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Article

Evaluating the Efficiency of Irrigation Methods and Their Interaction with Some Factors in a Control Program for Onion Leaf Blight Caused by the Fungus Stemphylium vesicarium

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Abstract: This study was conducted to evaluate the efficiency of two irrigation methods (drip and sprinkler) and their interaction with some chemical and agricultural treatments within an integrated program to control onion leaf blight caused by the fungus Stemphylium vesicarium. This was achieved through a field experiment that included nine treatments: potassium silicate, the fungicide trifloxystrobin, the insecticide acetamipride, basal leaf removal, binary interactions between these substances, and two control treatments (contaminated and uncontaminated). Each treatment was implemented under both drip and sprinkler irrigation methods. The results showed a significant advantage of drip irrigation over sprinkler irrigation in all studied traits. Drip irrigation recorded the lowest infection rate (60.00%) and lowest infection severity (0.17) compared to sprinkler irrigation (70.00%) and (0.20%), respectively. It also outperformed sprinkler irrigation in leaf area, biological weight, and yield. The interaction between irrigation method and treatments showed that the potassium silicate + trifloxystrobin fungicide treatment under drip irrigation achieved the best overall performance, recording the lowest infection rate (36.66%) and the highest yield (178.33 g/plant^{-1}), while the contaminated control treatment under sprinkler irrigation recorded the lowest results. These results indicate that using drip irrigation reduces the leaf wetness period and the associated conditions conducive to fungal spore germination, and that incorporating this irrigation method into integrated disease management programs contributes to reducing infection and improving productivity.

Keywords: Onion Leaf Blight, Stemphylium Vesicarium, Irrigation Method, Intervention, Integrated Pest Management

1. Introduction

Onions (*Allium cepa* L.) are among the most important strategic vegetable crops globally, ranking second only to tomatoes in terms of cultivated area, production, and consumption [1]. Their importance stems from their widespread economic and nutritional value, used fresh and dried in daily consumption, as well as their role as a raw material in the food and pharmaceutical industries [2]. They are also rich in vitamins, fiber, and minerals, and contain polyphenolic compounds with antioxidant and anti-inflammatory activity [3].

Onion crop productivity is significantly threatened by a number of fungal, bacterial, and viral diseases that cause quantitative and qualitative losses in the crop [4]. Among these diseases, onion leaf blight (Stemphylium leaf blight) is one of the most important fungal diseases affecting onions in various production areas. In recent decades, it has emerged as an epidemic disease that limits crop production in many countries worldwide, particularly in humid and semi-humid environments [5]. The disease is caused by the fungus Stemphylium vesicarium (Wallr.) E. Simmons infecting leaves and flower stalks, leading to reduced efficient leaf area and reduction in photosynthetic efficiency. This has an adverse effect on the bulb size, quality and seeds production; causing 20-70% loss [6, 7] based on severity of infection and environmental conditions. As no commercial varieties have sufficiently high levels of disease resistance, chemical control remains a key component of management. The excessive use of fungicides, however, leads to the emergence of strains that are less susceptible. This requires the exploration of alternatives or combination strategies comprising new fungicides, resistance inducers, and proper agronomic practices for effective and sustainable disease management [8, 9]. One of the major determinants affecting agriculture is the irrigation method adopted in the fields. Disease of leaf spots develops in association with the time required for leaf wetness and relative humidity on the vegetation surrounding. Sprinkler irrigation increases surface moisture and lengthens leaf wetness which creates a suitable environment for fungal spore germination and infection of the plant tissues. In contrast, a drip irrigation system only wet the root zone without keeping the leaves permanently wet thus may limit fungus outbreak [10, 11].

2. Materials and Methods

2.1 Location and Date of the Experiment

The field experiment was conducted on farmland in the Lower Zab district, west of Kirkuk Governorate. The land had been left fallow for three years prior to the experiment to eliminate the presence of weeds and accumulated pollinators. The land was plowed twice at right angles, leveled and furrowed according to the experimental plan. Onions were planted by the bulb method (bulblets) of the common yellow variety Texas Early Grano 502, which is widely cultivated in the region. This planting was done during the usual time of autumn planting for the crop in the area. The experiment was monitored until full maturity and harvest which was determined when the plants attained full maturity, the upper leaves fell and the necks of the bulbs hardened. Data on the studied traits and the harvested bulbs were collected at this stage.

2.2 Isolation and Diagnosis

Sampling was carried out from onion fields in a number of areas to the southwest of Kirkuk Governorate during the period from March 5 to 10, 2025. Leaves and stems were collected from infected onion plants showing symptoms described in previous scientific literature, which are small yellow to orange spots and dark brown necrotic spots. Samples were placed in paper bags, labeled, and transported to the laboratory for testing. The samples were sterilized using 2% sodium hypochlorite solution for two minutes, rinsed three times with distilled water, and then cultured on potato dextrose agar (PDA) and incubated at room temperature (25 ± 2°C). After five days of incubation and the emergence of fungal colonies, the colonies were purified by removing a part from the edge of the colony and culturing it on a different culture medium containing PDA. Upon colony growth, microscopic examination was performed, and identification was based on morphological characteristics using scientific references on fungal classification, under the supervision of the supervising professor, and in accordance with the taxonomic key for fungi indicated by Ellis (1971). The isolates were then stored on a slanted solid nutrient medium in the refrigerator at 4°C until use.

2.3 Testing the Pathogenicity of Fungal Isolates

9 cm diameter Petri dishes containing PDA medium were used. The center of each dish was inoculated with 0.5 cm diameter fungal discs taken from the edge of a five-day-old fungal colony, with three dishes per isolate. The dishes were incubated at 25 ± 2°C for five days. Cabbage seeds were carefully selected, placed in a beaker, and surface-sterilized with a 1% sodium hypochlorite solution for 5 minutes. They were then washed with sterile distilled water to remove any residue and floating seeds, placed on sterile filter paper to dry and inoculated. Once the fungal colony had reached maturity, the seeds were distributed in a circular pattern around the edge of the plate, covering one-third of the plate's area, at a rate of 10 seeds per plate. This treatment was repeated three times for each fungal isolate, with a control treatment left inoculated. The plates were incubated at 25 ± 2°C. After 7 days and germination was complete in the control treatment, the germination percentage for each isolate was calculated using the following equation:

Sedge Germination Percentage (%) = (Number of Germinated Seeds ÷ Total Number of Seeds Inoculated) × 100. After comparing the pathogenicity of the fungal isolates, the isolate that showed the greatest effect in reducing germination was selected and used for molecular diagnosis and research parameters.

2.4 Experimental Design and Irrigation Methods

The experiment was conducted in a split-plot randomized complete design. The two irrigation methods (drip and sprinkler) were assigned to the main plots, and the nine treatments were randomly assigned to the subplots in the main plot with three replicates for each treatment. The experimental plot was divided into two equal parts according to the irrigation method. Each part contained all treatments in three rows. Each row contained all treatments in the experimental treatments with 15 meters length and 50 centimeters width. The distance between the rows was 70 centimeters, and the length of each experimental unit (treatment) was 2 meters with a 0.5-meter gap between each treatment. The two parts of the experimental plot were separated by a 3-meter gap to prevent interference of the two irrigation methods. The drip irrigation system consisted of two lines per row while the sprinkler irrigation system consisted of one pipe per row, located on the opposite side to prevent interference of the other irrigation method.

The bulbs were planted in three rows per plot with 15 cm between rows and 10 cm between bulbs, giving 60 bulbs per experimental unit. After germination and the emergence of vegetative growth the empty holes were filled and competing weeds were removed manually periodically throughout the season. Granular diazinon was applied to the planting rows and the fungicide Rival was injected into all experimental treatments as a prophylactic against insect pests and root zone fungi, without affecting the studied control treatments.

2.5 Experimental Treatments

The experiment included the following nine treatments, each implemented under both drip and sprinkler irrigation: (1) potassium silicate, (2) the fungicide trifloxystrobin, (3) the insecticide acetamipride, (4) basal leaf removal, (5) potassium silicate + trifloxystrobin, (6) potassium silicate + acetamipride, (7) trifloxystrobin + acetamipride, (8) contaminated control (no control treatment), and (9) healthy control (no infection and no treatment).

The treatments were applied after the plant reached the 4-5 true leaf stage, in three stages with a 15-day interval between each treatment. The fungicide Trifloxystrobin (Flint 50%) was used at the rate of 0.25 g/L -1 as recommended by the manufacturer. Potassium silicate (35%/12%) was used at a concentration of 2 ml/L^{-1}, and the insecticide Acetamipride was used at a concentration of 0.5 g/L^{-1}. A spreading adhesive (Tween 20) was added to the solution of each substance to ensure adhesion to the waxy leaves of the onion plant before spraying it onto the foliage.

2.6 Field Inoculation with Stemphylium vesicarium Fungal Inoculum

After the plant reached the 4-5 true leaf stage and was treated with the first stage of the required materials, spray the spore suspension of the most virulent fungal isolate (approved after testing the pathogenicity of local isolates and their molecular identification) at a concentration of 1 x 10^8 spores mL^{-1} with the addition of a spreading adhesive. This was done in the evening after adequate humidity was achieved by irrigating the field prior to spraying. The following day, the field was sprayed with water using a knapsack sprayer for two days to concentrate the humidity in the evening and activate the fungus. The plants were covered with agricultural gauze to increase the persistence of the moisture film on the leaf surface. The healthy control treatment was sprayed with distilled water only and covered with agricultural gauze to protect it from airborne spores and natural infection. One week after inoculation, the second stage of treatment was initiated, and two weeks later, the third stage was implemented.

2.7 Criteria and Characteristics Investigated

Infection Rate (%): The infection rate was recorded 20 days after artificial inoculation with the fungal inoculum and the appearance of disease symptoms in the experimental treatments. This was based on examining all plants in the experimental unit and calculating the rate according to the following equation:

Infection Rate (%) = (Number of Infected Plants ÷ Total Number of Plants) × 100

Infection Severity: The severity of infection was calculated 20 days after artificial inoculation and the appearance of disease symptoms. This was based on examining 10 plants in each treatment and distributing the infection score according to a 5-point disease index based on a modified scale [12], as follows: 0 = No visible disease symptoms (healthy plant); 1 = Separate spots covering (1-10%) of the leaf area towards the tip; 2 = Several brown spots covering (11-20%) of the leaf area, with the length of each spot not exceeding 1 cm; 3 = Spots representing (21-40%) of the leaf area with (4-8) large spots with a lighter outer color; 4 = The spots transform into elongated lines covering (41-75%) of the leaf area, with tissue death affecting one-third of the leaf area; 5 = Complete drying of the plant and leaf breakage at the base. Equation [13] was applied to calculate the severity of the infection according to the following formula:

Severity of Infection = (Infection score × Number of plants in each group) ÷ (Total number of plants examined × Highest score in the disease index)

Leaf Area (cm^2): The leaf area was measured before the flowering stage by randomly selecting 10 plants from each experimental unit and taking 3 leaves from each plant (the terminal leaf and the two leaves below it). The leaf area was calculated according to the following equation [14] :

Leaf Area (cm^2) = Leaf Length × Maximum Leaf Width × Correction Factor (0.75) Where the factor of 0.75 represents a correction factor that takes into account the semi-cylindrical shape of onion leaves.

Biological Weight (g $plant^{-1}$): Three complete plants (shoot + root) were randomly harvested from each experimental unit at the pre-maturity stage, cleaned of dust and debris, and weighed using a sensitive balance. Then the mean weight was calculated for each treatment.

Plant Yield (g plant-1): During harvesting, the tubular blades of three plants from each experimental unit were cut when the bulbs have attained full maturity. The bulbs were washed free of dust and dirt, weighed using a sensitive balance, and the average weight of each treatment was computed and expressed in g $plant^{-1}$.

2.8 Statistical Analysis: Statistical analysis of all studied traits was carried out in the split plot randomized complete block design (RCBD), with irrigation method being the main factor and treatments being the secondary factors. The statistical software SAS was used, and the means were compared using Duncan's multiple range test at a probability level of 0.05.

3. Results and Discussion

3.1 Effect of Irrigation Method and its Interaction with Treatments on Infection Rate(%)

The results (Table 1) showed a clear and significant effect of the irrigation method on the infection rate of onion leaf blight. The drip irrigation method recorded an average infection rate of 60.00%, while it reached 70.00% with the sprinkler irrigation method. This indicates the superiority of the drip irrigation method in limiting the development of the disease. The results of the interaction between the treatments and the two irrigation methods showed a clear difference depending on the treatment type. The lowest infection rates of 36.66% with drip irrigation and 46.66% with sprinkler irrigation were obtained for potassium silicate + trifloxystrobin treatments respectively. Then, trifloxystrobin + acetamipride treatment showed the 43.33% and 50.00% infected by drip irrigation and sprinkler irrigation treatment, respectively. This was a significant difference from the contaminated control treatment, which recorded the highest infection rate at 83.33% with drip irrigation and 93.33% with sprinkler irrigation.

Table 1. Effect of Treatments, Irrigation Method, and Their Interaction on the Infection Rate (%) of Onion Leaf Blight.

Treatments	Drip Irrigation (%)	Spray Irrigation (%)	Treatment Mean (%)
Potassium Silicate	73.33 bc	76.66 bc	75.00 b
Trifloxystrobin Fungicide	50.00 d	66.66 c	58.33 c
Acetamipride Insecticide	76.66 bc	83.33 ba	80.00 ba
Basal Leaf Removal	66.66 c	76.66 bc	71.66 b
Potassium Silicate + Trifloxystrobin	36.66 d	46.66 d	41.66 d
Potassium Silicate + Acetamipride	50.00 d	66.66 c	58.33 c
Trifloxystrobin + Acetamipride	43.33 d	50.00 d	46.66 d
Diseased Control	83.33 ba	93.33 a	88.33 a
Irrigation Method Mean	60.00 b	70.00 a	—

3.2 Effect of Irrigation Method and Its Interaction with Treatments on Infection Severity

The results (Table 2) showed significant differences in the average effect of irrigation method on infection severity. Drip irrigation was superior, with an average infection severity of 0.17, compared to sprinkler irrigation, which had an average infection severity of 0.20. For the interaction effect between treatments and irrigation methods, the treatment of potassium silicate + trifloxystrobin had the highest significant difference with an average severity of 0.13 (drip irrigation) and 0.15 (sprinkler irrigation). This was followed by the trifloxystrobin + acetamipride treatment, with average severity of 0.13 and 0.15 for the two irrigation methods, respectively. This was compared to the contaminated control treatment, where the infection severity was 0.23 using drip irrigation and 0.28 using sprinkler irrigation.

Table 2. Effect of treatments, irrigation method and their interaction on the severity of onion leaf blight disease.

Treatments	Drip Irrigation	Spray Irrigation	Treatment Mean
Potassium Silicate	0.17 fge	0.21 cb	0.19 cb
Trifloxystrobin Fungicide	0.14 hg	0.17 fge	0.16 d
Acetamipride Insecticide	0.19 cde	0.21 cb	0.20 b
Basal Leaf Removal	0.18 fde	0.21 cd	0.19 cb

Potassium Silicate + Trifloxystrobin	0.13 h	0.15 hg	0.14 e
Potassium Silicate + Acetamipride	0.16 fg	0.19 cde	0.18 c
Trifloxystrobin + Acetamipride	0.13 h	0.15 hg	0.14 ed
Diseased Control	0.23 b	0.28 a	0.25 a
Irrigation Method Mean	0.17 b	0.20 a	—

3.3 Effect of Irrigation Method and its Interaction with Treatments on Leaf Area (cm^2)

The results in Table (3) indicate a close relationship and no significant differences between the two irrigation methods in leaf area, with a slight advantage for drip irrigation. The average leaf area was 60.54 cm^2 with drip irrigation and 59.25 cm^2 with sprinkler irrigation. When examining the interaction between the treatments and the two irrigation methods, the potassium silicate + trifloxystrobin treatment resulted in the highest average leaf area of 65.83 cm^2 under drip irrigation and 65.26 cm^2 under sprinkler irrigation. The next highest means for leaf area were recorded by the trifloxystrobin + acetamipride treatment with 63.70 cm^2 and 62.03 cm^2 for the two irrigation methods, respectively, while the contaminated control treatment recorded the lowest leaf area, 46.53 cm^2 with drip irrigation and 42.03 cm^2 with sprinkler irrigation.

Table 3. Effect of Treatments, Irrigation Method, and Their Interaction on Leaf Area (cm^2).

Treatments	Drip Irrigation (cm^2)	Spray Irrigation (cm^2)	Treatment Mean (cm^2)
Potassium Silicate	59.33 efd	58.26 gef	58.80 de
Trifloxystrobin Fungicide	61.03 cebd	60.70 ced	60.86 de
Acetamipride Insecticide	58.20 gef	57.13 gef	57.66 fe
Basal Leaf Removal	55.16 gf	54.60 g	54.61 f
Potassium Silicate + Trifloxystrobin	65.83 b	65.26 cb	65.55 b
Potassium Silicate + Acetamipride	62.20 cebd	61.36 cebd	61.78 cd
Trifloxystrobin + Acetamipride	63.70 cbd	62.03 cebd	62.86 cb
Diseased Control	46.53 h	42.03 i	44.28 g
Irrigation Method Mean	60.54 a	59.25 a	—

3.4 Effect of Irrigation Method and Its Interaction with Treatments on Biological Weight (g $plant^{-1}$)

The results in Table (4) indicate that the drip irrigation method had a significantly higher effect than the sprinkler irrigation method on biological weight, with drip irrigation recording 233.01 g $plant^{-1}$

and sprinkler irrigation 208.55 g plant^{-1}. The results of the interaction between treatments and irrigation methods showed that the potassium silicate + trifloxystrobin treatment achieved the highest significant advantage, with an average yield of 246.86 g/plant using drip irrigation and 225.20 g/plant using sprinkler irrigation, compared to the contaminated control treatment, which recorded 213.16 g/plant using drip irrigation and 177.96 g/plant using sprinkler irrigation. All treatments using drip irrigation were superior to those using sprinkler irrigation.

Table 4. Effect of treatments, irrigation method and their interaction on biological weight (g plant^{-1}).

Treatments	Drip Irrigation (g/plant)	Spray Irrigation (g/plant)	Treatment Mean (g/plant)
Potassium Silicate	216.86 fhg	197.53 lk	207.19 fe
Trifloxystrobin Fungicide	224.43 feg	201.53 jk	212.98 de
Acetamipride Insecticide	218.06 fhg	194.20 lk	206.13 fe
Basal Leaf Removal	214.00 fihg	188.96 l	201.48 fg
Potassium Silicate + Trifloxystrobin	246.86 c	225.20 fe	236.03 b
Potassium Silicate + Acetamipride	230.20 de	205.06 jik	217.63 dc
Trifloxystrobin + Acetamipride	237.30 dc	211.30 jih	224.30 c
Diseased Control	213.16 ihg	177.96 m	195.56 g
Irrigation Method Mean	233.01 a	208.55 b	—

3.5 Effect of irrigation method and its interaction with treatments on yield (g plant^{-1})

Effect of irrigation method and its interaction with treatments on The results of Table (5) showed that the average effect of drip irrigation method was significantly higher than the sprinkler irrigation method on yield, where the drip irrigation method recorded 165.70 g plant 1 compared to 154.00 g plant 1 for sprinkler irrigation method. The interaction results of the two factors showed that the potassium silicate + trifloxystrobin treatment achieved the highest significant yield increase, reached 178.33 g plant 1 using drip irrigation and 170.33 g plant 1 using sprinkler irrigation. This was followed by the trifloxystrobin + acetamipride treatment, with yields of 175.66 g plant 1 and 165.00 g plant 1, respectively. This contrasts with the contaminated control treatment, which yielded 139.00 g plant^{-1} using drip irrigation and 124.00 g plant^{-1} using sprinkler irrigation.

Table 5. Effect of Treatments, Irrigation Method, and Their Interaction on Yield (g plant^{-1}).

Treatments	Drip Irrigation (g/plant)	Spray Irrigation (g/plant)	Treatment Mean (g/plant)
Potassium Silicate	161.00 gef	145.33 ih	153.16 e
Trifloxystrobin Fungicide	172.33 cbd	163.33 efd	167.83 c

Acetamipride Insecticide	163.00 efd	155.66 gf	159.33 ed
Basal Leaf Removal	145.66 ih	140.33 i	143.00 f
Potassium Silicate + Trifloxystrobin	178.33 b	170.33 cebd	174.33 ba
Potassium Silicate + Acetamipride	167.00 ced	153.33 gh	160.16 d
Trifloxystrobin + Acetamipride	175.66 cb	165.00 efd	170.33 bc
Diseased Control	139.00 i	124.00 j	131.50 g
Irrigation Method Mean	165.70 a	154.00 ced	—

The combined results indicate a consistent and repeated superiority of drip irrigation over sprinkler irrigation in all studied traits (infection rate and severity, leaf area, biological weight, and yield). This is attributed to drip irrigation reducing the leaf wetness period and limiting infection development, as well as increasing water and nutrient use efficiency compared to sprinkler irrigation. This, in turn, helps maintain the leaves' efficiency in producing carbohydrates necessary for growth and increased yield. These results agree with the findings of [10, 11] that reduction of surface moisture on leaves is one of the most important agricultural practices for limiting disease development and improving crop productivity. On the other hand, sprinkler irrigation increases relative humidity and duration of leaf wetness period, creating optimum conditions for pathogen germination, penetration into plant tissues and development of new infections. This is in agreement with the findings of [15, 16] that increased humidity and duration of leaf wetness period are among the most important determinants of severity of onion leaf blight.

The interaction between irrigation method and chemical treatments showed a clear cumulative effect. The potassium silicate + trifloxystrobin treatment under drip irrigation conditions achieved the best overall performance among all treatments. This can be explained by the synergistic effect of potassium silicate in enhancing plant resistance [17] and the direct effect of the active ingredient, trifloxystrobin, in inhibiting fungal cellular respiration [18], along with the complementary role of the irrigation method in reducing environmental conditions favorable to disease spread.

On the contrary, the sprinkler irrigation increases the relative humidity rate and duration of leaf wetness which favours germination and penetration of pathogens into plant tissues with thus new infections. Our findings agree with [15, 16] that the severity of onion leaf blight is strongly influenced by humidity and leaf wetness period.

The results indicated a distinct interaction effect of the irrigation method and chemical treatments. Among treatments, potassium silicate + trifloxystrobin under drip irrigation conditions showed the best performance for all parameters. This is evidenced by the joint action of potassium silicate, which increases plant resistance [17] and the direct action of the active ingredient trifloxystrobin by inhibiting fungal cell respiration [18], associated with a complementary action resulting from decreased environmental conditions conducive to disease spread due to the irrigation method. On the other hand, sprinkler irrigation contaminated control treatment was used as the net worst case scenarios of severity infection and loss of yield. The lack of a control treatment together with the inappropriate application method that is, irrigation aggravated the severity of infection and its detrimental effect on productivity. Overall, these results indicate a clear negative relationship between disease severity and traits associated with productivity (leaf area, biological weight, and yield). These findings highlight the necessity of incorporating appropriate irrigation methods with other control measures in integrated disease management strategies for lowering losses associated with downy mildew and obtaining maximum bulb yield of onion.

4. Conclusions

- Compared with sprinkler irrigation, drip irrigation resulted in a significantly lower incidence and degree of onion leaf blight as well as greater leaf area, biological weight and yield (Table 2).
- Drip irrigation and the mixed treatments, especially potassium silicate + trifloxystrobin herbicide, generally had better results in reducing any infection and improving productivity than any single treatment.
- Drip irrigation was proposed in integrated pest management programs on onion leaf blight combined with proper chemical treatments for highest control efficiency and yield.

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