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Effects of Water Irrigation Methods Combined with Mulching Materials on the Growth and Yield of *Allium chinense* on Acid Sulfate Soil

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ABSTRACT

Background: To determine the optimal water irrigation method combined with covering material for *Allium chinense* growth and yield on acid sulfate soil.

Methods: The field experiment was carried out in a randomized complete block design, which include four treatments, each with four replications. The plot size was 83.3 m^2 (19.6 m in length, 4.25 m in width). Treatments were flooding irrigation combined with rice straw covering (FI-RS), flooding irrigation combined with *Eleocharis dulcis* covering (FI-ED, control), spray irrigation combined with rice straw covering (SI-RS) and spray irrigation combined with *Eleocharis dulcis* covering (SI-ED).

Result: Experimental results showed that *Allium chinense* planted on the treatment of SI increased clump height (47.2 cm) and weight of bulb (4.38 g), gave the highest yield of 40.9 t ha^{-1} and increased up to 25.9% in comparison to planted in conventional method (control). The spray irrigation method was more suitable than the flooding irrigation method for growing *Allium chinense*. Vitamin C content in bulbs was not changed under different water irrigation methods combined with mulching materials.

Key words: *Allium chinense*, *Eleocharis dulcis*, Irrigation methods, Mulching, Rice straw.

INTRODUCTION

Rakkyo, also known as oriental onion, sakurab, or scallion, *(Allium chinense* G. Don) is a commercially important root vegetable (Bah *et al*., 2012). Rakkyo has been used as food seasoning, food processing and as a folk medicinal herb due to containing steroidal saponins, furostanol saponins, spirostanol saponins and xiebai-saponins as antioxidants (Shahrajabian *et al.,* 2020). According to Pérez-Ortolá and Knox (2015), edible species of *Allium* and vegetables with shallow root systems could absorb water from the surface soil layers (18-40 cm) and were exposed to water stress under deficit irrigation. In addition, the available water for annual crops was low, with about 30% of the water amount in saturated soil under field conditions. Therefore, the cultivation of annual crops requires an appropriate irrigation regime to avoid water stress, especially in the dry season. Multiple studies have been carried out to evaluate the effects of mulch materials on improving the water status of dryland crops such as garlic (*Allium sativum* L.) (Barakat *et al.,* 2020), onion (*Allium cepa* L.) (Tehulie, 2022), corn (*Zea mays* L.) (Qin *et al.,* 2015; Sanders *et al.,* 2018; Gao *et al.,* 2019) and soybean [*Glycine max* (L.) Merr.] (Vincent-Caboud *et al.,* 2019). Mulching also improves crop growth and yield (Han *et al.,* 2022; El-Beltagi *et al.,* 2022). Mulches enhance soil properties by replenishing carbon and nutrients, increasing biological activities and retaining soil moisture (Chalker-Scott *et al.,* 2007).

In Tam Nong district, Dong Thap province, Vietnam where there is acid sulfate soil, farmers used to widely apply rice straw to cover the rakkyo crop. Rice straw has fast decomposition and cannot lift the palanquin leaves, causing poor growth. In addition, farmers tend to use flood irrigation which may induce loss of nitrogen and spread diseases therefore negatively affecting the yield (Fan *et al.,* 2014; Raza *et al.,* 2020). Recently farmers have used *Eleocharis dulcis* (Burm.f.) Trin. ex Hensch. as mulch and reported positive feedback about the effect of this material on the growth and yield of the rakkyo crop. However, there has been no study about whether using *Eleocharis dulcis* (ED) as mulch is effective in rakkyo cultivation. Another factor is the irrigation method that the farmers use to water the crop. Such information is beneficial to maximize the production potential while reducing the production cost of the crop. The research was carried out to evaluate irrigation methods combined with mulch materials suitable for growth and productivity in the field.

MATERIALS AND METHODS

The field experiment was conducted in Phu Tho commune, Tam Nong district, Dong Thap province, Vietnam in 12

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months from January 2021. The experiment was conducted in a randomized complete block design (RCBD) with four replications. Treatments consisted of flooding irrigation combined with rice straw covering (FI-RS), flooding irrigation combined with *Eleocharis dulcis* covering (FI-ED, control), spray irrigation combined with rice strawcovering (SI-RS) and spray irrigation combined with *Eleocharis dulcis* covering (SI-ED). The area of each lot was 83.3 m^{-2} (19.6 m in length, 4.25 m in width and 25 cm in height). The type is planted with a density of 20 × 10 cm. After planting, the soil was covered by mulches. *Eleocharis dulcis*was used to mulch only one time after planting (Fig 1). Rice straw was used to mulch two times after planting (right after planting and four months after planting). Vitamin C content and soil characteristics were analyzed at the lab of the lab of Faculty of Crop Science, College of Agriculture, Can Tho University. The characteristics of the soil including pH_{H_2O} (4.89), pH_{KCl} (3.76), CHC (5.89%), CEC (12.0 meq/100 g), N_{Total} (0.182%), P_{Total} (0.011%), K^+ (0.601 meq K^+/100) were measured before planting.

Data collection

Twenty clumps from the inner area of the plot were randomly collected at harvest time. Plant height, root length, number of leaves per plant, bulb weight and Vitamin C content were determined based on the twenty collected clumps. Plant height (cm) was measured from the soil surface to the highest growth peak. The number of leaves of each plant was counted at harvest time. Root length was measured from the base of the clump to the tip of the longest root. The average weight of a bulb was the weight of a clump without leaves and roots divided bythe number of bulbs per clump. Yield was determined by harvesting all the clumps per slot. Vitamin C content in the bulb was determined based on the 2.6 dichlorophenol indophenol titration method which was previously described by Denre (2014). Net profit was calculated according to Jayathilaka (2020). The cost of raw materials (inorganic fertilizers, DPR, plant protection drugs, seeds, water irrigation), labor and product sales were calculated according to 2021 prices.

Data analysis

The data presented in this paper are the mean values of four replications. All data were analyzed by one-way analysis of variance (ANOVA) using SPSS software package version 13.0 and were compared for significant differences in treatment effects using Duncan's test at $P<0.05$.

Fig 1: Rakkyo covered by ED after planting.

RESULTS AND DISCUSSION

Clump height

At harvest time, the plant height of the SI-ED treatment (47.2 cm) was significantly higher than that of the SI-RS treatment and FI-RS (Fig 2). However, there was no statistically significant difference between the two irrigation methods (unpublished data). Spray irrigation and flood irrigation using *Eleocharis dulcis*mulch for higher plant height than rice straw mulch irrigation methods because the structure of the mulch material was more durable than straw mulch materials, helping the soil retain moisture well and avoid weeds. In comparison with ED mulch, rice straw mulch was applied and faster weed growth required higher costs for weed control. In addition, rice straw decomposed so fast that it must be applied 2-3 times per crop season, costed more, showed lower land coverage and moisture retention, reduced biodiversity and increased the risks of pests and

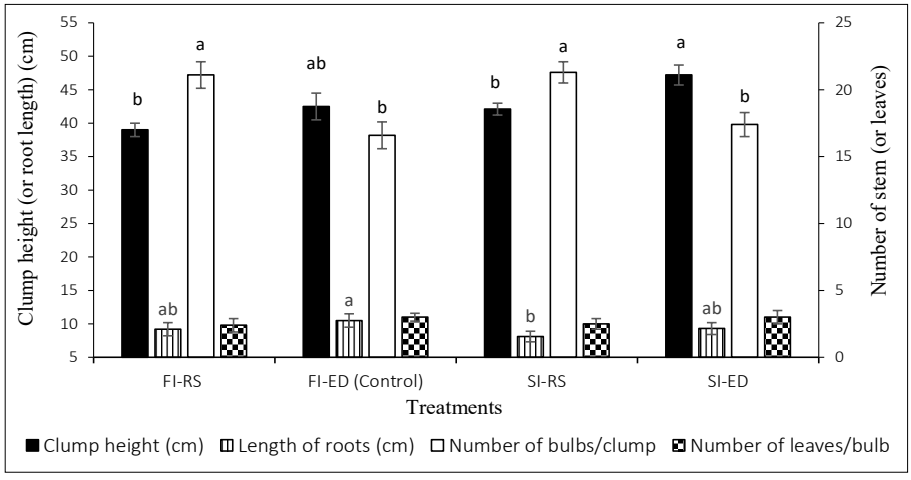

Fig 2: Plant height, root length, number of stems per clump and number of leaves per bulb.

diseases. Rice straw mulching quickly collapses and made the soil less ventilated than ED mulching (Fig 3).

Length of roots

Fig 2 showed that the root length of rakkyo in flood irrigation methods combined with *Eleocharis dulcis*mulching was significantly longer than those in SI-RS treatment. However, there was an insignificant difference in the root length of rakkyo in FI-RS and FI-ED. At harvest time, the root length of rakkyo in FI-ED treatment (10.5 cm) was significantly higher than that in SI-RS but insignificantly differed from the root length in other treatments. According to Seifu *et al.* (2017), the mulch material retained moisture, maintained stable soil temperature and improved the development of garlic's root system. Therefore, the FI-ED treatment could retain moisture and maintain stable soil temperature better than the rest treatments.

Number of bulbs/clump

The number of bulbs (stems) per clump at harvest time in the two straw-covered treatments was higher than in the other treatments (Fig 2). The number of bulbs (stems) per clump of rakkyo was consistent with the research results. According to the study of Bah *et al.* (2012) on four large genera of the same family (Amaryllidaceae) grown in sandy soil, the average number of bulbs developed after eight months of planting ranged from 10 to 25 shoots per clump.

Number of leaves per bulb

The number of leaves per bulb in the two *Eleocharis dulcis*covering treatments was higher than in the other two at harvest time (Fig 2). Because *Eleocharis dulcis*was covered only 1 time, it made the rakkyo leaf grew more favorably than rice straw that had to be covered 2 times. When mulching for the 2nd time, straw negatively affected leaf growth.

Weight of bulb

The average bulb weight in the SI-ED treatment was 4.38 g, higher than the two treatments of SI and FI combined with rice straw mulch (2.60 and 2.63 g, respectively) (Fig 4). There was no significant difference between the bulb weights (2.60-3.48 g bulb^{-1}) of SI-RS, FI-ED and FI-RS treatments. Thus, rakkyo cultivation using SI combined with *Eleocharis dulcis*mulching effectively increased average bulb weight compared to other treatments.

Vitamin C content

Fig 4 shows that the vitamin C content in rakkyo between different treatments was not significant. The average vitamin C content of 7.64 mg 100 g^{-1}, 3 times lower than the vitamin

Arrows indicate the collapses of rice straw or ED.

Fig 3: *Eleocharis dulcis* mulching (Left) and RS mulching (right) after two months.

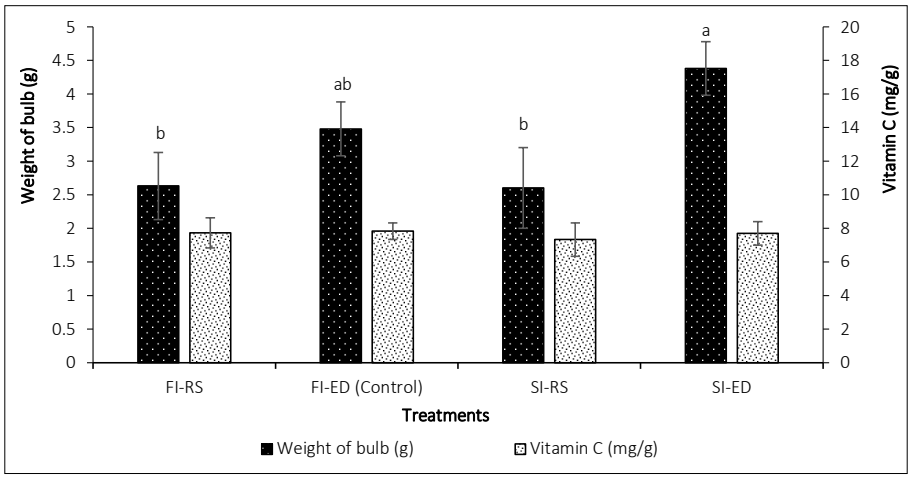

Fig 4: Weight of bulb and vitamin C content in bulb.

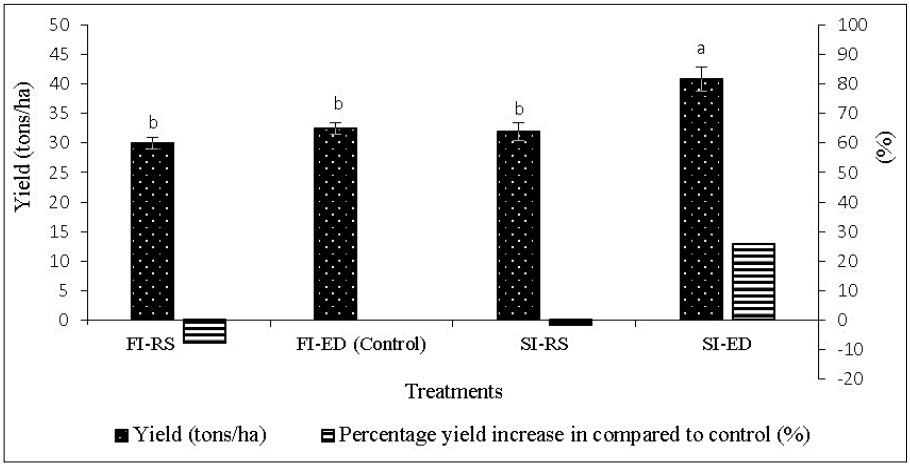

Fig 5: Yield and percentage yield increased compared to control on different treatments.

Table 1: The profit from different treatments of irrigation methods combined with mulching materials (VND 1,000).

Parameters	Treatments			
	FI-RS	FI-ED (Control)	SI-RS	SI-ED
Bulb yield (t ha^{-1})	30.0	32.5	31.9	40.9
Total cost in 2021	413,000.0	433,000.0	413,000.0	433,000.0
- Fixed cost expenses	363,000.0	363,000.0	363,000.0	363,000.0
- Rice straw	50,000.0	-	50,000.0	-
- *Eleocharis dulcis*	-	70,000.0	-	70,000.0
Revenue	510,000.0	552,500.0	542,300.0	695,300.0
Profit (3=2-1)	97,000.0	119,500.0	129,000.0	262,300.0
Profit compared to control	-18.8%	0%	8.0%	119.5%

Notes: *Allium chinense* 17,000 VND kg^{-1}.

C content in 100 g of garlic (Fahmi, 2019) and 4 times lower than in purple cabbage sprouts (Singh *et al.,* 2006).

Bulb yield

The spray irrigation method combined with *Eleocharis dulcis*mulching yielded 40.9 t ha^{-1}, 25.9% higher than the FI-ED of 32.5 t ha^{-1} (Fig 5). The yield in the FI-RS treatment (30.0 t ha^{-1}) was 7.7% lower than in the FI-ED (32.5 t ha^{-1}). Similarly, the yield of rakkyo in SI-RS was 1.9% lower than in the control treatment. This showed that *Eleocharis dulcis* mulching significantly increased rakkyo production. Similarly, with the same mulching material, the flood irrigation method yielded less than the spray irrigation method. This could be explained by the effectiveness of the mulching material (due to its durable structure, moisture, long use time, limited grass, *etc*.). The rice straw that was used to mulch decomposed so fast during the rakkyo season that it generated conditions for weed growth and negatively affected productivity. Because the objective of the experiment was not disease evaluation, it was impossible to collect grass samples to see the yield difference of the experiments.

Financial efficiency

Table 1 indicates that the profit from growing the *Allium chinense* was high (above 97 million VND ha^{-1}). Spray irrigation combined with water chestnut mulching for *Allium chinense* helped increase yield significantly higher than the FI-RS, FI-ED and SI-ED for *Allium chinense*. Flood irrigation methods combined with *Eleocharis dulcis* mulching increased the profit up to 25.9% in comparison with the control treatment as well as the treatment of SI-RS also increased up to 8.0%. The profit of the treatment of SI-ED dramatically increased up to 119.5% in comparison with the control treatment.

CONCLUSION

Rakkyo are grown on alkaline soil in Tam Nong district, Dong Thap province using a spray irrigation method combined with water *Eleocharis dulcis* was suitable for the growth and development of rakkyo. In the absence of *Eleocharis dulcis* sources, rakkyo cultivation using spray irrigation combined with rice straw mulching could achieve economic efficiency. In the production of rakkyo, the flood irrigation method needs to be replaced by spray irrigation.

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Conflict of interest

All authors declared that there is no conflict of interest.

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