The Effect of Plant Spacing and Planting Model on Multiple Cropping of Red Chili (*Capsicum annuum* L.) and Shallot (*Allium ascalonicum* L.) under Saline Soil Conditions

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**Key words:** LER, Multiple cropping, Plant spacing.

**ABSTRACT**

A field experiment was conducted from October 2018 to April 2019 at Sidomukti Village, Brondong Sub-District of Lamongan Regency, Province of East Java. The research was performed with the aim of examining and obtaining appropriate combinations of plant spacing and planting model for red chili (*Capsicum annuum* L.) and shallot (*Allium ascalonicum* L.) plants in saline soil conditions. The utilized design on this research was randomized block design. This research consists of 6 combinations that are repeated 4 times, resulting in 24 experimental units. Based on the research, it was found that the treatment of multiple cropping of red chilies i.e. 2 rows of shallot plants between rows of red chilies have land equivalence ratios (LER) greater than 1, being 1.32 and 1.41, which indicates that the treatment of multiple cropping leads to higher land effectiveness.

**INTRODUCTION**

Red chili (*Capsicum annuum* L.) plants are one of the horticulture commodities that are planted for their fruits. The red chili plant can grow in soil that possesses good drainage and aeration as well as sufficient water availability. Red chili plants demand soil with a neutral pH, between 6 and 7. According to Castellanos et al. (2017), the red chili plant is an important vegetable commodity around the world, considering its commercial and economic value. The production of red chili plants may be increased through extensification, or the utilization of lands that have not been planted with chili plants as well as making use of sub-optimal lands. One kind of sub-optimal land that may be utilized for the production of red chili plants are saline lands. Saline lands possess soil with a high content of dissolved salt; this may impede or even endanger the growth of plants. Salinity itself is one of the abiotic stresses that affect the growth of plants and it mostly has negative effects on the growth and yield of plants. According to Daliakopoulos et al. (2016), soil salinity is one of the factors that affect environmental resources, specifically soil that causes plants to be unable to grow optimally. Plant growth that is not optimal causes its production to be not optimal as well.

Increasing the production of red chilies on saline land can be accomplished by improving the cultivation method, such as utilizing a multiple cropping system (Indonesian: *tumpangsari*). Intercropping is a system where two or more different kinds of plants are planted together at a relatively same time or at different times (Ganajaxy et al., 2010; Mousavi and Eskandari 2011). Multiple crops are planted at specific distances with alternate planting on a field of land. Even so, multiple cropping does not necessitate that the plants are planted at the same time, only so that the plants are combined together in one place. The red chili plant can be multiple-cropped with other plants of different families, such as shallots (*Allium ascalonicum* L.). Shallot was used as the companion crop because it was a suitable plant in dry land condition and also had a different rooting, canopy and nutrient uptake pattern from red chili, so it will create a synergic intercropping system. Multiple cropping is performed with plants of different families because the plants would have different pests and diseases, which can then reduce infestation of insect pests and diseases. According to Getahun et al. (2018), multiple cropping has several advantages, including flexibility, profit maximization, risk minimization, land conservation, and improvement of soil fertility. In addition, multiple cropping is also important for reducing production costs, increasing profits and maintaining land resources. Cultivation with a multiple cropping system must consider several factors, including the control of plant spacing. According to Edgar et al. (2017), one key to the success of a cultivation system is the control...
of an optimal plant spacing so that plants can grow and develop to their maximum.

**MATERIALS AND METHODS**

The experiment was conducted from October 2018 to April 2019 at Sidomukti Village in Brondong Sub-District of Lamongan Regency, East Java. The utilized design for this research was randomized block design. These treatments consisted of 6 combinations with four replications, resulting in 24 experiment units: P₁ - intercropping red chilies with plant spacing 60 x 50 cm and a row of shallots, P₂ - intercropping red chilies with plant spacing 60 x 50 cm and two rows of shallots, P₃ - intercropping red chilies with plant spacing 60 x 50 cm and shallot in a row of plants, P₄ - intercropping red chilies with plant spacing 60 x 40 cm and a row of shallots, P₅ - intercropping red chilies with plant spacing 60 x 40 cm and two rows of shallots, P₆ - intercropping red chilies with plant spacing 60 x 40 cm and shallot in a row of plants. For comparing the result there were also planted monoculture red chilies both of plant spacing 60 x 50 and 60 x 40 cm and monoculture shallot with plant spacing 20 x 20 (Fig 1.)

Measurements conducted on the red chili and shallot plants. Observation of red chili was conducted non-destructively 5 times at 2, 4, 6, 8 and 10 weeks after planting (WAP). The parameter for growth measurement was plant height. The number of samples used in this observation was 4 plants. Measurement of the yield parameter for red chilies involved measurement of the number of flowers per plant, number of fruits per plant, fresh weight of fruits per plant, dry weight of fruits per fruit and fresh weight of fruits per hectare.

Measurement of the shallot plants involved the yield and harvest components. Measurement of dry weight of bulbs per plant, air-dry weight of bulbs per plot (plot size: 2.4 m²) and air-dry weight of bulbs per hectare were conducted destructively and at harvest, 8 WAP. Observation of the dry weight of harvested bulbs involved drying the shallot bulbs over a period of 7 days.

Measurement was also conducted on the percentage of sunlight interception and land equivalence ratio. Observation of sunlight interception was performed using a lux meter. Efficiency of sunlight interception, according to Sugito (2012), was calculated with the following formula:

\[
E_i = \frac{I_j - I_L}{I_j} \times 100
\]

Note:  
- \( E_i \) = Interception (%),  
- \( I_j \) = Escaped sunlight,  
- \( I_L \) = Captured sunlight

The calculation of the land equivalence ratio was performed to determine the land productivity and efficiency value of the yield of plants cultivated with the multiple cropping system compared to monoculture. This value indicates land efficiency, for which a value > 1 means a beneficial. Below is the equation, based on Hiebesch and McCollum (1987):

![Fig 1: Layout of the treatments. (a) P₁; (b) P₂; (c) P₃; (d) P₄; (e) P₅; (f) P₆; (g) monoculture red chilies with plant spacing 60 x 50 cm; (h) monoculture red chilies with plant spacing 60 x 40 cm and (i) monoculture shallots with plant spacing 20 x 20 cm.](image)
LER = \frac{\text{Yield of multicrop chilies} \times 100}{\text{Yield of monoculture chilies}} + \frac{\text{Yield of multicrop shallots}}{\text{Yield of monoculture shallots}}

Note: LER = Land Equivalence Ratio

Data from observations were then analyzed using analysis of variance (ANOVA) and then tested with the F test at an error rate of 5% to find out the effect of the treatments that were given. If significant differences were found from the treatments, then orthogonal contrast testing was conducted with rates of 5% and 1%.

RESULTS AND DISCUSSION

Plant height

The results of research on red chili plants showed that the treatments of planting spacing and planting model influenced the growth of the height of red chili plants (Table 1). The treatment of monoculture had greater plant heights compared to all intercropping treatments. The intercropping red chilies with plant spacing 60 x 50 cm and 2 rows of shallots (P_2) and red chilies with plant spacing 60 x 40 cm and 2 rows of shallots (P_4) showed greater plant heights compared to the other intercropping treatments. This is because there is competition for sunlight with the shallot plants. According to Gogoi et al. (2015), arrangement of plant spacing affects the yield and production of plants; a higher plant density lead to greater plant heights compared to treatments of lower plant density. Meanwhile, according to Sobkowicz (2006), the density of multiple cropping plants will affect the height of plants. Higher plant densities will lead to decreased plant height due to competition among plants.

Light interception

The percentage of sunlight interception by red chili plants with a higher plant density with spacing (60 x 40 cm) was higher than lower plant density (60 x 50 cm) (Table 2). Intercropping red chilies and 2 rows of shallots had the greatest sunlight interception among intercropping red chilies with 1 row and in a row of plants.

The percentage of sunlight interception by shallot plants was higher in monoculture compared to intercropping system (Table 3). Meanwhile, more rows of shallot plants in intercropping system (2 rows), lead to plants receiving a greater light intensity compared to fewer row (1 row) shallot intercrop and shallot intercrop planted within rows of red chilies. According to Liu et al. (2012), closer space between rows lead to higher sunlight interception efficiency compared to farther distances. In addition, control of row distances is important in the control of the plant canopy structure because a good plant canopy structure will result in better sunlight interception. In addition, according to Mohan et al. (2013),

Table 1: Plant height of red chilies.

| Contrast | 2 WAP | 4 WAP | 6 WAP | 8 WAP | 10 WAP |
|----------|-------|-------|-------|-------|-------|
|          | Average | F | Average | F | Average | F | Average | F | Average | F |
| M(50.40) | 7.41 | * | 14.50 | ns | 31.25 | ns | 45.75 | ns | 68.56 | ** |
| P (1 – 6) | 8.42 | 15.08 | 30.25 | 42.13 | 61.20 |
| M_{50} | 7.44 | ns | 13.44 | ns | 31.81 | ns | 47.00 | ns | 70.75 | ns |
| M_{o} | 7.38 | 15.56 | 30.69 | 44.50 | 66.38 |
| P (1 – 3) | 8.47 | ns | 15.00 | ns | 31.50 | * | 42.77 | ns | 59.96 | ns |
| P (4 – 6) | 8.38 | 15.17 | 29.00 | 41.48 | 62.44 |
| P | 8.31 | ns | 14.13 | ns | 30.50 | ns | 37.38 | ** | 55.50 | ** |
| P (2 – 3) | 8.55 | 15.44 | 32.00 | 45.47 | 62.19 |
| P_2 | 8.22 | ns | 14.50 | ns | 34.06 | ns | 45.31 | ns | 64.69 | ns |
| P_3 | 8.88 | 16.38 | 29.94 | 45.63 | 59.69 |
| P_4 | 8.19 | ns | 14.63 | ns | 30.81 | ns | 39.44 | ns | 60.69 | ns |
| P (5 – 6) | 8.47 | 15.44 | 28.09 | 42.50 | 63.31 |
| P_5 | 8.19 | ns | 16.06 | ns | 31.06 | ** | 52.25 | ** | 70.44 | ** |
| P_6 | 8.75 | 14.81 | 25.13 | 32.75 | 56.19 |
| F Tab 5% | 4.32 | 4.32 | 4.32 | 4.32 | 4.32 |
| F Tab 1% | 8.02 | 8.02 | 8.02 | 8.02 | 8.02 |
| CV | 11.71 | 13.22 | 9.55 | 10.32 | 5.73 |

WAP = Weeks after Planting. * = Significant different with orthogonal contrast test by 5 % rates. ** = Significant different with orthogonal contrast test by 5 % rates. ns = no significant different with orthogonal test. P_2 = Red chilies with plant spacing 60 x 50 cm and 1 row of shallots. P_4 = Red chilies with plant spacing 60 x 50 cm and 2 rows of shallots. P_5 = Red chilies with plant spacing 60 x 50 cm and shallots in the rows. P_{6} = Red chilies with plant spacing 60 x 40 cm and 1 row of shallots. P_{o} = Red chilies with plant spacing 60 x 40 cm and 2 rows of shallots and P_{5} = Red chilies with plant spacing 60 x 40 cm and shallots in the rows. M_{50} = Monoculture red chilies with plant spacing 60 x 50 cm and M_{o} = Monoculture red chilies with plant spacing 60 x 40 cm.
Table 2: Interception of light by red chilies.

| Contrast | 2 WAP | | 4 WAP | | 6 WAP | | 8 WAP | |
|----------|-------|---|---|---|---|---|---|
|           | Average | F | Average | F | Average | F | Average | F |
| M(50.40) | 6.46   | ns | 13.94   | ns | 48.89   | ns | 54.61   | ns |
| P (1 - 6) | 6.46   | 13.94 | 48.89 | 54.61 | | | |
| M_50    | 6.95   | 14.85 | 45.52 | 49.51 | | | |
| M_40    | 5.96   | 13.03 | 52.26 | 59.71 | | | |
| P (1 - 3) | 6.95   | 14.85 | 45.52 | 49.51 | | | |
| P (4 - 6) | 5.96   | 13.03 | 52.26 | 59.71 | | | |
| P_1    | 7.16   | 13.88 | 34.72 | 41.52 | | | |
| P (2 - 3) | 6.85   | 15.33 | 50.92 | 53.51 | | | |
| P_2    | 8.26   | 18.32 | 58.51 | 64.37 | | | |
| P_3    | 5.44   | 43.33 | 42.65 |  | | | |
| P_4    | 5.83   | 13.24 | 53.65 | 53.67 | | | |
| P (5 - 6) | 6.03   | 12.93 | 51.56 | 62.74 | | | |
| P_5    | 5.96   | 14.39 | 70.66 | 73.19 | | | |
| P_6    | 6.10   | 11.46 | 32.47 | 52.29 | | | |
| F Tab 5% | 4.32   | 4.32 | 4.32 | 4.32 | | | |
| F Tab 1% | 8.02   | 8.02 | 8.02 | 8.02 | | | |
| CV      | 12.96  | 4.16 | 2.32 | 1.35 | | | |

WAP = Weeks After Planting. * = Significant different with orthogonal contrast test by 5 % rates. ** = Significant different with orthogonal contrast test by 1 % rates. ns = no significant different with orthogonal test. P_1 = Red chilies with plant spacing 60 x 50 cm and 1 row of shallots. P_2 = Red chilies with plant spacing 60 x 50 cm and 2 rows of shallots. P_3 = Red chilies with plant spacing 60 x 50 cm and shallots in the rows. P_4 = Red chilies with plant spacing 60 x 40 cm and 1 row of shallots. P_5 = Red chilies with plant spacing 60 x 40 cm and 2 rows of shallots and P_6 = Red chilies with plant spacing 60 x 40 cm and shallots in the rows. M_50 = Monoculture red chilies with plant spacing 60 x 50 cm and M_40 = Monoculture red chilies with plant spacing 60 x 40 cm.

Table 3: Interception of light by shallot.

| Contrast | 2 WAP | | 4 WAP | | 6 WAP | | 8 WAP | |
|----------|-------|---|---|---|---|---|---|
|           | Average | F | Average | F | Average | F | Average | F |
| Mono     | 11.76   | ** | 25.76   | ** | 56.01   | ** | 52.56   | ** |
| P (1 - 6) | 4.99   | 12.92 | 39.98 | 23.69 | | | |
| P (1 - 3) | 4.96   | 13.39 | 42.45 | 24.74 | ns | | |
| P (4 - 6) | 5.02   | 12.45 | 37.52 | 22.64 | | | |
| P_1     | 4.96   | 13.79 | 32.61 | 18.85 | * | | |
| P (2 - 3) | 4.95   | 13.18 | 47.37 | 27.68 | | | |
| P_2     | 6.97   | 15.55 | 63.70 | 41.66 | ** | | |
| P_3     | 2.94   | 10.81 | 31.04 | 13.70 | | | |
| P_4     | 5.88   | 13.41 | 34.57 | 19.02 | ns | | |
| P (5 - 6) | 4.59   | 11.97 | 38.99 | 24.45 | | | |
| P_5     | 5.73   | 13.26 | 58.48 | 35.19 | ** | | |
| P_6     | 3.44   | 10.69 | 19.51 | 13.71 | | | |
| F Tab 5% | 4.41   | 4.41 | 4.41 | 4.41 | | | |
| F Tab 1% | 8.28   | 8.28 | 8.28 | 8.28 | | | |
| CV      | 12.90  | 8.83 | 7.39 | 18.31 | | | |

WAP = Weeks After Planting. * = Significant different with orthogonal contrast test by 5 % rates. ** = Significant different with orthogonal contrast test by 1 % rates. ns = Not significant different with orthogonal test. P_1 = Red chilies with plant spacing 60 x 50 cm and 1 row of shallots. P_2 = Red chilies with plant spacing 60 x 50 cm and 2 rows of shallots. P_3 = Red chilies with plant spacing 60 x 50 cm and shallots in the rows. P_4 = Red chilies with plant spacing 60 x 40 cm and 1 row of shallots. P_5 = Red chilies with plant spacing 60 x 40 cm and 2 rows of shallots and P_6 = Red chilies with plant spacing 60 x 40 cm and shallots in the rows. M_50 = Monoculture red chilies with plant spacing 60 x 50 cm and M_40 = Monoculture red chilies with plant spacing 60 x 40 cm.
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Table 4: Fresh weight of red chilli.

| Contrast | g fruit⁻¹ | g plant⁻¹ | ton ha⁻¹ |
|----------|------------|------------|----------|
|          | Average F | ns | ns | Average F | ns | ns | Average F | ns | ns |
| M(50.40) | 5.69 | 214.25 | ** | 6.46 | ** |
| P (1 - 6) | 5.58 | 167.52 | 5.04 |
| M₅₀ | 5.66 | 204.13 | ns | 5.44 | ** |
| M₄₀ | 5.72 | 224.38 | 7.48 |
| P (1 - 3) | 5.52 | 164.42 | ns | 4.38 | ** |
| P (4 - 6) | 5.63 | 170.62 | 5.69 |
| P₁ | 5.53 | 172.67 | ns | 4.60 | ns |
| P (2 - 3) | 5.52 | 160.29 | 4.27 |
| P₂ | 5.59 | 197.28 | ns | 5.26 | ** |
| P₃ | 5.45 | 123.30 | 3.29 |
| P₄ | 5.58 | 164.04 | ** | 5.47 | ns |
| P (5 - 6) | 5.66 | 173.91 | 5.80 |
| P₅ | 5.62 | 213.10 | ** | 7.10 | ** |
| P₆ | 5.70 | 134.71 | 4.49 |
| F Tab 5% | 4.32 | 4.32 |
| F Tab 1% | 8.02 | 8.02 |
| CV | 3.42 | 8.46 |

** = Significant different with orthogonal contrast test by 1 % rates. ns = Not significant different with orthogonal test. P₁ = Red chilies with plant spacing 60 x 50 cm and 1 row of shallots. P₂ = Red chilies with plant spacing 60 x 50 cm and 2 rows of shallots. P₃ = Red chilies with plant spacing 60 x 50 cm and shallots in the rows. P₄ = Red chilies with plant spacing 60 x 40 cm and 1 row of shallots. P₅ = Red chilies with plant spacing 60 x 40 cm and 2 rows of shallots and P₆ = Red chilies with plant spacing 60 x 40 cm and shallots in the rows. M₅₀ = Monoculture red chilies with plant spacing 60 x 50 cm and M₄₀ = Monoculture red chilies with plant spacing 60 x 40 cm.

Fruit weight

Plant spacing and planting model didn’t affect fruit weight per fruit but affected fruit weight per plant and per hectare. Monoculture resulted higher fruit weight per plant than intercropping at all plant spacing and model. Both on monoculture and intercropping, a higher plant density resulted greater fresh weight of fruit per hectare compared to lower plant density (Table 4). It indicated that decreasing yield was due to the lower quantity of fruit related with the lower plant population. The treatments of monoculture and multiple cropping with 60 cm x 40 cm plant spacing had a higher fresh weight of fruit per hectare compared to 60 cm x 50 cm plant spacing. Beside through plant spacing arrangement, land productivity can be increased by intercropping system. Based on a research conducted by Gogoi et al. (2015), a higher plant density was indicated to result in a greater number of plants per hectare compared to the treatment of a lower plant density. Intercropping sunlight absorbed by plants will increase with multiple cropping of plants. This is because sunlight that escapes from the primary plant of a higher canopy will be absorbed by intercrops with a lower canopy. Light interception by intercrops in the multiple cropping system will be lower compared to planting by monoculture because the light absorbed by the intercrops will be shielded or blocked by the primary plant with a higher canopy than the intercrops.

Table 5: Land equivalence ratio.

| Treatment | Yield (ton ha⁻¹) | LER |
|-----------|------------------|-----|
|           | Red Chilli | Shallot |
| P₁ | 4.60 | 0.36 | 0.95 |
| P₂ | 5.26 | 1.28 | 1.32 |
| P₃ | 3.29 | 0.39 | 0.71 |
| P₄ | 5.47 | 0.41 | 0.84 |
| P₅ | 7.10 | 1.67 | 1.41 |
| P₆ | 4.49 | 0.30 | 0.68 |
| M₅₀ | 5.44 | - | 1.00 |
| M₄₀ | 7.48 | - | 1.00 |
| Monoculture shallots | - | 3.60 | 1.00 |

P₁ = Red chilies with plant spacing 60 x 50 cm and 1 row of shallots. P₂ = Red chilies with plant spacing 60 x 50 cm and 2 rows of shallots. P₃ = Red chilies with plant spacing 60 x 50 cm and shallots in the rows. P₄ = Red chilies with plant spacing 60 x 40 cm and 1 row of shallots. P₅ = Red chilies with plant spacing 60 x 40 cm and 2 rows of shallots and P₆ = Red chilies with plant spacing 60 x 40 cm and shallots in the rows. M₅₀ = Monoculture red chilies with plant spacing 60 x 50 cm and M₄₀ = Monoculture red chilies with plant spacing 60 x 40 cm.

system is able to increase production per unit of area and time and the intercropping system is also able to increase the efficiency of land use (Singh et al., 2010; Baghdadi et al., 2016).
Land equivalence ratio (LER)
The results of land equivalence ratio (Table 5) among treatments of multiple cropping showed that intercropping of red chilies and 2 rows of shallot (P<sub>2</sub> and P<sub>3</sub>) had a greater than 1 (1.32 and 1.41) while other treatments (P<sub>1</sub>, P<sub>4</sub>, P<sub>5</sub> and P<sub>6</sub>) were lower than 1. This indicates that intercropping of red chilies at a plant spacing of 60 x 40 cm or 60 x 50 cm with 2 rows of shallot leads to a better land utilization. LER presented how many hectares monoculture land needed to equal with 1 hectare production of intercropping. It showed that intercropping having LER >1 give a profitable yield. P<sub>2</sub> and P<sub>3</sub> resulted the optimal plant population to produce higher yield while other intercropping treatments (P<sub>1</sub>, P<sub>4</sub>, P<sub>5</sub> and P<sub>6</sub>) reduced shallots population respectively 25, 15, 25 and 20 % compared to monoculture and resulted the lower yield.

CONCLUSION
The favorable combination of planting spacing and planting model of red chili plants and shallots on saline land is intercropping of red chilies with a plant spacing of 60 x 40 cm and 2 rows of shallots (P<sub>2</sub>). The intercropping patterns of red chili plants and 2 rows of shallots (P<sub>2</sub> and P<sub>3</sub>) on saline land have LER values of greater than 1, respectively 1.32 and 1.41, which indicate that the intercropping patterns with a planting model of 2 rows of shallot indicate greater land effectiveness.

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