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Onion-Seed Yield and Quality as Affected by Irrigation Management[1]

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ABSTRACT

The effects of soil moisture, sprinkler irrigation, and misting (5 min at 30-min intervals) on hybrid onion-seed (*Allium cepa* L.) production were evaluated at Kimberly, Idaho. Sprinkling and misting treatments were included to determine if sprinkler irrigation could be used for onion-seed production, and if evaporative cooling (misting) would alleviate the scalding of umbels at excessively high temperatures. Results showed that reasonable onion-seed yields could be obtained with sprinkler irrigation in spite of anticipated adverse effects on pollination. In areas with high daytime temperatures, misting could be used to cool the umbels, as much as 15 C for about 20 min, although it does not seem necessary for the low 32 to 35 C daytime temperatures at Kimberly. The highest onion-seed yields were obtained with the furrow-irrigation treatment where water was applied when tensiometers at 20-cm depth read about 0.5 bar soil moisture tension (furrow adequate). The addition of misting to furrow irrigation decreased seed yields 19%. Furrow irrigating at 0.4 bar decreased yields 26% below those obtained with irrigation at 0.5 bar. While overirrigation adversely affected yield, irrigation treatment had only a slight effect on seed weight and vigor.

Additional index words: **Sprinker-cooling, Mist-cooling, Seed-vigor, Germination, *Allium cepa* L.**

ONION-Seed production is economically important in the USA: 41,500 ha (102,600 acres) of onions were harvested in 1975 for fresh market and processing at a market value of $258 million (1975 USDA Statistical Reporting Service). The two major U.S. onion-seed producing areas are 1) southern California and southwestern Arizona, where seed for "short-day" onions is grown, and 2) Idaho, Oregon, Washington, and northern California, where seed for "long -day" onions is grown (7).

Onion (*Allium cepa* L.) seed yields, especially of hybrid seed, have been erratic the past 15 years. According to Franklin (3), a decline in yields started about 1961 with numerous unexplained instances of complete or nearly complete seed failure. The lowest and highest hybrid seed yield often occurred the same year, with bulbs from a single field transplanted in different fields sometimes failing and sometimes producing high yield. Before 1961, low yields and seed failure for both hybrid and open-pollinated crops were attributed to poor husbandry, disease, or inbred parents known to be reproductively weak. Recently, causes for poor yields have been much more difficult to identify.

Nye et al. (12) outlined conditions needed for pollination and fertilization. A large number of cultural practices and environmental conditions are suspected of reducing seed yields. Of concern to this study are the effects of high temperature and water stress during pollination and seed development. Pollen viability and stigma receptivity can be adversely affected, leading to poor fertilization or abortion of developing seeds.

It has been shown that under certain natural field conditions parts of the onion umbel do reach temperatures sufficiently high to denature protein (4, 5, 10, 13). Because of the nature of the onion plant, the water balance of the umbel is different than most agronomic crops and there is little evaporative cooling by transpiration. Climatic conditions can therefore be a major factor in seed crop performance. Poor root growth, root diseases, and high evaporative demand can lead to water stress in umbels, even with adequate soil moisture. The hollow scape terminates in a spherical umbel with as many as 1,000 florets, each supported by a pedicel. Millar et al. (10) found the lowest water potentials in the onion plant existed in the flowers and pedicels, indicating there is considerable resistance to the flow of water from the soil to the florets. They found that for a 1-bar change in turgor the changes in stomatal conductance of onion leaves were about 3 times greater than for snap beans, indicating that onion stomata are very sensitive to

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water deficit. Furthermore, onion leaves have very low turgor pressure compared to other plants, which may significantly affect stomatal opening.

Hawthorn (6) obtained the highest seed yields of yellow 'Sweet Spanish' onions with high soil moisture on a Millville gravelly loam (Atypic Rendoll) at Logan, Utah. *High, medium,* and *low* soil-moisture treatments were obtained with furrow irrigation applying water where soil-moisture tensions reached 0.5 bar at 15-cm soil depth, and when the soil moisture was at the wilting percentage at 8 and 15-cm soil depths, respectively. Germination and seed maturity were not affected by any of these soil-moisture treatments. Onion-seed yields at the 91-cm (36-in) row spacing were about 680, 470, and 560 kg/ha (615, 425, and 500 lb/acre) for high, medium and low soil-moisture treatments, respectively. MacGillivray (9), who used three soil-water treatments on a Yolo loam (Atypic Xerochrept) at Davis, Calif., found that on onions planted in November seed heads matured earlier in August on dry than on wet plots, but irrigation during seed development did not materially affect the germination percentages or seed size of yellow Sweet Spanish onion. His dry, medium, and wet treatments consisted of no irrigation, 130 mm (5 in) water in two irrigations, and 380 mm (15 in) water in five irrigations, respectively. Winter rainfall of 390 mm (15.5 in) wetted all plots to field capacity by spring. Onion-seed yields ranged from about 450 kg/ha (400 lb/acre) for the dry plots to 780 kg/ha (700 lb/acre) for wet plots. The smallest seeds occurred on the dry treatments and the largest on the medium-wet.

Sprinkler irrigation and mist-cooling have not previously been used on onion-seed crops because of the belief that sprinkler-applied water would result in dilution of nectar and decrease bee activity. However, Waller (14), using an artificial-flower as a feeder for bees, found that nectar containing sucrose between 30 and 50% was preferred to higher or lower concentrations. Sugar concentrations are frequently above 60% with furrow irrigation. Waters (15) observed bees in onion fields rejecting flowers containing nectar with concentrations above 60%, while nectar collected from honey crops of captured bees averaged 48.3%.

The objectives of our study were to determine if irrigation methods or practices could favorably modify the microclimate during pollination of onion flowers, and to determine the effects of sprinkler irrigation and misting on onion-seed yield and quality as compared with that of furrow irrigation alone, and with misting.

MATERIALS AND METHODS

Following exploratory studies in 1970-72, this study was conducted in 1973 on a Portneuf silt loam soil (Xerollic Calciorthid) near Kimberly, Idaho. The study was designed to include four irrigation treatments: F_w (furrow wet)—furrow-irrigated when tensiometer readings reached 0.35 to 0.4 bar; F_a (furrow adequate)—furrow-irrigated when tensiometer readings reached 0.45 to 0.5 bar; F_{am} (furrow adequate + misted)—furrow-irrigated when tensiometer readings reached 0.45 to 0.5 bar, and misted during anthesis when the air temperature was above 30 C; and S_{am} (sprinkler adequate + misted)—sprinkler-irrigated like treatment F_{am}. It was not economically feasible to completely randomize the treatments because of the large amount of sprinkler equipment required. Also, we could not easily and economically

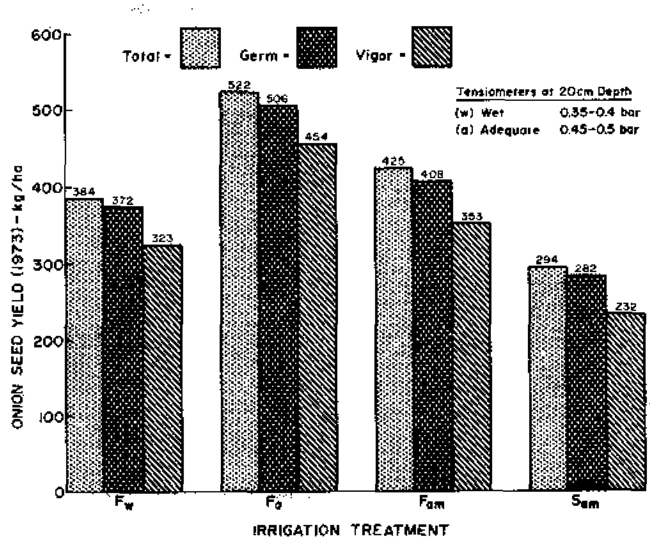

Fig. 1. Effect of irrigation treatment on onion seed yield. The total bar represents the seed yield after cleaning. The germination bar represents the total viable seed, and the vigor bar represents the most vigorous seeds (1973).

prevent drifting of mist from adjacent randomized plots due to frequent winds. Thus, the treatments were randomized, but the plots within each treatment were arranged in blocks for ease of applying the irrigation treatments. The plots were arranged so that all data could be analyzed for interpretation by using the Student's t-test for paired observations of the effects of irrigation methods, moisture level, and misting on seed yield and quality.

Ammonium sulfate was applied to the entire study area at 56 kg N/ha and treble-superphosphate at 98 kg P/ha as recommended by the seed company furnishing the onion bulbs. After the seedbed was prepared and the fertilizer applied, dacthal W-75 mixed in 380 liters of water was applied preplant for weed control at 9 kg/ha and mixed into the soil with a roto-harrow.

Eight 9 × 9-m plots/treatment were used. Rows were spaced 91 cm, and onion bulbs 50 to 90 mm in diam. were planted about 15 cm apart within the row on 10 to 11 Apr. 1973. Two (male-fertile) rows were planted on each side of four (male-sterile) rows. Ethion[3] (5% granular) was applied dry at 28 kg/ha on the onion bulbs to control onion maggots before the bulbs were covered with soil. Before anthesis, diathane M-45 at 2.5 kg/ha and dimethoate at 1.2 liters/ha were mixed in 380 liters of water and sprayed on all plots to control purple blotch and thrips, respectively.

Six hives of honeybees were placed at the lower end of the plot at 10% bloom, and six additional hives at 50% bloom to provide pollination.

Two tensiometers were placed at a 20-cm depth within each treatment block in the onion row to indicate when to irrigate. Sprinkler lines 50 mm in diam. were placed around the 9 × 9-m misted and sprinkler-irrigated plots, with sprinkler heads spaced 9 m apart. Quick change 2.4-mm nozzles were used in the sprinkler heads while misting, and quick change 3.2-mm nozzles were used during normal sprinkler irrigations. An electronic controller and temperature sensor, developed and described by Wright et al.[4], was used to sense the air temperature and initiate misting whenever the air temperature exceeded 30 C during anthseis. The temperature sensor was located in a shelter about 1 m aboveground near the onion plots. A 30-min misting cycle involved 5 min of sprinkling and 25 min of drying.

[3] Trade names are provided for the convenience of the reader and do not imply endorsement or recommendation by USDA.

[4] Wright, J. L., J. L. Stevens, and M. J. Brown. 1974. Controlled cooling of onion umbels by periodic sprinkling. Am. Soc. Agron. Abstr., p. 12.

Table 1. Seed weight, percent vigor, and percent germination of cleaned seed taken from harvest yield samples to determine seed quality (1973).

Treatment	Seed wt.	Vigor	Germination
	mg	%	%
F_w (furrow wet)	5.0 a*	84 a	97 a
F_a (furrow adequate)	5.0 a	87 a	97 a
F_{am} (furrow adequate + mist)	5.4 b	83 a	96 a
S_{am} (sprinkler adequate + mist)	5.3 b	79 b	96 a

* Numbers in the same column followed by the same letter are not significantly different at the 5% level, according to paired observations using the Student's t-test.

Table 2. Moisture treatment effects on development of florets, buds, and seeds/umbel, seeds/floret, and seed weight (1973).

Treatment	Florets/ umbel	Buds/ umbel	Seeds/ umbel	Seeds/ floret	Seed wt.
	no.	no.	no.	no.	mg
F_w	262 a*	158 a	765 a	2.9 a	4.6 a
F_a	245 a	101 b	765 a	3.1 a	4.8 b
F_{am}	273 a	193 c	812 a	3.0 a	4.9 b
S_{am}	233 b	231 d	691 a	3.0 a	4.8 b

* Numbers in the same column followed by the same letter are not significantly different at the 5% level, according to paired observations using the Student's t-test.

To evaluate the effects of sprinkling on dilution of flower nectar, sugar concentrations were measured by determining the concentration of nectar taken from the honey stomach of the bees removed from the flowers. A Bausch and Lomb, low-range (0 to 60%) hand-refractometer was used to measure the sugar concentration.

The plots were hand-harvested 27 to 29 Aug. 1973. Every onion plant harvested to measure seed yield was uprooted to determine percent root rot. The umbels were dried, placed in a scarifier to remove the seeds, which were cleaned with a small seed cleaner. Cleaned seeds were placed in a large pan containing water so that the light seeds floating on the surface could be skimmed off and discarded. Heavy seeds were air-dried and weighed to determine seed yield and quality. Many discarded light seeds were viable, but we did not measure their germination percentage.

Seed vigor was determined as the percentage of heavy seeds which germinated after 5 days of incubation at 20 C. The percentage germination was measured after 10 days of incubation at 20 C.

To determine the number of florets, buds, seeds/floret, and weight/seed, seed characteristics of three umbels from each plot for a total of 24 umbels/irrigation treatment were analyzed in detail. Umbels were selected visually from these 24 to represent the 8 poorest, 8 best, and 8 average seed-set/umbel/treatment. The florets and buds[5] were cut from each of these umbels and counted separately. The florets containing the seeds were hand-threshed and cleaned, and seeds were counted. All seeds were counted with a photoelectronic seed-counter, designed and built at the Kimberly laboratory (2) for these purposes.

RESULTS AND DISCUSSION

Onion Seed Yield

The seed yields decreased in the order: F_a (furrow adequate) > F_{am} (furrow adequate + mist) > F_w (furrow wet) > S_{am} (sprinkler adequate + mist (Fig. 1). Onion seed yield (506 kg/ha) was highest for the F_a plots irrigated at 0.5 bar. The yield on the F_w plots irrigated at 0.4 bar was 26% less than that of the F_a plot, which may have been due to decreased aeration. Hawthorn (6) obtained 450 to 670 kg/ha at Logan, Utah, at about the same moisture level as the F_a plots on an irrigated Millville gravelly loam. Presently, grower yields in Idaho average about 220 to 560 kg/ha.

Onion-seed growers in southern Idaho seem to maintain soil moisture as high, or higher, than that of our F_w treatment, because they believe the high incidence of root rot reduces the capacity of roots to extract water from drier soil. We found 57% root rot on our F_w plots, as compared with 66% on the F_a plots, which was significantly different at the 1% level. However, the F_a plots still produced the largest yield in spite of the higher root rot incidence and lower available moisture.

When comparing treatments F_a and F_{am}, misting decreased seed yield 19%, which was significant at the 1% level. However, even though misting decreased yield significantly, the F_{am} plots yielded 7% more than the F_w plots, which indicated that misting did not decrease yield as much as the higher soil moisture condition. Our results indicated that furrow irrigating at a higher soil water level than that used on the F_w treatment may decrease yields even more than the 26% in this study.

Seed germination and vigor were high for all treatments (Table 1). The most vigorous seeds are expected to survive a wider range of adverse physical stresses, like temperature and moisture extremes, and soil crusting. Vigor values are used by seed companies as a measure of seed emergence potential and as an indicator of potential growth rate since seeds with the highest vigor are expected to emerge faster and to survive better.

Refractometer readings showed that before misting plants, the flower nectar was above 60%. Also, the sugar concentration obtained from honey crops of the few captured bees foraging these flowers was above 60%. After misting these same plants, the sugar concentration in the bees' honey crop dropped to a 43% average, ranging from 22 to 58%, which is in agreement with the findings of Waller (14) and Waters (15).

Onion Seed Quality

Misting significantly increased seed weight at the 5% level and significantly decreased seed vigor at the 10% level, but had no significant effect on germination (Table 1). Sprinkling significantly decreased seed vigor at the 5% level. Otherwise, treatments had no effect on seed weight, vigor, or germination.

Maintaining high soil moisture, misting, and sprinkler irrigation significantly increased the number of buds/umbel (Table 2), which would contribute to decreased yields. The number of seeds/floret did not differ significantly, and the high moisture level significantly decreased seed weight at the 5% level. The number of florets/umbel was significantly greater for the F_{am} treatment than for the S_{am} treatment. Sprinkling significantly decreased the average number of seeds/umbel at the 10% level.

[5] Florets as used in this paper were fertilized flowers which developed one or more seeds per flower. Buds were flowers that did not develop any seed because they either aborted or were not fertilized.

High soil moisture may have caused a physiological change within the onion plant that affected pollen germination and development of pollen tubes. According to Brewbaker and Majumder (1), the viability of pollen and pollen-tube growth is affected almost immediately by an irregularity in plant vigor. Sprinkling and misting may have caused sudden temperature changes that decreased pollen viability by either stopping pollen-tube growth or decreasing it sufficiently to cause it to abort. Drastic temperature changes could possibly be avoided by sprinkling at night when the bees are not foraging and after pollen germination and pollen-tube growth have occurred. Nye et al. (11) found pollen was 2 to 3 times more viable in the morning than in the afternoon. Sprinkler-irrigating in the morning when pollen is most viable may prevent pollen from adhering to the bees, which would decrease the transfer of pollen. This may have caused low yields on our sprinkler-irrigated plots. This should not be a problem with misting because temperatures would not normally call for misting in the morning. Under greenhouse conditions, Mann and Woodbury (8) found that pollen tubes extended one-third to three-fourths of the length of the style, about 4 mm, in 24 hours. Thus, sprinkler-irrigating at night should have the least detrimental effect on pollen germination and pollen-tube growth.

Umbel Temperature

The decrease in umbel temperature caused by misting was dependent on the duration of misting, air temperature and humidity, windspeed, and sunlight intensity. Misting for 5 min seemed to wet the umbels sufficiently to achieve maximum cooling without excessive dripping. As an example of cooling effects, when the umbel temperature was about 40 C, with an air temperature of 32 C, low windspeed and a relative humidity of 30%, misting for 5 min lowered the umbel temperature about 15 to 20 C, giving umbel temperatures of 20 to 25 C. Umbel temperatures then remained depressed for 20 min or longer, depending on ambient weather conditions and maturity of the umbel (Wright et al.[4]). At Kimberly, air temperatures are generally less than 34 C and measured umbel temperatures were usually less than 40 C. Since the critical temperature for tissue damage is generally considered to be greater than 40 C, benefits of cooling by misting would not be expected under Kimberly climatic conditions. However air temperatures are usually much higher (10 C or more) in the major onion-seed producing areas such as western Idaho, California, and Arizona. The studies were conducted at Kimberly for convenience of developing the procedures and assessing the general effects of sprinkler application of water to onion umbels. Results have successfully demonstrated that onion seed can be produced with sprinkler irrigation and a small amount of misting will maintain temperatures below critical levels. Also, they have indicated that onion-seed yields could be decreased by overirrigating.

Studies need to be extended to the hotter onion-seed producing areas to determine yield effects and economical benefits. Based on our results, we anticipate that mist cooling, which depresses umbel temperatures below lethal levels, would result in increased seed yields.

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