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Manually Feed NPK Fertigation Increases the Growth and Yield of Chili Pepper Hybrids in Ultisols

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ABSTRACT

Extending the planting area to less-fertile soil, such as Ultisols, become an inevitable choice to increase the national chili pepper production in Indonesia as these types of soil are the largest part of the dry land of Indonesia. It is estimated at around 51 million ha or about 29.7%. However, efforts to increase their productivity by providing sufficient fertilizers to plants are most frequently inefficient. Conventional fertilizer application, broadcasted dry granular fertilizers, on the soil beds under the plastic mulch, is less successful due to less solubility as well as less availability of its nutrients for the plant throughout its growing period. Fertigation with diluted NPK fertilizer sources offers substantial flexibility for NPK fertilizer management and could be used to solve the problem. The objective of this study was to determine the best NPK fertigation method for increasing the growth and yield of four chili pepper hybrids. The experiment was conducted in a randomized complete block design with three replications, and the treatments were arranged in a split-plot design. The experiment included factorial combinations of five NPK fertigation intensity, i.e. 100%, 75%, 50%, 25% or 0%, and four chili pepper hybrids, i.e. 'Maxima', H39, H14, and 'UNIB CHR17'. The NPK fertigation intensity was assigned as a main plot with the remnant fertilizers were circularly broadcasted surrounding the plant and the chili pepper hybrids as a subplot. The results showed that there was no interaction effect of fertigation intensity, meaning that all hybrids evaluated in this study showed a similar pattern of responses to the changing fertigation schema. The hybrid H39 possessed the most vigorous vegetative growth, whereas 'Maxima' and H14 showed the highest yield amongst examined hybrids in Ultisol. The 100% fertigation was the best method of NPK fertilizer application for chili pepper in Ultisols. This study demonstrates that NPK fertigation, especially at 100%, can be used to increase chili pepper hybrid growth and yield in Ultisols.

INTRODUCTION

Ultisols are widely distributed in the tropical regions of Indonesia as well as in the world. High acidity and low fertility of Ultisols limits plant growth and reduces crop yields. However, this soil type has been inevitably utilized to increase chili pepper production in Indonesia as the more fertile soil becomes less available. Ultisols were characterized by high soil erosion, high acidity (average pH <4.5), high Al-dd levels, high saturation of aluminum, low cation exchange capacity (CEC), high soil density, poor macronutrient content especially

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P, K, Ca, Mg, low organic matter content, and low soil permeability that ultimately contribute to very low P availability and other nutrients for plant growth (Prasetyo and Suriadikarta, 2006). Ultisol fertility rate is classified as low to very low with a very high danger of Al toxicity (Alibasyah, 2016).

The high rate of fertilizer application, therefore, becomes a common practice in commercial chili pepper growing area under the plastic mulch system to meet its nutrient need. However, in such a growing system, the conventional fertilizer application, in which the fertilizers are circle-dressed under the plastic mulch, is frequently ineffective and the excessive use of fertilizer may also contaminate water resources in the agricultural ecosystem (Latifah *et al.*, 2019).

Most of the time, the fertilizer applied under the mulch is found in granular form until the end of the growing season due to limited water reaching and dissolving the fertilizer. Consequently, the nutrient released by the applied fertilizer is also limited (Strik *et al.*, 2017). Method of fertilizer application and where it is placed into the soil determine the effectiveness of nutrient availability for the plant (Simonne *et al.*, 2017). The application of fertilizer along with irrigation, commonly known as fertigation, is an alternative method to solve the ineffectiveness of the conventional fertilization practices for commercial vegetable growing in the field (Nicola and Sambo, 2015).

Many previous works have reported that the fertigation system could improve the growth and yield of various plants. Fertigation technique was proofed to increase the yield of cotton (Jayakumar *et al.*, 2014), maize (Chauhdary *et al.*, 2017), eggplant (Ughade and Mahadkar, 2015), strawberry (Kachwaya and Chandel, 2015) tomato (Mali *et al.*, 2016) and many other vegetables and fruits (Reddy *et al.*, 2017). However, in the field without an irrigation system, automatic or semi-automatic fertigation is inapplicable. Manually feed fertigation, therefore, may be part of the solution. Unfortunately, there was limited information on this technique to improve plant chili pepper growth and yield in Ultisols. The objective of this study was to determine the best N, P, and K fertilizer fertigation strategies for growth and yield of chili pepper grown in Ultisols.

MATERALS AND METHODS

This research was conducted from March to August 2019 in Desa Bentiring Permai, Kecamatan Muara Bangkahulu, Bengkulu, Indonesia.

The experimental site was at about 15 m above sea level, with Ultisol type of soil. The experiment was conducted with a Complete Randomized Block Design (RCBD) arranged in a Split Plot with three replications. NPK fertigation schema, i.e. 0, 25, 50, 75, or 100% fertigation were assigned as the main plot, while chili pepper hybrid genotypes, i.e. Maxima, H39, H14, and Unib CHR17F as the subplot. The experimental units were plots of 1 m wide and 4 m long, containing 20 plants per plot.

The seeds of four chili pepper hybrids, UNIB CHR17F1, Maxima, H14, and H39, were soaked in warm water 400C for 10 minutes to accelerate germination before being germinated on wet tissue papers for five days. The young germinated seeds with radicle length of 1-2 mm were planted in seedling trays of 72 cells filled with mixed media of soil: compost (1:1 v/v).

Seedling maintenance was done following the procedure of the commercial chili pepper growers. The seedlings were raised in the nursery until five weeks after seeding.

Land preparation was carried out for a couple of weeks before transplanting. Before planting, the land was cleared from vegetation and plant debris such as wood and twigs. The soil was disc-plowed, and then manually loosened using a hoe and raised to form soil beds of 1m wide, 4 m long, and 20 cm high. Cow manure, at a rate of 10 tons/ha, was broadcasted on the beds as the basic fertilizer and mixed thoroughly with the soil. The soil beds were then covered with plastic mulch, and incubated for a week before transplanting.

Five-week-old seedlings were transplanted manually in two rows per bed with 50 cm distance between rows and 40 cm apart within the rows.

Planting holes were made by perforating the plastic mulch with a sharpened milk can, 10 cm in diameter, and the planting holes were made by punching the soil-bed, 8 cm deep, with a sharpened-end wood stake, 8 cm in diameter. Carbofuran insecticide was applied in the holes at the rate of 20 kg/ha before transplanting. The seedlings were put into the planting holes, single transplant per hole, and their root-ball were covered with the soil and pressed firmly to make a good transplant stand.

Fertilizer application of N, P, and K, in the form of urea, SP36, and KCl, in the rate of 300, 300, and 150 kg/ha, respectively, was done at the designated treatment. The treatment of 0% fertigation denoted that the whole fertilizers were circle-dressed surrounding the plant stem. On the contrary, the 100% fertigation meant that the whole fertilizers were diluted in the water at the concentration of 2 g/L and fertigated to the plant at a rate of 200 mL per plant. Side-dressed fertilizer application was done at planting time with a 50% rate of urea and the whole rate of SP36 and KCl. The rest of urea was circle-dressed at four weeks after transplanting. Fertigation treatment was carried out weekly starting at transplanting until reaching the designated rate of fertilizer in the base of 2g/L applied concentration so that there were different times of fertigating.

Plant maintenance during this study was watering, plant staking, axillar- shoot removing, weeding, and pest and disease controlling. Watering was done every day in the morning or evening as needed to maintain favorable soil moisture content. Replanting was done at 7 days after transplanting (DAT) to replace the plants that died during transplanting to reach the maximum plant stand. Plant staking with 75-cm-long bamboo stakes was carried out at 5 weeks after transplanting (WAT). The plant stems were then tied loosely to the stake to make upright plant stands. Axilar buds growing on the main stem below the first dichotomous branch were removed anytime they emerge to ensure good vegetative growth. The weed growing in the mulching hole and space between soil beds were controlled monthly. Plant pest and disease controls were carried out preventively every 10 days with insecticides with active ingredients of Imidacloprid or Profenofos insecticides, Mankozeb fungicide, Samite acaricide, and wetting agent with the concentration of 2 ml/L, 2 g/L, 1.5 ml/L, and 2 ml/L, respectively.

Harvesting was made on mature fruits with the criteria of at least 50% of the fruit part had turned red color. Harvesting was done at intervals of 5 days until all fruit formed from the first flowering period was harvested.

All observation was performed on 30% samples accounting for 6 plants per bed, except for the yield per plot. The observed variables were plant height, dichotomous height, stem diameter, level of leaf greenness, shoot fresh weight, root fresh weight, shoot dry weight, root dry-weight, fruit length, fruit diameter, fruit weight per plant and yield per plot. Data were analyzed with analysis of variance (ANOVA) at a=5%, and the mean comparison was performed with the Duncan's Multiple Range Test (DMRT) at a=5%.

RESULT AND DISCUSSION

The land used in this study was composed of Ultisol type of soil which previously has never been received any treatments. The results of soil analysis showed that the soil possessed a pH (H2O) of 5.00 (acidic), nutrient content N-total levels of 0.19% (very low), P-Bray content of 2.04 ppm (very low), K-dd 0, 21 m3/100 g (low), Al3+ 0.22 me/100g (very low) and H+1.98 me/100g (very low). Indeed, the soil fertility was considered poor, but, fortunately, the exchangeable Al was also low. This condition makes soil fertility improvement through fertilizer application become promisingly successful as the Al properties of this soil might not interfere with nutrition availability.

During the study, the temperature was in the range of 26 to 280C which was suitable for growth and yield of chili pepper. The rainfall intensity at the beginning of the research was relatively high, 300 – 400 mm/month; however, in the last couple of months, the rainfall was very low. Watering was done almost every day whenever there was no precipitation.

Overall, the plants grew normally.

The results of the analysis of variance indicated that there was no interaction effect of the fertigation treatments and hybrids on both growth and yield of chili pepper. All hybrids showed a similar response pattern to the changing in fertigation schema. Genotypes significantly affected plant height, dichotomous height, stem diameter, number of dichotomous branches, fresh canopy weight, fruit weight per plant, and yield per plot. While fertigation schema significantly affected the number of fruits, fruit length, fruit weight per plant, and yield per plot (Table 1).

a. Effect of Hybrids Genotype on Growth and Yield of Chili Pepper in Ultisol

Hybrid genotype H39 had the highest plant height, about 25% higher than that of other hybrids which were similar in height. Moreover, hybrid H39 also demonstrated the highest dichotomous height followed by Unib CHR17 F1 and Maxima, and the shortest one was H14. The largest stem diameter was observed for H39 hybrid genotype, while the smallest for Maxima. Although the stem diameter of the H39 genotype was not signify-cantly different from H14, it was significantly larger than that of Unib CHR17 or Maxima (Table 2).

Chilli hybrid H39 exhibited the highest number of dichotomous branches was, while the other hybrids were not significantly different from each other. The number of branches of H39 was 30% higher than that of the other hybrids. Similar to the number of branches, shoot fresh weight also exhibited the same pattern. The shoot fresh and dry weight of hybrid H39 was the highest among hybrids evaluated.

The other hybrids possessed the same shoot fresh or dry weight. Other growth components, such as root length, root fresh weight, or root dry weight of all hybrids was about similar to each other. Shoot fresh or dry weight of H39 was about 55% higher than that of H14, Unib CHR17, or maxima (Table 2).

Unlike the growth components, the highest fruit weight per plant was demonstrated by hybrid H14 and Maxima which were about 20% higher than that of the least one, H39. Fruit weight per plant of Unib CHR17 was the second-lowest, although it was no statistically different from that of H4 of Maxima (Figure 1). With regard to yield per 2 m2 plot and estimate yield per hectare, hybrid Maxima, Unib CHR17, and H14 were the same.

While hybrid H39 was the lowest one, about 17% lower than that of Maxima or Unib CHR17 (Figure 2).

One of the most determining morphological

Table 1. Calculated F of the analysis of variance (ANOVA) on the effect of N-P-K fertigation on growth and yield of four chili pepper hybrids in Ultisol

Variables	Hybrids	N-P-K fertigation	Hybrids x fertigation interaction
Plant height	12.88^{*}	2.63^{ns}	0.39^{ns}
Dichotomous height	11.04^{*}	0.81^{ns}	1.18^{ns}
Stem diameter	5.09^{*}	2.91^{ns}	1.09^{ns}
Number of branches	6.57^{*}	2.71^{ns}	1.08^{ns}
Leaf greeness	1.39^{ns}	2.58^{ns}	0.43^{ns}
Shoot fresh weight	3.23^{*}	0.56^{ns}	0.83^{ns}
Root fresh weight	1.28^{ns}	0.87^{ns}	0.33^{ns}
Root length	1.15^{ns}	0.42^{ns}	1.04^{ns}
Shoot dry weight	3.53^{*}	0.17^{ns}	0.93^{ns}
Root dry weight	1.45^{ns}	0.87^{ns}	1.02^{ns}
Number of fruit / plant	1.16^{ns}	4.39^{*}	1.75^{ns}
Fruit length	1.70^{ns}	4.92^{*}	1.24^{ns}
Fruit diameter	2.01^{ns}	0.77^{ns}	0.83^{ns}
Fruit weight per plant	5.12^{*}	4.35^{*}	2.07^{ns}
Yield per plot	3.81^{*}	8.92^{*}	1.30^{ns}

Note: * = significantly difference 5 %, ns = non significantly difference

Table 2. Growth and yield of four hybrids of chili pepper in Ultisol

Hybrids	Plant height (cm)	Dichoto-mous height (cm)	Stem diameter (mm)	Number of branches	Shoot fresh weight (g)	Shoot dry weight (g)	Fruit weight per plant (g)	Yield per 2 m^2 plot (kg)
Maxima	75.11 b	28.41 bc	10.30 c	57 b	145 b	47.85 b	1872 a	2.71 a
H39	95.40 a	33.69 a	11.87 a	81 a	223 a	73.59 a	1563 b	2.32 b
H14	75.07 b	27.55 c	11.27 ab	58 b	143 b	47.19 b	1886 a	2.64 a
Unib CHR17	77.39 b	30.65 b	10.74 bc	59 b	145 b	47.85 b	1775 ab	2.71 a

Note: Numbers in the same column followed by the same leters were not significantly difference based on DMRT at a=5%

traits for an ideal type of new chili pepper hybrid is the dichotomous height (Arif *et al*., 2013). High dichotomous height is considered more beneficial in chili plants because it can prevent fruit from splashing water from the soil so that it can reduce the potential for disease infection. A short dichotomous caused chili pepper fruits to come in contact with mulch or soil and was prone to direct splash of rainwater increasing fruit diseased incidence (Rommahdi *et al*., 2015).

A stem is a place for channeling water and plant nutrients in the form of ions through xylem tissue, and then the phloem tissue delivers photosynthetic product food from leaves to any part of the plant including the growing fruits. The larger the diameter of the stem of a plant, the greater the water and nutrients flowed throughout the plant. The larger stem is also able to give better support for the vigorous growth of chili plants (Shweta *et al.*, 2018). The greater the number of dichotomous branches formed in plants, the greater the potential for plants to produce fruit so that the yield will also be higher. The higher number of dichotomous branches that will potentially affect the number of leaves formed leading to a higher rate of photosynthetic activity which, in the end, the system potentially prone to higher yield.

Good vegetative growth highly correlation with a high yield of the chili pepper plant (Chowdhury *et al*., 2015). However, the yield of chili pepper is genetically determined by many factors related to the yield components such as the number of fruit, fruit size, fruit length, fruit diameter, and weight per fruit (Benchasri and Pruthikanee, 2018).

In the present study, the plant posture of H39 was morphologically, indeed, more vigorous with high and branchy canopy. However, its yield per plant or per area was lower than that of Maxima or Unib CHR17. Considering the number of fruit per plant which was no variation in all hybrids, the difference in fruit weight per plant might be due to variation in the size and weight per fruit. Visually, the fruit shape of hybrid H39 was slimmer than that of other

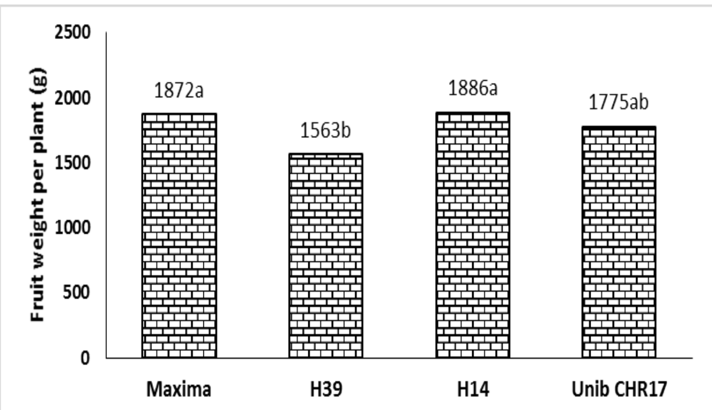

Figure 1. Fruit weight per plant of four hybrids grown in Ultisol

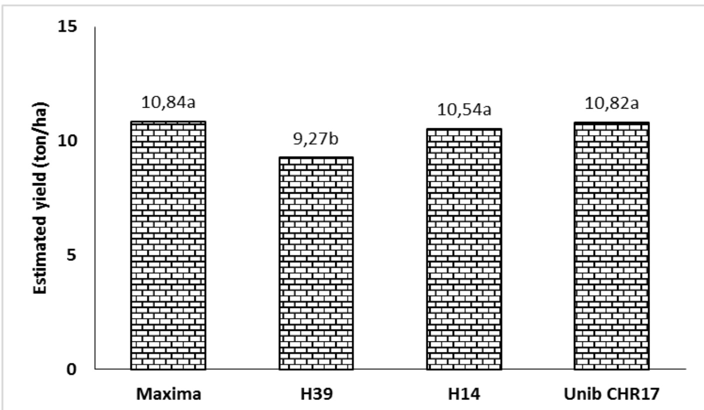

Figure 2 . Estimated yield per hectare of four hybrids grown in Ultisol

hybrids. Besides that, it also possessed smaller seed size and thinner fruit mesocarp than other hybrids. Those characteristics were attributable to by a genetic factor of the hybrid parents.

The weight of fruit per plant and yield per plot is certainly determined by the genetic properties of the plant. Variation in genetic makeup potentially exhibits variation in growth and yield performance amongst genotypes. The number of fruits was positively correlated to fruit weights per plant. The more the number of fruits, the higher the weight of fruit per plant (Benchasri and Pruthikanee, 2018). In this study, the highest weight of fruit per plant and yield per plot were hybrid H14 and Maxima. A genetic factor not only influences the morphological shape up of the plants but also determine the adaptiveness of genotypes to certain environmental condition. A variety of plants grown in different environmental conditions will exhibit different genotype responses (Nilahayati and Putri, 2015). Those hybrids, therefore, were the most potential chili pepper hybrids for low altitude and Ultisol land areas.

b. Effect of Fertigation Schema on Growth and Yield of Chili Pepper in Ultisol

Fertigation schema of N, P, and K fertilizers did not affect vegetative growth of chili pepper plants. All growth components, such as plant height, dichotomous height, stem diameter, number of branches, root length, shoot fresh and dry weight, root fresh and dry weight were about similar at all fertigation treatments.

Fertigation schema significantly affected only on yield components including the number of fruit, fruit length, fruit weight per plant, and fruit weight per plot, but not significantly affected fruit diameter.

Previous studies reported that the higher the percentage of fertigation, the better the yield components and the yield. The highest number of fruits, 100 fruits per plant, was at 100% fertigation (0% circle-dressed), although it was not significantly different from that of 75% fertigation (25% circle-dressed), which was 82 fruits. The longest fruit length was also noticeable in 100% fertigation, although it was not significantly different from that of 75% fertigation. They were about 1 cm longer than that in 100% circle-dressed fertilizer application (Table 3).

Similarly, the weight of fruit per plant and yield per 2 m2 plot at 100% fertigation was the highest amongst those of the other fertigation schema. Both of which were about 45% higher than that of non-fertigation treatment (all circle -dressed fertilizer application). The second heaviest fruit per plant (Figure 3) or estimated yield per hectare (Figure 4) was at 75% fertigation, and the lowest one was at non-fertigation.

The effectiveness of fertilization comprehends how high the applied fertilizer provides nutrients for plants. This is governed by many factors, and the most important one is the availability of water to make the applied fertilizer become soluble and release ions absorbable by roots. Moreover, the method of fertilizer application is another determining factor (Ngosong *et al*., 2018).

Fertigation is a method of fertilizer application accompanied by irrigation at the same time. Diluted fertilizer makes the nutrient has become readily ionized and available to the plant. At the high land field with no irrigation

Table 3. The effect of fertigation schema on yield components of chili pepper hybrids in Ultisol

Treament	Number of fruit per plant	Fruit length (cm)	Fruit weight per plant (g)	Yield per 2 m^2 plot (kg)
0% CD - 100% F	100.14 a	12.73 a	577.92 a	3.81 a
25% CD - 75% F	81.95 ab	12.53 a	513.98 ab	2.89 b
50% CD - 50% F	72.05 b	11.71 b	402.06 bc	2.21 bc
75% CD - 25% F	76.47 ab	11.69 b	403.91 bc	2.19 bc
100% CD - 0% F	60.20 b	11.69 b	320.86 c	1.86 c

Note: CD: circle-dressed fertilizer application; F: fertigation. Numbers in the same column followed by the same leters were not significantly difference based on DMRT at a=5%

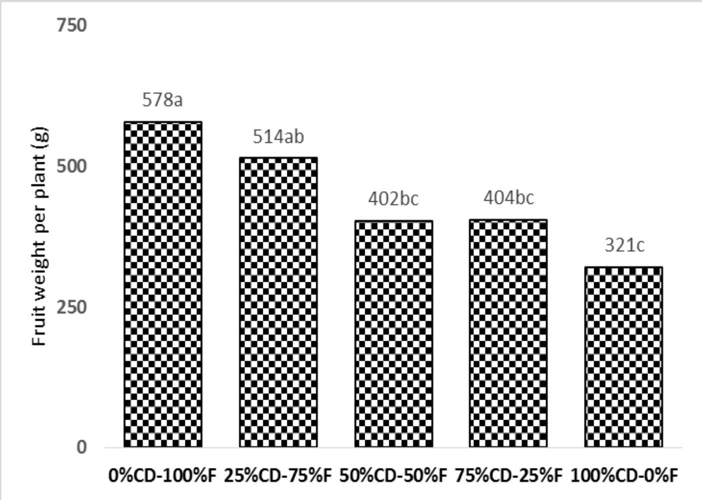

Figure 3. Fruit weight per plant of chili pepper on five fertigation schema in Ultisol

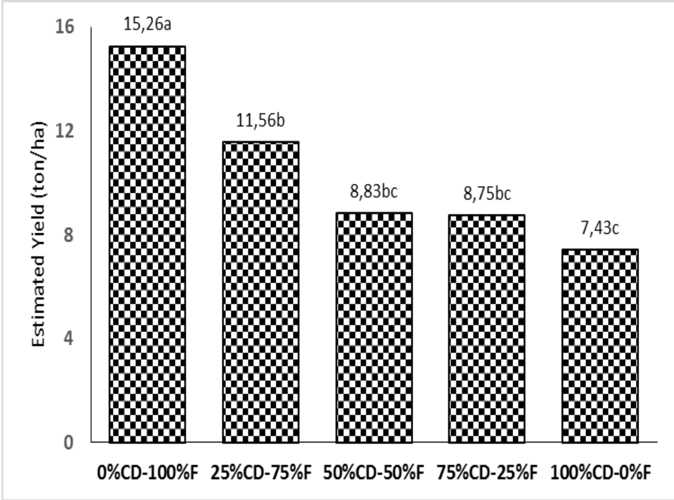

Figure 4. Estimated yield per hectare of chili pepper on five fertigation schema in Ultisol

system, fertigation is done by manually drenching as much as 200 ml per plant of diluted fertilizer at a concentration of 2 g/l, weekly, and, consequently, it is laborious. The present study was aimed at finding the best fertigation scheme for chili pepper which supports increasing yield but less labor. The result showed that fertigating the whole fertilizer seems the best scheme to increase the yield of chili pepper up to 45% greater than that of 100% circle-dressed application. This level of increase is certainly able to compensate for the cost of additional use of labor to manually feed fertigation. Further study implementing automatic drip irrigation in chili pepper culture might potentially further improve the economic profitability of the fertigation system.

During fertigation, plant nutrient behavior varies depends on the chemical properties of the nutrient in the fertilizer. In fertigation, nitrogen from urea becomes susceptible to volatilization and loss to the atmosphere as ammonia. The rest, in the form of ammonium, is usually oxidized by soil bacteria to form nitrate which is dispersed in the soil. Phosphorus (P) in solution is subject to interactions with inorganic and organic constituents in the soil. The H2PO4- ion from diluted phosphor fertilizer remains stable in the solution and readily absorbable for the plant root. Potassium cation from fertigated potassium fertilizer is also stable and present as exchangeable cations (Sandal and Kapoor, 2015). Higher nutrient absorbability in the present study might be responsible for higher yield in a 100% fertigation scheme. The result of this study was in harmony with the previous study of fertigation on pepper (Kumar *et al.*, 2017), tomato (Mali *et al.*, 2016), or eggplant (Ughade and Mahadkar, 2015).

CONCLUSION

All hybrids evaluated in this study showed a similar pattern of responses to the changing fertigation schema. The hybrid H39 possessed the most vigorous vegetative growth whereas ‘Maxima’ and H14 showed the highest yield amongst evaluated hybrids in Ultisols. The 100% fertigation was the best method of NPK fertilizer application for chili pepper in Ultisols.

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