Effect of Deficit Irrigation on the Cost of Producing Native Spearmint Oil in Washington State

WASHINGTON STATE UNIVERSITY EXTENSION FACT SHEET • FS130E

Introduction

Irrigated agriculture is facing increasing competition for dwindling water resources, especially in the arid and semi-arid areas of the world. Potential water-saving strategies that limit water losses should be applied in agriculture today to ensure sustainable and efficient use of available water resources. One water-saving strategy is deficit irrigation. Deficit irrigation is defined as deliberately irrigating a crop with less water than it would use if it were being fully irrigated. Successful application of deficit irrigation requires knowing how a specific crop will respond to various water-stress levels. Also, it is important to know how deficit irrigation affects the profitability of these crops.

In this publication, we discuss the impact of deficit irrigation on the costs of producing native spearmint oil. Washington is the largest producer of mint oil in the United States. Mint is grown primarily for the oil produced from its foliage. Known commonly as mint hay, mint foliage is steam-distilled to produce the spearmint oil, which is used as a flavoring ingredient in chewing gum and confectionery products. It is also used in perfumes, dental products, and pharmaceutical products.

Effect of deficit irrigation on spearmint hay and oil yield

The relationship between native spearmint hay yield and water applied used in this study was derived from a field experiment conducted at Washington State University's Irrigated Agriculture Research and Extension Center (IAREC) near Prosser, Washington. The experiment was carried out to quantify the effect of deficit irrigation on native spearmint in terms of yield, quality, and financial return.

Native spearmint was grown for two years (2011 and 2012) using surface drip irrigation at four different water-stress levels, which were applied at different times during the crop's growth period. The four irrigation levels examined in this study were 40%, 54%, 80%, and 100% of the maximum crop-water requirement. (A level of 54% instead of 60% was used because the emitter specifications of the available drip tubing had an application rate equivalent to the 54% irrigation level). These irrigation levels were applied to various plots in the field throughout the crop's growing period. Other plots in the field were fully irrigated and the deficit-irrigation levels only applied 21, 14, and 14 days before harvest.

Mint hay yields decreased with increasing water stress, with the driest treatments producing the lowest hay yields. However, water stress did not significantly affect native spearmint oil yield or quality. Oil yield and quality were maintained, even though hay yields were reduced significantly with increasing water stress. This result suggests that water stress may have encouraged oil accumulation in the plant leaves. The increase in oil accumulation seen in mint leaves as water stress increased was confirmed by the increase in oil concentration (percentage mass (lb) of mint oil extracted per pound of hay) as water stress increased (Nakawuka et al. 2014).

Estimated annual expenses

The data on various production costs are provided in the native spearmint budget shown in Table 1. This cost information is based on the data contained in the WSU publication *2010 Cost of Producing Native and Scotch Spearmint under Rill and Center-Pivot Irrigation in Washington* (Gallardo 2011). Some adjustments were made to the values in the budget in order to better reflect drip-system installation and maintenance costs and also to reflect what growers consider to be the most recent costs in native spearmint establishment and production for the 2012 growing season. Growers can adjust these values to estimate their own production costs. Water stress during the establishment year should not be considered, since it would hinder proper establishment of the mint field and negatively affect growth and yield in subsequent years.

Economic analysis

Mint production costs are divided into two groups—direct (D) and switching (S) costs. Direct costs for this study were defined as those costs that are not affected by either changes in water use or hay yield.

Table 1. Production costs per acre for surface-drip-irrigated native spearmint under deficit irrigation. (Numbers circled in red correspond to numbers in Table 2.)

Costs (per acre)	Costs for Full Production* (Years 2–6)	Direct (D) or Switching (S) with Water Use	Adjustment Factor**	Annual Costs under Water-Stress Program***
Field Activities (chemical and application costs)				
Harrowing	—	D		—
Herbicide application	180.65	D		180.65
Fertilizing	256.46	D		256.46
Fertigation	137.38	D		137.38
Insecticide and fungicide application	68.95	D		68.95
Irrigation labor and water charge	90.00	D		90.00
Irrigation system annual repair and maintenance	15.00	D		15.00
Irrigation electricity charge (water-pumping costs)	92.00	S	40%	36.80
Weeding	10.00	D		10.00
Field border spraying	12.00	D		12.00
Harvest				
Removing and reinserting drip lines	80.00	D		80.00
Actual harvesting	76.38	D		76.38
Transporting and distillation of hay	563.62	S	79.33%	447.12
Market assessment	24.00	D		24.00
Residue disposal	40.00	S	79.33%	31.73
Maintenance and Repairs				
Machinery repair	44.02	D		44.02
Machinery fueling and lubrication	85.58	D		85.58
Other Costs				
Crop insurance	14.00	D		14.00
Land rent	310.00	D		310.00
Management charge	100.00	D		100.00
Total Cost (per acre)	**2,200.02**			**2,020.07**

*Column 2 shows costs of production under full irrigation (100%) for a full year of production.
**Column 4 shows the adjustment factor for a 40% irrigation level as calculated in Table 2. (Adjustment factors are multipliers to costs for a specified irrigation level compared to costs under full irrigation.)
***Column 5 shows costs of production after adjustment for the 40% irrigation level.

Direct costs include the following:

- Application of herbicides, fertilizers, insecticides, and fungicides
- Irrigation labor
- Water charges
- Irrigation system repair and maintenance
- Weeding and border spraying
- Market assessment
- Harvesting costs
- Machinery fueling, lubrication, and repair
- Crop insurance, land rent, and management charges.*

*The management charge is an opportunity cost for management during the production year.

Switching costs vary with water-use changes. In Washington State, individuals or groups are given water rights that permit them to use a predefined quantity of water per growing season. Water is charged at a fixed rate per acre; therefore, the cost of water per acre is constant. Only water-pumping costs vary directly with changes in water use.

Pumping costs depend on following factors:

- pumping lift
- fuel price
- pump discharge pressure
- pumping efficiency
- number of acre-inches of water applied during the growing season

Pumping costs were reduced in proportion to the reduction in the amount of water applied. For full irrigation (an irrigation level of 100%), the annual cost of pumping was estimated at $92 per acre (the average estimation of pumping costs based on the feedback from a sample of mint growers for the 2012 growing season). However, for an irrigation level of 54%, for instance, 46% of water was saved and pumping costs decreased by 46% to $49.68.

Costs for hauling hay to and from the field and the distillation unit, hay distillation, and residue disposal, all depend on hay yield. Since hay yield declines with increasing water stress, less hay will be transported and distilled. Fewer trips will be made to and from the field and the distillation unit, and there will be fewer residues to dispose of. The costs just quoted are therefore reduced in proportion to the reduction in hay yield due to water stress. A linear regression function was used to estimate hay yield per acre (h(w) in terms of water applied (w):

$$h(w) = 0.308w + 17.92$$

Study assumptions

In order to compare profitability between full irrigation and deficit irrigation, the following assumptions were made:

- Water-pumping costs were reduced in proportion to the reduction in applied water. The percentage reduction in water applied was compared to the maximum crop-water-use requirement.
- Costs for transporting hay, distillation, and residue disposal were reduced in proportion to the reduction in hay yield caused by water stress. Table 2 shows the percentage drop in hay production depending on the amount of water applied.
- Savings were calculated as the difference between the total cost of production under full irrigation and the total cost of production under water-stress conditions.
- The production practices described in the *WSU Extension Publication 2010 Cost of Producing Native and Scotch Spearmint under Rill and Center-Pivot Irrigation in Washington* (Gallardo 2011) were assumed.

Estimated savings in total cost of production

When the percentage reductions in costs from Table 2 are applied to the variable costs in the budget shown in Table 1, savings in annual total crop production costs can be estimated. Table 3 shows irrigation amounts and savings in both water and production costs for the irrigation levels that were examined in the study.

Water-stress risks

The benefits of deficit-irrigating native spearmint are significant (as shown in Table 3). However, there are risks associated with this irrigation practice. There is a limit to how much you can stress your native spearmint before the gains turn into losses. Our research shows that an irrigation deficit of up to 60% (using drip irrigation) is economically profitable. More severe water stress causes significant thinning of the plant stands, which could die out as the growing season progresses, thus affecting yield. Regrowth in subsequent years could also be affected.

Even with the recommended levels of water stress, growers are encouraged to irrigate fully at the beginning of the growing season and after each cutting. Full irrigation

Table 2. The effect of reduced amounts of water applied have on hay yield.* (Numbers circled in red correspond to numbers in Table 1.)

Paramaters	Value
Irrigation level (%)	40%
Acre-inches of water under full irrigation	30.58
Acre-inches of water under water stress	12.23
Tons of hay produced under full irrigation	27.34
Tons of hay produced under water stress	21.69
Reduction in hay production (%)	20.67%
Hay produced under water stress compared to full irrigation	79.33%

*Amounts of water applied and hay yield are estimated for a one-acre farm.

Table 3. Irrigation amounts applied and water and cost savings for the different irrigation levels.

Irrigation level (%)	Acre-inches applied	Acre-inches saved	Total cost of production ($)	Cost savings (%)	Dollar amount saved ($)
40	12.2	18.4	2,020	8.2%	180
54	16.5	14.1	2,062	6.3%	138
80	24.5	6.1	2,140	2.7%	60
100	30.6	0.0	2,200	0.0%	0

at these times provides the plant with enough water to develop a strong stand that can tolerate water stress later in the season. Fully irrigating at the end of the growing season prevents winter freeze damage to roots and ensures the next year's spring vigor.

Since water stress causes reductions in hay yields, there is more room for weeds to grow. Pressure from weeds could increase with increasing water stress. Thus, growers need to be vigilant in controlling weeds throughout the season in water-stressed fields.

Summary

In order to maximize grower profits, both production costs and revenues have to be considered. Revenue (that is, yield multiplied by the crop price) minus total cost of production equals the grower's net profit. Applying up to 60% less water to native spearmint plants can yield similar oil quantity and quality to that obtained from fully irrigated plants. However, some costs of production vary with the amount of water applied and/or hay yield. Costs can be reduced by reducing the amount of irrigation, which increases net farm income. Therefore, deficit irrigation has the potential to increase grower profits when properly managed.

Growers can use the results of this study as a starting point for estimating how the costs in their enterprises will be affected by a reduction in water applied. Since several growers may be using other irrigation systems, such as center pivots, they should adjust the costs in the budget to suit their farms. The reader is advised to closely examine the procedures and the assumptions used in this fact sheet and adjust costs to reflect their own situation.

Acknowledgement

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By **Prossie Nakawuka**, Post-Doctoral Research Associate, WSU Prosser Irrigated Agriculture Research & Extension Center; **Troy Peters**, Extension Irrigation Specialist, WSU Prosser Irrigated Agriculture Research & Extension Center; and **Karina Gallardo**, Assistant Professor and Extension Specialist, School of Economic Sciences, Tree Fruit Research and Extension Center, Center for Precision and Automated Agricultural Systems, Washington State University, Wenatchee, WA .

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