Effect of spacing on growth and yield of Sangga Sembalun garlic variety of Sembalun Highland West Lombok

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Abstract: This study was carried out to determine the effect of plant spacing on growth and yield of local garlic (Allium sativum sativum) variety named Sangga Sembalun from Sembalun Highland of West Lombok District, Indonesia, from June 2018 to March 2019. The on-farm experiment was conducted in randomized complete block design (RCBD) for three plant spacing treatments; 12 cm × 12 cm (T1), 12 cm × 10 cm (T2), and 10 cm × 10 cm (T3) with nine replications in 10 m² plot size for each. The results showed that there was no significant difference on effect of spacing on plant height, number of leaves, fresh weight, dry weight, moisture content, bulb weight, bulb size (length and diameter), cloves number, and cloves weight. However, plot yield of T3 (4.84 kg m⁻²) was higher than T2 (3.71 kg m⁻²) and T1 (3.77 kg m⁻²) due to significant increase in population which was, in average, 153, 107, and 90 plant per m² for T3, T2, and T1 respectively. Moreover, weight lost from fresh to dry yield was lower in T3 (55.32%) than T1 (58.13%). Weight lost in T3 was consistently the lowest at 4.35% after six months storage to produce seed bulb.

1. Introduction
Indonesian import of garlic continues to increase every year as national production unable to meet the demand. In 2017, demand of garlic reached 475,750 tons while national production was 41,750 tons which was meet only 8.77% of demand. The remaining 434,000 tons were imported from various countries such as China and India [1]. China is the world's largest producer of garlic with a production of 20 million tons, followed by India 1.25 million tons, South Korea 0.35 million tons, Egypt and Russia 0.26 million tons each [2].

Low national garlic production was due to a high land conversion from highland agriculture to non-agriculture purposes such as hotels and villas following development of tourism sector. Moreover, farmers tend to grow more economic vegetable than garlic, for example shallot, potatoes, cabbage, tomatoes, and carrot. In 1995, the planting area of garlic reached 21,896 ha then dropped sharply to 2,407 ha in 2016. Meanwhile, Indonesia needs 72,249 ha of garlic harvest area with average productivity at 8.35 t ha⁻¹ to meet national demand of 603,000 tons of garlic [1].

Nusa Tenggara Barat (NTB) province is one of potential area for garlic development in Indonesia. Based on the census in 2013, the area of garlic cultivation in NTB reached 243.75 ha which was managed by 1,476 households [3]. East Lombok District where Rinjani Mountain and the valley named highland of Sembalun located has potential of 1,162 ha for garlic. Secondly, potential zone for...
garlic in NTB is Bima District where 4,443 area potential for garlic extensification program covering sub-district of Tambora, Ambalawi, Sanggar, Sape, Soromandi, and Wera.

Apart from having suitable land resources for garlic development, NTB also has local garlic varieties named Sangga Sembalun. The Sangga Sembalun variety was registered and released in 1995 based on Kepmenan No. 79/Kpts/TP.240/2/1995 [4]. This variety is fairly adaptive to wide range of altitude from highlands to medium plains with average productivity at 9–10 t ha\(^{-1}\). In the 1980s, Sembalun highland was the main garlic national producer. Since 2017, the Sembalun highland was designated as bulb seed production center by considering all of its potential.

Optimizing land use is one of strategy to increase garlic productivity. Spacing is important to obtain the optimum population in units of land. Garlic spacing varies depending on the variety and location of planting. Spacing that is too dense can reduce yields due to competition for solar radiation, water and nutrients, in contrast, wide spacing causes premature bulb germination and fibrous bulb [5]. National recommendation for bulb seed production of garlic is 15 cm between rows and 10 cm within rows, with 4–5 cm diameter of hole using plastic mulch [6]. Meanwhile, Basuki and Efendi recommended spacing of 10 cm×10 cm or 12.5 cm×12.5 cm [7]. This study aimed to determine the effect of spacing on the growth and yield of local garlic (Sangga Sembalun variety) grown in the Sembalun area.

2. Materials and methods
The on-farm experiment was conducted at Sembalun Bumbung Villlage of Sembalun sub-district, East Lombok, Nusa Tenggara Barat Province at S -8°22’47” × E 116°32’19” and 1,183 meter above sea level. Research start during garlic season from land preparation in June to harvest in September 2018, and followed by six months storage to produce bulb seed.

The experiment was arranged in a RCB design with three spacing treatment where T1 for 12×12 cm, T2 for 10×10 cm, and T3 for 8×8 cm, and there were 64, 100, 144 hole m\(^{-2}\) for T1, T2, and T3 respectively. Each treatment was replicate in nine small plots (1 m x 10 m) and randomly assigned in 1,000 m\(^{2}\) field area.

Sangga Sembalun variety collected from local farmer and the cloves were separated from the bulbs about two days before planting. In addition, 500 kg ha\(^{-1}\) of dolomite sown during soil preparation, and a week after, 5 t ha\(^{-1}\) of manure and 300 kg ha\(^{-1}\) of SP-36 applied as basal fertilizer during plotting and mulching. Planting is done in the morning by immersing the cloves 2–3 cm deep. Plant maintenance includes fertilizing, weeding and watering. Second and third fertilizers were NPK-phonska, Urea and ZA at dosage of 500 kg ha\(^{-1}\), 200 kg ha\(^{-1}\), and 100 kg ha\(^{-1}\) respectively. Weeding is done before the second and third fertilizer application at 7–15 days after planting/DAP and 30–35 DAP. Watering is done in 2-week intervals. Pest and disease control are carried out by spraying pesticides and insecticides when the threshold has exceeded.

Data was collected from 18 randomly taken plants at harvest (110 DAP) to measure plant height (cm), fresh and dry leaves, fresh biomass (g/plant), sun dried biomass (g/plant), weight lost (%), bulb biomass ratio (%), bulb weight (g), bulb diameter (mm), bulb height (mm), cloves number, and cloves weight (g). Yield was determined from 1 m×1 m harvest plot, including data of bulb number, fresh and dry biomass, and weight of bulb seed. All data collected were subjected to analysis of variance for RCB design as per Gomez and Gomez [15] and Duncan least significant difference (LSD) was used to separate the means at 0.05 probability levels using Statistic Tools for agricultural Research (STAR) version 2.0.1 [8].

3. Results and discussion
Plant spacing did not significantly affect growth and yield of garlic, except percentage of fresh leaves number and plant fresh weight. Spacing is significantly increase plant population that represent variation on bulb number, fresh weight, dry weight, and bulb seed weight.
3.1. Soil properties and rainfall of experimental site

Garlic season in Sembalun Highland is started in May just after the rainy season (November to April), and planting reached the peak during June (Figure 1) for optimum solar radiation and minimum pest/disease problem. The soil texture consists of sand, clay and dust at 31.07%, 36.27% and 32.66% respectively. The N-total was 0.24%, C-organic was 1.24%, K-ex was 0.13 cmol kg⁻¹, Na-ex was 0.01 cmol kg⁻¹, Ca-ex 0.07 cmol kg⁻¹, Mg-ex was 0.39 cmol kg⁻¹, available P₂O₅ was 42.39 ppm, P-potential was 128.5 ppm, and K-potential was 22.49 ppm. CEC at 42.39 ppm and pH of 4.96. Additional dolomite (500 kg ha⁻¹) was applied to increase soil pH.

3.2. Plant growth

Spacing did not significantly affect plant height and fresh leaf number, but significantly affected percentage of fresh leaf. In Table 1 shown that plant height of Sangga Sembalun variety was ranged from 54.08 at T3 to a wider spacing at T1 (58.58 cm), while the number of leaves was between 11–12. Similar to this result, Ara et al [9] reported that the results of observations of tomato plant height tended to increase with wider spacing [9]. Based on the description of the Sangga Sembalun that released in 1995, the number of leaves ranges between 11–12 leaves, while the plant height is about 80–85 cm [4]. Comparing the results of this study, the average plant height was reduced by 30 cm within 24-year interval from 1995 to 2018, while the number of leaves did not change.

**Table 1.** Effect of spacing on plant height, leaf number and percentage of fresh leaf of Sangga Sembalun variety of garlic grown in June-October 2018 at Sembalun Highland.

| Spacing treatment | Parameter | Plant Height (cm) | Leaf number per plant | Fresh leaf (%) |
|-------------------|-----------|------------------|----------------------|---------------|
| T1 (12x12 cm)     |           | 58.58            | 11.83                | 66.19 a 1)    |
| T2 (10x10 cm)     |           | 56.33            | 11.67                | 48.59 b       |
| T3 (8x8 cm)       |           | 54.08            | 10.83                | 63.07 ab      |
| CV (%)            |           | 10.15            | 16.40                | 16.09         |

1) Number followed by same alphabet is not significantly different at 5% probability level.

The spacing affected the percentage of fresh leaves number that significantly higher in wider spacing (Table 1). In the wider the spacing, the plants tend to have longer and wider leaves as it gets less competition to get sufficient light intensity, nutrients, and water. For example, leaf area on onions is better at a wide spacing [10], or green bean leaf length is also better at a loosely distance [11]. In this study, height and leaf number of Sangga Sembalun was similar between less dense population in T1 (64 plant m⁻²) to more dense population in T3 (144 plant m⁻²).

Besides affecting the percentage of fresh leaves number, spacing also affects the fresh biomass weight. Table 2. shows weight of fresh biomass in wider spacing was significantly higher. This might...
be contribution of higher water content in higher percentage of fresh leaves (Table 1). The moisture content in T1 (12×12 cm) was about 65% which was similar to the plant description [4].

Table 2. Effect of spacing on fresh weight, dry weight, weight lost, and bulb biomass ratio of Sangga Sembalun variety of garlic grown in June-October 2018 at Sembalun Highland.

| Spacing treatment | Parameter                      | Fesh biomass weight (g/plant) | Dry biomass weight (g/plant) | Weight lost (%) | Bulb biomass ratio (%) |
|-------------------|--------------------------------|-------------------------------|-------------------------------|-----------------|------------------------|
| T1 (12×12 cm)     |                                | 41.95 \(^a\)                 | 16.40                         | 61.50           | 86.74                  |
| T2 (10×10 cm)     |                                | 34.75 \(^b\)                 | 15.20                         | 43.59           | 84.71                  |
| T3 (8×8 cm)       |                                | 31.63 \(^b\)                 | 16.05                         | 38.98           | 87.57                  |
| CV (%)            |                                | 6.35                          | 49.55                         | 39.55           | 6.19                   |

\(^a\) Number followed by same alphabet is not significantly different at 5% probability level.

Furthermore, weight of dry biomass, weight lost, and bulb biomass ration were not affected by treatment. Dry weight of Sangga Sembalun variety was ranged between 15.20 g (T2) to 16.40 g (T1). In contrast, weight lost in T1 was higher (61.50%) than T3 (38.98%). This data indicating that freshness (high percentage of fresh leave) of garlic in wider spacing was relatively higher than dense spacing. Moreover, interesting data shown in bulb biomass ratio where the higher bulb biomass ration found in T3 at 87.57%. It means that bulb development of Sangga Sembalun was relatively good in dense population of 144 plant m\(^{-2}\).

Table 3. Effect of spacing on bulb diameter, bulb height, cloves number, and cloves weight of Sangga Sembalun variety of garlic grown in June-October 2018 at Sembalun Highland.

| Spacing treatment | Parameter                      | Bulb diameter (cm) | Bulb height (cm) | Cloves number | Cloves weight (gr) |
|-------------------|--------------------------------|--------------------|------------------|---------------|-------------------|
| T1 (12×12 cm)     |                                | 5.00               | 4.33             | 14.33         | 0.90              |
| T2 (10×10 cm)     |                                | 4.23               | 3.09             | 11.17         | 1.33              |
| T3 (8×8 cm)       |                                | 3.80               | 3.03             | 14.67         | 0.80              |
| CV (%)            |                                | 32.71              | 37.40            | 38.90         | 49.45             |

\(^a\) Number followed by same alphabet is not significantly different at 5% probability level.

Variance analysis of bulb diameter, bulb height, cloves number, and cloves weight were not affected by spacing treatment (Table 3). In general, garlic produced a bigger bulb, less but heavier cloves in a wider spacing. This size of bulb is prepared for consumption. In line to this result, Naruka and Shaka [12] reported that all growth parameters, yield and yield components of garlic tubers were better at a wider spacing at about 15 cm [12]. Furthermore, growth, yield and quality of garlic were reported to be optimum in spacing at 14 cm between rows of 14 cm and 5–11 cm within rows [13]. In this study, closer spacing produced a smaller bulb but higher number of cloves. This size of bulb is prepared as bulb seed by the local farmers to minimize cost for seed.

3.3. Yield of Sangga Sembalun garlic

Plant population increased following spacing in planting garlic. The results of the analysis of the variability listed in Table 4. In 1 m\(^2\) harvested plot, the bulb number, fresh biomass weight, dry biomass weight, and bulb seeds weight were significantly higher in dense population of T3 at spacing of 8×8 cm.

In Table 4, T3 produced the highest number of bulb that in average 153.33 bulb m\(^{-2}\). Number of bulbs in all treatment was higher that number of planting holes, it was possible due to development of cloves that multiplied during generative stage. In this study, probability to get the higher number of bulbs is increasing in a higher population. In turn, fresh biomass was significantly higher in dense population. Fresh biomass of T3 was 4.84 kg m\(^{-2}\), and dry biomass become 2.26 kg m\(^{-2}\), and finally after stored for six months, the bulb seed weight of T3 was 2.16 kg m\(^{-2}\). Garlic production is highly
depending on the number of plants per unit of land, so proper spacing is needed to increase production and maintain bulb quality at the same time [14].

Table 4. Effect of spacing on bulb number, fresh weight, dry weight, bulb seed weight of 1m² harvested plot of Sangga Sembalun variety of garlic grown in June-October 2018 at Sembalun Highland.

| Spacing treatment | Parameter                   | Bulb number m⁻² | Fresh biomass weight (kg m⁻²) | Dry biomass weight (kg m⁻²) | Bulb seed weight (kg m⁻²) |
|-------------------|-----------------------------|-----------------|-------------------------------|----------------------------|----------------------------|
| T1 (12×12 cm)     |                             | 90.00 c         | 3.77 b                        | 1.67 b                     | 1.59 b                     |
| T2 (10×10 cm)     |                             | 106.67 b        | 3.71 b                        | 1.71 b                     | 1.62 b                     |
| T3 (8×8 cm)       |                             | 153.33 a        | 484 a                         | 2.26 a                     | 2.16 a                     |

CV (%)  

1 Number followed by same alphabet is not significantly different at 5% probability level.

Figure 2. Effect of spacing in number of bulb (a) and estimation of dry yield production (b) of Sangga Sembalun variety of garlic grown in June-October 2018 at Sembalun Highland.

Based on the results from harvested plot, estimation of dry yield production of garlic was the highest at T3 (13.57 t ha⁻¹), followed by T2 (10.25 t ha⁻¹), and the lowest at T1 (10.03 t ha⁻¹). Figure 2 shows the distribution pattern of the dry yield production was following the pattern of bulb number in each treatment. Bulb number in T1 was more fluctuate and less homogeneous between nine replications when compared to T2 and T3.

4. Conclusion

Effect of spacing on growth and yield of individual plant of Sangga Sembalun variety was similar between treatments, with slight significant different in percentage of fresh leaf and fresh biomass. Garlic productivity was significantly increased following the increase of plant density from 10.03 t ha⁻¹ in 12×12 cm spacing to 13.57 t ha⁻¹ in 8×8 cm spacing, but bulb size was getting smaller. Further assessment to find out effect of spacing, clove size, and row arrangement is needed to obtain optimum spacing for Sangga Sembalun variety.

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References

[1] Dirjen Hortikultura 2017a Pengembangan Bawang Merah Nasional (National Shallot
Development) Kementerian Pertanian Available from: http://riph.pertanian.go.id/ (cited 31 December 2017)

[2] FAO 2017 Garlic Production in 2014 Food and Agriculture Organization of The United Nations, Statistic Division Available from: http://www.fao.org/faostat/en/#data/QC (cited 1 January 2018)

[3] BPS 2013 Sensus Pertanian Provinsi Nusa Tenggara Barat (Agriculture Census of West Nusa Tenggara Province) 2013 Available from: https://ntb.bps.go.id/ (cited 10 November 2019)

[4] Dirjen Hortikultura 2012 Database Varietas Terdaftar Hortikultura (A Database of Registered Horticultural Varieties) Available from: http://varitas.net/dbvarietas/deskripsi/2031.pdf (cited 9 November 2019)

[5] Gupta P K and Gupta R P 2016 Proc. National Seminar on Planting Material Production in Spices (Kozhikode: Directorate of Arecanut and Spices Development) p 65–78

[6] Dirjen hortikultura 2017b Standar Operasional Prosedur Perbenihan Bawang Putih (Standard Operating Procedures for Garlic Seeding) (Jakarta: Direktorat Perbenihan Hortikultura, Kementerian Pertanian)

[7] Basuki R S and Efendi A M 2019 Teknologi Inovatif Bawang Putih (Innovative Garlic Technology) (Bandung: Balai Penelitian Tanaman Sayuran)

[8] STAR 2014 Stastical Tool for Agricultural Reserch (STAR) 2.0.1. International Rice Research Institute Available from: http://bbi.irri.org/products (cited 6 August 2019)

[9] Ara N, Bashar M K, Begum and Kakon S 2007 Int. J. Sustain. Crop Prod. 2 35–9

[10] Khsay Y, Belew D and Abay F 2014 Afr. J. Agric. Res. 9 931–40

[11] Monald H, Malik S K and Mailty T S 1993 Scientific Journal of Agriculture 1 117–25

[12] Naruka I S and Dhaka R S 2001 Journal of Spices and Aromatic Crops 10 111–7

[13] Muner N, Hussain M, Ahmad M J, Khan N, Hussain N and Hussain B 2017 IJAAR 10 42–51

[14] Kumar P 2017 Effect Of Spacing And Different Doses Of Nitrogen On Growth, Yield, And Quality Parameters In Garlic (Allium sativum L) (Phagwara: Lovely Professional University)

[15] Gomez K A and Gomez A A 1984 Statistical Procedures for Agricultural Research 2ed (New York: John wiley and sons)