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# Nitrogen-water Relationships of Onions Grown on Organic Soil[1]

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*Abstract.* **Field experiments were conducted on organic soil for 2 years to evaluate the influence of frequent irrigation and topdressings with N on growth, maturity and storage life of onions (*Allium cepa* L.). With no irrigation, growth to midseason, maturity, and final yield were not influenced by increasing amounts of N. The growth to midseason, and the final yield increased and maturity was earlier with increasing amounts of N applied to onions receiving 5 cm of rainfall + irrigation per week. Sprouting in storage was earlier with high N and latest with no N or with the low N rates. The effect was greater with irrigation.**

**Onions did not respond to N topdressing without irrigation even though rainfall was regular. With irrigation, the highest yield and earliest maturity was obtained with 22 or 34 kg of N/ha applied whenever the crop received 10 cm of water. No advantage in yield or maturity was obtained by applying N after mid-July. Maturity was earlier without irrigation regardless of N treatment.**

The effectiveness of N applications to onions grown on organic soil is determined by the amount of moisture received by the crop. Previous research (5) indicates that onions grown with varying amounts of N without adequate rainfall mature uniformly although yields may be reduced with high N applications. However, with adequate or excessive rainfall, increasing amounts of N are required for optimum growth and maturity. Because the utilization of N fluctuated greatly according to moisture supply; and under dry conditions high rates of N may be detrimental to crop growth; experiments were initiated to study the effect of varying rates of N applied as a topdressing and of different levels of moisture on the growth and maturation of onions grown on organic soil in the Bradford area of Ontario.

## Methods and Materials

The trials were conducted at the Organic Soils Research Station at Bradford, Ontario on a muck (2) soil composed of 84% organic matter (OM) which originated from reeds and sedges and had a pH of 5.7 with 128 kg/ha of available N ($NO_3$-N released after 1 week incubation). The land was tile drained with the water table maintained at 76 cm. In each experiment, 57.8 kg/ha of P and 111.5 kg/ha of K was broadcast and disced into the soil prior to seeding 'Autumn Spice' onions in 2 row plots 7.62 m long with 0.43 m between rows with guard rows between plots using a randomized block design with 4 replications. Seeding was done with a Planet Jr. seeder which was set to deliver 16-18 seeds per 30 cm of row. One-half of the onions received water only from rainfall and the other half was irrigated twice weekly to provide 5 cm of water per week including rainfall.

Standard pest and weed control measures were employed (1). When the onion tops in all plots were at least 75% fallen over, the plants were pulled and cured in windrows. After curing, the onions were topped mechanically, weighed, and placed in storage to evaluate keeping quality as indicated by sprouting. The data were treated by analysis of variance and the means were compared using Duncan's multiple range test at the 5% probability level.

In 1968, onions seeded on April 24 were topdressed with $NH_4NO_3$ at 2 and 4 week intervals at rates of 6, 11, 22, and 34 kg of N/ha. A control with no N was included. In 1969, onions were seeded on May 2 and topdressed with $NH_4NO_3$ at 22 kg of N/ha. The no. of topdressings varied from 1 to 8 beginning on May 14 and progressing at 2 week intervals to August 20 when all plots except the 0 N control were topdressed.

## Results

Onion growth before bulbing (Table 1) or at harvest (Tables 2 and 3) was not increased by N when the plants received water only from rainfall. With supplemental irrigation, growth to midseason was greater with increasing amounts of N (Table 1). This response was greater in the leaves than in the bulbs and was more evident in 1968 than in 1969. Yield of irrigated onions increased with each increment of N with applications at 2 or 4 week intervals except for the 5.6 kg N/ha treatment every 4 weeks (Table 2).

In 1969, the greatest yields were obtained with 4 and 5 topdressings of 22 kg N/ha (Table 3) which indicates that topdressings applied earlier than late June or early July may not be effective even with sufficient water. Also, the topdressing on August 20 when the plants were maturing was not effective.

Irrigation reduced the individual plant size at midseason (Table 1) and the total yield (Tables 2 and 3) of the plants grown with 0 N. This could be due to leaching since plant growth with N applications was equal to or exceeded the growth of onions which were not irrigated.

Table 1. Effect of irrigation and N topdressings on growth to midseason (July 31) of 'Autumn Spice' onions on organic soil at Bradford, Ontario in 1968.

| N topdressing (kg/ha) | | Fresh wt (g/plant) | | | | | |
|---|---|---|---|---|---|---|---|
| | | Irrigated | | | Not irrigated | | |
| Per application | Total applied | Leaves | Bulbs | Total | Leaves | Bulbs | Total |
| 0 | 0 | 34d[z] | 17b | 51c | 42a | 23a | 65a |
| | | *Applications at 2 wk intervals* | | | | | |
| 6 | 36 | 45abcd | 23a | 68abc | 47a | 22a | 69a |
| 11 | 66 | 51ab | 26a | 78ab | 47a | 23a | 70a |
| 22 | 132 | 50abc | 23a | 73ab | 43a | 24a | 67a |
| 34 | 204 | 55a | 26a | 80a | 41a | 25a | 66a |
| | | *Applications at 4 wk intervals* | | | | | |
| 6 | 18 | 37cd | 22ab | 59bc | 44a | 22a | 66a |
| 11 | 33 | 37cd | 22ab | 59bc | 51a | 22a | 72a |
| 22 | 66 | 46abcd | 22ab | 68abc | 44a | 21a | 65a |
| 34 | 102 | 50abc | 25a | 76ab | 53a | 24a | 77a |

[z]Mean separation, within columns, by Duncan's multiple range test, 5% level.

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Table 2. Effect of irrigation and time of N topdressings on the yield of 'Autumn Spice' onions grown on organic soil at Bradford, Ontario in 1968.

| N topdressing (kg/ha) | | Yield (MT/ha) | |
|---|---|---|---|
| Per application | Season total | Irrigated | Not irrigated |
| 0 | 0 | 44.6d[z] | 49.6a |
| | | *Applications at 2 wk intervals* | |
| 6 | 45 | 53.3c | 50.8a |
| 11 | 90 | 57.0abc | 51.5a |
| 22 | 179 | 63.1ab | 53.9a |
| 34 | 269 | 63.4a | 51.9a |
| | | *Applications at 4 wk intervals* | |
| 6 | 22 | 44.0d | 54.3a |
| 11 | 45 | 55.4bc | 54.9a |
| 22 | 90 | 57.7abc | 52.1a |
| 34 | 134 | 61.4ab | 53.6a |

[z]Mean separation, within columns, by Duncan's multiple range test, 5% level.

Table 3. Effect of irrigation and N topdressings on the yield of 'Autumn Spice' onions grown on organic soil at Bradford, Ontario in 1969.

| No. of N applications | Starting date | Total N applied (kg/ha) | Yield (MT/ha) Irrigated | Yield (MT/ha) Not irrigated |
|---|---|---|---|---|
| 0 | – | 0 | 40.5c[z] | 53.1a |
| 1 | Aug. 20 | 22 | 42.4bc | 51.2a |
| 2 | Aug. 6 | 45 | 51.3ab | 52.4a |
| 3 | July 23 | 67 | 50.2abc | 52.5a |
| 4 | July 9 | 90 | 57.3a | 55.4a |
| 5 | June 25 | 112 | 59.2a | 58.6a |
| 6 | June 11 | 134 | 52.6ab | 56.1a |
| 7 | May 28 | 157 | 55.6a | 56.5a |
| 8 | May 14 | 179 | 44.8bc | 56.9a |

[z]Mean separation, within columns, by Duncan's multiple range test, 5% level.

Onion maturity was delayed with irrigation (Tables 4 and 5). Although, increasing N levels increased the percentage of tops fallen in the irrigated onions, maturity with the highest N rate was still not as complete on August 19 as the maturity of those onions grown without irrigation (Table 4). In 1969, the irrigated onions matured earlier with 5 or more applications of N which indicates that N applied before June 25 is more effective in stimulating earlier maturity than late season applications (Table 5).

The storage life of the onions was influenced more by the N treatments than by the water the crop received during growth (Tables 6 and 7). In both years sprouting was generally delayed in onions grown with the low N treatments for both irrigated and non-irrigated onions. The percentage of bulbs sprouted was approximately the same between irrigated and non-irrigated onions for each N level at each sampling date which indicates that water had less effect than N level on storage life.

## Discussion

The response of onions to N applications with high and low moisture levels in this study was similar to that obtained previously with onions grown in different wet and dry seasons, that is: increasing N rates increased yields in the wet season but had no effect on or decreased yields in the dry season (5). Since seasonal differences other than moisture were difficult to evaluate in the previous study, this research was conducted with wet and dry conditions in the same growing season.

The toxic effect reported (5) from using high N levels during dry growing conditions was not evident in this study with non-

Table 4. Effect of irrigation and N topdressings on the maturation of 'Autumn Spice' onions grown on organic soil at Bradford, Ontario in 1968.

| N topdressing (kg/ha) | | Maturation (% tops fallen) | | | | |
|---|---|---|---|---|---|---|
| | | Irrigated | | | Not irrigated[y] | |
| Per application | Total applied | Aug. 8 | Aug. 12 | Aug. 19 | Aug. 8 | Aug. 12 |
| 0 | 0 | 1b[z] | 1a | 23c | 43a | 75a |
| | | *Applications at 2 wk intervals* | | | | |
| 6 | 45 | 3ab | 10a | 56abc | 40a | 86a |
| 11 | 90 | 3ab | 27a | 66ab | 54a | 96a |
| 22 | 179 | 2ab | 5a | 75ab | 40a | 88a |
| 34 | 269 | 9ab | 46a | 89a | 60a | 91a |
| | | *Applications at 4 wk intervals* | | | | |
| 6 | 22 | 6ab | 23a | 40bc | 34a | 74a |
| 11 | 45 | 4ab | 27a | 73ab | 46a | 89a |
| 22 | 90 | 3ab | 9a | 56abc | 44a | 91a |
| 34 | 134 | 10a | 35a | 76ab | 41a | 94a |

[z]Mean separation, within columns, by Duncan's multiple range test, 5% level.

[y]On August 19, 100% of the tops had fallen for all treatments grown without irrigation.

irrigated onions although the total amount of N applied for the entire season was similar. Applying N frequently in small amounts throughout the growing season may have avoided any detrimental effect which could occur with a single large application. Also the rainfall in 1968 and 1969 was slightly more than in the 2 dry seasons in the previous paper. This could have diluted or leached the fertilizer sufficiently to prevent any injury; however, the water received in 1968 and 1969 with the non-irrigated onions was still not sufficient to obtain a growth response to increasing amounts of N.

N applied to onions under dry conditions or with moderate rainfall or irrigation had no effect on onion growth, maturation, or storage life. In a soil with a high OM content, sufficient N may be released through the decomposition of the OM (2, 6) to sustain an adequate rate of growth, and additional N would not be necessary. On organic soils with a low OM content microorganisms may utilize the soil N (2) and additional N may be beneficial with all moisture levels. Increasing soil moisture reduces the amount of available N by leaching and reduces bacterial decomposition of the OM (6) through low temperature and poor aeration (2). Also, these conditions will reduce the

Table 5. Effect of irrigation and N topdressings on the maturation of 'Autumn Spice' onions grown on organic soil at Bradford, Ontario in 1969.

| No. of N applications | Total N applied (kg/ha) | Maturation (% tops fallen) | | |
|---|---|---|---|---|
| | | Irrigated[y] | | Not irrigated[x] |
| | | Aug. 26 | Aug. 29 | Aug. 22 |
| 0 | 0 | 36a[z] | 50ab | 89a |
| 1 | 22 | 19a | 29b | 99a |
| 2 | 45 | 24a | 40ab | 96a |
| 3 | 67 | 28a | 51ab | 98a |
| 4 | 90 | 30a | 44ab | 94a |
| 5 | 112 | 48a | 75a | 94a |
| 6 | 134 | 35a | 78a | 98a |
| 7 | 157 | 34a | 76a | 99a |
| 8 | 179 | 60a | 73a | 98a |

[z]Mean separation, within columns, by Duncan's multiple range test, 5% level.

[y]On Aug. 22, none of the tops had fallen for all treatments with irrigation.

[x]On Aug. 26, 100% of the tops had fallen for all treatments without irrigation.

Table 6. Effect of irrigation and N topdressings on the storage life of 'Autumn Spice' onions grown on organic soil at Bradford, Ontario in 1968.

| N topdressing (kg/ha) | | Storage life (% bulbs sprouted) | | | | | |
|---|---|---|---|---|---|---|---|
| | | Irrigated | | | Not irrigated | | |
| Per application | Total applied | April 15 | May 15 | June 20 | April 15 | May 15 | June 20 |
| 0 | 0 | 5b[z] | 21d | 65d | 14b | 34d | 78bc |
| | | | | *Applications at 2 wk intervals* | | | |
| 6 | 45 | 7ab | 27cd | 72bcd | 16b | 44bcd | 84bc |
| 11 | 90 | 11ab | 41abc | 82abc | 18b | 51ab | 86ab |
| 22 | 179 | 17a | 49ab | 84ab | 16b | 40cd | 79bc |
| 34 | 269 | 18a | 54a | 87a | 28a | 57a | 93a |
| | | | | *Applications at 4 wk intervals* | | | |
| 6 | 22 | 7ab | 22d | 70cd | 14b | 38cd | 79bc |
| 11 | 45 | 9ab | 37abcd | 80abc | 18b | 45bc | 80bc |
| 22 | 90 | 9ab | 34bcd | 81abc | 16b | 42bcd | 79bc |
| 34 | 134 | 15ab | 47ab | 86a | 14b | 37cd | 75c |

[z]Mean separation, within columns, by Duncan's multiple range test, 5% level.

Table 7. Effect of irrigation and N topdressings on the storage life of 'Autumn Spice' onions grown on organic soil at Bradford, Ontario in 1969.

| No. of N applications | Total N applied (kg/ha) | Storage life (% bulbs sprouted) | | | | | |
|---|---|---|---|---|---|---|---|
| | | Irrigated | | | Not irrigated | | |
| | | April 20 | May 20 | June 20 | April 20 | May 20 | June 20 |
| 0 | 0 | 11d[z] | 49b | 85c | 8b | 49b | 88a |
| 1 | 22 | 8d | 49b | 89bc | 10b | 46b | 87a |
| 2 | 45 | 12cd | 57ab | 92abc | 11b | 52ab | 84a |
| 3 | 67 | 22a | 74a | 96a | 9b | 57ab | 92a |
| 4 | 90 | 14bcd | 59ab | 89abc | 13ab | 54ab | 86a |
| 5 | 112 | 20ab | 69a | 93ab | 13ab | 63a | 90a |
| 6 | 134 | 22a | 73a | 92abc | 18a | 64a | 92a |
| 7 | 157 | 18abc | 67a | 92abc | 12ab | 57ab | 89a |
| 8 | 179 | 23a | 66a | 95ab | 12ab | 52ab | 92a |

[z]Mean separation, within columns, by Duncan's multiple range test, 5% level.

metabolic activity of the plant and increase the effectiveness of N applications near the roots.

With irrigation, increasing N levels increased yield and stimulated earlier maturity. This response was obtained previously in the wet seasons (5) and is similar to other reports (4, 8) that onions will mature earlier with N applied in excess of that required for maximum yield. Yields with the greatest amount of N were equal to or greater than the corresponding treatments grown without irrigation suggesting the desirability of supplying the crop with regular moisture to obtain maximum effectiveness of N applications. A severe N deficiency will prevent normal maturity (7). This did not occur, but maturity was delayed when N was limiting with high moisture conditions. All irrigated onions matured a week or more later than nonirrigated onions, even with the highest rates of N. This response indicates that maturity is controlled more by the moisture supply than by N. Evidence in this study and that of Drinkwater and Janes (3) indicates that heavy irrigation should be avoided to prevent delays in onion maturity.

The storage life as indicated by sprouting of the bulbs was shorter with high rates of N than with 0 N or low N rates for both irrigated and nonirrigated onions, but the response was less without irrigation. The onions grown with low N may have entered dormancy later (late maturity) and would emerge from dormancy later also, assuming the period of dormancy is somewhat constant for a given cultivar. However, limiting N to prolong the storage life of onions is not desirable because of simultaneous poor yields and later maturity. Irrigation did not have a marked effect on the storage life of onions in this study. However, Drinkwater and James (3) indicated that irrigation does improve the quality of the stored product, since irrigated onions lost a smaller percentage of their original stored wt than onions grown without irrigation.

The pattern of irrigation (5 cm/week) in this study, accompanied by frequent topdressings of N, indicates that N could be applied to the crop according to the amount of water the crop receives. This information would be useful in determining the amount of N which should be injected into or applied with an irrigation system. Since N is less effective and may be toxic under dry conditions, adding N in small quantities whenever moisture is present, may avoid any injury and waste which could occur with a single large application of N at the beginning of the season. Such a program would be more effective early in the season to stimulate the leaf growth of young plants, since large plants, before bulbing is initiated, generally produce larger bulbs at harvest than small plants. Nitrogen rates of 6 kg/ha and above applied after every 10 cm of irrigation or 11 kg/ha and above applied after every 20 cm of irrigation was sufficient to overcome the effects of heavy irrigation and provided yields comparable to onions grown with no irrigation. The highest yields and earliest maturity were obtained with 22 or 34 kg of N/ha/10 cm of water and 34 kg of N/ha/20 cm of water. Thus adequate recovery from leaching and other detrimental effects of high moisture might be obtained with rates of topdressing ranging from 8.5 to 17 kg of N/ha/5 cm of water received by the crop.

The most effective time interval to topdress appears to be from mid-June to mid-July or between 1½ to 2½ months after seeding. Five topdressings beginning June 25 were as effective as 6 to 8 topdressings starting earlier in the season in providing adequate yields and early maturity in irrigated onions since the N already present in the soil may have been adequate for seedling growth in May and early June. Four topdressings beginning on July 9 provided a satisfactory yield but the maturity was poorer than with treatments starting earlier. Less response was obtained from topdressings starting at times later than July 9. This indicates that only 1 or 2 topdressings in late June or early July may be necessary, but the continuity of the treatments to the end of the season may be important. Some resonse to the late topdressings was obtained which indicates some value in these treatments, but the plants may have suffered from N shortages and a full recovery may not have been possible.

Scheduling N applications according to the amount of water the crop receives offers some promise as a guide to applying N in areas with variable rainfall since soil and plant analysis for N are unreliable under these conditions. Water is related to leaching of N and utilization of N by plants, and correlating N applications with rainfall or irrigation should improve the efficiency of N applications and minimize N losses to the environment.

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# Electrical Conductivity of 'Shamouti' Orange Peel during Fruit Growth and Postharvest Senescence[1]

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*Abstract.* **Electrical conductivity (EC) measurements were carried out in orange (*Citrus sinensis* (L.) Osbeck) peel (with stainless steel electrodes penetrating 2 mm deep), during fruit growth and subsequent prolonged storage on shelf. Values at the equator were quite generally lower than at the stem and especially at the stylar ends. A curve showing two maxima, one at a very young fruitlet stage (late May) and the other two months before maturation was found. The decrease in EC toward maturation continued for some time postharvest while the water content of tissues decreased, but was followed by an increase with progressive tissue senescence. This last part of the curve is tentatively explained by an increased role of symplast conductance due to tissue aging.**

Electrical gradients are probably a major component of many physiological processes occurring in plant tissues (9). Easy-to-measure biophysical parameters for the evaluation of growth stages and viability of citrus fruits are badly needed. It seems therefore logical to test electrical conductivity (EC) of tissues as such a parameter. This has been done with peaches (10), with avocado (2), with pears (1), but no work has been carried out along these lines with oranges. The peculiar structure of a citrus fruit, a hesperidium with clear differentiation between a thick, spongy mesocarp and an endocarp composed of juice vesicles (i.e. not a tissue in the accepted meaning of the term), seems to lend a special interest to such studies with citrus fruits (7).

## Materials and Methods

Twenty-five 'Shamouti' oranges were picked at roughly monthly intervals from May to Dec., 1975 from 20-year-old trees, growing at B, in the coastal plain of Israel about 5 miles from the sea in loamy sand on sweet lime stock but inarched to sour orange.

Mature fruit from 2 existing preharvest experiments were used for the postharvest determinations during the 1974/75 season: a) 18-year-old trees on sweet lime stock on light sandy loam, also in the coastal plain at S, laid out in a randomized factorial layout with 2 regulator treatments × 5 irrigation schedules × 6 blocks with replicates of 1 tree each (Sasson and Monselise, in preparation). Trees were harvested Jan. 14, 1975. b) a randomized block layout with 5 growth regulator treatments × 4 blocks with replicates of 2 trees each at B. Trees were picked on Feb. 24, 1975. Fruits were tested at harvest and at monthly intervals after storage at 17°C. Composite samples of 16 fruits each were obtained from each of the 5 treatments at B and, of 24 fruits each from each of the 5 irrigation schedules at S.

EC was measured with a Conductivity Meter CDM2 of Radiometer N.V., Copenhagen, sensitive between 0 $\mu$mhos and

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