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Spray Hose Irrigation System Increased Yield of Polyethylene Mulched Shallot

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Abstract

Spray hose is a micro-irrigation system using perforated hose as for micro irrigation. Shallot conventional cultivation requires lots of water and labor man days therefore is more efficient. Shallot cultivation system needs to be developed to increase yield and to reduce production cost. This research was conducted to compare conventional cultivation methods with using spray hose and polyethylene mulch for shallot production. This research was conducted in a hydromorphic alluvial soil type at the Center for Tropical Horticulture Studies Field Station in Kersana, Brebes, Central Java (S 6 °, 55', 20.536"; E 108°, 51", 50618") from May to July 2016. The experiment was arranged in a randomized complete block design (RCBD) with a single factor and three levels of planting system, i.e. conventional 'Surjan' system without mulch, one line spray hose with mulch, and two lines spray hose with mulch, with five replications. The result showed that shallots production using of polyethylene mulch and two-line spray hose had higher yields than the conventional method. In addition, this system is more efficient in terms of labor requirement. Cost Revenue Analysis shows that conventional cultivation R/C ratio was 1.72, one-line spray hose R/C ratio was 1.92, while two-line spray hose was 2.26. The use of polyethylene mulch combined with two-line spray hose significantly improved shallot growth, increased bulb production and is more cost efficient, so this system could be adopted for shallot production in the area.

Keywords: R/C ratio, micro irrigation, labor, 'Surjan' system, soil drench, fertilizer

Introduction

Shallot (*Allium ascalonicum* L.) is a seasonal lowland horticultural crop that has a high economical value. Shallot production in Indonesia had exponential increases from 0,964 million tons in 2012 to 1,233 million tons 2014 (BPS, 2015). However, there was a decline in production in 2015 to 1,228 million tons. Even though the national shallots production is quite high Indonesia is still importing shallots to supply the high national demand; hence it was important to increase the national shallot production to meet this demand.

In the farmer level, conventional system of shallot cultivation is called Surjan system. The Surjan system requires more labor and uses water in large quantities. The Center for Socioeconomic and Agricultural Policy (2010) reported that the labor needed for one season of shallots planting in Brebes, Central Java, Indonesia, is 400 man day per ha. According to PFI3P (2007) water consumption of shallot crops grown conventionally is 500 $m^3.ha^{-1}$. Hence, it is important to develop a shallot planting system that can reduce labor requirement and is more water efficient.

Fertilizer is generally applied to shallot crops by broadcasting directly on the bed which resulted in the applied fertilizer not being entirely absorbed by the crops. Some of the nutrients evaporated, washed away, or carried over by the irrigation flow. Combining irrigation practice with mulching has potentials to reduce fertilizer losses in the field. Irrigation using spray hose or perforated irrigation and polyethylene mulch can be applied to reduce fertilizer losses through broadcast application. Irrigation using spray hose can improve the efficiency of water use and promote root growth (Isoda et al., 2007).

One of the constraints in the cultivation of shallot was that shallot is shallots sensitivity to abiotic environmental stresses, including from flood or drought that can result in the reduced bulb formation. These problems can be solved by employing cultivation techniques such as the use of polyethylene mulch. Black silver polyethylene mulch usually used to cover the soil and maintain soil moisture and soil temperature (Samiati et al, 2012). This study aims to compare conventional cultivation technique 'Surjan' system with shallot cultivation using spray hose and polyethylene mulch and to investigate how these two methods affect shallot growth and yield.

Materials and Methods

The research was conducted at the Center for Tropical Horticulture Studies Field Station in Kersana, Brebes County, Central Java (S 6 °, 55', 20.536"; E 108°, 51", 50618") from May to July 2016; the soil type in the area is hydromorphic alluvial. A single factor experiment was arranged in a completely randomized block Design (RCBD) with four replications. Treatments were shallots planting systems with three levels, i.e. (1) conventional cultivation Surjan system; (2) without mulch (P0) and one-line spray hose with mulch (P1), and (3) two-line spray hose with mulch (P2). Plant spacing was 20 cm x 15 cm within the bed; each bed measures 1 m x 22m x 0.5 m (width x length x height).

The mulch was polyethylene Sumisansui-MARK II. Spray hose was 50 mm tube width (flattened) set to 130-420 $mm.min^{-1}.m^{-1}$ water feed rate to cover 200-cm width of irrigated beds. Shallot seed bulb planting materials was "Bima Curut". NPK 16-16-16 (16N-16 P_2O5, 16 K_2O) was applied at rate of 500 $kg.ha^{-1}$. Organic matter from cow manure was applied at 20 ton per ha^{-1} by broadcasting to the planting bed, mixed well with the 20-cm top soil prior to mulching. Pesticide used was 25% metomyl (insecticide) with a concentration of 2 $ml.L^{-1}$, and 80% mancozeb (fungicide) with the same concentration.

The land was prepared one week before planting which also included lime application (pH 6.5) and 20 $tons.ha^{-1}$ cow manure application. The height of the bed was 50 cm with the distance between beds of 50 cm. In the conventional Surjan system (PO) the ditch between the beds were flooded with water for manual irrigation. Pre-plant fertilizer was applied for treatment P1 and P2 by broadcasting 50% of the total NPK requirement (16-16-16) before the beds were covered with silver black polyethylene mulch 0.038 cm thickness. Spray hose was placed on the surface of polyethylene mulch in the middle of the bed. Half of the NPK (16-16-16) dose was broadcasted in the treatment of P0.

Plant watering for the conventional Surjan treatments (PO) was manual soil drenching using a bucket from the ditch with 77 L per bed. One-line spray hose (P1) and two lines spray hose (P2) were watered every morning with 40.71 L per bed, and 67.87 L per bed, respectively. Weeds were controlled by pulling the weeds manually every three days. Side dressing fertilizer application for P1 and P2 were applied with irrigation water (fertigation) with soil drench five times on a weekly basis for 10% of recommendation rate with NPK (16-16-16). Second fertilizer application for the conventional treatment (P0) was applied at 20 days after planting with 50% of the remaining NPK. Plant pest and disease control was conducted using 80% mancozeb fungicide applied by bulb soaking and insect pests were sprayed with 25% methomyl when required. Harvesting was carried out 60 days after planting when the shallot leaves have turned yellow, more than 60% of the leaves have dropped, and neck of the stem over the bulb has turned soft.

Scoring was conducted on plant height (cm), number of leaf, number of bulbs per plant, bulb diameter (mm), bulb weight per plant (g), bulb weight per bed (g); dry bulb weight per hectare (ton), bulb weight per plant, per bed, and per hectare was measured after air drying. Water use was calculated by measuring total volume of water manually applied soil drench with bucket on top of bed for 22 m2 bed size (PO). Water use for P1 dan P2 was calculated by measuring volume of water for 1 m length of spray hose per minute then multiply by the length of spray-hose per bed (22 m), and multiply by 5 for 5 minutes irrigation application time.

Results and Discussion

Water Requirement

Irrigation in the conventional planting system was conducted by applying the water on the ditch between beds. Before planting, the ditch between beds was flooded with water to about a half of the bed's height. This system uses and wastes a lot of water because some of the water in the bed can evaporate and get carried away by the flow of irrigation. There was no control over the amount of water applied so the water application becomes inefficient.

The volume of water used for the conventional, one spray hose, and two spray hose was 77 L per bed, 40.71 L per bed, and 67.87 L per bed, respectively (Table 1). This indicates that irrigation using spray hose uses water more efficiently, because the volume of water can be controlled according to the duration of the pump operation. Planting system using spray hose is more water efficient because the applied water was stored in the tank and was directly applied to the field. Planting systems using spray hose did not flood the ditch therefore reduce evaporation and water loss through leaching.

The volume of water applied at P1 (40.70 L per bed) is less than P2 (67.87 L per bed). This is because

Table 1. Volume of water application for different cultivation techniques of shallot

Treatments	Replication			Average	Water volume per bed (L per minute)
	1	2	3		
P0	3.50[1]	3.50[1]	3.50[1]	3.50	77.00[3]
P1	0.35[2]	0.38[2]	0.38[2]	0.37	40.70[3]
P2	0.63[2]	0.61[2]	0.61[2]	0.61	67.87[3]

Note: P0 (conventional planting system); P1 (one-line spray hose); P2 (two-line spray hose); 1 ($L.m^{-1}$); 2 ($L.m^{-1}$. $minute^{-1}$); 3 (L per bed); watering through spray hose applied for 5 minutes

P1 uses a one-line spray hose (one hose each bed) while P2 uses two-line spray hose (2 hoses per bed), so the volume of water applied on P2 was higher and more evenly spread than P1. Generally the volume of water from one-line spray hose is 0.38 $L.m^{-1}$ (Arifin, 2012).

Shallot Growth

The production of shallot with conventional Surjan planting system is inefficient in terms of fertilizer and water uses. More efficient production can be achieved by providing sufficient amount of fertilizer, adequate water, and by creating favorable environment to plant growth (Singh et al., 2013).

Table 2 shows that the average number of leaves per plant using two-line irrigation system was higher than those of the conventional method, whereas the crops irrigated with one-line system had the fewest number of leaves per plant.

Table 3 shows that the plant height at one week after planting (WAP) was not significantly different amongst the treatments. The average plant height began to show significant differences starting 2 WAP to 7 WAP. The average plant height of P2 was significantly higher than P0 at 2, 3, 6 and 7 WAP. This may have been caused by pest attacks that had interfered with plant growth. Pest attacks can disrupt crops at every growth phase (Samudera, 2006). The use of one-line spray hose resulted in the shortest crop posture.

The average growth of the crops from two-line spray hose (P2) was significantly higher than one-line spray hose (P1) and the control (P0) for most of the observation time, indicated by taller and more leaves per plant with P2 and P1.

Plastic mulch can increase the average plant height by up to 41% (Woldetsadik, 2003), whereas fertilizer application through irrigation water (fertigation) allows the crops to absorb nutrients directly (Dole and Wilkins, 2005) because the fertilizer has been

Table 2. The effect of irrigation systems on number of leaves per plant of shallot at week one to week seven after planting

Treatments	Number of leaves per plant at week						
	1	2	3	4	5	6	7
P0	7,24[b]	10,30[b]	11,94[b]	17,94[b]	19,76[b]	20,32[b]	20,40[b]
P1	7,22[b]	10,58[b]	13,06[b]	17,34[b]	18,02[c]	18,54[c]	18,72[c]
P2	9,40[a]	12,90[a]	15,74[a]	19,56[a]	20,94[a]	21,94[a]	22,02[a]
F-test	**	**	**	**	**	**	**

Note: P0 (conventional planting system); P1 (one-line spray hose); P2 (two-line spray hose); ** highly significant according to Least Significant Difference (LDS) test at 0.05.

Table 3. The effect of irrigation systems on plant height of shallot at week one to week seven after planting

Treatments	Plant height (cm) at week						
	1	2	3	4	5	6	7
P0	10.27	23.66[b]	31.72[b]	37.26[a]	38.62[a]	39.41[b]	39.48[b]
P1	9.76	23.12[b]	28.38[c]	34.65[b]	35.93[b]	37.77[c]	38.23[c]
P2	10.65	25.52[a]	34.48[a]	37.90[a]	39.87[a]	40.98[a]	41.35[a]
F-test	ns	**	**	*	**	*	*

Note: P0 (conventional planting system); P1 (one-line spray hose); P2 (two-line spray hose); * and ** are significant and highly significant according to Least Significant Difference (LSD), respectively.

dissolved in the water. Fertilization in treatment P1 was applied by soil drench. However, the amount of water applied on P1 is less than P2 because only one hose was used along the bed which may not be sufficient for plant growth. Similar results were reported in shallot production in Africa (Kemal, 2013).

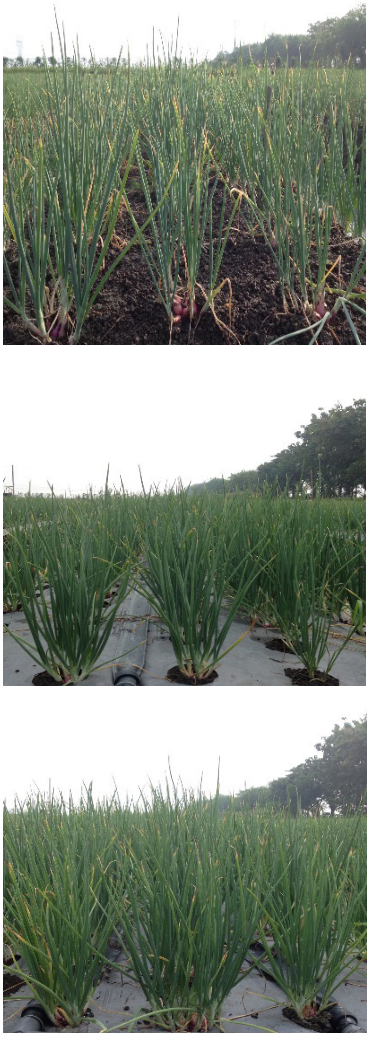

Figure 1. Shallot growth with conventional planting system (P0, top), one-line spray hose (P1, middle) and two-line spray hose (P2, bottom) at five weeks after planting

Shallot Yield

Based on Table 4 the number of bulbs from shallot crops in P2 was significantly higher than those in P1 which was 8.06 and 7.16 bulbs, respectively. In addition, crops with P2 had the highest bulb diameter of 25.28 mm which was significantly higher than bulbs from P1 (23.09 mm). This showed that planting systems using two-line spray hose provided ample water required by the crops. The bulb weight per plant on P2 was significantly higher (42.42 g) than the P0 (40.65 g). The bulb weight per bed of P2 (26.80 kg) was significantly higher than P0 (24.58 kg); when converted to bulb weight per ha, P2 had 7.91 tons which was significantly higher than the PO (7.26 tons). Fertilization on P1 and P2 was applied by fertigation.

Fertilizer application by soil drench in Kumoro's study (Kumoro et al., 2004) increased shallot yield by up to 18% whereas the uses of mulch increased bulb weight by up to 26% (Woldetsadik, 2003). This increase in yield was likely caused by more optimal soil moisture for shallot bulb growth. Similar results were reported in onion (Vavrina and Roca, 2000); onion grown with plastic mulch had greater marketable yields compared to bare ground.

P1 shows the least bulb yield (6.72 tons) which may be due to the crops receiving the lowest amount of water as compared to the conventional 'Surjan' and the two-line irrigation systems. In a study on onion reported that water status of the top 30 cm of the soil column is crucial (Vickers et al., 2007), whereas Roy et al (2014) stressed the importance of sufficient water status during flowering. Lack of water can significantly reduce bulb yield (Kemal, 2013).

Revenue Cost Analysis

Based on the Revenue Cost (R/C) analysis (Table 6) the R/C ratio of conventional system, one-line spray hose, and two-line spray hose were 1.72, 1.92, and 2.26, respectively. According to Maulidah (2013) R/C ratio > 1 indicates that the cultivation system is feasible

Table 4. The effect of irrigation systems on number of bulb, bulb diameter, bulb weight per plant, bulb weight per bed and bulb weight per ha of shallot

Treatments	Number of bulb (bulb)	Bulb diameter (mm)	Bulb weight per plant (g)	Bulb weight per bed (kg)	Bulb weight per ha (ton)
P0	7.68[ab]	24.22[ab]	40.65[b]	24.58[b]	7.26[b]
P1	7.16[b]	23.09[b]	39.79[b]	22.76[c]	6.72[c]
P2	8.06[a]	25.28[a]	42.42[a]	26.80[a]	7.91[a]
F-test	*	**	**	**	**

Note: P0 (conventional planting system); P1 (one-line spray hose); P2 (two-line spray hose); * and ** are significant and highly significant according to Least Significant Difference (LSD), respectively.

Table 6. Revenue Cost Analysis for one ha of shallot production

Treatment	Bulb weight per ha (ton)	Price per kg (IDR)	Revenue (IDR)	Cost (IDR)	R/C Ratio	Benefit (IDR)
P0	7.26	18,000	130,680,000	75,850,000	1.72	54,830,000
P1	6.72	18,000	120,960,000	62,990,000	1.92	57,970,000
P2	7.91	18,000	142,380,000	62,990,000	2.26	79,930,000

Note: P0 (conventional planting system); P1 (one-line spray hose); P2 (two-line spray hose).

Table 7. Analysis of labor requirement for one ha of shallot production

Activities	Labor requirement (man days)		
	P0	P1	P2
Soil Preparation	20	20	20
Planting	16	16	16
Maintenance			
Irrigation and weeding	180	40	40
Pesticide Spraying	10	10	10
Fertilizer application	4	30	30
Harvesting	22	22	22
Total	252	127	127

Note: P0 (conventional planting system); P1 (one-line spray hose); P2 (two-line spray hose).

to be implemented. Irrigation with two-line spray hose showed the highest R/C ratio which indicated that the two-line spray hose irrigation system was the most profitable cultivation system among the three systems tested.

The cost difference between the conventional system and spray hose system was in the cost of irrigation, fertilization, and weeding. The cost of irrigation, fertilization, and weeding of conventional system was IDR (Indonesian Rupiah) 13,500,000, whereas in the spray hose system it was IDR 5,250,000. This demonstrated that spray hose system was more cost efficient than the conventional system.

Table 6 showed the benefits obtained spray by using the conventional system, one-line spray hose and the two-line spray hose were, IDR 54,830,000, IDR 57,970,000, and IDR 79,930,000, respectively. This indicates that two-line spray hose had the greatest advantage due to the increase in yield and lower production costs.

Table 7 shows the differences in labor requirements between the conventional system, line and two-line spray hose. The amount of labor required in the conventional system (P0) is 252 man days compared to the line spray irrigations which required 127. The labor requirement in the conventional system was caused by the intensive labor requirement for applying water and weeding which had to be conducted manually.

Conclusion

Irrigation of shallot with two-line spray hose resulted in a better crop growth and a higher yield than conventional planting system and one-line spray hose for polyethylene mulched shallot. Conventional planting system using more water and labor requirement than the two other treatments. Combination of two-line spray hose and polyethylene mulch had the most eficient cost production of shalot compared to the conventional system and one-line spray hose.

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