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Optimization of Sowing Density for Improving Fruit Yield of Tomatoes Grown in Open-field Crop

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ABSTRACT

Background: Sowing density optimal is rated a less expensive solution for enhancing the output of tomato yield in the background of extending food requirements worldwide.

Methods: The main objective of this study is to investigate the sowing density effect on the growth and tomato yield planted in Don Duong district of Lam Dong province, Vietnam. The study was conducted during the spring tomato crop (January to June 2020) with five different sowing densities varying from 33000 to 50000 plants/ha based on drip irrigation system supply approximately 100% of actual evapotranspiration.

Result: Results pointed out that among investigated sowing densities, sowing density 45830 plants/ha obtained the optimal fruit yield (OFY) up to 87.8 tons/ha compared with different sowing densities while other observed variations as the number of bunches, fruit weight per plant and diameter were no significant difference. Based on the findings, tomato growers can sow with a density 45830 plants/ha to obtain the OFY thereby contributing to increase profits.

Key words: Evapotranspiration, Fruit yield, Household, Optimal, Sowing.

INTRODUCTION

In recent decades, tomatoes are commonly grown in Vietnam with an estimated area about 24 thousand ha (Afari-Sefa, 2012; Dang, 2020). In there, the southern area is estimated to account for 40% with an area of 9000 ha, of which Lam Dong has the largest area of 7000 ha (Dang, 2020; Dinh and Dang, 2020a). However, its yield is lower than expected level (Nguyen and Nguyen, 2015; Lee and Dang, 2020) as well as comparing the standards of the international market (Genova *et al*., 2013; Silva *et al*., 2017) because of pests, disease problems, adverse environmental conditions as well as due to inappropriate sowing density are one of the major problems in tomato production (Ismail and Moussa, 2014; Hachmann *et al*., 2014). Studies on the growth processes of tomatoes stated that tomatoes are very sensitive to environmental conditions (Hachmann *et al*., 2014; Nguyen and Nguyen, 2015). In the context of increasingly limited arable land for other activities and farming conditions approaching optimal productivity, increase in sowing density is considered one of the effective solutions to increase crop yield (Amare and Gebremedhin, 2020; Wahab and Hasan, 2019). Numerous studies on finding solutions to OFY have indicated an increase in fruit yield of tomatoes when sowing density was increased (Amare and Gebremedhin, 2020; Mulatu *et al*., 2019), however other studies reported that high fruit yield of tomatoes is also dependent on cultivar selection, cultivation method and crop sowing periods (Falodun and Emede, 2019). According to Falodun and Emede (2019), most plants appear to increase yield per unit area as sowing density increases, however, it only ends up to a certain sowing density, if sowing density exceeds the allowable limit yield per unit area will decrease (Hachmann *et al*., 2014; Chernet *et al*., 2017). A study on the relationship between sowing densities and fruit yield of tomatoes conducted by Falodun and Emede (2019) reported that total marketable yield, tomato fruit quality, fruit size and harvesting periods are certainly affected by sowing density. Sowing density plays, therefore, an important role to contribute the OFY (Dinh and Dang, 2022b; Hachmann *et al*., 2014). Ismail and Moussa (2014) conducted to the investigation of the effect of row spacing and sowing density on the growth and productivity of tomatoes. They reported that a treatment of D2 (two plants per dripper) increased total fruit yield by 122-168% compared to a treatment of D1 (single plant per dripper). In Nigeria, Falodun and Emede (2019) studied the effect of sowing densities on tomato yield for an experimental farm at the University of Benin. They conducted an experiment on three tomato varieties (Roma savanna, UC 82 and Roma VF) and three sowing densities (0.30 m^2, 0.375 m^2 and 0.3375 m^2). Their results pointed out that the spacing of 0.30 m^2 obtained superiority in plant height and leaf area

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compared with different sowing densities. In Vietnam, Nguyen and Nguyen (2015) investigated the effect of sowing density on growth and tomato yield in Thai Nguyen province. Their results indicated that a treatment with 25974 plants/ha had the good results in the plant parameters as well as fruit yield compared with the other treatments.

In Vietnam, Lam Dong is known as one of the provinces with the largest annual tomato production (Dang, 2020; Lee and Dang, 2020). Like other provinces, the fruit yield of tomatoes across Lam Dong province has not met the expected level (Dang, 2020; Lee *et al*., 2020). The main cause may be little information on sowing densities when tomatoes are sown in an open environment (Falodun and Emede, 2019; Lee *et al*., 2020). According to Lee and Dang (2020), the sowing density of tomatoes in Lam Dong province is based on traditional cultivation practices and recommendations from seed supply companies. It lacks, therefore, the investigation on the most suitable sowing densities for each cultivar to obtain optimal yields.

The main objective of this work was to investigate the response of the crop parameters as well as tomato yield to different sowing densities, contributing to increasing yield as well as optimising profits.

Table 1: Nutritional ingredients for supplying the growth stages of tomato plant through drip irrigation system.

Nutrient	Growth stages	
	Vegetative (g/m^3)	Fruit (g/m^3)
K	2.3	3.4
Ca	1.5	1.8
Zn	0.018	0.021
Fe	0.014	0.019
N	2.3	2.9
P	0.6	0.8
S	0.75	1.19
Mg	0.85	0.98
KH_2PO_4	0.28	0.49
$MgSO_4$	0.25	0.47
$Ca(NO)_2$	0.42	0.69
KNO_3	0.28	0.64
$NaNO_3$	0.17	0.23
$MnSO_4$	0.46	0.53

MATERIALS AND METHODS

Description of the study area

The study was deployed in the tomato cultivation farm in Don Duong district of Lam Dong province, Vietnam during the spring tomato crop from January to June 2020. The study area is located in a tropical monsoon climate with an average annual temperature of about 21.5°C and average annual rainfall is approximately 1700 mm. The area has an average humidity around 84% and daily average sunshine is approximately 6.8 hours (Dang, 2020), which are favourable for crop season such as tomatoes (Afari-Sefa, 2012; Dang, 2020). According to Shamshiri *et al*. (2018), the growth of tomatoes is sensitive to environmental factors as rainfall, temperature and solar radiation.

Soil and crop characteristics

The 10 days old tomato cuttings were sown at 20 cm from the soil furrow surface where soil is coved by plastic mulches. In this study, sowing densities varying from 33000 to 50000 plants/ha (40 cm×70 cm, 45 cm×70 cm, 50 cm×70 cm, 55 cm×70 cm and 60 cm×70 cm) were selected to implement this test. Supply *water is wated by using* drip irrigation system corresponding to 100% of actual evapotranspiration (Fig 1). A drip irrigation system was set up consisting of a 4000 L tank which was located at a height of 2.0 m to providing irrigation water and nutrients Nutritional and fertilizer ingredients era mixed with irrigation water through drip system to provide plants (Table 1).

The physicochemical characteristics of the soil across the study area obtained from the collected soil samples. The soil textural across the study area have been classified based on the basic soil textural classes according to USDA particle sizes (USDA, 2019) and described in Table 2. The main soil textural comprises 47.6% sand, 35.7% silt and 16.7% clay with the soil water content at saturation 38 vol%, field capacity 15 vol%, permanent wilting point 7.0 vol% and saturated hydraulic conductivity 2200 mm/day (Dang, 2020).

Plant characteristics

Plant data were collected after four weeks sowing. Six tomatoes cuttings were randomly choosen from each plot and signed for the purpose of checking results. Plant parameters were surveyed consists of plant height, the number of brunches, fruits per plant, stem diameter, fruit weight and fruit yield.

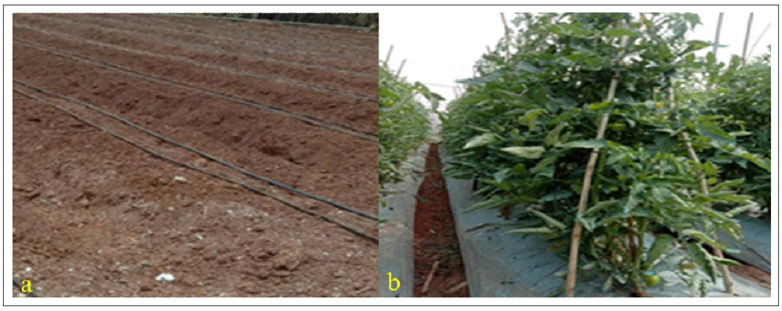

Fig 1: Illustration of a) soil preparation procedures and b) drip irrigation system for for implementing the study.

Meteorological data

The meteorological data during the study period consisted of the temperature, precipitation, sunshine hours, humidity and evapotranspiration were collected from hydrometeorological forecasting center of Lam Dong province and showed as (Table 3).

Table 2: The physicochemical properties of soil analyzed across the study area.

Soil properties	Values	Unit
Sand	43.6	%
Silt	38.7	%
Clay	17.7	%
Textural class	Clay loam	-
Soil water content	38	vol%
Field capacity	15	vol%
Saturated hydraulic conductivity	2200	mm/day
Organic matter	1.2	g*100 g^{-1}
Total N	3.6	g*100g^{-1}
K^+	0.21	cmol kg^{-1}
Ca^{2+}	1.37	cmol kg^{-1}
Mg^{2+}	1.49	cmol kg^{-1}
pH (H_2O)	5.4	-

Statistical analysis

Statistical treatment of the obtained data was conducted based on analysis of variance (ANOVA) using Tukey's test in the R software packages. When significant differences among the investigated factors were detected, Tukey's test at 5.0% probability level (P<0.05) was appllied to compare treatment means.

RESULTS AND DISCUSSION

Relationship between sowing densities and plant parameters

The findings of tomato height and number of bunches were presented in Table 4 and Fig 3. Results indicated that height of tomato at maturity stage has a close relationship with sowing densities. Specifically, among designed sowing densities, the plant height measured in ranging from 158 to 169 cm, in which the lowest plant height recorded 158 cm (33000 plants/ha), whereas the highest height of tomato measured up to 179 cm (50000 plants/ha).

Table 3: Meteorological factors during the stage of tomato sowing crop.

Meteorological variables	Jan	Feb	Mar	Apr	May	June
Temperature (°C)	15.9	16.8	17.9	18.9	19.3	19.4
Sunshine hours (hours)	11.2	11.4	11.7	12.2	12.5	12.7
Precipitation (mm)	11.8	24.5	62.8	145.4	180.9	172.8
Humidity (%)	81	80	76	84	88	89
Evapotranspiration (mm)	61	65	82	57	43	45

Table 4: Relationship between sowing densities on plant parameters.

Space(cm)	Plant height(cm)	No. of bunches	No. of fruits	Diameter(cm)	Weight (g)	Yield (ton/ha)
40 × 75	179a	12a	73b	4.7a	87a	87.8a
45 × 75	172b	11b	65b	5.1b	93b	80.7b
50 × 75	167b	9a	59a	5.4b	106a	73.4ab
55 × 75	163a	8a	55a	5.9a	112b	68.3a
60 × 75	158a	7b	49b	6.3b	120b	62.9a
CV	8.10	2.07	9.23	0.63	13.53	9.86

Means with the same letter in the columns are not significantly different according to Tukey's test at 5.0% probability level (P<0.05).

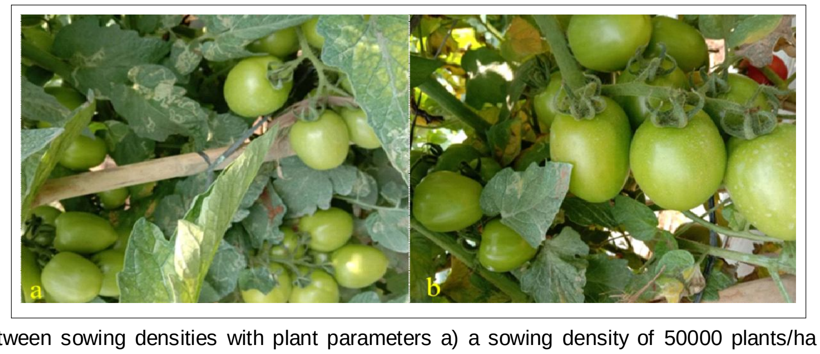

Fig 2: Relationship between sowing densities with plant parameters a) a sowing density of 50000 plants/ha and b) a sowing density of 33000 plants/ha.

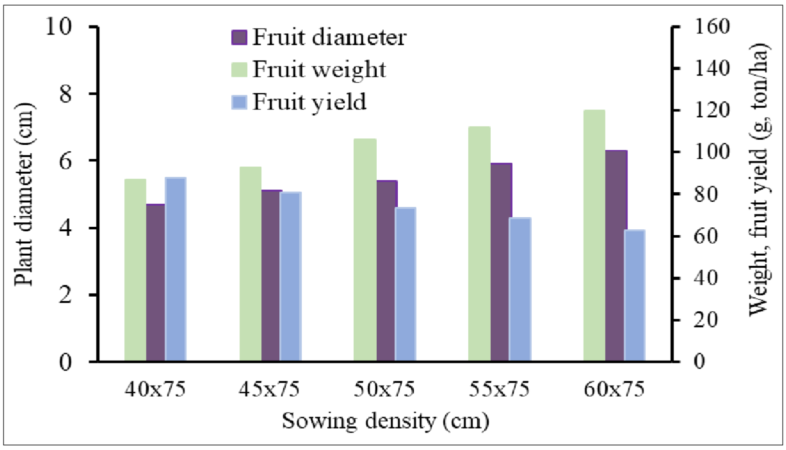

Fig 3: Relationship between sowing densities with diameter, weight and fruit yield

It implies that the height of tomato at the maturity stages of small sowing density was higher compared to large sowing density, which accommodates the finding of Falodun and Emede (2019). They conducted a study on the effect of sowing densities on tomato Roma savanna, UC 82 and Roma VF varieties in Nigeria. Their results indicated that the 33333 plants/ha obtained highest fruit yield. For the number of bunches and fruits per plant, measured data pointed out that the number of bunches and fruits per plant will be proportional sowing density. Specifically, among sowing densities, the 50000 plants/ha measured 12 bunches and 73 fruits per plant while the 33000 plants/ha obtained only seven bunchers and 49 fruits per plant. Similar results also were carried out by Amare and Gebremedhin (2020) that small sowing density will result in a 50% fruit yield increment than the large sowing density. In general, sowing density is inverse proportional to the height, number of branches and fruits per plant (Table 4).

Analysis of diameter of fruits pointed out that sowing density of 50000 plants/ha obtained mean fruit diameter 4.7 cm while sowing density of 33000 plants/ha recorded mean fruit diameter up to 6.3 cm. It means that small sowing density will obtain small fruit diameter. In other words, fruit diameter is proportional to the sowing density of tomato plants (Fig 2).

Relationship between sowing densities with fruit weight and yield

For fruit weight of tomato, the analysis indicated that fruit weight of tomato measured varying from 87 to 120 g corresponding to sowing densities varying 33000 to 50000 plants/ha. Specifically, sowing density of 50000 plants/ha obtained mean fruit weight 87 g while sowing density of 33000 plants/ha harvested mean fruit weight up to 120 g. It implies that small sowing density given small fruit weight. For fruit yield, analysis indicated that sowing density 33000 plants/ha was obtained the highest fruit yield up to 87.8 tons/ha while other designed sowing densities were only made fruit yields varying from 62.9 to 87.8 tons/ha (Table 4). However, analysis pointed out that sowing density 33000 plants/ha still obtained similar statistical results in terms of plant parameters compared with other designed sowing densities (Fig 3). A similar report was also stated by Falodun and Emede (2019) that highest fruit yield was obtained with sowing density (75 cm × 50 cm) and they recommended, therefore, tomato growers should examine in this locality.

Accordingly, the low fruit yield with the high sowing density would not be suitable for tomato growers based on economic considerations. The results are in agreement with the reports of Dinh and Dang (2022b). They conducted an investigation on the sowing density effects of tomatoes grown in a greenhouse to determine the optimal sowing density. Their study was deployed with seven different sowing scenarios varying from 25000 to 50000 plants/ha. Their results carried out that sowing density 25000 plants/ha is obtained an optimal market production.

CONCLUSION

The study was implemented to investigate the sowing density effect on the growth and fruit yield of tomatoes planted in the tomato farm belonging to Don Duong district of Lam Dong province, Vietnam. Based on the tested sowing scenarios, sowing density 50000 plants/ha was created an optimal fruit yield of tested tomato varieties. Results pointed out that, 50000 plants/ha is an optimal sowing density, of which tomato growers can apply to improve fruit yield as well as profit optimization.

Compliance with Ethical Standards

Funding

This study was not funded by any agency.

Author contributions

Conceptualization, T.A. Dang, K.H.T. Dinh; methodology, analysis the database, T.A. Dang, prepares the draft, K.H.T. Dinh. T.A. Dang edits the original draft. Authors have read and agreed to the published version of the draft.

Ethical approval

This article does not contain any studies with human participants or animals performed by any of the authors.

Conflict of interest

Author has not received study grants from any agency or rganization. Author confirms that I have no conflict of interest.

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