International Journal of Design & Nature and Ecodynamics
Vol. 20, No. 8, August, 2025, pp. 1899-1905
Journal homepage: http://iieta.org/journals/ijdne

Fertilization Methods and Varietal Selection Enhance True Shallot Seed Production in Lowland Indonesia: A Focus on Bauji Variety Performance

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https://doi.org/10.18280/ijdne.200819

Received: 6 May 2025
Revised: 18 July 2025
Accepted: 25 July 2025
Available online: 31 August 2025

Keywords:
bulb, low land, seed weight, broadcast fertilization, soluble fertilizers

ABSTRACT

Shallot cultivation in Indonesia nowadays still uses planting material in the form of bulbs that potentially carry viruses. The virus in the shallot bulb results in a decrease in productivity. Shallot botanical seeds, commonly called True Shallot Seed (TSS), are an alternative planting material to overcome this problem. Apart from being free from viruses, using TSS as plant material can reduce farming costs by 43% compared to bulbs. However, shallots' flowering and seed formation in the lowlands is still relatively low. Efforts have been made to use fertilizer application methods and select suitable varieties to support shallot flowering and seed formation. This research was conducted in a field with an altitude of 129 meters above sea level using a factorial complete randomized block design. The first factor is the fertilization method, consisting of broadcast and soluble fertilization. The second factor is shallot varieties, consisting of Bima Brebes, Bauji, Tajuk, and Batu Ijo. The results showed that the broadcast fertilization method on the Bauji variety gave higher seed weight per stalk (0.9 grams), seed weight per clump (1.19 grams), and seed weight per plot (4.30 grams) than other treatments. Fertilization of the soluble fertilizing method gives a faster flowering time than the broadcast method (5 weeks after planting). The Bima Brebes variety gives a faster flowering time than all varieties (4.3 weeks after planting), and the Tajuk variety gives a higher flower weight per clump (6.4 grams).

1. INTRODUCTION

Shallots (*Allium cepa* var. *aggregatum group*) are an essential horticultural crop in Indonesia. However, 24 out of 33 provinces that produce shallots in Indonesia experienced a deficit in 2022 [1]. The low productivity of shallot plants is caused by bulbs as planting material. The quality of planting material affects shallot plants' productivity [2]. Shallot propagation is mostly done vegetatively. Farmers in Indonesia rarely use shallot seeds for propagation [3]. Shallot bulbs have the same properties as their elders. However, they have the potential to carry pathogens that cause plant diseases [4].

Shallot botanical seeds, called True Shallot Seed (TSS), are an alternative for shallot propagation [5]. Growing shallots using seeds has lower risks and increases yields by up to three times [6]. Shallot propagation using TSS only requires 5-6 kg of seeds and reduces costs by 43% compared to bulbs [7, 8]. TSS as planting material also has advantages in terms of storage; it can be stored longer and saves more space. The current problem is the low percentage of flowering plants in shallots in the lowlands [9]. The low percentage of flowering in shallots results in the low TSS produced. Efforts are needed to increase shallot flowering in the lowlands so that shallot seed production can increase.

The flowering and seed formation of shallots in the lowlands can be induced by meeting their nutritional needs and choosing suitable varieties. Fertilization is a process that aims to meet the nutrient needs of plants so that they can complete their life cycle properly [10]. Nutrition influences the initiation process in the *Allium* genus [11]. Nutritional pathways are involved in the induction of shallot flowering. Excessive or deficient nutrients can alter flowering timing [12].

The fertilizer used in this study contains N, P, K, and S. The N element plays a role in stimulating stem and leaf growth, while the S element plays a role in tuber formation [13]. Increasing the concentration of potassium (K) also increases the size of Phalaenopsis flowers [14].

The application of fertilizer containing phosphorus (P) can aid the generative process, accelerating flower formation and improving the quality of shallot seeds. The phosphorus content in fertilizer can stimulate plant growth, resulting in flower production and accelerated seed maturity [15]. Phosphorus supports root growth, flower formation, cell division, meristem tissue growth, carbon dioxide fixation, and the breakdown of carbohydrates into energy in olive trees [14]. Increased phosphorus is involved in the initiation of flower primordia, leading to increased flower number, size, and yield attributes in *Tagetes erecta* [16].

Fertilization in this research was done by broadcast or soluble fertilization. Broadcast fertilization is one of the oldest fertilizer application methods in agriculture, which involves broadcasting fertilizer around the plant roots. Soluble fertilizing involves dissolving the fertilizer in water and then pouring it around the plant roots [17].

Varieties also influence the success of flowering and seed formation in shallot plants. The genetics of each variety affect flowering. Not all shallot varieties can flower in the lowlands [18, 19]. Indonesia has a high diversity of shallot varieties. Therefore, it is necessary to evaluate the flowering ability of each variety in the lowlands.

The Bima Brebes variety has a relatively high productivity of 10 tons/ha. The Bima Brebes variety of shallots can be harvested at 55-60 days after planting [20]. The Bima Brebes variety flowers relatively easily in highlands with temperatures of 20.3-21.3℃, but has difficulty flowering in lowlands.

The Bauji variety is a local variety from Nganjuk Regency, as listed in the description from the Indonesian Ministry of Agriculture of the Bauji variety of shallots. This variety is popular with farmers due to its relatively high productivity. Bauji shallots can flower as early as 45 days after planting. The Bauji variety is also resistant to rain, allowing it to produce flowers and full seeds during the rainy season [21]. The Bauji variety has a higher flowering capacity than the Tajuk, Pikatan, Mentes, and Miserati varieties [22].

The Tajuk shallot variety is an introduced plant from Thailand, as listed in the description from the Indonesian Ministry of Agriculture of the Tajuk shallot variety. The Tajuk shallot variety has superior leaf count, which supports photosynthesis and produces good growth results [23].

One of the varieties used in this study is the Batu Ijo variety. Developing local shallot varieties, such as the Batu Ijo variety, is one way to increase shallot production. The Batu Ijo variety boasts the advantage of producing large bulbs. Based on its variety description as explained by the Indonesian Ministry of Agriculture, the Batu Ijo variety is a variety that can adapt well to highland conditions. This study aimed to evaluate the fertilizer application method and varieties on the flowering and seed formation of shallots in the lowlands and to determine the effect of flowering and seed formation on the quality of shallot bulbs.

2. MATERIALS AND METHODS

This research was conducted in Gunungsari, Ngringo Village, Jaten Subdistrict, Karanganyar Regency, and the observation of flower and seed weights was carried out at the Chemistry Laboratory, Integrated Laboratory Unit, Sebelas Maret University. The coordinates of the research area are -7°32'57.2" south latitude, 110°52'09.2" east longitude, with grumusol soil order and altitude of 129 meters above sea level (masl).

Table 1. Initial soil chemical properties characteristics

Variable	Value	Unit
N-total	0.60	%
P-available	4.83	Ppm
K-available	0.13	$Cmol.kg^{-1}$
C-organic	0.92	%
pH	6.13	-

Based on the results of the initial soil analysis, the soil in the research area had a total N content of 0.60% which is classified as high, available P of 4.83 ppm which is classified as low, available K of 0.13 $Cmol.kg^{-1}$ which is classified as low, organic C of 0.92% which is classified as very low, and pH of 6.13 which is classified as slightly acidic (Table 1).

The time of this research was the dry season in May-August 2023. The air temperature in the research area ranged from 25.9-42.5℃ (Figure 1) with relative humidity of 22-90% (Figure 2) and light intensity of 26,300-49,700 lux (Figure 3). Rainfall during the study was low at 0 mm/month.

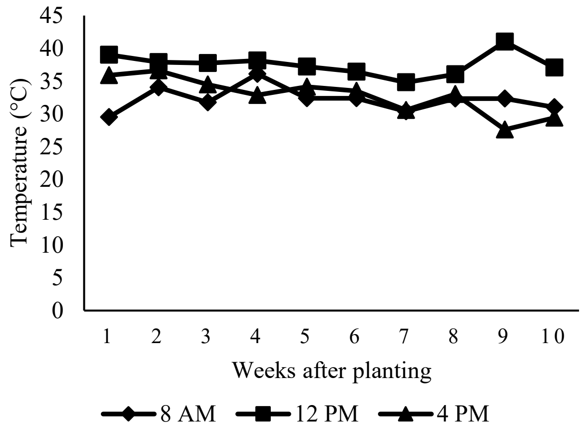

Figure 1. Daily temperature during the planting period

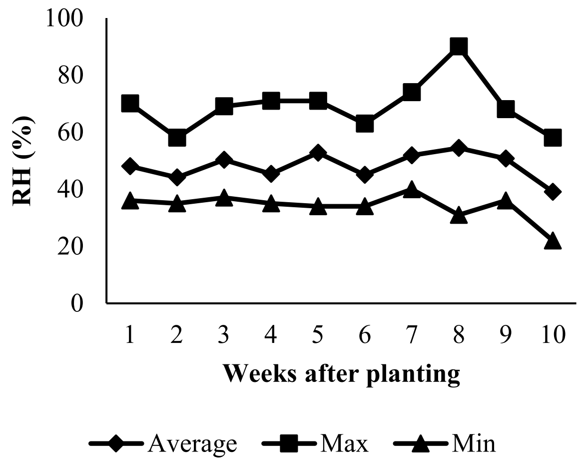

Figure 2. Relative humidity during the planting period

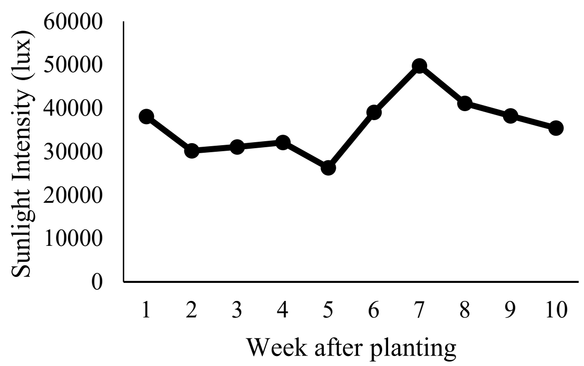

Figure 3. Average light intensity during plant growth

Experimental design and variables: The experimental design used was a factorial complete randomized block design with four replications. The first factor is the fertilization method, broadcast and soluble fertilizers. The second factor is shallot varieties, consisting of Bima Brebes, Bauji, Tajuk, and Batu Ijo. Plant vegetative growth variables consisted of plant height and the number of leaves per clump. Plant vegetative growth was observed from the first to the fifth week after planting. Flowering and seed formation variables consisting of flowering time, number of umbels per clump, number of umbels per plot, percentage of flowering per plot, number of flowers per umbel, number of seed capsules, flower weight per clump, seed weight per umbel, seed weight per clump, and seed weight per plot. Observations were made on pollinator insects to determine the types of insects that pollinate shallot flowers. The tuber yield variable consisted of the tuber weight of flowering and non-flowering plant clumps and tuber damage.

Data analysis: Data were analyzed using IBM SPSS Statistics version 27.0.1. The effect of treatments on the observed response variables was analyzed using Analysis of Variance at a 5% error level. Variables that showed significant differences were compared with the Least Significant Difference (LSD) and Duncan's Multiple Range Test (DMRT). The correlation between variables was tested using correlation analysis, and flowering and non-flowering bulb weights were compared using a t-test.

3. RESULT

3.1 Vegetative growth of shallots

All varieties of shallot plants, both with broadcast fertilization and soluble fertilizing methods, experienced an increase in height from the first week to the fifth week. At five weeks after planting, the heights of the shallot varieties Bima Brebes, Bauji, Tajuk, and Batu Ijo were 40.33 cm, 40.57 cm, 37.60 cm, and 41.43 cm, respectively. Based on the variety description, the Bima Brebes variety has a height of 25-44 cm, the Bauji variety has a height of 35-43 cm, the Tajuk variety has a height of 26.4-40.0 cm, while the Batu Ijo variety has a height of up to 50 cm.

Table 2. Effect of variety on the number of leaves of shallot plants

Varieties	Number of Leaves
Bima Brebes	37.46±3.72bc
Bauji	34.87±5.05b
Tajuk	41.10±5.19c
Batu Ijo	23.79±3.40a
Sig.	0.00

Notes: Numbers followed by the same letter indicate that they are not significantly different according to DMRT at a 5% error level. Sig.: Significance.

The number of leaves in all varieties of shallot plants with broadcast and soluble fertilizing treatments increased from 1-5 weeks after planting. Table 2 shows that the Tajuk variety has 41 leaves, similar to the Bima Brebes variety, which has 37 leaves. The lower number of leaves is shown in the Batu Ijo variety, which is 23 leaves.

3.2 Shallot flowering and seed formation

Genotype is one factor that affects shallot flowering of the 4 varieties used; one variety, the Batu Ijo variety, cannot produce flowers. Therefore, data analysis was carried out on three varieties that could flower and produce seeds: the Bima Brebes, Bauji, and Tajuk varieties.

The soluble fertilizing method provides a faster flowering time compared to the broadcast fertilization method. Table 3 shows that plants with the soluble fertilizing method flowered on average at 5.04 weeks after planting, while plants with the broadcast method flowered at 5.6 weeks after planting. Table 3 shows that the Bima Brebes variety gives a faster flowering time at an average of 4.36 weeks, significantly different from the Bauji and Tajuk varieties. Shallot flowering time is not correlated with other observation variables.

The results in Table 4 show that the number of umbels per clump ranged from 1 to 1.5. The average number of umbels per clump in the Bima Brebes and Bauji varieties was 1.13-1.50 and 1.38 umbels per clump, respectively. The formation of umbels per clump in this study was lower than the description of each variety from the Indonesian Ministry of Agriculture. Based on the variety description, the Bima Brebes variety can produce as many as 2-4 umbels per clump, and the Bauji variety produces 2-5 umbels per clump. The number of umbels per clump does not correlate strongly with other observational variables. However, there is a moderate correlation with the number of flowers per umbel (r=-0.542).

The flowering ability of shallots in this study was still very low. The number of umbels per plot produced in this study ranged from 1.25 to 5 umbels (Table 4). The variable number of umbels per plot strongly correlates with seed weight per plot (r=0.921) and strongly correlates with seed weight per clump (r=0.675). The percentage of flowering per plot from this study was also low, with values of 5-20% and less than 50% (Table 4). The correlation test results showed that the percentage of flowering per plot was very strongly correlated with the number of umbels per plot (r = 1) and seed weight per plot (r = 0.921) and strongly correlated with seed weight per clump (r = 0.675). The number of flowers per umbel produced in this study reached 79.33-131.17 (Table 4). Based on the correlation test results, the number of flowers per umbel had no strong correlation with other observational variables. However, the results showed that the average percentage of drupes was above 50%, which was 64-78% (Table 4). The correlation test results showed that the percentage of seed capsules did not have a strong correlation with other observational variables.

Variety has a significant effect on the weight of umbels per clump. The Tajuk variety has a higher than other variety in weight per clump, which is 4.75 g. Based on Table 5, the weight of umbels per clump of the Tajuk variety is significantly different from the Bima Brebes and Bauji varieties. The correlation test results show that the weight of umbels per clump does not have a strong relationship with other observation variables.

Based on Table 6, the broadcast method of fertilization on the Bauji variety resulted in a higher than other treatment in seed weight per stalk of 0.90 g per stalk. Meanwhile, the soluble fertilizing method on the Bauji variety resulted lower than other treatment in lower seed weight per stalk of 0.26 g per stalk. Based on the results of the correlation test, seed weight per stalk is strongly correlated with seed weight per clump (r = 0.839) and strongly correlated with seed weight per plot (r = 0.721).

The broadcast fertilizing method on the Bauji variety gave a higher average value of seed weight per clump, which was 1.19 g per clump. Table 6 shows that this treatment significantly differed from the other treatment combinations. The correlation test results showed that seed weight per clump was strongly correlated with seed weight per plot (r = 0.823), seed weight per stalk (r = 0.839), and strongly correlated with the number of umbels per plot (r = 0.675), and flowering percentage per plot (r = 0.675).

Table 3. Effect of fertilization methods and varieties on flower emergence time and umbel weight per clump of shallot plants

Treatment	Time to Flower Appearance (WAP)	Umbel Weight per Clump (g)
Fertilization Method		
Broadcast	5.67±0.38a	4.21±0.74
Soluble	5.04±0.48b	3.95±0.94
Varieties		
Bima Brebes	4.36±0.25a	3.46±0.69a
Bauji	5.37±0.48b	3.40±0.93a
Tajuk	6.38±0.48c	4.75±0.60b
Sig. Fertilization Method	0.03	0.84
Sig. Variety	0.00	0.02

Notes: Numbers followed by the same letter indicate not significantly different according to LSD at a 5% error level. WAP: Week After Planting. Sig.: Significance.

Table 4. An average number of umbels per clump, number of umbels per plot, percentage of flowering per plot (%), percentage of seed fruits (%), number of flowers per stalk (%) in different fertilizer application methods, and several shallot varieties

Treatment	Number of Umbels per Clump	Number of Umbels per Plot	Flowering Percentage per Plot (%)	Seed Fruit Percentage (%)	Number of Flowers per Umbel (%)
Broadcast + Bima Brebes	1.13±0.14	3.00±2.31	12.00±9.24	73.46±3.30	123.08±21.91
Broadcast + Bauji	1.38±0.53	5.00±2.83	20.00±11.31	78.02±10.54	131.17±17.68
Broadcast + Tajuk	1.00±0.00	1.25±0.50	5.00±2.00	71.83±9.24	126.75±22.10
Soluble + Bima Brebes	1.50±0.58	3.75±2.36	15.00±9.45	76.72±12.61	111.64±30.30
Soluble + Bauji	1.38±0.48	2.00±0.82	8.00±3.27	70.62±17.41	98.88±42.73
Soluble + Tajuk	1.33±0.58	2.00±1.00	8.00±4.00	63.57±11.85	79.33±16.97
Average	1.28±0.38	2.83±1.64	11.33±6.54	72.37±10.83	111.81±25.28

Table 5. Effect of varieties on umbels weight of shallot plants

Treatment	Umbel Weight per Clump (g)
Bima Brebes	3.46±0.69a
Bauji	3.40±0.93a
Tajuk	4.75±0.60b
Sig. Variety	0.02

Notes: Numbers followed by the same letter indicate not significantly different according to LSD at a 5% error level. WAP: Week After Planting. Sig.: Significance.

Table 6. Effect of interaction between fertilization methods and varieties on seed weight of shallot plants

Treatment	Seed Weight per Stalk (g)	Seed Weight per Clump (g)	Seed Weight per Plot (g)
Broadcast + Bima Brebes	0.52±0.15b	0.64±0.23ab	1.62±0.14a
Broadcast + Bauji	0.90±0.06c	1.19±0.36c	4.30±2.10b
Broadcast + Tajuk	0.32±0.24ab	0.32±0.24a	0.37±0.23a
Soluble + Bima Brebes	0.51±0.16b	0.72±0.25b	2.01±1.46a
Soluble + Bauji	0.26±0.14a	0.30±0.13a	0.50±0.32a
Soluble + Tajuk	0.35±0.16ab	0.44±0.18ab	0.62±0.41a
Sig. Interaction	0.00	0.00	0.00

Notes: Numbers followed by the same letter indicate that they are not significantly different according to DMRT at a 5% error level. Sig: Significance. KK (%): Coefficient of Variance.

Table 7. Comparison of bulb weights of flowering and non-flowering shallot plants

Tests	n	Descriptive Statistics	Independent t-test		
		M (Std. D)	t	*df*	Sig. (2-tailed)
Flowering bulbs	21	84.56 (8.08)	-3.089	43	0.004*
Non-flowering bulbs	21	109.45 (7.98)			

Notes: *: Significant at 0.05 error level.

(a) (b)

Figure 4. Bulb damage (a) flowering plant bulbs, (b) non-flowering plant bulbs

The broadcast fertilizing treatment on the Bauji variety gave a higher than other treatments in average value of seed weight per plot, which was 4.30 g and significantly different from the other treatments (Table 6). Based on the correlation test results, seed weight per plot was strongly correlated with the number of umbels per plot (r = 0.920), flowering percentage per plot (r = 0.920), and seed weight per clump (r = 0.822), strongly correlated with seed weight per stalk (r = 0.721).

3.3 Shallot bulb yield

The t-test results in Table 7 show a significant difference between the weight of flowering plant bulbs and the weight of non-flowering plant bulbs, with a value of 0.004. The weight of flowering bulbs, 84.56 g, is lower than the weight of non-flowering bulbs, 109.45 g. The observation results show that there is damage to shallot bulbs due to delays in harvesting, in the form of bulb rot, growth of new shoots, hollow bulbs, discoloration, and softening (Figure 4).

4. DISCUSSION

The Batu Ijo variety is unable to flower, presumably due to its low adaptability in the lowlands. It is a shallot variety originating from Batu, Malang, which has an altitude of 680-1200 meters above sea level. The Batu Ijo shallot variety grown in the highlands also has a low flowering ability, which is 11.66% [24]. The Batu Ijo variety also shows poor vegetative growth and is lower than the variety description.

Flowering is a transition period between the vegetative and generative phases. The nutrient P influences the age of the flowering process. The flowering process will be faster if the plant's need for P nutrients is met [25]. The results showed that the application of fertilizer by soluble fertilizing is faster in providing nutrients to plants, so that plants flower faster.

P is involved in the initiation of flower primordia formation, leading to increased flower number. Applying soluble fertilizer results in faster flowering, presumably because the fertilizer's dissolution makes the P element more readily available to the plant, leading to an increase in nutrient uptake. Water-soluble fertilizers provide a site-specific nutrient supply quickly and minimize losses compared to conventional fertilizers in horticultural crops [26]. Water-soluble fertilizers provide a highly effective and adaptive nutrient management method, allowing precise control over nutrient distribution to the plant due to their solubility [27].

Each variety of shallots has different flowering abilities. Although planting is done simultaneously, the formation and development of shallot flowers are not always uniform. The Bima Brebes variety provides a faster flowering time compared to other varieties. The results of this study show that the variety of Bima Brebes flowers is faster than the attachment to the Decree of the Minister of Agriculture. The Bima Brebes variety is a variety that can adapt to the lowlands. The Bima Brebes variety is a superior variety that is adaptive to be planted in the lowlands [10].

The results also showed an interaction between fertilization methods and varieties on seed weight per stalk, seed weight per clump, and seed weight per plot. Applying fertilizer by broadcast on the Bauji variety gave higher seed weights per stalk, seed weights per clump, and seed weights per plot than other treatments.

The Bauji variety's ability to produce higher seed weights per stalk, seed weights per clump, and seed weights per plot is thought to be due to its adaptability to lowland conditions. According to the Indonesian Minister of Agriculture, the Bauji variety, a local variety from Nganjuk, Indonesia, grows well in lowland areas.

Broadcast fertilization supports seed growth by providing nutrients during seed filling. Seed formation and filling are also supported by nutrient availability. According to Sukerta et al. [28], phosphorus improves root structure, increasing the absorption of Fe, copper (Cu), and zinc (Zn), resulting in increased growth of shoots, flowers, fruit, and seeds. The P element obtained by shallot plants in this study was obtained from the application of SP-36 fertilizer. Pandiangan et al. [14] explained that the application of P fertilizer can accelerate seed ripening and improve seed quality.

K also plays a crucial role in shallot seed formation. Research by Bakri et al. [29] indicated that the application of K fertilizer positively interacts with the variety for shallot seed formation. K in plants plays a role in triggering the translocation of photosynthetic products, thus providing energy for seed formation and maturation. Research by Kurniasari et al. [30] showed that K increases capsule formation, which affects seed weight in shallot plants. K is obtained by shallot plants through the application of KCl fertilizer.

Plant generative growth is strongly influenced by genetic and environmental factors. Flowering time is observed the week after the plant begins to grow a single umbel. Flowering time is a parameter for the shallot plant's ability to initiate flowering. Flowering is a transitional period between vegetative and generative phases. The time of flowering is influenced by the availability of phosphorus. According to

Hantari et al. [31], flowering will accelerate if the plant's phosphorus requirements are met. Phosphorus availability supports energy transfer, root growth, and flower and seed formation. Phosphorus is directly involved in the formation of flower primordia, the initial stage of flower development.

The broadcast fertilization treatment on the Bauji variety gave a higher average seed weight per stalk than the other treatments, which was 0.9 g per stalk. The results of this study were higher than previous research, which resulted in seed weight per stalk ranging from 0.003-0.09 g [32]. The treatment of the broadcast fertilization method on the Bauji variety gave a higher average value than other varieties, which was 1.19 g per clump. The seed weight per clump in this study was higher than the results of other studies, which is 0.01-0.22 g per clump [32]. The treatment of the broadcast fertilization method on the Bauji variety gave a higher average value than the other treatments, namely 4.30 g per plot. Shallot seed formation is influenced by the suitability of the variety to the surrounding environment. The Bauji variety can be fertilized by broadcast, not by soluble fertilizers.

The seed weight produced in this study was quite high because cultivation was carried out during the dry season with low rainfall. Seed filling during the dry season is better than during the rainy season. Many pollinating insects are found in the dry season, which helps the pollination of shallot plant flowers [33]. Some types of insects found in the meadow are honey bees and bumblebees. Successful pollination increases the percentage of fruit, thus increasing seed weight. Rainwater causes small shallot flowers to fall off, resulting in small and empty seeds.

The average weight of flowering bulbs is lower than non-flowering bulbs. Flowering shallot bulbs gave an average weight of 84.56 grams, while non-flowering bulbs gave a higher average weight of 109.45 grams. Shallots that produce seeds need to be harvested longer than shallots cultivated to produce consumption bulbs. The shallot bulbs produced are only a by-product of the TSS harvest, so the yield is lower. Bulbs that do not flower can still be used as consumption bulbs. However, some bulbs are damaged due to late harvesting, which requires a sorting process to be accepted by the market. Shallots are layered bulbs whose outer skin dries out easily, especially at high temperatures, so they also easily experience weight loss. Weight loss is caused by transpiration and respiration, so that the moisture in the shallot bulb is lost more quickly. The high temperature at the research location resulted in a higher respiration rate. High temperature and humidity cause shallot bulbs to shrink quickly [34].

5. CONCLUSIONS

The broadcast fertilization method on the Bauji variety gave higher seed weight per stalk (0.9 grams), seed weight per clump (1.9 grams), and seed weight per plot (4.30 grams). Fertilization by soluble fertilizers gave a faster flowering time compared to broadcast. The Bima Brebes variety gave a faster flowering time (4.38 WAP), and the Tajuk variety gave a higher flower weight per clump (4.9 grams). Flower formation results in a decrease in the weight and quality of shallot bulbs.

Based on the results of this study, research on the effects of fertilization methods and varieties on shallot flowering in mid-latitudes, during the rainy season, and on different soil types is still needed. Farmers growing shallots for bulb production are advised to prune the flowers to avoid compromising bulb quality.

ACKNOWLEDGMENT

This work is supported by Penelitian Hibah Grup Riset Universitas Sebelas Maret 2023.

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