ns: not significant, **: significant at P<0.01, *: significant at P<0.05. WAT: week after transplanting
[1)]Orthogonal polynomial regression, L: linear, Q: quadratic.

Table 3. The chilli pepper leaf chlorophyll A, chlorophyll B and total chlorophyll at various N sources and N rate fertilizer

Treatment	The chlorophyll content (mg g^{-1})		
	Chlorophyll a	Chlorophyll b	Total chlorophyll
Source of N			
NPK	4.18	1.35	5.53
Urea	4.63	1.54	6.17
ZA	4.71	1.66	6.37
F test	ns	ns	ns
Rate of N (kg $N.ha^{-1}$)			
0	3.83	1.25	5.08
115	4.58	1.52	6.10
230	5.39	1.43	6.82
345	4.46	1.61	6.07
460	4.27	1.78	6.05
Response[1)]	Q**	-	L**Q**
N sources x rates	ns	ns	ns

Note: Values followed by the same letters in the same column is not significantly different according to DMRT at P<0.05; ns: not significant, **: significant at P<0.01, *: significant at P<0.05.
[1)]Orthogonal polynomial regression, L: linear, Q: quadratic.

Days to 50% Anthesis and 50% Fruit Maturity

Time to 50% anthesis was not affected by source of N fertilizer and its interaction with N rates (Table 4). Karapanos et al. (2008) reported that tomato, chilli and eggplant's flowering and fruit maturity are determined by biotic and abiotic factors, including crop management, pest and disease infestation and environment. High availability of N can promote vegetative growth and delay flowering (Karapanos et al. 2008).

The rates of N fertilizer had a quadratic effects to the number of days to 50% anthesis and 50% maturity (Table 4). Time to anthesis and fruit ripening were accelerated with the increases in N rates up to 230 kg N.ha^{-1} and delayed at higher N rates (Table 4). Similarly, Aminifard et al. (2012) and Ortas (2013) reported that high N and K fertilization promoted earlier time to anthesis by five to six days compared to the without fertilization. The effects of N fertilization on flowering was related to changes in the concentration of endogenous phytohormones, as N is one of the auxin constituents (Marschner, 2012).

Chilli Pepper Yield

The interaction between source and the rate of N fertilizer had no significant effect on yield parameters (Table 5). The source of N fertilizer significantly

Table 4. Days to 50% anthesis and 50% fruit maturity at the various N sources and N fertilizer rates

Treatment	The number of days to 50% anthesis	The number of days to 50% fruit maturity
Source of N		
NPK	31.25	76.30
Urea	31.40	76.60
ZA	32.00	76.30
F test	ns	ns
Rate of N (kg N.ha^{-1})		
0	30.75	76.25
115	30.17	76.00
230	29.58	75.58
345	32.58	77.58
460	34.67	76.58
Response[1)]	L**Q**	L*Q*
N sources x rates	ns	ns

Note: Values followed by the same letters in the same column is not significantly different according to DMRT at P<0.05; ns: not significant, **: significant at P<0.01, *: significant at P<0.05.
[1)]Orthogonal polynomial regression, L: linear, Q: quadratic.

Table 5. The number of chilli pepper fruits per plant, fruit weight per plot, and fruit weight per hectare at various N sources and N fertilizer rates

Treatment	Fruit number per plant	Fruit weight per plant (g)	Fruit weight per plot (kg)	fruit weight per hectare (ton)
Source of N				
NPK	414.25 a	365.27	8.99 a	9.99 a
Urea	370.25 ab	337.02	7.67 b	8.53 b
ZA	360.35 b	361.15	7.51 b	8.34 b
F test	*	ns	**	**
Rates of N (kg N.ha^{-1})				
0	302.17	277.25	5.94	6.61
115	365.00	348.95	7.93	8.82
230	423.92	387.27	8.97	9.96
345	431.75	404.90	9.23	10.25
460	385.25	354.04	8.22	9.13
Response[1)]	L**Q**	L**Q**	L**Q**	L**Q**
N sources x rates	ns	ns	ns	ns

Note: Values followed by the same letters within the same column is not significantly different according to DMRT at P<0.05; ns: not significant, **: significant at P<0.01, *: significant at P<0.05.
[1)]Orthogonal polynomial regression, L: linear, Q: quadratic.

affected yields, including the number of fruits per plant, fruit weight per plot, and fruit weight per hectare, whereas sources of N fertilizer affected yield parameters (Table 5). NPK had the best effect on crop yields, likely because NPK gradually provides the availability of P and K for the crops. NPK has N in the form of NO_3^- and NH_4^+, P_2O_5 and K_2O. P can increase plant root growth, increase plant resistance and stimulate tissue growth (Barus, 2006). Optimal root growth correlates positively with nutrient absorption, resulting in increases in crop yields. According to Widyanti and Susila (2015) K is involved with the activation of enzymes that form the structures of organic compounds, such as starch or protein, and involved in cell division, and contribute to increasing crop yields

Increasing rates of N fertilizer increased crop yields, including the number of fruits per plant, fruit weight per plant, fruit weight per plot, and fruit weight per hectare (Table 4). The yield of chilli pepper was affected by the availability and uptake of N. Increasing N rates fertilization up to 213 kg.N.ha^{-1} increased maximum yield in tomato (Subhan et al., 2009) and up to 100 kg.N.ha^{-1} in hot pepper (Mebratu et al., 2014; Ayodele et al., 2015). According to Ortas (2013) N promoted vegetative growth which eventually increased weight total fruit yield in tomatoes and chilli.

The Optimum Nitrogen Rates to Obtain a Maximum Chilli Pepper Yield

The response of chilli pepper yield to N rate fertilization is in Figure 1. The fruit weight per plant shows the maximum yield of 407.27 g per plant with N fertilization at 290.72 kg N.ha^{-1}. N fertilization at 259 kg.N.ha^{-1} resulted in the maximum fruit weight of 9.03 kg per plot, whereas the maximum yield of fruit weight of 10.43 t.ha^{-1} was achieved with 287 kg N.ha^{-1} (Figure 1).

Plant Growth and Yield Correlation Analysis

Correlation between growth and yield parameters are described in Table 6. N uptake and total dry matter at 6 WAT had a positive correlation as indicated by strong relationships (> 0.50) with the number of fruits per plant, fruit weight per plant, fruit weight per plot, and fruit weight per hectare (Table 6).

Nitrogen uptake and total dry matter are important indicators of the plants' ability to produce assimilate. In sweet pepper, according to Del Amor (2008), vegetative growth of plants significantly decreased

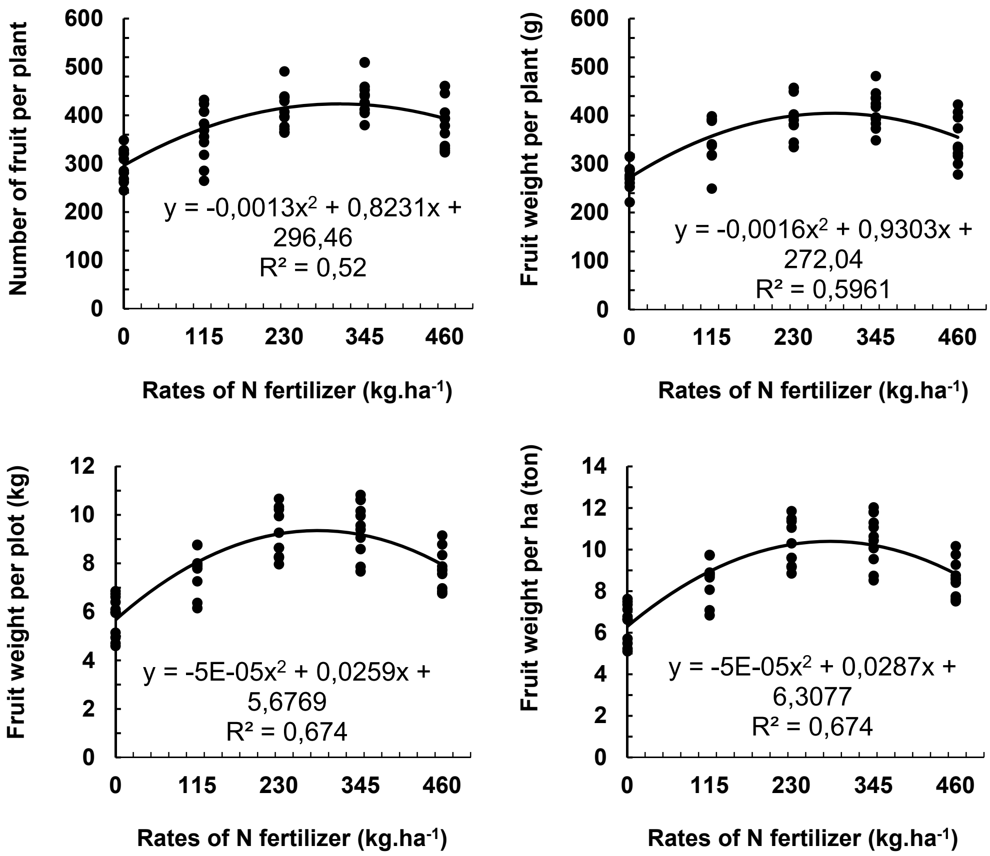

Figure 1. Number of chilli pepper fruits per plant, fruit weight per plant, fruit weight per plot and fruit weight per hectare at the various N sources and rates

Table 6 Pearson's correlation test for chilli peper growth and yield parameters

Variables	PH10	TDM6	TC	PNU6	FNP	FWT	FWP
TDM6	0.53 **						
TC	0.19 ns	0.14 ns					
PNU6	0.51 **	0.94 **	0.24 ns				
FNP	0.57 **	0.73 **	0.07 ns	0.66 **			
FWT	0.54 **	0.64 **	0.19 ns	0.58 **	0.90 **		
FWP	0.61 **	0.74 **	0.14 ns	0.66 **	0.84 **	0.79 **	
FWH	0.61 **	0.74 **	0.14 ns	0.66 **	0.84 **	0.79 **	0.99 **

Note: **: significant at P <0.01, *: significant at P <0.05; ns: not significant; PH10: plant height at 10 week after transplanting (WAT), TDM6: total dry matter at 6 WAT, TC: total chlorophyll, PNU6: plant N uptake at 6 WAT; FNP: fruit number per plant, FWT: fruit weight per plant, FWP: fruit weight per plot, FWH: fruit weight per plot hectare.

in the early phase of fruit formation which acts as the main sink for assimilation results. Fageria (2009) added that there was a high positive correlation between N rates and the total dry matter. Therefore N accumulation is very important in increasing high crop yields.

Conventional fertilization method is still commonly carried out by Indonesian chilli growers. N fertilization through drip irrigation provides advantages compared to conventional methods; it is more efficient and effective to regulate fertilizer placement to the root zone. This study has demonstrated that it is important to apply an optimum rate of N, and to use the best source of nitrogen fertilizer for a drip irrigation system. The results of this study have provided N fertilizer recommendation of drip irrigation method for chilli pepper production.

Conclusion

Application of at 250 to 290.72 kg per ha resulted in the maximum yield of chilli pepper of 407.27 g per plant, 9.03 kg per plot, or equivalent to 10.43 t.ha^{-1}. Application of NPK increased yield by 17% compared to Urea, and by 20% compared to ZA, therefore NPK is preferable over ZA and Urea to increase chilli pepper yield.

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