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PROJECT TITLE

Optimizing sub-surface drip irrigation and living-mulches for enhanced profitability in Michigan asparagus

PROJECT SUMMARY

Key problems addressed:

Michigan asparagus growers face a number of economic and biological challenges that threaten the viability of the industry including 1) increased incidence of heat and drought stress and 2) limited availability of suitable, disease-free land.

Drought stress. The increased incidence of heat and drought stress in recent years has contributed to declines in asparagus fern health and yield. Although asparagus is deep rooted and drought tolerant compared to many crops, dry conditions during fern growth can 1) directly reduce crop yields the following year through reductions in photosynthesis and production of soluble carbohydrates (Drost 1999) and 2) indirectly lower yields by reducing crop resilience to diseases that increasingly plague the Michigan asparagus industry (Hausbeck, unpublished). Rainfall patterns in Michigan over the past 15 years suggest that rainfall does not provide sufficient moisture to compensate for evapo-transpirational losses during peak asparagus fern growth, and that timely irrigation is likely to boost yields. During harvest, irrigation may have the added benefit of cooling spears and reducing the risk of heading out due to heat stress. This potential improvement in spear quality is increasingly important as growers move towards more fresh market production. Recognizing the potential benefits of irrigation, Michigan asparagus growers have begun installing irrigation systems, but little information is available to help them with their irrigation decision making.

Limited availability of suitable, disease-free land. For profitable production, asparagus requires sandy soils and microclimates typical of Western Michigan. Much of the prime land for asparagus production has been farmed with asparagus for decades, forcing growers to replant into fields that may have elevated levels of disease (e.g. *Phytophthora* and *Fusarium*) or phytotoxins that can limit asparagus productivity. More efficient use of limited land is an important component for maintaining the long-term viability of the Michigan asparagus industry. Irrigation can improve land-use efficiency by facilitating higher planting densities and by maintaining dense stands through reduction in drought and disease stress.

Irrigation can also facilitate adoption of complementary management practices which maintain and enhance soil quality and ultimately spear quality and yield. In irrigated asparagus production, cover crops may be grown during the fern stage with minimal risk of competition for water. In these “living mulch” systems, cover crops growing beneath the asparagus canopy can protect the soil from wind and rain erosion, add organic

matter, fix or recycle nutrients and suppress weeds. During harvest, residue remaining from these cover crops can help reduce the risk of sand-blasted and curved spears due to windblown and rain-splashed sand. As with irrigation, several innovative growers are experimenting with living mulch systems, but information on the likely impacts of living mulches on soil moisture content, weed suppression, soil health and asparagus yields is not currently available.

PROJECT APPROACH

Objective 1. Overhead and sub-surface drip irrigation. A field experiment was initiated in 2010 in Hart, MI examining irrigation (none, overhead or subs-surface drip) effects on two varieties of asparagus (Guelph Millenium and Jersey Supreme). Crowns were planted at a density of approximately 16,600 crowns per acre in spring 2010. Sub-surface drip tubing was placed below the crowns at planting. In 2011, 0.5"-1" inch of irrigation was applied per event at approximately weekly intervals during dry periods in July and August. Volumetric soil moisture content was monitored at multiple depths with a Diviner 2000 soil moisture probe throughout the summer. In addition, light interception by the developing fern was estimated by measuring photo-synthetically active radiation (PAR) above and below the canopy. Asparagus fern was sampled on 10/4, dried, separated into cladophyll (leaf-like modified petioles) and stem tissue and weighed. A visual rating of purple spot severity and the number of mature marestalk (*Conyza canadensis*) plants per plot were assessed in August.

Objective 2. Irrigation and Living Mulch. A field trial was initiated at the Asparagus Research Farm in Hart, MI in asparagus (cultivar "Jersey Giant") that had been established from crowns in 1999. Following the final asparagus harvest in late June, four experimental treatments were established consisting of two different management systems (conventional vs living mulch), each with two levels of irrigation (no irrigation vs irrigation) (Table 1). The same management systems were maintained in the same plots each year from 2008-2010.

Table 1. Summary of treatments examined

	Irrigation	Cover	Tillage	PRE herbicides
1. Herbicide/No irrigation	No	None	No	Dual/Spartan/Karmex
2. Herbicide/Irrigation	Yes	None	No	Dual/Spartan/Karmex
3. Living Mulch/No irrigation	No	Rye	Yes	None
4. Living Mulch/Irrigation	Yes	Rye	Yes	None

Six replicates of each treatment were included in plots measuring 25' x 13.5', with 3 rows of asparagus spaced 4.5' apart in each plot. The herbicide system consisted of no-tillage with application of a tank-mix of Roundup (1 Q/A), Dual (1.5

pt/A), Spartan (4 oz/A) and Karmex (1.2 lbs/A). In the living-mulch system, winter rye (*Secale cereale*) was broadcast at 3 bu/A and a roto-tiller was used to simultaneously kill weeds and incorporate rye to a depth of 1-2". No residual herbicides were used in the living-mulch system, and no post emergence herbicides were used in either system. Irrigation was accomplished using 7 micro-sprinklers per plot to simulate overhead irrigation. Soil moisture sensors (EC-5 sensors, Decagon Devices) were installed at 6" and 24" in 4 replicates of each treatment to monitor soil volumetric water content (VWC). Irrigation was used initially to establish rye, and then to maintain VWC at or above 50% of available water through the middle of August. On the sandy soils of the experimental site, field capacity was approximately 11% VWC and the permanent wilting point approximately 5% VWC at 24" depth.

Weed density, rye dry weight, rye number and fern stem number were assessed in early September. Weed density was evaluated by counting the number of weeds greater than 12" in height (for erect weeds) or diameter (for rosette/spreading weeds) in the entire plot. Asparagus yield was assessed from the middle row of each plot during 18 harvest events in spring 2009 and 25 harvest events in spring 2010.

Objective 3. Economics of irrigation. The costs of irrigation were estimated using a variety of sources including field data collected from the experiments described above, and conversations with growers and suppliers. Long-term average annual yield increases required to justify irrigation expenditures were calculated based on multiple assumptions about future costs and asparagus prices. Calculations were based on a 20 acre field with sub-surface drip irrigation, or a 40 acre field with center pivot irrigation. For buried trickle it was assumed that tubing was placed below every row at a cost of \$1200/acre (\$24,000 total investment). For center pivot systems it was assumed that a 8" well was required and that the total cost to irrigate was \$1,910/acre (\$63,000 total investment). Monte-Carlo simulations were run using historic weather data to generate a distribution of expected returns under different assumptions about yield improvements with irrigation.

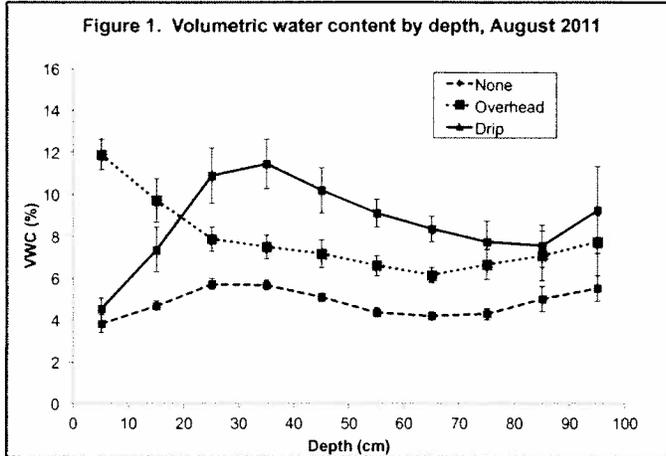
GOALS AND OUTCOMES ACHIEVED

Goals and Objectives. The goal of this proposed research was to improve the quality, yield and profitability of Michigan asparagus production. Specific objectives to accomplish this goal were:

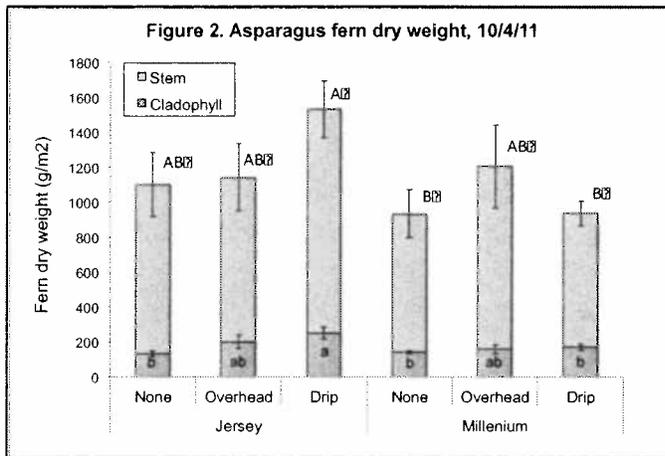
- 1) *Assess the impact of overhead and sub-surface drip irrigation systems on yield of two asparagus varieties.*
- 2) *Evaluate the impact of irrigation and living-mulches on asparagus yield, weed management and soil quality.*

3) Evaluate the economic costs and benefits of overhead and sub-surface drip irrigation for Michigan asparagus.

Objective 1 Outcomes. Overhead and subsurface drip irrigation.



than that of Guelph Millenium (Figure 2).



responsive to sub-surface drip irrigation compared to overhead irrigation, and vice-versa for Guelph Millenium.

Soil water content and distribution.

Soil volumetric water content in irrigated treatments was significantly higher than in the un-irrigated control for much of August. Overhead irrigation resulted in higher soil moisture at the surface, but lower soil moisture at depth compared to sub-surface drip irrigation (Figure 1).

Fern growth and dry weight.

Jersey Supreme fern dry weight was greater than that of Guelph Millenium (Figure 2). Sub-surface drip irrigation increased cladophyll dry weight of Jersey Supreme. No statistically significant effect of irrigation on total fern dry weight was detected for either variety (Figure 2). However, irrigation resulted in reduced light penetration below the fern (Figure 3), indicating that fern leaf area was significantly increased under irrigation. Trends in both fern dry weight and light penetration suggest that Jersey Supreme fern growth may be more

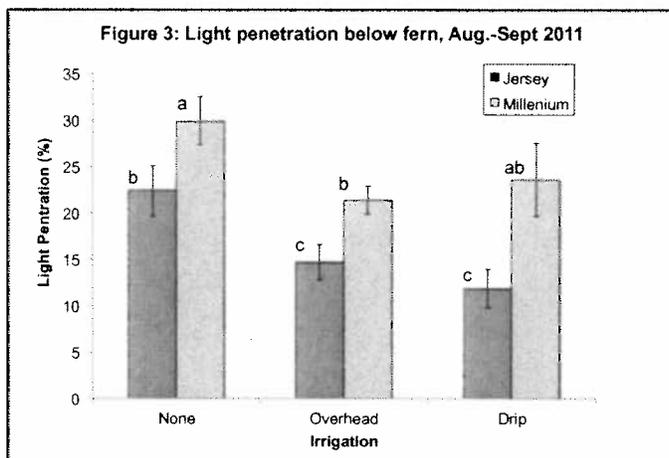
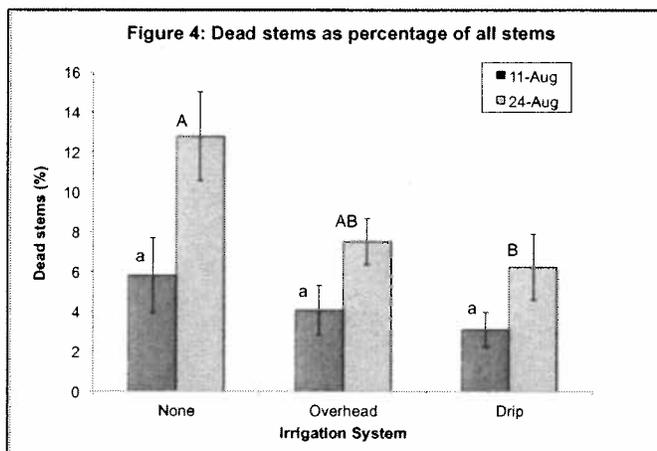


Table 1. Purple spot visual rating and marestalk density, August 2011.

	Purple spot rating ¹	Marestalk Density
	-----0-10-----	--#/100ft ² --
Jersey Supreme		
No irrigation	4.9 a	2.8 a
Overhead	4.3 a	3.0 a
Sub-surface drip	4.4 a	3.4 a
Guelph Millenium		
No irrigation	4.8 a	10.4 b
Overhead	4.8 a	5.0 ab
Sub-surface drip	4.3 a	6.9 b

¹ Scale from 0-10; 0=no disease; 10=severe

Irrigation effects on weeds, purple spot and stem death. We had anticipated that overhead irrigation might increase purple spot severity by increasing leaf wetness relative to sub-surface drip and non-irrigated treatments. However, no detectable effect of irrigation on purple spot was detected for either variety in 2011 (Table 1). We also hypothesized that overhead irrigation would promote weed growth by increasing moisture availability at the soil surface. However, no effect of irrigation on weeds was detected (Table 1). Interestingly, marestalk density was higher in Guelph Millenium treatments relative to Jersey Supreme treatments (Table 1), presumably due to greater light penetration (Figure 3) under the smaller Millenium fern. The number of dead stems increased during the month of August, with the greatest increase occurring in the non-irrigated treatments (Figure 4). By the end of August, approximately 13% of stems in non-irrigated controls had died, compared to approximately 7% in irrigated treatments (Figure 4).



Objective 2 Results. Irrigation and Living Mulch.

Irrigation, rainfall and soil water content. Without irrigation, soil VWC at 24" in rye living mulch treatments was approximately 2% below the bare soil treatment during August (6-8 wks after sowing) (Figure 1), resulting in prolonged periods near the permanent wilting point in 2008 and 2009. In irrigated treatments, VWC was maintained at or above 50% available water (8% VWC), with the exception of 2008, when VWC fell

to 4-5% in all treatments by late August, before heavy rainfall and cool temperatures in September restored VWC to field capacity. In 2008 and 2009 VWC ranked in the following order: Bare+irrigation > Bare = Rye+irrigation > Rye. In 2010, steady rainfall throughout the summer resulted in little need for irrigation, and few differences in soil VWC between treatments.

Living mulch failed to control summer annual weeds after 3 years. The dominant weed species during fern growth were Powell amaranth (*Amaranthus powellii*) and sandbur (*Cenchrus longispinus*). In 2008, densities of sandbur were slightly higher in rye living mulch compared to herbicide treatments (Table 1). In 2009, cooler conditions resulted in more vigorous rye growth, and both weed species were suppressed by rye, resulting in no differences in weed density between treatments. However, in 2010, densities of both Powell amaranth and sandbur were much higher in rye living mulch treatments compared to herbicide treatments. Failure of rye living mulch to suppress weeds in 2010 was likely the result of 1) poor rye establishment due to unusually high temperatures in 2010, and 2) higher weed seedbanks of these species resulting from higher weed seed production in previous years. Although Powell amaranth could have been controlled with an application of a post-emergence herbicide like Sandea, grasses like sandbur pose a challenge in fields where rye living mulches are used, since graminicides that kill sandbur, would also likely kill the rye living mulch.

Table 2. Effects of irrigation and rye on weeds in late summer, 2008-2010

	Total			Powell amaranth			Sandbur		
	2008	2009	2010	2008	2009	2010 ^b	2008	2009	2010
	-----Plants/m ² -----								
Herbicide/no-till									
Not irrigated	0.14 b	0.24 a	0.12 c	0.08 b	0.12 a	0.11 c	0.03 b	0.13 a	0.02 b
Irrigated	0.48 ab	0.26 a	0.46 b	0.29 ab	0.09 a	0.44 b	0.10 b	0.18 a	0.02 b
Rye (June) /till									
Not irrigated	0.58 ab	0.53 a	3.74 a	0.11 b	0.35 a	2.42 a	0.47 a	0.18 a	1.32 a
Irrigated	0.73 a	0.45 a	3.26 a	0.53 a	0.26 a	1.99 a	0.20 ab	0.19 a	1.27 a

Note: Only weeds greater than 1' in height or diameter were included

Column means with a letter in common are not significantly different (Fisher LSD Method; $P=0.05$)

Living mulch helped suppress marestalk but not sandbur when herbicides dissipated. The dominant weed species during asparagus harvest were marestalk (*Conyza canadensis*), sandbur and Powell amaranth in 2010 (Figure 2). In 2008 and 2009, all three species were well controlled with a standard combination of burndown and pre-emergence herbicides applied in early spring. However, in 2010, PRE herbicides failed to provide adequate control and differences in weed populations under rye living mulch

and herbicide treatments were readily apparent by early June. Under these circumstances, marestail populations were lower where rye living mulch was grown, while sandbur populations were higher (Figure 2). The suppressive effect of rye living mulch on marestail in 2010 was likely due to the presence of a heavy rye residue in late summer of 2009, which prevented marestail from establishing successfully. Rye living mulch had a similar suppressive effect on dandelion, although dandelion did not become a problem in asparagus during this study.

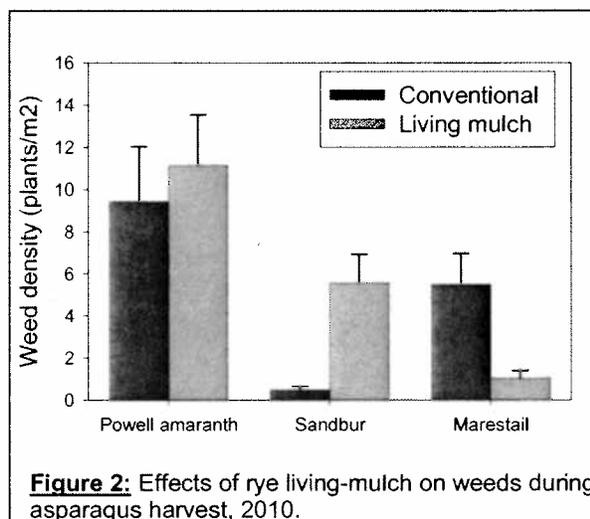


Figure 2: Effects of rye living-mulch on weeds during asparagus harvest, 2010.

Asparagus yields were not affected. Neither irrigation nor rye living mulch had any detectable effect on asparagus yield in the 2009 and 2010 seasons (Figure 3). However, large variability in fern health across the experimental site made it difficult to adequately assess yield effects. Our soil moisture data suggests that rye living mulch (without irrigation) increases the risk of drought stress of asparagus fern during late summer. In warm years (like 2010), rye living mulch is also unlikely to adequately suppress summer annual weeds, thus posing risks of weed-asparagus competition unless supplemental herbicides are used. On the other hand, rye living mulches used in combination with irrigation pose fewer risks, and may benefit asparagus through increases in soil organic matter and reductions in soil erosion. Long term research is needed to better understand the potential effects of living mulches and irrigation on asparagus. Research assessing alternative cover crop species, different methods of irrigation (e.g. sub-surface drip) and complementary weed management practices may prove beneficial for improving the resilience of asparagus to stress and increasing farm profitability.

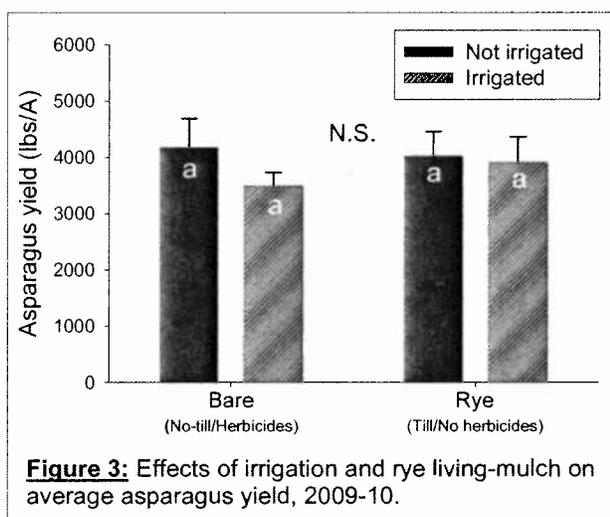


Figure 3: Effects of irrigation and rye living-mulch on average asparagus yield, 2009-10.

Objective 3 Results. Economics of irrigation. The estimated profit associated with different irrigation systems depended on assumptions about: asparagus prices; yield improvements associated with irrigation; costs of irrigation; and weather patterns.

Estimated yield increases from irrigation required to justify costs ranged from 5 to 10% under most reasonable assumptions (see Figure 4). Such yield improvements were not observed in the 2009 and 2010 growing seasons in experiments associated with Objective 2. However, these experiments were conducted in a mature stand of Jersey Giant during growing seasons with above average rainfall. We anticipate that increases in stem and cladophyll growth observed in experiments associated with Objective 1 may result in substantial yield improvements, particularly for Jersey Supreme under sub-surface drip irrigation. Moreover, we believe that indirect yield benefits derived from irrigation systems in which fertilizers and pesticides are applied through the irrigation system are likely to further boost yields and profits of irrigated asparagus.

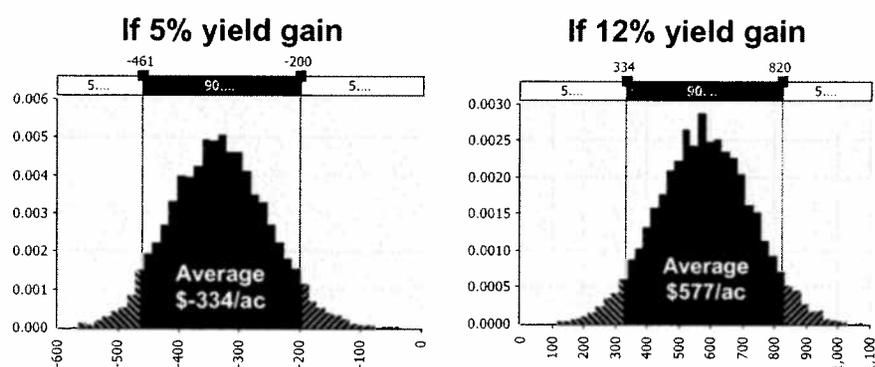


Figure 4. Estimated returns from an investment in sub-surface drip irrigation under low (L) and high (R) assumptions regarding yield improvements of irrigation under drought stress.

BENEFICIARIES

The primary beneficiaries of this project are asparagus growers and their employees in the state of Michigan. In 2009, there were 220 asparagus farms with 10,700 acres in production and cash receipts of \$16.5 million (The Packer; 4/12/2010). Michigan is second only to California in asparagus acreage, and a close third to Washington in value. Improvements in asparagus resilience to drought and disease pressure will help improve the profitability of asparagus producers in both the short and longer term. A 5-10% increase in crop yields due to irrigation and associated practices would directly increase cash receipts to asparagus growers by over \$1 million annually.

Asparagus producers also grow a diversity of other specialty crops including cherries, peaches, apples, carrots, squash, pickles, sweet corn and Christmas trees. For many of these operations, maintaining profitable asparagus production is critical since it attracts the labor force needed to maintain and harvest all the following crops. While the economic value of these operations is difficult to estimate, the benefits they provide the Michigan economy in terms of employment and income generation far exceeds the cash receipts directly associated with asparagus production.

LESSONS LEARNED

Objective 1. Irrigation resulted in increases in light interception, stem growth, cladophyll growth, and root soluble carbohydrates, all of which are anticipated to contribute to increased yields in asparagus in 2012 and beyond. Our results also suggest that sub-surface drip irrigation will have several advantages relative to overhead irrigation including reduced water- and energy-use, lower weed and disease pressure and higher crop yields following dry years. We expect that these effects will vary with asparagus variety and with weather conditions. Information from this trial will help growers understand the circumstances under which irrigation is likely to improve profitability, and help growers get the greatest benefit from irrigation systems. Based in part on observations of our field trials, several influential growers have begun investing in irrigation, and we anticipate that adoption will continue, resulting in improvements in the profitability and sustainability of asparagus production in Michigan.

Outcomes for Objective 2. Our results suggest that 1) soil-improving rye cover crops can partially suppress weeds but may also compete with asparagus for soil moisture in dry years unless irrigation is used; and 2) successful use of rye living mulches for weed management will depend on identification of complementary weed management practices to avoid build-up of the summer annual weed seedbank.

Outcomes for Objective 3. Our economic analysis of irrigation systems for asparagus is helping growers decide whether to invest in irrigation systems, as well as which systems and complementary practices are likely to provide the greatest benefits. Ultimately, we anticipate that this information will improve profitability of asparagus production in Michigan by reducing drought stress, improving crop resilience to disease, and enhancing opportunities for soil improvement through cover cropping.

PUBLICATIONS AND PRESENTATIONS

Brainard, D.C., J. Bakker, N. Myers and D.C. Noyes. 2012. Rye living-mulch effects on soil moisture and weeds in asparagus. *HortScience* 47:58-63.

Brainard, D.C. and B. Byl. 2011. "Sub-surface drip and overhead irrigation effects on Jersey Supreme and Guelph Millenium". Great Lakes Fruit, Vegetable, and Farm Market Expo, Grand Rapids, MI, December.

Brainard, D.C. and B. Byl. 2011. "Irrigation research update". Oceana Vegetable Research Tour. Hart, MI, September.

Brainard, D.C. 2011. Rye living-mulch effects on soil moisture and weeds in asparagus. ASHS Annual Conference, Waikoloa, HA, September 25-28. HortScience 46(9): S216

Brainard, D. C. and B. Byl. 2010. "Irrigation and Rye Living-mulch in Asparagus Production". Great Lakes Fruit, Vegetable, and Farm Market Expo, Grand Rapids, MI, December x.

Brainard, D.C. 2010. Carrot and Asparagus Research Update. Consultant's Breakfast. MSUE Extension Office, Hart, MI., June 28, 2010.

Popular Press Articles featuring asparagus research:

Vegetable Growers News. 2011. Featured article July 14. "Irrigation experiments continue at MSU asparagus field. Website:

<http://vegetablegrowersnews.com/index.php/magazine/article/i/>

Brainard, D.C. 2011. Irrigating asparagus has its advantages. *Vegetable Growers News.* April 15. Website:

<http://vegetablegrowersnews.com/index.php/magazine/article/irrigating-asparagus-has-its-advantages>