Welcome to the

2006 INTERNATIONAL SPINACH CONFERENCE

13-14 July 2006

Maple Hall, La Conner
Washington, USA

2006 INTERNATIONAL SPINACH CONFERENCE
13-14 July 2006, La Conner, WA

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ACKNOWLEDGEMENTS & SPONSORS

The organizing committee of the 2006 International Spinach Conference includes **Lindsey du Toit, Tim Miller, Louise Brissey, Mike Derie, and Carl Libbey from the Washington State University Mount Vernon NWREC**. The committee expresses their appreciation to the many sponsors, without who's support this conference would not be possible. The committee particularly thanks **Mel Aoki** from Alf Christianson Seed Co. for recruiting sponsorship from California and Arizona.

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PROGRAM

Thursday, 13th July 2006

8:00-8:30 am: Registration at Maple Hall, La Conner. Coffee, tea, juice, and refreshments provided **courtesy of Ag Alternatives and Skagit Seed Services**. The proceedings book is sponsored by **HelmAgro**.

Oral presentations

General Production

8:30-9:15 am: *Puget Sound Vegetable Seed Production: Past and Present*. Tyler Clark, Ag Alternatives; and Kirby Johnson, Seed Grower and President of the Puget Sound Seed Growers' Association. (Abstract on pages 8-12)

9:15-9:45 am: *Spinach Seed Production in Denmark.* Lise Christina Deleuran and Birte Boelt, Danish Institute of Agricultural Sciences. (Abstract on pages 13-15)

9:45-10:15 am: *History of Spinach Production in the United States.* Teddy Morelock and Jim Correll, University of Arkansas. (Abstract on page 16)

10:15-10:45 am: Refreshment break.

Weed Control

10:45-11:15 am: *Coordinated Research for Leafy Vegetable Weed Control in the U.S.* Lynn Brandenberger, Oklahoma State University. (Abstract on page 17)

11:15-11:45 am: *Weed Control in Spinach Seed Production.* Tim Miller, Washington State University. (Abstract on page 18)

Horticulture

11:45 am -12:15 pm: *Evaluation of Various Fertilizer Regimes for Spinach.* Larry Stein, Texas Cooperative Extension. (Abstract on page 19)

12:15 –1:30 pm: **BBQ lunch at Maple Hall, courtesy of Alf Christianson Seed Co.**

Plant Pathology

1:30-2:00 pm: *Overview of Races of the Downy Mildew Pathogen on Spinach and Efforts to Develop Molecular Markers Linked to Disease Resistance Loci.* Jim C. Correll, C. Feng, S.T. Koike, T.C. Bentley, A.N. Tomlinson, B.M. Irish, and T.E. Morelock, University of Arkansas. (Abstract on page 20)

2:00-2:30 pm: *Genetic Mapping and Identification of Important Traits in Spinach Using a Genomic BAC Library.* Abel N. Tomlinson, J.C. Correll, C. Feng, and B.M. Irish, University of Arkansas. (Abstract on page 21)

2:30-3:00 pm: *Efficacy of Mustard Cover/Biofumigant Crops for Management of Weeds and Fusarium Wilt in Spinach Seed Production.* Lindsey du Toit and Tim Miller, Washington State University. (Abstract on pages 22-25)

3:00-3:30 pm: Refreshment break.

3:30-4:00 pm: *Efficacy of Seed Treatments for Control of* Stemphylium botryosum *in Spinach.* Lindsey du Toit, Mike Derie, and Louise Brissey, Washington State University. (Abstract on pages 26-28)

4:00-4:30 pm: *Screening for Resistance to Stemphylium Leaf Spot of Spinach.* Beiquan Mou, USDA; Steven T. Koike, University of California; and Lindsey J. du Toit, Washington State University. (Abstract on pages 29-30)

4:00-5:00 pm: **View posters & spinach plant disease demonstration.**

Posters

Generation of an Open Pollinated Near-Isogenic Spinach Line with Homozygous Resistance to the Downy Mildew Pathogen. Traven C. Bentley, B.M. Irish, and J.C. Correll. (Abstract on page 31)

Genetic and Molecular Characterization of Isolates of Verticillium dahliae. Maria I. Villarroel, L.J. du Toit, and J.C. Correll. (Abstract on page 32)

Electron Beam Irradiation as a Tool to Improve Food Safety and Extend Shelf-Life. Frank Dainello, Texas A&M University. (Abstract on page 33)

Spring 2006 Spinach Preemergence Herbicide Screening Study. Lynn Brandenberger and L.K. Wells, Oklahoma State University. (Abstract on pages 34-35)

6:00-8:00 pm: Reception (snacks and no-host bar) at La Conner Seafood & Steakhouse in La Conner **courtesy of Osborne International Seed Co., Bejo Seeds, Inc., and Schafer Ag Services.**

>8:00 pm: Dinner in La Conner (at your own expense). La Conner has many good restaurants within walking distance of Maple Hall, La Conner Country Inn, and La Conner Channel Lodge.

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FIELD TOUR

Friday, 14th July 2006

The field tour and lunch have generously been sponsored by

Gowan Seed Co., Keithly-Williams Seed Co., Santa Clara Seeds, Santa Maria Seeds, Schafer Ag Services, Snow Seed Co., & TS&L Seed Co.

7:30-8:00 am:	Board tour buses at La Conner Country Inn.
8:00–9:00 am:	Tour Skagit Seed Services seed cleaning, conditioning, and treatment facility, La Conner, WA.
9:00-10:30 am:	Tour spinach, cabbage, mustard, and red beet seed crops in Skagit Valley
10:30 am–12:00 pm:	Tour Alf Christianson Seed Co. seed cleaning, conditioning, and treatment facility, Mount Vernon, WA.
12:00-12:30 pm:	Drive to Bowman Bay, Deception Pass State Park.
12:30-2:00 pm:	Lunch at Bowman Bay, Deception Pass State Park.
2:00-4:00 pm:	Tour additional seed crops and research trials on Whidbey Island and Skagit Co.
4:00-5:00 pm:	Return to La Conner.

The drive to SeaTac International Airport from La Conner takes ~2 hours. Traffic can be slow through Seattle on Friday evening. One tour bus may return to La Conner immediately after lunch for those who need to depart for SeaTac Airport in the early afternoon.

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FIELD TOUR MAP

Puget Sound Vegetable Seed Production: Past & Present

Tyler Clark, Ag Alternatives, LLC, Sedro-Woolley, WA; and
Kirby Johnson, President of the Puget Sound Seed Growers' Association, Mount Vernon, WA.

Introduction and Orientation:

Washington State may be best known for apples and wheat, and more recently wine; however the small-seeded vegetable seed grown in this state is the foundation for a major share of vegetable production in the United States and worldwide. There are two major seed production areas in Washington: Puget Sound and the Columbia Basin, which together account for more than 15,000 acres of seed production. The major seed crops are: table beet, cabbage and related brassicas, carrot, onion, Radish, spinach and many herb seeds such as coriander, dill, and parsley. This presentation will feature the Puget Sound region with a special emphasis on the Skagit Valley.

The heart of the Puget Sound seed industry is the Skagit Valley with its rich alluvial soils. The valley is located 60 miles north of Seattle at latitude 49^{o}N, which is similar in latitude to Paris, France. The Skagit River, which spills out of the North Cascades mountain range, is the most dominant feature of the Valley and provides approximately one-third of the fresh water that enters Puget Sound. Winters are cool and rainy with 80% of the average annual rainfall occurring between October and May. Summers average a comfortable temperature range of 19-24^{o}C and, together with the low rainfall during this period, make for excellent seed production conditions.

Month	Avg. Precipitation (centimeters)	Avg. Temp (^{o} Celsius)
January	10.7	4.1
February	7.6	5.8
March	6.9	7.2
April	6.4	9.1
May	5.5	12.0
June	4.5	14.7
July	3.2	16.4
August	3.7	16.8
September	5.1	14.2
October	7.5	10.4
November	10.9	6.8
December	10.7	4.4

Source: WSU/Skagit Co. Cooperative Extension, 40-Year Norms

History:

The United States vegetable seed industry began on the East Coast. Over time, however, the hot and humid climate proved less than ideal for many crops. In the late 1880's, the vegetable seed industry began it's westward migration towards Washington State, while seed marketing operations remained on the East Coast.

Washington's seed industry predates statehood. The oldest seed company is believed to be the Tillinghast Seed Company, founded in 1885 by Alvinza Gardner Tillinghast in Padilla, Washington. Mr. Tillinghast moved to the West from Pennsylvania and began his business initially by purchasing seed from eastern companies for packaging and sale. After the company moved to La Conner, Washington, Tillinghast began contracting with local farmers for cabbage seed production. In 1985, the Skagit County/WSU Extension Agent, Marvin Jarmin interviewed some of the "old timers" of the seed industry to document and honor the seed industry for the 75th diamond anniversary of the Western Washington Horticulture Association.

During the next few minutes you will hear narration by: Alf Christianson Jr., who's father emigrated from Sweden and founded Alf Christianson Seed Company in 1926; Austin Swanson, a local seed grower; Dorothy Leckenby, who's family established Leckenby Seed Co.; and Clyde Whittaker, who was a WSU horticulturalist from the 1930's thru the 1960's. These pictures will show some of the early cabbage, beet and spinach seed production up to about 1945.

"Lily was one of the largest seed growers in the US, if not the largest, I'm sure of that. They were situated in Seattle. These ladies would sit there all day long and these little machines with an endless belt with a treadle type. The early ones were a treadle type, like the old sewing machines, that they would run with their feet. Then we really made a big leap forward when they put a little motor on a shaft that ran through all these machines and they ran with a motor."

"Ned and Jim went together and called it Leckenby Seed, which was an outgrowth of the Lily Co. Most of what I did was with the Leckenby Seed from 1935, 1936, on. And before that I was familiar with the stuff because I had tramped around here with my father."

"They put seeds in packets and put some right here where people could reach in and grab 'em themselves and then they could sell more seeds retail than they would where they had to measure these things out. And so they started putting them in the dime stores and found that the next development was they made their own racks and they developed them already set up."

"This is my father and the model T Coupe I used to ride in when I was about 6-8 years old and I would go with him out to the different cabbage fields."

"In the older days our cabbage was all open-pollinated. There was no hybrid cabbage. While we had no herbicides our labor costs were, you might say, minimal compared to now. If you paid 25 cent per hour for your labor you could do quite a bit of that handwork."

"We staked and strung all of our cabbage, and while our rows were wider, we had quite good yields most of the time. We didn't have the insects to contend with or the disease that we have now."

"They had a single row planter with a few horses pulling it and a barrel for the water. I have been told that in the old days some of the boys kept their beer and whiskey in the barrel to keep it

cool. And one fellow got so drunk that they had to set him in the seat, but he was able to plant anyway, by instinct I guess."

"In those days if a man had 10 acres of cabbage it was a lot because it was all done by hand. It was cut by hand, cultivated with horses and it took time. And the trashing with those old combines was nothing like it is today. They're thrashing cabbage; they'd bring it in on sleds with a horse and pitch it off by hand. It was all hand labor then."

"At first I remember that if you couldn't use a pitchfork, so you took one cabbage stake and put it under the pile with your hand on top and lifted it into the basket and when you had a load you went up to the trashing machine and drove along side and this basket or what you could call it got on the back side and just tipped it over and the cabbage seed rolled out onto the canvas that was laid out in front of the feeder on the thrashing machine."

"One of the comments made by Jim Hulbert Sr. at the time, was that the dominant wind direction was from the southwest toward the northeast and the thrashing of the vegetable seed or grains seeds, either one, they would point the spout of the thrashing machine toward Mt. Baker. That would get away from the backfall of the residue and dust from the thrashing operation."

"Some of the main hazards of the cabbage seed production in the 1930s & 40s era was called black blight. Sclerotinia was a problem from year to year in the residue of the stalks and one of the cures that was recommended at the time by the research people was to burn the stacks and that became a problem during the war because of the restrictions of fire."

"In the years of 1935-45 was a period when production of vegetable seeds was particularly low. It was a known factor that it was low, but the need was there. Just what was the cause of the need was an unknown factor at the time. A study was made of the production of cabbage seed and table beet seed and it was found that the average production of cabbage seed was about 300-400 lbs per acre and table beet seed production was about 208 lbs. Research work was established because of that need and the interest was widespread in the NW, as well as, clear back to Washington DC because of the need of production of foodstuffs during and after the war. Representatives were sent here from Washington DC and from Wisconsin, and from that start it was established a widespread interest because if this disease factor, and a man was sent in here to make a study of that. Within a period of about 3-4 years the cabbage seed yield was raised from that 300-400 lbs/acre to about 1000 lbs/acre, and table beet seed yield was raised from 208 to about 800 lbs. That created a widespread interest in the production of it, and there was a little bit of dollar return to the man who was trying to produce it on the farm. Without that study and that research work it is doubtful that we would have research work being done here at the WSU Mount Vernon Research Center."

The Post War Era:

In the post-war era of the 1950's, the vegetable seed industry continued to expand and field sizes increased as many small companies started operating in the area. Farm machinery was improving which facilitated ground preparation, but the majority of cultural work in cabbage fields was still accomplished with hand-labor. Domestic seed companies were the primary contractors but interest from European companies was starting to pick up. Beet and cabbage seed production remained the most important seed crops. Spinach seed continued to be produced but did not represent significant acreage. All of the varieties produced were open-pollinated.

The 1960's and the Introduction of Hybrids:

To be historically correct, the first hybrid spinach produced in the Skagit Valley was in 1956 when about 3 acres of Hybrid No. 7 was grown. However, it wasn't until the start of this decade that hybrid varieties, primarily developed by USDA researchers, started gaining a wider acceptance by the commercial vegetable growers and as a result demands for hybrid seed production increased rapidly. Alf Christianson, Asgrow, Ferry Morse, Harris Moran, Keystone, Daehnfeldt, and many others were producing spinach varieties such as No. 7, 7R, and 424 released by USDA. The primary market for this seed was the canning industry in California. Although the cartoon character "Popeye" made spinach famous, it is a widely held belief amongst children of this era, that most parents used the threat of having to eat canned spinach for dinner as a behavior modification tool

Later in this decade, marketing innovators such as Bob McDonald of Alf Christianson Seed Company were starting to work with Asian seed companies, primarily from Japan. One story goes that McDonald collaborated with Mr. Satoshi Fujii of Fujii Seed Company to cross oriental pollinators with western type female lines. Three crosses were made and given the highly scientific designations of Fujii No. 1, Fujii No. 2, and Fujii No. 3. Mr. Fujii came to visit. He looked at the F1 hybrids and said, "I choose No. 2". To the production department at Alf Christianson this variety became known as Fujii No. 2 and was produced for more that 20 years. During this same time other Japanese companies such as Sakata and Takii started to discover the rich soils and favorable climate of the Skagit Valley, and hybrid spinach production increased rapidly. The increase in spinach seed production brought with it an equally large increase in the need for field labor for rogueing. One must remember that the female lines used to make the early F1 and F2 hybrids were mostly the "female" plants selected out of open-pollinated varieties. Some of the so-called female lines contained 20-40% male plants that had to be removed in the field. In the late 1970's and 80's, when hybrid spinach seed production in the Skagit Valley was reaching 4,000 acres (about 1600 hectares), more than 1500 school children between the ages of 12 and 16 were being hired to rogue spinach. Most companies used re-fitted school buses to move the crews from field to field. For many young people a summer job meant "picking spinach" and became a right of passage until they turned 16, when they could get a driver's license and a "real job".

The 1990's and Beyond:

Spinach breeding work that started back in the 60's, 70's and 80's seemed to accelerate at lightning speed in the 90's. The demand for varieties with new resistance, the shift to more fresh market consumption, and especially the introduction of baby-leaf spinach, created new challenges and higher quality standards for seed production in the Skagit Valley. Sex-reversing old spinach parent lines and better breeding techniques ended the need for hundreds of school kids being bused to the spinach fields to rogue. Germination rates accepted as minimum went from 85 to 90% and higher. Disease free seed with no off-types or inbreds were demanded in a market place where farmers were sowing 3 million seeds or more and paying rent of up to $3000 per acre to grow crops of fresh spinach. Likewise, seed production demands also increased. Precision seeding machines replaced the old scatter shoes and the amount of stock seed required per acre dropped 75%. The market changed and the farmers of the Skagit Valley responded, just as their forefathers had decades before.

Summary:

The 2006 International Spinach Conference being held here in La Conner, Washington is both historically significant and timely. It pays tribute to the history of seed production in the Puget Sound region that had its birthplace in La Conner in 1885, and honors all of those hard working families that provided the cornerstone of many farming techniques used today. Furthermore, this Conference is timely because it marks the 50^{th} anniversary of spinach seed production in the Skagit Valley. From the first three acres produced in 1956, to the more than 3000 acres of hybrid spinach seed that will be harvested this season, it shows our industry has traveled far, and has done so successfully, due to the farmers, scientists, and seed professionals, both past and present. On behalf of everyone who has made this presentation possible, please accept our sincere appreciation for your attendance and contribution at the 2006 International Spinach Conference. Let's all work together to make the next 50 years even better. Thank you.

Acknowledgements:

Appreciation is expressed to the following people who assisted in making this program possible:

Marvin Jarmin, WSU Extension Agent (retired)
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ORAL PRESENTATION ABSTRACTS AND PROCEEDINGS

Spinach Seed Production in Denmark

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Abstract

The Danish climate and soil conditions together with the very skilled farmers secure a quite unique quality spinach seed production. In 2005 the production area was close to 4,500 ha. Approximately 70% of the world's spinach seed is produced in Denmark. The seed is widely used all over the world for industry, fresh market and baby leaf.

Research within spinach seed production has been carried out for several years covering aspects such as irrigation, fertilisation, sowing methods, crop rotation, disease and weed control. In the latter case there is a constant need for research and efficacy evaluations of new products. In 2005 a new five-year programme focusing on seed quality in spinach was initiated.

Introduction

The history of Danish vegetable seed production is several hundred years old. In the beginning, the production mainly ensured self-sufficiency for the grower, but in the second part of the 18th century the market gardeners developed a more organised, commercial production. Today, approximately 70% of the world's spinach seed is produced in Denmark. In 2000, spinach seed production was carried out on approximately 3,500 hectares, producing a total of 7-8,000 tonnes of seed. Figures in 2005 were close to 4,500 and the production area was further increased in 2006. Spinach is widely used for industry, fresh market and the rapidly increasing baby leaf market.

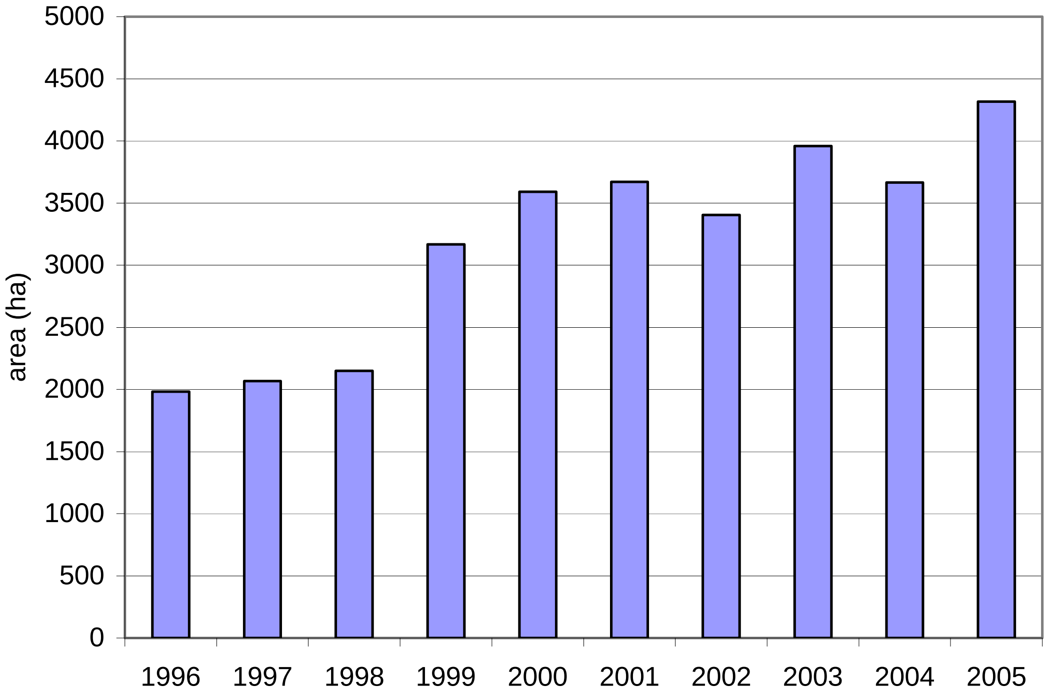

Figure 1. Danish area (ha) with spinach seed in the years 1996-2005.

Spinach seed production

There are several reasons why Denmark has this remarkable position within spinach seed production – climatic conditions, the soil, quality aspects, price, trust and last but not least – the farmers.

Breeding today focuses on late flowering varieties. The growing season in Denmark is characterized by long days and a cool coastal climate, which favours this kind of production. In the growing season the plants get 16-18 hours of daylight, with temperature averages of between 12-16°C and the monthly rainfall is 40-60 mm. The Danish soils are glacially created sandy loam soils – moraine soils originating from the last ice age 10,000 years ago. The pH value in these soils is quite high (7.5-7.8). These are all parameters, which, together with superior farmer competence, create an ideal environment for spinach seed production of the late flowering varieties.

Ninety percent of the production is with hybrids. The pollination of the hybrids is eased by the fairly long flowering period, and favoured by sowing the male lines 2-3 times. Since spinach is pollinated by wind, cross-pollination easily occurs, if isolation distances are not maintained. For open-pollinated varieties the demand is 1200 m between fields and for hybrids 1500 m between fields in the same group and up to 10,000 m between different groups. Open-pollinated varieties are only grown in the northwestern part of Denmark, where no hybrids are grown. Isolation of the cultivars has not been a problem. Most of the production is carried out on the islands or is divided between round or prickly-seeded species in selected areas. The quality demands are very high. A maximum of three weed seeds are allowed in a sample of 250 grams and no soil or plant material is allowed in the sample. The purity must be 99.9%. Most companies in Denmark clean their spinach seeds by additional use of a colour cleaner.

Research approaches

More formalised research within spinach seed production began in 1948 at the request of the Royal Danish Agricultural Society. For the last ten years, research within production methods has been co-financed by the seed industry. A new five-year programme on seed quality has been initiated in 2005.

During recent years much work has been done within chemical control of weeds. Many well-known products have been taken out of production and there is a need for new products. Investigations on when and where spinach can be placed in the crop rotation has had a high priority. The relative seed yield is found to decrease the more frequent spinach occurs in the crop rotation, mainly due to the propagation of root-pathogenic fungi. The recommendations from the trials are a crop rotation with 5-6 years between two spinach seed crops.
Irrigation during flowering has been found to have an important effect on the seed quality, and could improve seed yield by approximately 500 kg ha^{-1} in dry years. A series of trials with different nitrogen management strategies supported earlier trials on optimum nitrogen amounts. Trials with organic seed production showed that the seed yield was reduced by 1/3 compared with conventional farming.

New research programme

Recent investigations have shown a remarkable yield increase by the use of Opera (pyraclostrobin 133 g a.i.l^{-1} + epoxiconazol 50 g a.i. l^{-1}) and Signum (pyraclostrobin 67 g a.i.l^{-1} + boscalid 267 g a.i. l^{-1}). However, no clear effect on the seed quality was found. Seed quality will be the focus of a new research programme initiated in 2005.

ORAL PRESENTATION ABSTRACTS AND PROCEEDINGS

History of Spinach Production in the United States

T.E. Morelock[1] and J.C. Correll[2]
[1]Department of Horticulture, University of Arkansas, Fayetteville; [2]Department of Plant Pathology, University of Arkansas, Fayetteville

Spinach is a highly nutritious leafy green vegetable that is a good source of vitamins and minerals as well as being high in lutein and other antioxidants. Processed spinach is basically holding its own as far as market share is concerned but fresh spinach has made significant market increases recently particularly in the baby leaf area. Spinach acreage has remained rather stable in the United States but there have been significant acreage shifts in the past few years with major increases occurring in the Western United States, i.e., California and Arizona. Along with these acreage shifts there have been dramatic changes in production practices with higher plant populations, wide bed culture and a shift to mechanical harvest of fresh market spinach. There has been a shift in the stage of maturity when harvest occurs with the leaf size of the harvested product becoming smaller and the shift from bunched spinach to prepacked lose leaf spinach i.e. baby leaf. These new production practices have also helped development of very serious new pest problems. Leaf miner has become a serious production problem in western production areas. It has also lead to the development of 7 new races of downy mildew in the past 15 years and this rapid race development will very likely continue if current production practices continue without modification.

Coordinated Research for Leafy Vegetable Weed Control in the U.S.

Lynn Brandenberger
Department of Horticulture, Oklahoma State University

Obtaining new chemistries for weed control in vegetable crops is challenging because of the relatively small acreage that vegetables have compared to major agronomic crops in the U.S. Compound this situation with the fact that leafy vegetables have even less acreage than several other vegetable crops and it becomes evident that a more consolidated effort is needed to obtain new labeling for weed control in this crop grouping. With this in mind, efforts have been initiated to develop a working group consisting of Land Grant university researchers from 11 different states including both east and west coasts, Midwest, south eastern, and mid south areas of the U.S. The group plans to screen and develop herbicides that show promise for use in leafy vegetable crops. A majority of these researchers have been involved with U.S.D.A.'s IR-4 project and WSSA. The goals of this group are simply to coordinate efforts in screening herbicides, report those efforts to IR-4 and others, and possibly obtain some extramural funding to help pay for the work. Five working groups have been developed including brassica greens, brassica head crops, chenopods, herbs, and lettuce. Each group has a designated coordinator who will help to bring their group's efforts to completion. The entire group plans to publish a report of their results including research methods used and discussion of the data. The group has decided to make an effort to gather data in a uniform manner including field plot soil information, crop injury ratings, plant counts, weed control ratings, and harvest data. The plan is to have test results ready for distribution by early 2007.

Weed Control in Spinach Seed Production

Tim Miller
Washington State University Mount Vernon NWREC

Trials for improving weed control in spinach seed have been conducted at Washington State University Northwestern Washington Research and Extension Center since the 1950s, and have been primarily aimed at screening herbicides for crop safety. Herbicides available for grassy weed control in spinach seed are quite effective on the annual grasses prevalent in this region. These products include clethodim (Select or Prism), fluazifop (Fusilade), quizalofop (Assure II), and sethoxydim (Poast). Two widely-used broadleaf herbicides in spinach, diethatyl ethyl (Antor) and chloropropham (CIPC), are no longer manufactured or sold in the U.S., leaving producers with few products available to control broadleaf weeds. Unfortunately, most broadleaf herbicides are selected by manufacturers based in part on their ability to control the widely distributed weed species common lambsquarters (*Chenopodium album*), which is closely related to spinach. Consequently, most herbicides labeled in other crops cause unacceptably high injury to spinach. Herbicide screening occasionally does identify selective products, however, and cycloate (Ro-Neet), ethofumesate (Nortron), phenmedipham (Spin-Aid), and s-metolachlor (Dual Magnum) have been labeled for use in spinach seed. Even these labeled products, however, occasionally cause spinach injury. Broadleaf herbicides recently identified as being at least somewhat selective in spinach seed include flufenocet (Define), pyrazon (Pyramin), EPTC (Eptam), rimsulfuron (Matrix), and nicosulfuron (Accent). Testing of organic weed control strategies has also been a focus at WSU NWREC during the last three years. Flaming prior to spinach emergence was helpful for weed control, although crop damage was evident primarily due to variable emergence between replicates and the quickness of emergence of cotyledons (some as soon as one week after seeding). An infrared flamer provided effective postemergence weed control, although damage to spinach was apparent after early postemergence use. Vinegar and clove oil in shielded applications beside the crop row were less effective than flaming. Vinegar (Weed Pharm, 20% acetic acid) caused slight injury to weed foliage, yellowing, but not killing, soft-leaved weeds such as pale smartweed (*Polygonum lapathifolium*), ladysthumb (*Polygonum persicaria*), and common chickweed (*Stellaria media*). Clove oil (Matran 2) activity was substantially improved when applied at 15% in 2005 and 2006 than when used at 10% in 2004, but still was not as effective as flaming.

Evaluation of Various Fertilizer Regimes for Spinach

Larry Stein, Frank Dainello, Marcel Valdez and Kenneth White
Texas Cooperative Extension

The standard fertility requirement for spinach in Texas has been 120-75-80. In most cases our soils have adequate K and P, but P is often added. Nitrogen is almost always low. A three year study was conducted from 1996-1999 to evaluate increasing N and P rates on spinach yield; N rates included 0, 175, 250 and 375 lbs/A; P rates were 0, 50, 150 and 250 lbs/A. The residual 3 year average for P was 290 ppm at 1-12 inches. There was no yield increase with any level of P nor was there an increase in yield once the N level went over 250. Tissue analysis of the spinach revealed no accumulation of N or P even at the 375 N and 250 P levels. There was sufficient carry over fertility to produce 50 and 73 bushels/A corn in '97-'98 and '98-'99 respectively. Another three year study was conducted from 1999-2002 to evaluate the timing of N applications on spinach yield. Total N ranged from 220-290 lbs/A with P rates of 74 and 148 lbs/A. All P was applied pre-plant. N applications were pre-plant followed by 1 to 4 additional applications at the following stages: 4 leaf stage, 6-8 leaf stage, bed top close, after first cut and 2 weeks after first cut. There was difference between 74 and 148 lbs of P and no significant increase above 250 N. Time of nitrogen and number of applications did not affect final yield. Our industry is now converting to an 80" wide bed production system. Studies were initiated in 2005-2006 to evaluate various fertility levels on both fresh and processing spinach. N rates included 0, 100, 150, 200 and 250 lbs/A and P rates were 0, 50 and 100 lbs/A. Half of th treatments also received 1 qt/A crop mix - 4% Zn, 1% Mn, 1% Fe, and 3.5% S. Three soil additives were applied to a standard treatment of 100-50-0. All P and all but 40 units of each N treatment were applied pre-plant. The remaining N was applied via the irrigation water. The highest yield was obtained with 100-100-0, but it was not significant from 100-50-0. There was no significant increase with crop mix and soil additives did not increase yield over 100-50-0. Similar treatments were applied to processing spinach with no treatment differences. However, true results may have been hampered by the late planting of this plot. One year's data suggests that standard fertility rates of 100-50-0 works well on wide bed spinach. Studies will continue in 2006-2007.

Overview of races of the downy mildew pathogen on spinach and efforts to develop molecular markers linked to disease resistance loci

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Downy mildew of spinach, caused by *Peronospora farinosa* f. sp. s*pinaciae*, continues to be an economically important disease in most spinach growing areas worldwide. Our efforts on this disease include characterizing races of the downy mildew pathogen, screening for disease resistance to the various races, developing a better understanding of the genetics of resistance, and the development of molecular markers to facilitate breeding elite disease-resistant spinach genotypes. These efforts are being conducted in collaboration with the California Spinach Research Committee and Naktuinbouw (NAKT), The Netherlands, and the International Peronospora Working Group. The collaborative group established a standardized set of spinach differentials for characterizing races of the downy mildew pathogen. In the U.S., race 10 continues to be recovered at the highest frequency. A number of isolates have also been recovered from the race 1-10 resistant cultivar Lazio. However, a number of these isolates have not been able to infect Lazio in greenhouse tests. There are several plausible hypotheses to explain these data. Tests are ongoing to verify if any of the isolates originating from Lazio are variants of the pathogen that can overcome race 1-10 resistant lines. We are continuing an effort to develop near-isogenic (NIL) spinach lines with different downy mildew resistance loci isolated in a common genetic background. One NIL has been developed (UA-1) which contains the *Pfs-1* locus. This locus confers resistance to multiple races of the downy mildew pathogen. In conjunction with several companies, we have been evaluating the utility of several molecular markers. One marker, Dm-1, closely linked to the *Pfs-1* locus, is quite robust and can distinguish homozygous resistance (RR), heterozygous resistance (Rr), and homozygous susceptibility (rr) at the *Pfs-1* locus.

Genetic mapping and identification of important traits in spinach using a genomic BAC library

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The genetic control of economically important traits in spinach (*Spinacia oleraceae*) is not well understood. In an effort to develop a better understanding of the genetic control of important traits in spinach and to advance the potential for marker assisted selection in breeding programs, a genomic bacteria artificial chromosome (BAC) library is being developed. Approximately 33,000 BIBAC clones, with an average insert size of 150 kb, will be needed for a 5X coverage of the spinach genome, which is composed of 6 chromosomes and 989 Mb. To further facilitate examination of the spinach genome, genetic mapping populations are being developed by crossing various parental spinach genotypes either resistant or susceptible to the downy mildew (*Peronospora farinosa* f. sp. *spinaciae*) and white rust (*Albugo occidentalis*) pathogens. Previously, a marker (Dm-1) was identified that was tightly linked to the *Pfs-1* resistance locus for race 6 of the downy mildew pathogen in spinach. The spinach BAC library is being used to identify the resistance gene residing at the *Pfs-1* locus. Additional molecular markers are being developed from spinach and related species to construct the genetic map.

Efficacy of Mustard Biofumigant Crops for Management of Weeds and Fusarium Wilt in Spinach Seed Production: 2002-03 and 2004-05

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The following is summarized from *Biological & Cultural Tests 21:V001 & 19:V004*.

2002-03 Trial: One-year rotation out of a spinach seed crop
A trial was established in Sep 02 at the Washington State University Mount Vernon NWREC on Puget silt loam soil with a recent (2002) history of Fusarium wilt on spinach. The trial consisted of a randomized complete block design with a strip-plot arrangement of a 5 x 2 factorial combination of treatments in each of four replications. Five main-plot treatments consisted of two high-glucosinolate mustard cover crops (a *Brassica juncea* cultivar blend and a *B. juncea*/*B. hirta* cultivar blend), a winter wheat cover crop, a high-glucosinolate mustard seedmeal (*B. hirta*) amendment, and spring fumigation with metam sodium. Mustard cover crops were planted (13 lb seed/A) on 9 Sep 02 and the winter wheat cover crop was planted (60 lb seed/A) on 11 Sep 02. Remaining plots were left fallow until 15 Apr 03, then volunteer spinach and weeds were mowed and the plots rototilled. Mustard and wheat cover crop plots were mowed and rototilled, and the mustard seed meal broadcast and rototilled (~2000 lb/A) on 28 Apr 03. Sectagon 42 was applied (45 gpa in the top 3 to 4 in soil, and 30 gpa at 11 to 12 in soil depth) on 30 Apr 03. All plots were rototilled again on 14 May 03, and split-plot (20 x 24 ft) treatments of two proprietary female spinach inbreds, one resistant and one susceptible to Fusarium wilt, were seeded (~30 in. spacing between rows, 2-3 in. spacing within rows) on 15 May 03. Weed, volunteer spinach, and cover crop biomass samples were collected on 28 Apr 03, prior to cover crop incorporation. Fertilizer (18-46-0) was broadcast over plots (4 lb/plot) on 28 May 03. Spinach samples were collected 24 Jun, 16 Jul, and 20 Aug 03, and weed samples on 24 Jun 03 for biomass assessments. Following weed biomass harvest, plots were maintained free of weeds by manual weeding. Percentage weed control of shepherd's purse (*Capsella bursa-pastoris*) and common lambsquarters (*Chenopodium album*) was assessed on 13 Jun 03. Incidence of healthy, wilted, and dead spinach plants was assessed on 1 and 14 Jul 03. A 20 in.-length of each of four rows of spinach plants was harvested on 20 Aug 03 from each plot. Plants were dried until 26 Aug, then the seed was threshed, cleaned and sized according to commercial standards. Yield was measured as weight of clean seed. Total precipitation and mean temperature for fall (Sep to Nov 02), winter (Dec 02 to Feb 03), spring (Mar to May 03), and summer (Jun to Aug 03) were 4.63 in. and 51.0ºF, 8.32 in. and 36.9ºF, 7.69 in. and 50.2ºF, and 0.7 in. and 63.0ºF, respectively.

The *B. juncea*, *B. juncea* + *B. hirta*, and winter wheat cover crops yielded mean dry weights of 8,943, 6,510, and 4,234 lb/acre, respectively, prior to incorporation. Dry weights of volunteer spinach (originating from seed remaining in the field after harvest of a spinach seed crop in

2002) on 28 Apr 03 averaged 5,458 lb/acre for plots without winter cover crops, 1,460 lb/acre for the winter wheat cover crop, and 518 and 112 lb/acre for the *B. juncea* + *B. hirta* and *B. juncea* cover crops, respectively. Suppression of weeds through the winter was greatest for mustard cover crops. There were no significant differences among treatments for total dry biomass of all plants (weeds, cover crop, and volunteer spinach) prior to incorporation of cover crops. All cover crop treatments afforded less effective control of weeds and Fusarium wilt than fumigation with Sectagon 42. For all measurements of weed control, biomass, wilt incidence, and seed yield, there was no significant interaction between fumigant/cover crop treatments and spinach cultivars. However, there were significant differences among cover crop treatments for shepherd's-purse control, spinach crop biomass, incidence of wilt, and seed yield. Fumigation with Sectagon 42, followed by *B. juncea* then *B. juncea* + *B. hirta* cover crops, provided the best control of shepherd's-purse. Spinach biomass, reduction in incidence of wilt, and seed yield were greatest in plots fumigated with Sectagon 42, but not significantly different among cover crop and seedmeal treatments. Incidence of wilt for the Fusarium wilt-susceptible cultivar was 2x and 6x that of the resistant cultivar on 1 and 14 Jul 03, respectively. The resistant cultivar yielded 5x as much seed as the susceptible cultivar. Mean healthy stand in Sectagon 42 plots planted with the resistant cultivar was 75%. The very high incidence of Fusarium wilt in this trial resulted from much greater disease pressure than typically encountered by spinach seed growers in western Washington, as the spinach seed crop planted in the trial site the previous season had a severe outbreak of Fusarium wilt. Development of Fusarium wilt was exacerbated further by unusually warm and dry conditions for western Washington in the summer.

	% Weed control (13 Jun 03)		Dry biomass (oz/0.5 ft^2, 24 Jun 03)		Fusarium wilt-free plants (%)		Seed yield (oz/ft of row)
Treatment	Shepherd's-purse	Lambs-quarters	Weeds	Spinach crop	1 Jul 03	14 Jul 03	
Fumigant or cover crop							
Sectagon 42 …………	87 a[z]	59	0.32	0.36 a	81.1 a	46.3 a	0.66 a
B. juncea …………….	68 ab	75	0.36	0.11 b	43.9 b	17.2 b	0.41 b
B. juncea + *B. hirta* ….	62 abc	79	0.26	0.05 b	34.6 b	14.3 b	0.21 b
B. hirta seedmeal ……	52 bc	81	0.36	0.10 b	40.1 b	16.7 b	0.37 b
Winter wheat ……….	40 c	87	0.38	0.11 b	48.5 b	33.3 ab	0.36 b
LSD	28	NS	NS	0.14	17.7	19.8	0.22
Spinach cultivar[y]							
Resistant …………….	61.3	77.6	0.31	0.12	67.1 a	44.7 a	0.68 a
Susceptible …………..	62.1	74.4	0.37	0.17	32.2 b	6.5 b	0.13 b
LSD	NS	NS	NS	NS	11.2	12.5	0.14

[z] No significant interactions between main effects of fumigant/cover crop treatment and spinach cultivar in the analyses of variance. Means separation results are presented separately for fumigant/cover crop treatments and spinach cultivars. Means followed by different letters within a column for fumigant/cover crop treatments or for spinach cultivars are significantly different based on Fisher's Protected LSD ($P \leq 0.05$).

[y] Proprietary female inbreds resistant or susceptible to *Fusarium oxysporum* f. sp. *spinaciae*.

2004-05 Trial: Four-year rotation out of a spinach seed crop

A trial was established in Sep 04 at the Washington State University Mount Vernon NWREC on Puget silt loam soil where a spinach seed crop was grown in 2001. The trial consisted of a randomized complete block design with a strip-plot arrangement of a 5 x 2 factorial combination of treatments in each of four replications. Five main-plot treatments consisted of two high-glucosinolate mustard cover crops (a *Brassica juncea* cultivar blend and a *B. juncea*/*B. hirta* cultivar blend), a winter wheat cover crop, a high-glucosinolate mustard seed meal (*B. hirta*) amendment, and spring fumigation with metam sodium. Mustard cover crops were planted (11 lb seed/A) on 21 Sep 04 and the winter wheat cover crop was planted (60 lb seed/A) on 22 Sep 04. Remaining plots were left fallow until rototilled on 27 Apr 05. Mustard and wheat cover crop plots were mowed and rototilled, and the mustard seed meal broadcast and rototilled (~2000 lb/A) on 27 Apr 05. Sectagon 42 was applied (45 gpa at 3 to 4 in. and 30 gpa at 11 to 12 in. soil depth) on 28 Apr 05. All plots were fertilized (18-46-0 broadcast at 400 lb/A) and rototilled again on 12 May 05. Split-plot (20 x 24 ft) treatments of two proprietary female spinach inbreds, one resistant and one susceptible to Fusarium wilt, were seeded on 13 May 05 at 30 in. spacing between rows and 2-3 in. within rows (8 rows/inbred/plot). Weed and cover crop biomass samples were collected on 4 Apr 05, prior to cover crop incorporation. Spinach samples were collected 30 Jun and 19 Aug 05, and weed samples on 30 Jun 05 for biomass assessments. Plots were then maintained free of weeds by manual weeding. Percentage weed control of shepherd's purse (*Capsella bursa-pastoris*), common lambsquarters (*Chenopodium album*), and smartweed (*Polygonum* spp.) was assessed on 13 Jun 05. Incidence of healthy, wilted, and dead spinach plants in 3.3 ft of each of the center 4 rows/plot was assessed on 11, 22, and 26 Jul 05. A 10 ft-length of each of the center four rows of spinach/plot was harvested on 8 and 12 Sep 05 from the Fusarium wilt-susceptible and resistant inbreds, respectively. Plants were dried in the field on Remay cloth for 4 days, and then the seed was threshed, cleaned, sized to marketable standards (screen sizes 6-14), and weighed. Total precipitation and mean temperature for fall 04 (Sep to Nov 04), winter (Dec 04 to Feb 05), spring (Mar to May 05), summer (Jun to Aug 05), and early fall 05 (Sep) were 12.95 in. and 50.2ºF, 8.46 in. and 39.8ºF, 8.61 in. and 50.8ºF, 4.86 in. and 60.1ºF, and 1.96 in. and 54.7ºF, respectively.

The *B. juncea*, *B. juncea* + *B. hirta*, and winter wheat cover crops yielded mean dry weights of 4,426, 3,144, and 5,533 lb/acre, respectively, prior to incorporation. Suppression of weeds through winter was significantly greater in plots with cover crops than in fallow plots to be treated with Sectagon 42 or mustard seed meal in spring 05 (data not shown). Total dry biomass (weeds + cover crop) prior to incorporation of cover crops was highest for winter wheat, followed by *B. juncea* and *B. juncea* + *B. hirta*. For weed control, biomass, Fusarium wilt, and seed yield, no significant interactions were detected between fumigant/cover crop treatments and spinach cultivars, i.e., effects of the fumigant/cover crop treatments were consistent for the Fusarium wilt-resistant and susceptible inbreds. Fumigation with Sectagon 42, and incorporation of *B. juncea* + *B. hirta* or winter wheat cover crops provided the best control of shepherd's-purse, followed by *B. juncea* cover crop and mustard seed meal. Smartweed also was controlled best by Sectagon 42, followed by mustard seed meal, and wheat and the *B. juncea* + *B. hirta* cover crops. The *B. juncea* cover crop gave poor control of smartweed. Not much lambsquarters grew in the trial (data not shown). Differences in total weed biomass on 30 Jun reflected results for shepherd's-purse control. Spinach biomass was not significantly different among cover crop/fumigant treatments or between resistant and susceptible spinach inbreds on 30 Jun. However, by 19 Aug spinach biomass was significantly greater in plots treated with Sectagon 42 or mustard seed meal compared with cover crop plots, and the Fusarium wilt-resistant inbred had more than 2x the biomass of the susceptible inbred. Incidence of Fusarium wilt increased through the season in all plots, but remained significantly lower in plots treated with Sectagon 42 or mustard seed meal. No significant difference in Fusarium wilt incidence among the three cover crops was found. Incidence of wilt for the susceptible inbred was 4x and 2x that of the resistant inbred on 11 and 26 Jul, respectively. Spinach seed yield was greatest in plots treated with Sectagon 42, followed by mustard seed meal, the mustard cover crops, and the winter wheat cover crop. Seed yield in plots planted to the winter wheat cover crop was about half the yield of plots that received mustard seed meal, and about a third the yield of plots fumigated with Sectagon 42. Yield of the resistant inbred was 4x that of the susceptible inbred. Results suggest that Sectagon 42, mustard seed meal, and mustard cover crops may contribute to management of Fusarium wilt in spinach seed crops in this cool maritime region.

Treatment	Dry weed + cover crop biomass (lb/A, 4Apr)[z]	% Weed control (13 Jun) Shepherd's-purse	% Weed control (13 Jun) Smart-weed	Dry biomass ($oz/1.6\ ft^2$) Weeds (30 Jun)	Dry biomass ($oz/1.6\ ft^2$) Spinach crop 30 Jun	Dry biomass ($oz/1.6\ ft^2$) Spinach crop 19 Aug	Incidence of Fusarium wilt (% of plants) 11 Jul	Incidence of Fusarium wilt (% of plants) 26 Jul	Seed yield (lb/A)
Fumigant/cover crop									
Sectagon 42 ……..	1,192 d[y]	84 a	92 a	1.44 a	1.46	17.33 a	23 a	52 a	1,700 a
B. juncea ………...	4,550 b	65 b	26 c	3.02 bc	0.77	7.48 b	40 bc	75 b	955 bc
B. juncea + *B. hirta*	3,411 c	81 a	59 b	2.46 ab	1.02	7.85 b	40 bc	73 b	1,010 b
B. hirta seed meal	1,287 d	57 b	72 b	4.44 c	0.91	15.24 a	30 ab	64 ab	1,235 b
Winter wheat ……	5,967 a	77 a	61 b	2.30 ab	0.86	5.78 b	58 c	78 b	650 c
LSD	975	11	13	1.48	NS	4.32	-[x]	-	344
Spinach cultivar									
Resistant ………..	--	28	38	2.61	1.05	14.64 a	15 a	43 a	1,750 a
Susceptible ……..	--	27	38	2.86	0.96	6.83 b	61 b	94 b	471 b
LSD	--	NS	NS	NS	NS	2.73	-	-	218

[z] Weed + cover crop biomass prior to incorporating cover crops (27 Apr 05). Plots to be treated with seedmeal and Sectagon 42 were fallow until 27 Apr 05.

[y] Means followed by different letters in a column for fumigant/cover crop treatments or spinach cultivars are significantly different based on Fisher's Protected LSD ($P \leq 0.05$).

[x] '-' indicates % means shown, but log or arcsin-square root transformation used for analyses because of heterogeneous variances.

Efficacy of seed treatments for control of *Stemphylium botryosum* on spinach

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Seed of each of two proprietary spinach cultivars, '1' and '2', infected with *Stemphylium botryosum* at 41 and 96% incidence, respectively, were used to evaluate seven conventional and two organic fungicides as seed treatments for control of *S. botryosum*. For each treatment except Natural II, a sample of 19 g seed was placed in a slurry of a blue liquid colorant (Spectrum FulFilm 139 at 4.0% by seed weight) and Apron XL (20.8 ml/100 kg seed), to which the appropriate fungicide was added. The seed and slurry were shaken in an Erlenmeyer flask until the slurry was adsorbed completely onto the seeds. Seed were treated with water, colorant, and Apron XL for the control treatment. The proprietary organic seed treatment Natural II was applied by the manufacturer (AgriCoat, LLC, Soledad, CA). Seed germination was tested for four replications of 100 seed/treatment using the blotter assay of the Association of Official Seed Analysts (AOSA). Freeze-blotter seed health assays and greenhouse grow-out assays were also carried out. For the freeze-blotter seed health assay, four replications of 100 seed/treatment were placed onto damp blotters in plastic Petri plates (20 seed/plate). The seed imbibed on the blotters in the dark for 24 h, and were then incubated at –20ºC for 25 h followed by 12 d at 24ºC under a 12 h/12 h day/night cycle with near-UV and cool white fluorescent light by day. The seed were examined using a dissecting microscope (8 to 100X magnification) 5, 9, and 14 to 17 d after plating. For the grow-out assay, one flat consisting of 200 cells (each cell 1.57 cm^2 x 3.56 cm deep) was planted with seed from each treatment (1 seed/cell into pre-moistened Redi-Earth Peat-Lite planting mix). Four replications of 1 flat/treatment were planted and placed on benches under greenhouse lights on a 9 h/day schedule. A micro-sprinkler system applied a fine spray of water over the flats for 10 seconds every 30 minutes throughout the assay to promote conditions conducive for seed transmission of *S. botryosum*. Stand counts were taken 7, 10, 14, and 21 d after planting. Emerged seedlings were examined for symptoms of infection (necrotic lesions on the cotyledons and/or first true leaves) every 3 to 4 d after planting. Symptomatic plants were removed at each rating to minimize secondary spread of *S. botryosum*.

Results are presented in the table at the end of this article. The AOSA blotter assay of seed lot 1 demonstrated no significant differences in germination among treatments except for seed treated with Natural II, which reduced germination significantly at 7 and 14 d, but not by 21 d. Based on these results, the Natural II seed treatment protocol was altered by the manufacturer for lot 2. There were no significant differences in germination among treatments applied to lot 2. Natural II, Pristine XCF, and Rovral 4F displayed the best efficacy against *S. botryosum* in the seed health assays for both seed lots, reducing the incidence of seed infected by this fungus to <2% for lot 1 and ≤20% for lot 2. Maxim 4FS, Thiram 42-S, and Dynasty 100FS displayed intermediate efficacy against *S. botryosum* for each lot. In contrast, Mertect 340F, Serenade, and

Topsin-M 70WP did not have any significant effect on seedborne *S. botryosum*. For lot 1, all treatments except Serenade and Dynasty 100FS significantly reduced the incidence of *Cladosporium variabile* to <1% compared to 9% for the control treatment. Lot 2 was not infected with *C. variabile*. Mertect 340F, Natural II, and Topsin-M 70WP displayed the greatest efficacy against seedborne *Verticillium* and *Fusarium*. In the grow-out assay, Natural II reduced emergence significantly compared to the control treatment for lot 1, but none of the treatments affected emergence significantly for lot 2, reflecting results of the blotter germination assay. The incidence of seed transmission of *S. botryosum* averaged 0.3 and 1.0% for seed lots 1 and 2, respectively, with no significant differences among treatments for lot 1. For lot 2, only seed treated with Rovral 4F, Pristine XCF, or Thiram 42-S resulted in significantly less transmission of *S. botryosum* compared to the control treatment, demonstrating the value of these fungicides for minimizing seed transmission of this leaf spot pathogen. Of the two organic seed treatments evaluated, Serenade and Naturall II, only Natural II controlled seedborne *S. botryosum*. The phytotoxic effects of the Natural II treatment observed on lot 1 but not on lot 2 illustrates the necessity of precise parameters for this organic seed treatment.

Seed treatment[a]: Product (rate/100 kg seed)	Seed treatment[a]: Active ingredient % of product	Germination assay: % Seed germination (d after plating) 7	14	21	Seed health assay: % Seed infected — *Stemphylium botryosum*	*Cladosporium variabile*	*Verticillium* spp.	*Fusarium* spp.	All other fungi	Greenhouse grow-out assay: % Emergence (d after planting) 7	21	% Transmission of *S. botryosum*
Seed lot 1												
Control	-	66 ab	73 a	73 a	40.8 a	8.8 a	20.5 a	6.5 abc	95.5 a	55.8 a	70.3 ab	0.3 a
Serenade ASO 326 ml[b]	*Bacillus subtilis* 1.3%	69 a	75 a	75 a	38.3 a	9.5 a	17.3 a	8.8 a	90.0 b	50.6 ab	67.4 b	0.4 a
Mertect 340F 122 ml	Thiabendazole 42.3%	67 ab	72 a	72 a	47.5 a	0.0 b	0.0 d	0.0 f	96.5 a	54.8 a	71.6 ab	0.6 a
Topsin-M 70WP 500 g	Thiophanate-methyl 70.0%	66 ab	72 a	72 a	46.8 a	0.3 b	0.0 d	0.5 ef	95.5 a	47.6 b	68.6 b	0.5 a
Dynasty 100FS 25 ml	Azoxystrobin 9.6%	65 ab	73 a	73 a	12.8 b	4.3 a	7.3 b	3.5 cd	76.8 b	46.4 b	66.6 bc	0.0 a
Thiram 42-S 521 ml	Thiram 42.0%	64 ab	71 a	73 a	10.3 b	0.0 b	7.5 b	1.5 de	41.0 d	47.3 b	71.1 ab	0.6 a
Maxim 4FS 10 ml	Fludioxonil 40.3%	64 ab	72 a	72 a	8.8 b	0.5 b	8.3 b	4.3 bcd	55.8 c	51.3 ab	67.6 b	0.5 a
Pristine XCF 499 ml	Boscalid 25.0% + pyraclostrobin 25.0%	60 ab	69 a	70 a	0.8 cd	0.3 b	3.3 bc	1.8 de	61.5 c	50.3 ab	74.1 a	0.1 a
Rovral 4F 1,042 ml	Iprodione 41.6%	60 b	70 a	72 a	1.8 c	0.0 b	3.3 cd	8.8 ab	26.5 e	51.3 ab	68.1 bc	0.0 a
Natural II[c]	Unknown[c]	39 c	60 b	66 a	0.0 d	0.0 b	0.0 d	0.0 f	14.8 f	25.3 c	52.4 c	0.1 a
LSD (Pr < 0.05)[d]		8.5	7.4	NS	-	-	-	-	-	6.08	-	-
Seed lot 2												
Control	-	69 a	82 a	84 a	95.5 a	0.0 a	1.0 ab	1.3 abc	92.3 a	71.5 a	76.9 a	1.5 ab
Serenade ASO 326 ml[b]	*Bacillus subtilis* 1.3%	72 a	81 a	82 a	93.8 a	0.0 a	1.8 abc	1.3 abc	95.0 a	74.6 a	78.8 a	1.1 bc
Mertect 340F 122 ml	Thiabendazole 42.3%	66 a	84 a	86 a	94.0 a	0.0 a	0.0 c	0.0 d	93.3 a	77.9 a	80.9 a	2.5 a
Topsin-M 70WP 500 g	Thiophanate-methyl 70.0%	68 a	82 a	84 a	95.8 a	0.0 a	0.0 c	0.0 d	97.8 a	72.9 a	76.6 a	1.4 ab
Dynasty 100FS 25 ml	Azoxystrobin 9.6%	69 a	84 a	84 a	68.0 b	0.0 a	0.8 abc	1.0 cd	94.5 a	70.1 a	74.8 a	1.0 bc
Thiram 42-S 521 ml	Thiram 42.0%	61 a	82 a	83 a	51.5 c	0.0 a	0.3 bc	0.8 cd	51.0 b	77.8 a	84.8 a	0.5 cde
Maxim 4FS 10 ml	Fludioxonil 40.3%	74 a	87 a	89 a	64.8 b	0.0 a	2.8 a	0.8 bcd	55.5 b	74.5 a	79.4 a	1.4 abc
Pristine XCF 499 ml	Boscalid 25.0% + pyraclostrobin 25.0%	70 a	86 a	88 a	9.5 d	0.0 a	0.5 bc	2.3 ab	95.0 a	76.0 a	80.6 a	0.1 de
Rovral 4F 1,042 ml	Iprodione 41.6%	68 a	85 a	86 a	11.0 d	0.0 a	1.0 bc	3.0 a	33.3 c	76.0 a	82.4 a	0.0 e
Natural II[c]	Unknown[c]	63 a	83 a	85 a	20.5 d	0.0 a	0.0 c	0.0 d	15.8 d	72.9 a	82.4 a	0.9 bcd
LSD (Pr < 0.05)[d]		NS	NS	NS	-	-	-	-	9.11	NS	NS	-

[a] All treatments, except Natural II, also included Spectrum FulFilm 139 blue dye (4.0% by weight) + Apron XL (20.8 ml/100 kg seed). Pristine XCF is a water-based formulation of BAS 500XCF + BAS 510XCF from BASF Corporation (not yet available commercially).

[b] Serenade ASO is certified for organic use under the USDA National Organic Program.

[c] Natural II is a proprietary seed treatment certified for organic use under the USDA National Organic Program, and was applied to the seed lots by AgriCoat LLC at an unknown rate. The manufacturer altered the seed treatment protocol for lot 2 after we demonstrated reduction in germination of seed from lot 1 that had been treated with Natural II.

[d] LSD = Fisher's protected least significant difference. Means followed by the same letter within a column are not significantly different. '-' indicates mean % values presented, but means separation by LSD is based on Friedman's non-parametric rank test or transformation of the data (logarithmic, square root, or arcsin square root trasnformation) because of heterogeneous variances and/or non-normal distribution of residuals. NS = not significantly different at $P = 0.05$.

Screening for Resistance to Stemphylium Leaf Spot of Spinach

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Background:
In 1997, a new leaf spot disease was found in spinach fields in California. The pathogen was identified as *Stemphylium botryosum*. The continued occurrence of the disease indicates the pathogen has established in the state. *S. botryosum* has also been reported as a foliar pathogen of spinach in Arizona, Delaware, Florida, Maryland, Oregon, Washington, and Quebec, Canada. Recent research has shown this pathogen is commonly seedborne and can be seed transmitted. Quality standards for fresh market spinach are extremely high, so this emerging disease poses another challenge for spinach growers to produce high quality, defect-free products. Resistance to Stemphylium leaf spot in spinach has not been reported. Information on the resistance (or susceptibility) of the USDA spinach germplasm collection compared with commercial cultivars may be very useful for developing Stemphylium leaf spot-resistant varieties.

Methods:
Public germplasm collection: The entire USDA spinach germplasm collection obtained from the USDA-ARS North Central Regional Plant Introduction Station at Iowa State University (338 accessions) was evaluated in a preliminary screening, along with 22 commercial spinach cultivars, at the Agricultural Research Station of the USDA in Salinas, California in 2004. For each of two replications per entry, 8 seed were planted in a 4 inch pot, and thinned to 5 plants per pot after emergence. A conidial suspension (about 10^5 conidia per ml) of the pathogen was sprayed onto the 10 plants of each genotype at the 4- to 6-true leaf stage, using a hand-held mister. Plants were incubated in a humidity chamber at 100% relative humidity for 72 h, and then maintained in a greenhouse. Control plants were sprayed with sterile distilled water and handled in the same manner. After 3 weeks, plants were evaluated for incidence and severity of leaf spot symptoms (% diseased leaf area). Isolations were conducted to confirm the presence of the pathogen. Putative resistant accessions from the initial screening were retested in 2005 along with susceptible control entries, using four replications to confirm the results.

Proprietary germplasm collection: A request was sent to seed companies to contribute seed samples of proprietary spinach germplasm (cultivars or experimental breeding lines) to be screened for resistance to Stemphylium leaf spot in a greenhouse at the Washington State University Mount Vernon NWREC. All entries were coded for anonymity of companies and cultivars or breeding lines. In addition, 10 accessions from the USDA-ARS North Central Regional Plant Introduction Station at Iowa State University that were also screened in the public germplasm collection in California, were included. For each of 3 replications arranged in a randomized complete block design, 8 seed of each entry were planted in a 4 inch pot and thinned to 5 plants per pot after emergence. At the 4- to 6-true leaf stage, plants were inoculated with a conidial suspension of *S. botryosum* (~10^5 conidia/ml) as for the public germplasm screen. The inoculated plants were immediately enclosed in a frame covered with plastic and Remay cloth for 3 days to maintain high humidity, and then uncovered and maintained in the greenhouse for 3 weeks. Plants were rated for severity of leaf spot (% leaf area with symptoms) approximately 3 weeks after inoculation. The resistance screen was carried out from February to April of 2004, and repeated from January to March of 2005. Seed companies A, B, C, D, and E participated in the study, contributing 26, 10, 27, 70, and 4 entries, respectively, for a total of 148 entries (only 138 entries were screened in 2004, because seed from Company B had not yet been received).

Results:

Public germplasm collection: There were significant differences in the amount of leaf spot observed on the genotypes tested. No genotype was completely immune to the disease. In the preliminary screening in 2004, disease incidence ranged from 10 to 100% and averaged 53.4 ± 7.3% (mean ± standard error), while disease severity had a range of 0.1 to 7.3% with a mean of 2.2 ± 0.1% among genotypes. From the initial screening, 24 putative resistant accessions were identified. These accessions, plus 8 susceptible accessions and the 22 commercial cultivars, were included in another leaf spot resistance test. Disease incidence in this test ranged from 5 to 100% with an average of 52.3 ± 7.2%, while disease severity ranged from 0.3 to 12.8% and averaged 5.0 ± 0.3%. Two accessions from Turkey, PI 169685 and PI 173809, consistently had low disease incidence and severity ratings. None of the 22 commercial cultivars tested consistently showed low levels of disease incidence and severity. The two Spinacia tetrandra and four Spinacia turkestanica accessions screened were all susceptible. No correlation between disease incidence/severity and leaf type was observed. S. botryosum was consistently isolated from the leaf spots. None of the control plants treated with water developed symptoms.

Proprietary germplasm collection: As for the public germplasm collection, significant differences in severity of Stemphylium leaf spot were observed among the 148 entries screened. In 2004, severity of leaf spot averaged 4.6 ± 0.3% (mean ± standard error), with a range from 0 (entry A65) to 33.3% (D29) for individual entries. Ten entries had mean ratings >10%. Three entries had mean severity ratings <1%, including PI 494751 (0.7% leaf spot severity), a *Spinacia turkestanica* entry from Uzbekistan. There was not enough seed remaining to retest PI 494751 in 2005. An additional 27 entries had severity ratings <2.0%, including PI 171863 (*S. oleracea* 'Dikenli' from Turkey). In 2005, severity of leaf spot averaged 5.3 ± 0.3% (mean ± standard error) for 147 entries, ranging from 0 (D3) to 28.3% (A60) for individual entries. Fourteen entries had mean severity ratings >10%, of which six also had high severity ratings in 2004. Two entries had mean ratings <1%, both of which had severity ratings <2.7% in 2004. Although the order in which entries were ranked for severity of leaf spot differed between in 2004 and 2005, the screens identified entries that are highly susceptible to *S. botryosum*, and entries with putative resistance to this pathogen. Further screening under field conditions is needed.

POSTER ABSTRACTS

Generation of an open pollinated near-isogenic spinach line with homozygous resistance to the downy mildew pathogen

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Spinach (*Spinacia oleracea*) is an economically important vegetable crop in the United States. Recent trends have shown a substantial increase in fresh market spinach production which may be influencing downy mildew, caused by *Peronospora farinosa* f. sp. *spinaciae*, a major disease of spinach worldwide. Ten races of the pathogen have been reported with six new races (races 5-10) identified since 1998. The races are identified by qualitative disease reactions on a genetically diverse set of spinach differentials. There is a need to develop a set of near-isogenic lines (NILs) with different resistance genes in a common genetic background. To initiate the development of these spinach differentials, a cross was made between the cultivar Viroflay (susceptible to all known races) and the hybrid Lion (reported resistance to races 1 to 9). Progeny were screened for resistance to race 6 and resistant progeny backcrossed to Viroflay. Four generations of backcrosses and screening were conducted. Progeny from two BC_4S_2 lines, 17A and 12F, were assessed for race 6 resistance. Based on pathogenecity tests, all progeny tested (204 for line 17A; 14 for line 12F) were resistant to race 6. Screening with a co-dominant molecular marker (Dm-1) indicated that all progeny screened were homozygous resistant (RR) at the previously identified resistance locus, *Pfs-1*.

POSTER ABSTRACTS

Genetic and molecular characterization of isolates of *Verticillium dahliae*

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Verticillium dahliae is a cosmopolitan soilborne pathogen that affects many crops and was recently reported to be a pathogen of spinach in Washington, U.S. Infested spinach seed can introduce *V. dahliae* into production fields, which can lead to disease problems when rotating spinach and potato crops, a common practice in the Pacific Northwest. The objective of this research was to characterize the genetic and molecular variation among isolates of *V. dahliae* from spinach. Isolates of *V. dahliae* were provided by du Toit (Washington State University), from seed lots of different origins: US, Denmark, and the Netherlands. These isolates are being analyzed for vegetative compatibility, mtDNA RFLPs, and ITS sequences. Preliminary results from 124 isolates from spinach indicated that 90 belonged to VCG 4B and 34 to VCG 2B. Also, 3 potato isolates were analyzed, 2 belonged to VCG 4B and 1 belonged to VCG 2B. For mtDNA RFLPs and ITS sequences isolates of *V. dahliae* are currently being analyzed. In addition, spinach germplasm from the USDA collection is being screened for resistance to *V. dahliae*. Preliminary results from these tests indicate that there is a wide range of disease reactions to *V. dahliae*.

POSTER ABSTRACTS

Electron beam irradiation as a tool to improve food safety and extend shelf-life

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An exhibit depicting the potential value of electron beam irradiation as a tool to improve food safety and extend shelf-life will be on display. In addition, other information on the Texas A&M University E-Beam facility and its potential uses and services will be available. The TAMU E-beam facility came about as a result of a cooperative effort between the University and the former SureBeam Corporation. The intended use of the facility is to conduct research to improve food safety, insure food security, reduce application of toxic compounds applied to fruits and vegetables, water quality, etc. Design and logistic of implementation of this technology for commercial application is also a goal. The facility has the capability of treating sample samples to semi-truck lots. The role of Extension is to conduct short courses and to provide educational materials to help dispel the myths associated with the use of this valuable technology.

POSTER ABSTRACTS

Spring 2006 Spinach Preemergence Herbicide Screening Study

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Spinach is an important crop to Oklahoma producers for use in the canning industry and for fresh market. Preemergence weed control in this crop is limited to Dual Magnum (S-Metolachlor). Due to limited preemergence herbicides, the objective of this study was to identify and begin development of new pre herbicides for use in this crop. The study was completed in spring 2006 at the Oklahoma Vegetable Research station in Bixby, Oklahoma. The study design was a randomized block design with four replications that included 22 herbicide treatments and un-weeded and weeded checks (Table 1). On 4/11/06 two pre-plant incorporated treatments were applied (hand-boom $C0_2$ sprayer) and incorporated then spinach (Asgrow cultivar 'Padre') was direct seeded for the entire study. Premergence treatments were applied on 4/12/06 to previously planted plots and irrigated immediately following with 0.5 inches of overhead irrigation to incorporate all treatments. All plots received a total of 70 lbs/acre of nitrogen in three split applications on 5/02/06, 5/15/06, and 5/25/06. Supplemental water for the study was supplied through overhead irrigation with the study area receiving 1 to 2 inches of water per week. Crop injury ratings were recorded on 4/26/06 and 5/09/06, efficacy ratings and plant counts on 5/30/06, and yield on 6/08/06. The number of plants per 0.5 meter squared varied for several of the treatments. It ranged from 0 for the two higher rates of KIH 485 to nine plants for Far-Go at 1.5 lbs ai/acre (Table 1). The treatments with higher plant numbers included the weeded check, Far-Go at 1.25 and 1.5 lbs ai/acre, and Lorox at 0.1 and 0.2 lbs ai/acre. Crop injury was lowest for the untreated and weeded checks followed by Far-Go and Lorox treatments (Table 1). Injury was observed primarily as stunting, but the KIH 485 and the Eptam treatments resulted in few to no emerged seedlings. Control of Palmer amaranth (*Amaranthus palmeri* S. Wats.) was highest for the weeded check followed by treatments with Barricade, Define, Dual Magnum, and KIH 485 (Table 1). Although yields were lower due to the study beginning late in the season, there were differences observed in yield (Table 1). Yield ranged from a high of 5,173 lbs/acre for Dual Magnum to 0 lbs/acre for Eptam and KIH 485 treatments (Table 1). The weeded check yielded 4,019 lbs/acre and Define at 0.3 lbs ai/acre, Far-Go at 1.25 lbs ai/acre, Nortron at 0.5 lbs ai/acre, and Outlook at 0.125 lbs ai/acre yielded 4,495, 3,446, 3,171, 4,228 lbs/acre, respectively.

Table 1. Spring 2006 Spinach pre-emergence weed control, Bixby, OK.

Treatment lbs ai/acre	Number plants [z]	Percent Injury 4/26/06	Percent Injury 5/9/06	Amaranth control [y]	Yield lbs./acre [x]
Untreated check	5.8 abcd [w]	0 e	0 i	0 g	999 cde
Weeded check	7.0 ab	0 e	0 i	100 a	4019 ab
Aim 0.03	2.3 def	38 cd	25 defgh	23 fg	627 de
Aim 0.015 + Roundup ?	1.3 ef	48 bc	68 c	45 cdef	267 e
Barricade 4FL 0.66	2.3 def	8 de	69 c	71 abc	1179 cde
Define DF 0.3	5.5 abcd	8 de	21 efghi	70 abc	4495 ab
Define DF 0.6	4.7 bcde	36 cd	40 de	75 abc	3314 abc
Dual Magnum 0.65	6.5 abc	14 de	10 ghi	75 abc	5173 a
Kerb 1.0	0.3 f	93 a	98 ab	51 bcdef	186 e
Eptam 7E (PPI) 1.3	0.0 f	91 a	97 ab	18 fg	0 e
Eptam 7E (PPI) 3.5	0.0 f	100 a	100 a	26 defg	0 e
Far-Go 1.25	7.3 ab	10 de	2 hi	25 efg	3446 abc
Far-Go 1.5	9.0 a	0 e	4 hi	29 defg	2254 bcde
KIH 485 60 WDG 0.05	1.3 ef	48 bc	76 bc	89 ab	633 de
KIH 485 60 WDG 0.1	0.0 f	93 a	100 a	95 a	0 e
KIH 485 60 WDG 0.15	0.0 f	91 a	99 a	95 a	0 e
Lorox 0.1	7.0 ab	0 e	9 ghi	26 defg	2416 bcde
Lorox 0.2	7.3 ab	4 e	19 efghi	43 cdef	2097 bcde
Nortron 0.5	6.3 abcd	6 de	11 ghi	36 cdefg	3171 abcd
Nortron 1.0	2.3 def	30 cde	45 d	29 defg	1347 cde
Outlook 0.125	6.5 abc	23 cde	15 fghi	29 defg	4228 ab
Outlook 0.25	5.8 abcd	25 cde	29 defg	30 defg	2509 bcde
Outlook 0.5	1.3 ef	71 ab	73 c	63 abcde	424 e
Prowl H_2O 0.5	2.8 cdef	18 cde	38 def	64 abcde	2416 bcde

[z] Number plants = actual number of spinach plants in 0.5 square meter.
[y] Amaranth (*Palmer amaranth*) control ratings on 5/30/06.
[x] Yield data on 6/8/06.
[w] Numbers in a column followed by the same letter exhibited no significant differences based on Duncan's Multiple Range Test where P=0.05.

2006 INTERNATIONAL SPINACH CONFERENCE
13-14 July 2006, La Conner, WA

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100	EW	Ritchie	Wintergarden Spinach Producers	Uvalde	TX	USA		830-278-6661
101	Anthony	Romero	Santa Clara Seeds	Greenfield	CA	USA	robindalton@redshift.com	831-674-5225
102	Christine	Rucjstuhl	Norseco	Laval	QC	CANADA	cr@norseco.com	514-332-2275
103	Margaret	Savage	Alf Christianson Seed Co	Mt Vernon	WA	USA	margaret_savage@alfseed.com	360-661-2047
104	Steve	Scattini	Valley Star Seed	Templeton	CA	USA	scattini@calinet.com	805-610-0825
105	Jay	Schafer	Schafer Ag Services LLC	Mt. Vernon	WA	USA	schaferj@gte.net	360-202-5951
106	Merlin	Schantz		Hydro	OK	USA	schantzfam@hotmail.com	405-542-7738
107	Michael	Shapiro	Schafer Ag Services LLC	Mt. Vernon	WA	USA	shap40@peoplepc.com	360-420-5604
108	Cees	Sintenie	Bejo Zaden B V	Warmenhuizen	NH	NETHERLANDS	c.sintenie@bejo.nl	613-518-72983
109	Steve	Slocum	Gowan Seed Company	Salinas	CA	USA	sslocum@gowanseed.com	831-422-2820
110	Jose	Solorzano	American Takii Inc	Yuma	AZ	USA		928-341-0434
111	Doug	Sousa	Mission Ranches	King City	CA	USA	dsousa@missionranches.com	831-240-5755
112	Larry	Stein	Texas Cooperative Extension	Uvalde	TX	USA	larrystein@tamu.edu	830-278-9151
113	Richard	Stewart	TS&L Seed Company	Woodland	CA	USA	richs@tslseed.com	530-666-1239
114	Steve	Strand	Alf Christianson Seed Co	Mt Vernon	WA	USA	steve_strand@alfseed.com	360-661-1871
115	Joyce	Takeyasu	Ag Alternatives	Corvallis	OR	USA	jtakeyasu@yahoo.com	541-230-0067
116	Tim	Thompson	Seminis Vegeatable Seeds	Yuma	AZ	USA	tim.thompson@seminis.com	928-920-9292
117	Nick	Tichinin	Universal Seed Co	Monmouth	OR	USA	nick@universalseed.com	503-507-3506
118	Lara	Timmerman	Pop Vriend Seeds	Andijk	NH	NETHERLANDS	laratimmerman@popvriendseeds.nl	316-204-12484
119	Abel	Tomlinson	University of Arkansas	Fayetteville	AR		atomlin@uark.edu	479-575-4721
120	Sam	Underwood	TS&L Seed Company	Yuma	AZ	USA	samu@tslseed.com	760-996-5029
121	Marcel	Valdez	Wintergarden Spinach Producers	Uvalde	TX	USA		830-278-6661
122	Gerthon	Van De Bunt	Pop Vriend Seeds	Andijk	NH	NETHERLANDS	gvandebunt@popvriendseeds.n1	312-285-93354
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124	Manuel	van Eijk	Enza Zaden Beheer BV	Enkhuizen	NH	NETHERLANDS	m.van.eijk@enzazaden.nl	312-283-50174
125	Johannes	van Kuijk	Enza Zaden Beheer BV	Enkhuizen	NH	NETHERLANDS	j.ruiter@enzazaden.nl	003-122-8350177
126	Eddie	Vernor	Champion Seed Co	Uvalde	TX	USA	champion@rionet.coop	830-278-5850
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131	Grant	Wilson	Seed & Field Services	Pukekohe	NZ	NEW ZEALAND	gwilson@sfse.co.nz	649-237-1153
132	Steven	Winterbottom	Tozer Seeds Ltd	Cobham	SU	UNITED KINGDOM	steve@tozerseeds.com	440-193-286205